Ethernet Surge Protective Device (SPD) Electrical Design Considerations

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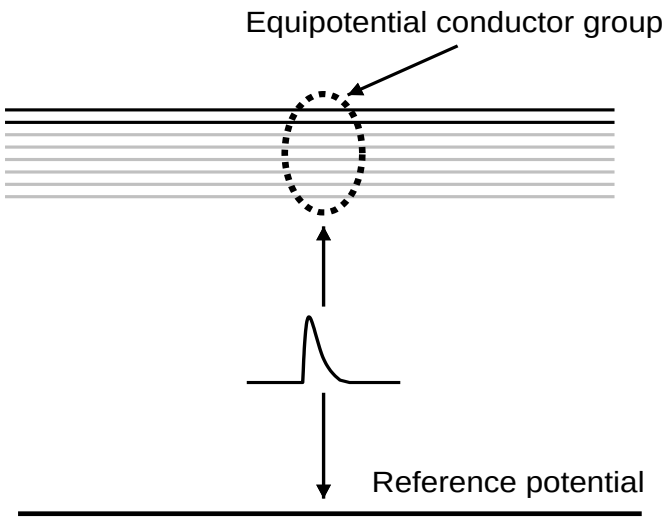
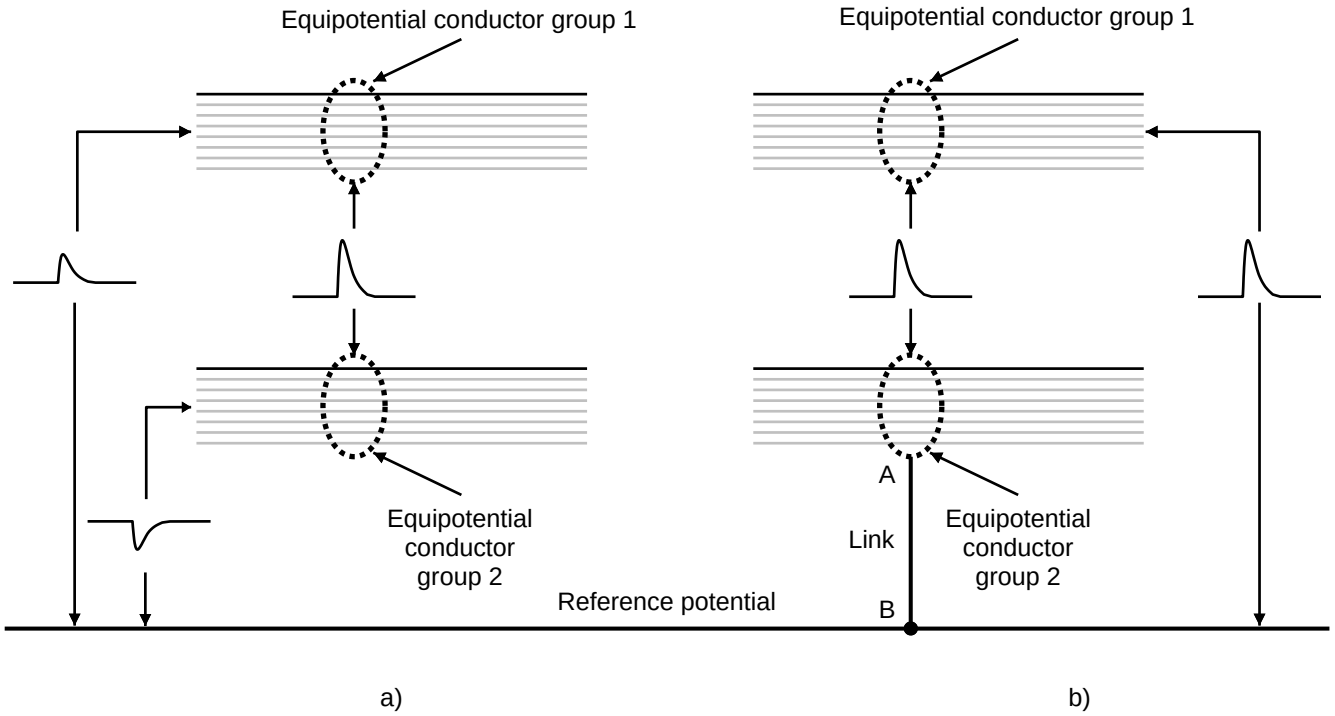
Surge Types - Common-mode voltage



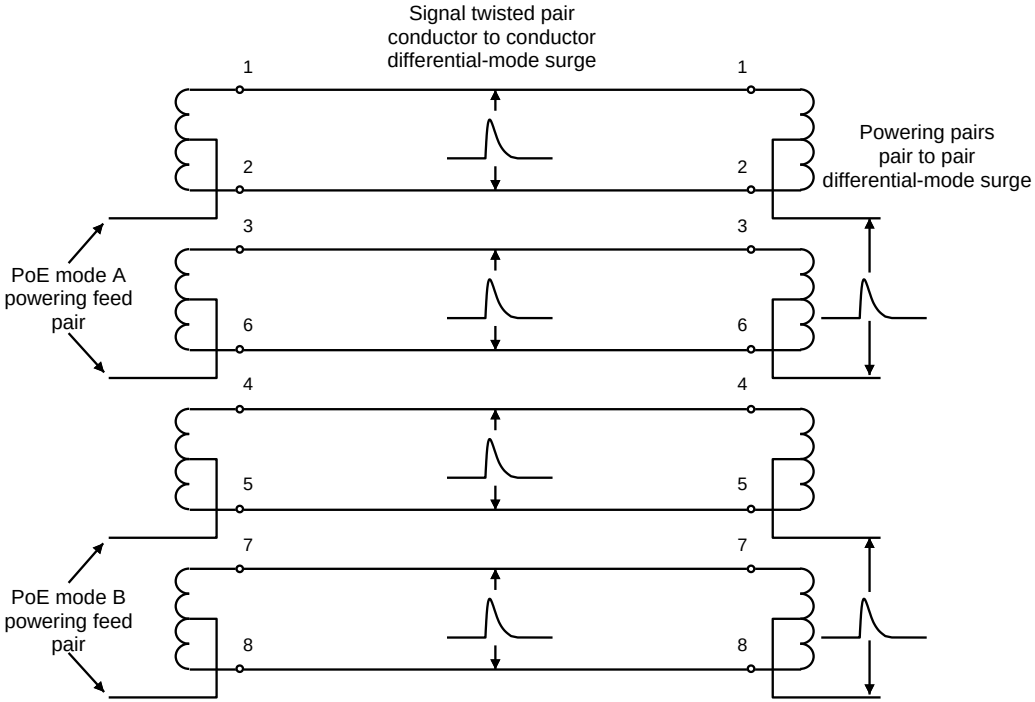
surge appearing equally on all conductors of a group at a given location

Surge Types - Differential-mode voltage a) balanced and b) unbalanced



surge occurring between any two conductors or two groups of conductors at a given location

Surge Types - Differential-mode voltage in an Ethernet system

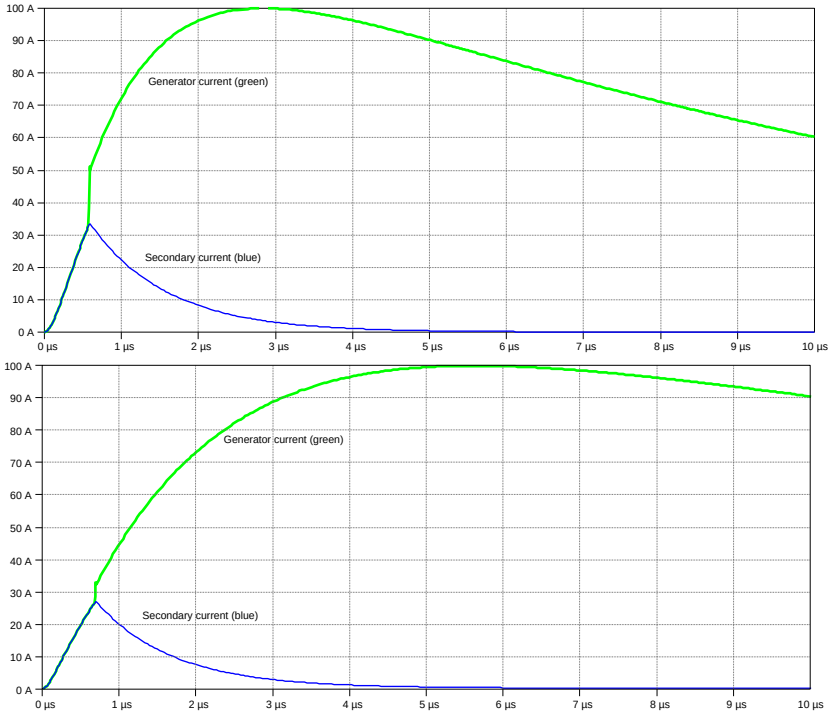


Ref: *Surges and their mitigation*
Modes of PROTECTION and SURGE

Ethernet system

- At surge frequencies the port loading is effectively resistive capacitive and non-linear.
- The port Ethernet transformer presents a d.c. load of about $1\ \Omega + 1\ \Omega$
- The PoE PD circuits consists of a diode bridge, avalanche diode and capacitance.
- The PoE PSE circuits consists of a regulating IC, series pass element, some protection and capacitance.
- Most of the PoE PD and PSE ICs are rated about 100 V

Unexpected consequences - Surge generators 1
Differential surge on Ethernet signal port



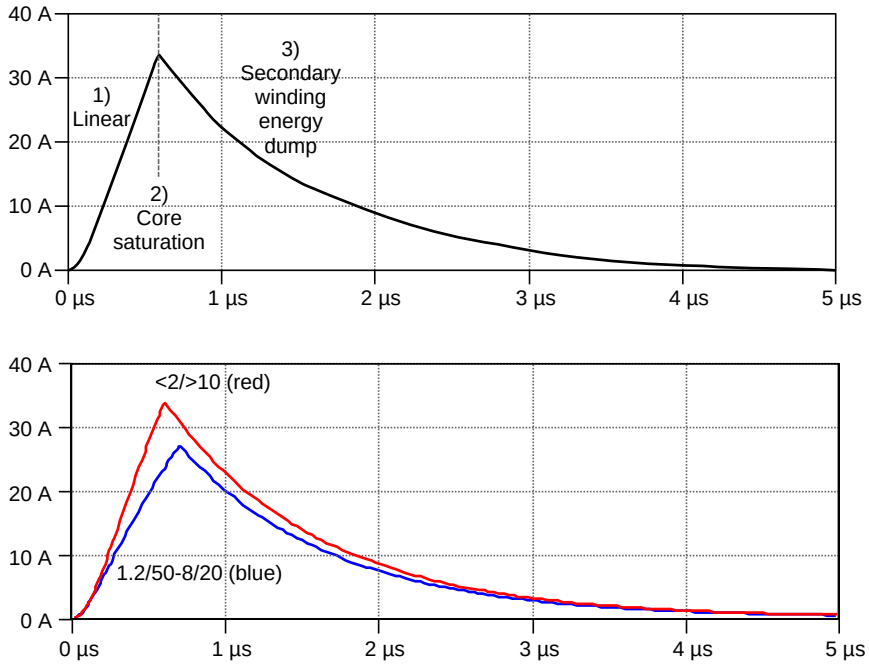
<2/>10, 800 V, 100 A

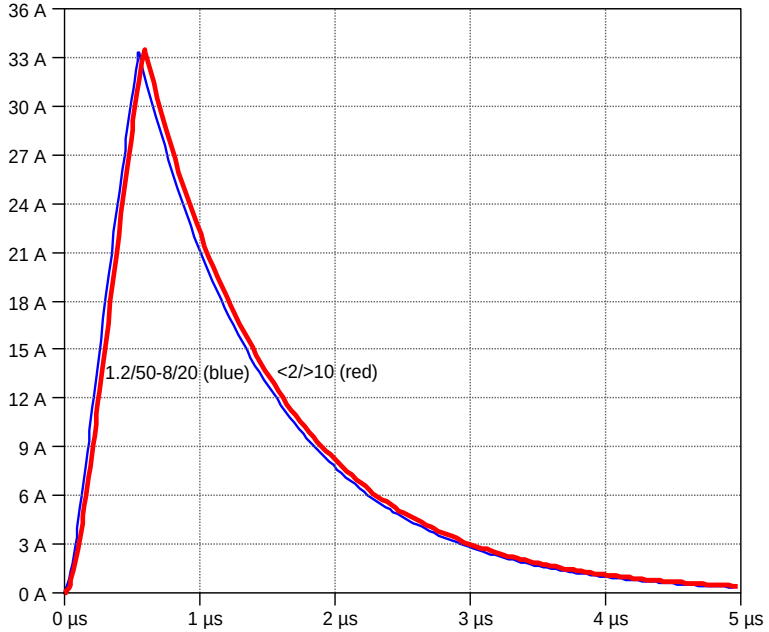
≠ (not the same result)

1.2/50-8/20 , 800 V, 100 A

(shorted secondary)

Unexpected consequences - Surge generators 2

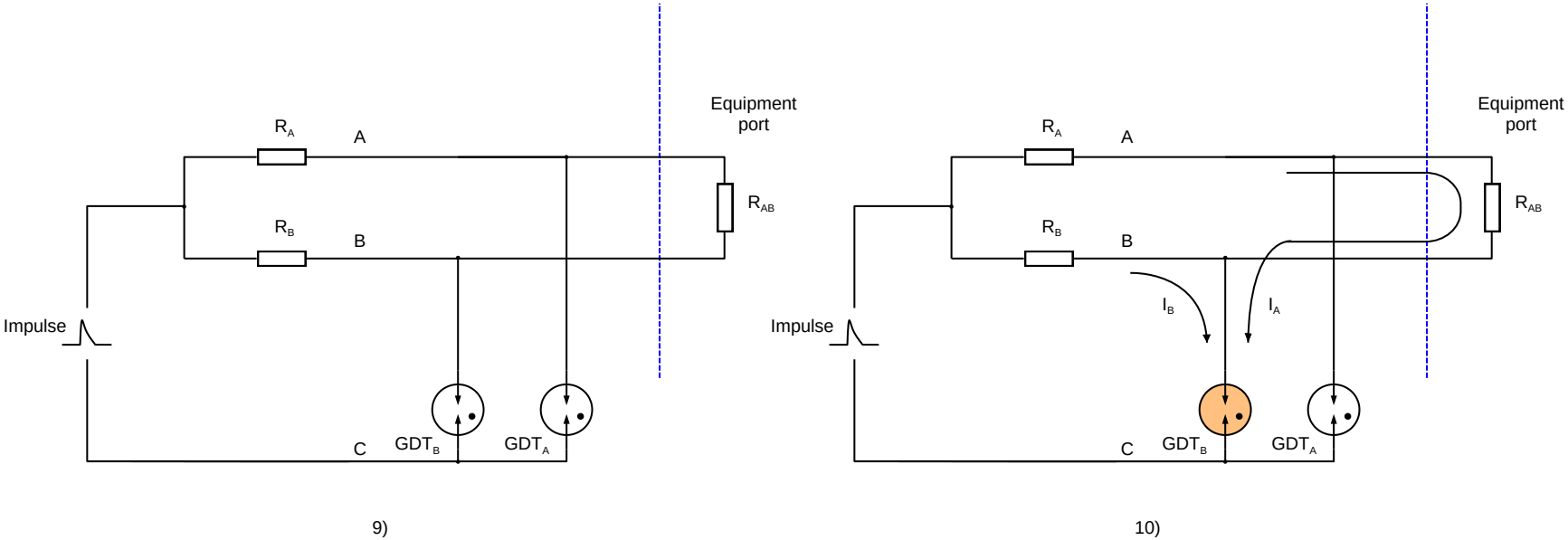




<2/>10, 800 V & 1.2/50-8/20, 1214 V

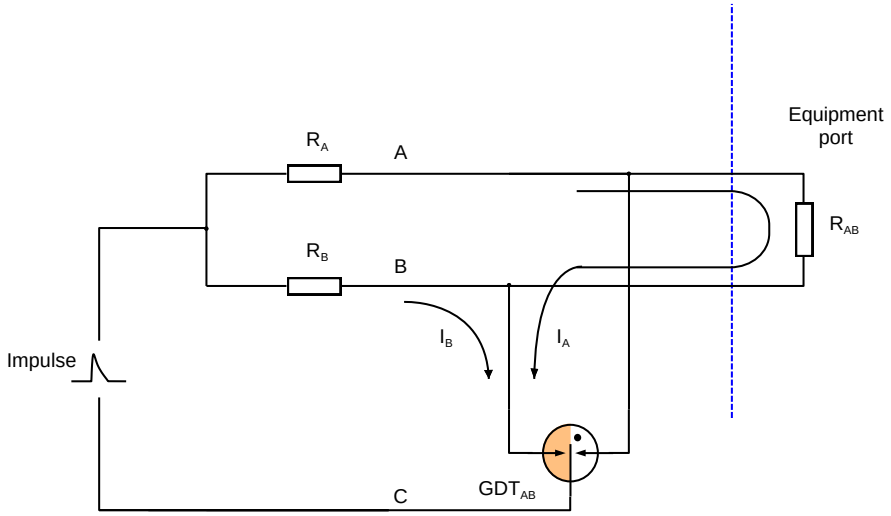
Refs: *Ethernet differential surge testing - di/dt*
Differential surge stress reduction by Ethernet magnetics

Unexpected consequences – Gas Discharge Tubes - 1



GDT_B conducts and hogs both conductor currents, I_A & I_B. The summation of GDT_B arc voltage and low voltage drop I_A x R_{AB} prevents GDT_A sparkover . Equipment port suffers a differential surge of I_A.

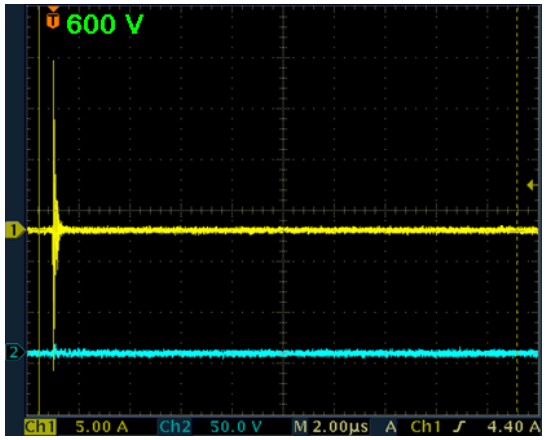
Unexpected consequences – Gas Discharge Tubes 2

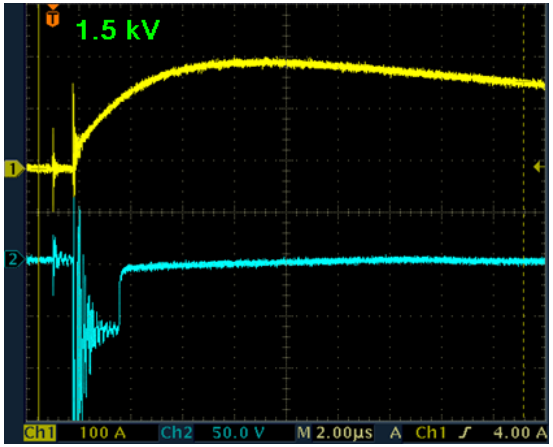


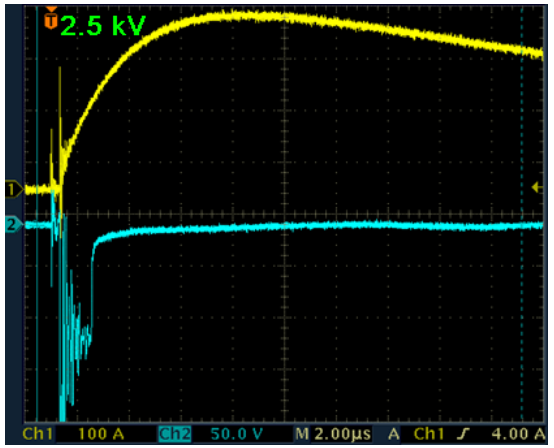
11)

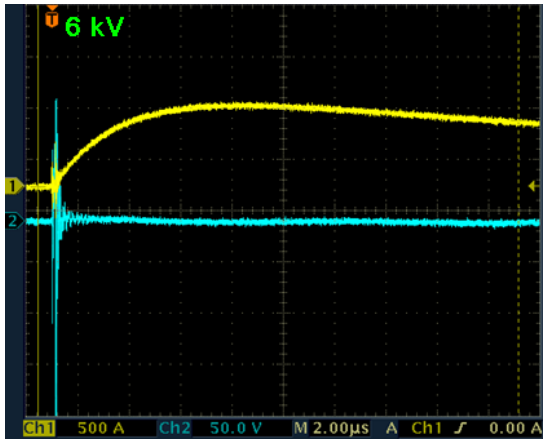
When the two outer GDT electrodes are independently surged, conduction of both halves occurs in well under 1 µs. Low resistance Ethernet signal ports bridge the two outer electrodes lowering the non-conducting GDT section voltage. The lower electric field voltage field takes longer to attract the conducting section plasma. As a result it can take many microseconds before both GDT sections conduct. Before simultaneous conduction occurs, a major portion of the surge front is applied differentially to the equipment port.

Unexpected consequences – Gas Discharge Tubes 3



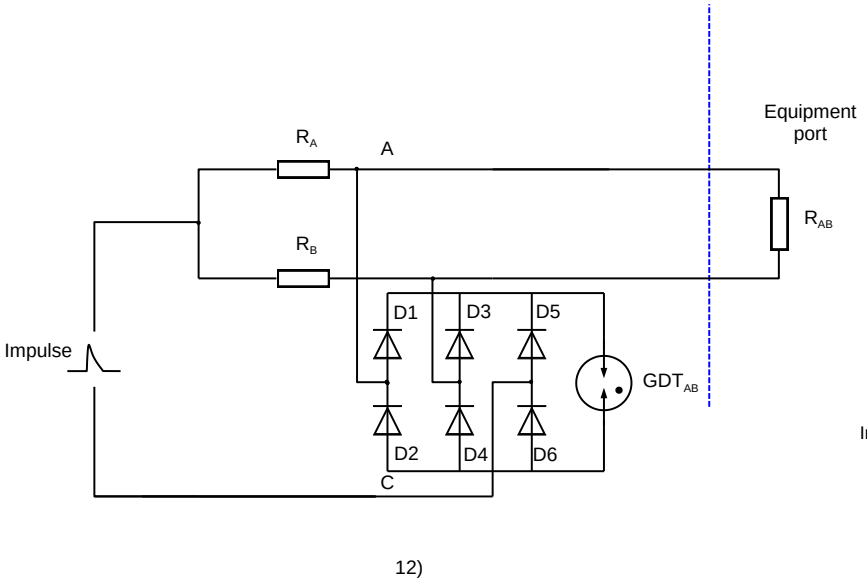




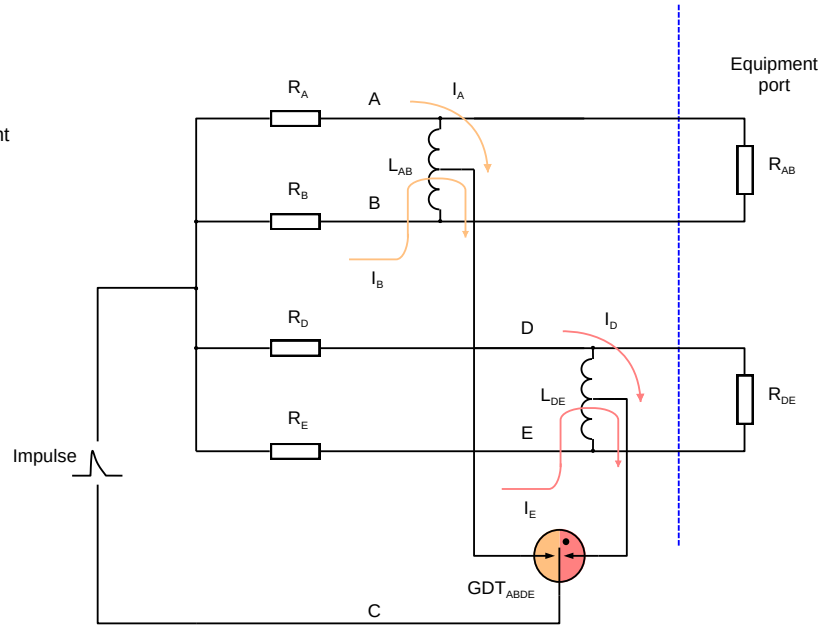


- Differential port voltage (cyan line, difference between electrode voltages) and surge current (yellow line) for generator voltages of 600 V, 1.5 kV, 2.5 kV and 6 kV.
- Nominal GDT sparkover 1.1 kV.
- Graphics created by Tatjana Gazivoda-Nikolic and kindly supplied by Bourns Inc.

Unexpected consequences – Gas Discharge Tubes 4



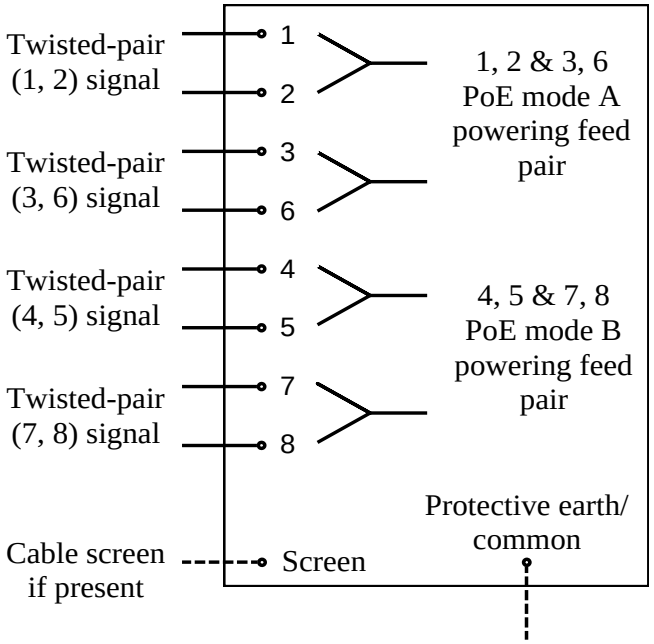
12)



Many simultaneous voltage limiting circuit solutions are available. The above two diagrams show circuits using a multi-phase diode bridge and centre-tapped choke approaches.

General - Port connections

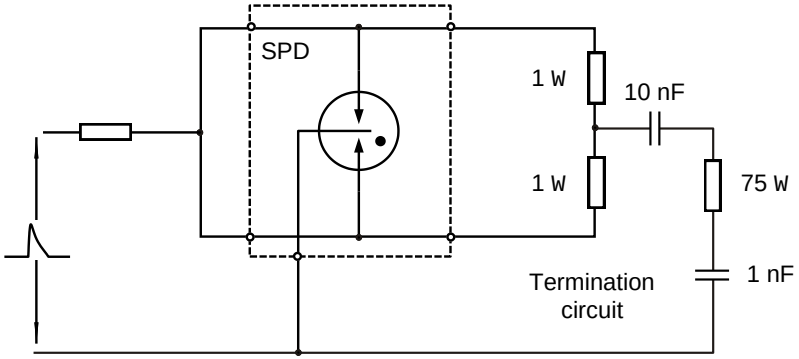
- An SPD performance specification should comprehend the connector capability and not just the internal component capability.
- A hard-wire connector may be required when the RJ45 contact currents exceed 1 kA or voltages between adjacent contacts will exceed 4 kV.



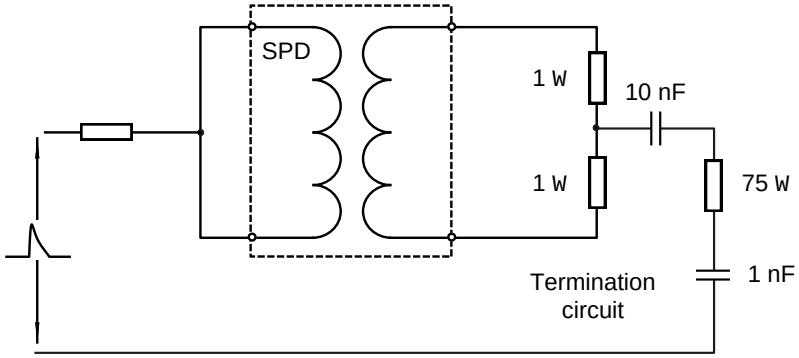
Ethernet RJ45 contact connections

General - Protective function

A generic Ethernet SPD performance specification should try to be technology neutral on the surge protective components (SPCs) used in the SPD.

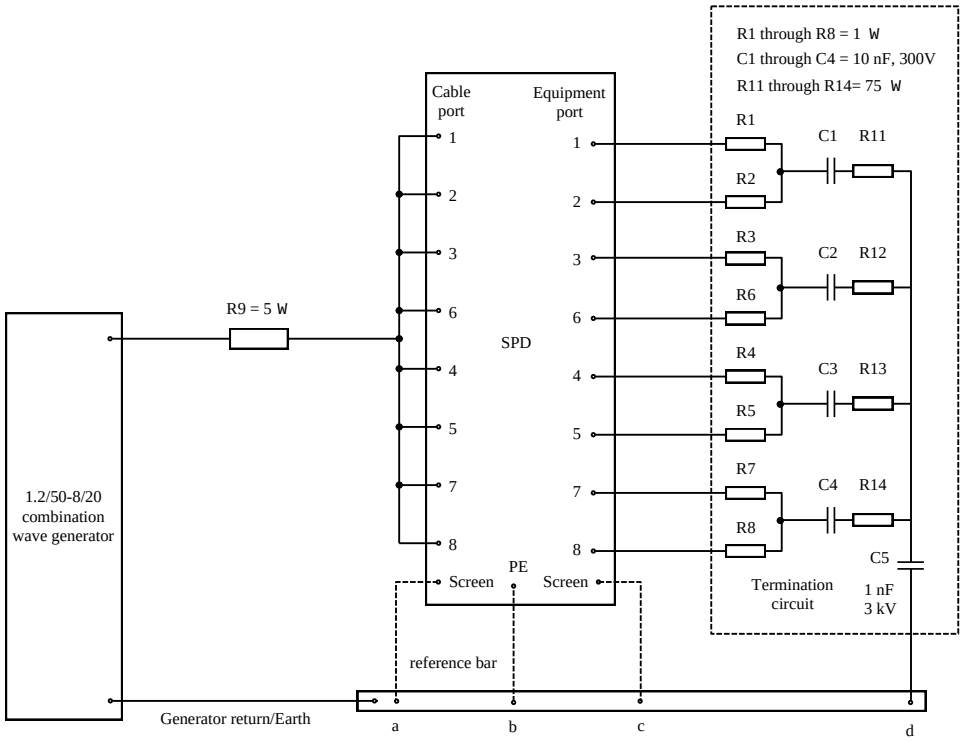


GDT common-mode voltage limiting (partial circuit for only one twisted pair)



Isolating transformer common-mode voltage blocking (partial circuit for only one twisted pair)

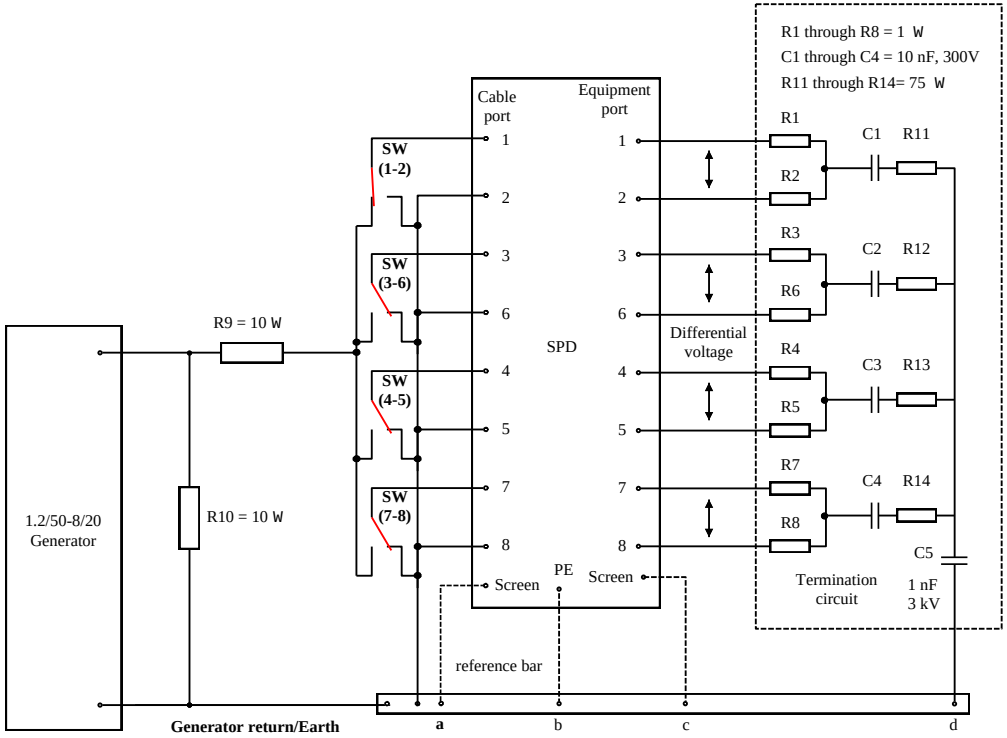
Surge tests - Common-mode



- Common source for maximum stress on breakdown paths
- Simulated Equipment port
- Voltage limiting and isolation technologies covered
- DC tested after impulses

Generator charge voltage kV	Maximum equipment impulse limiting voltage kV
2.5	1.0
6	1.5
12	2.0
Manufacturer defined	Manufacturer defined

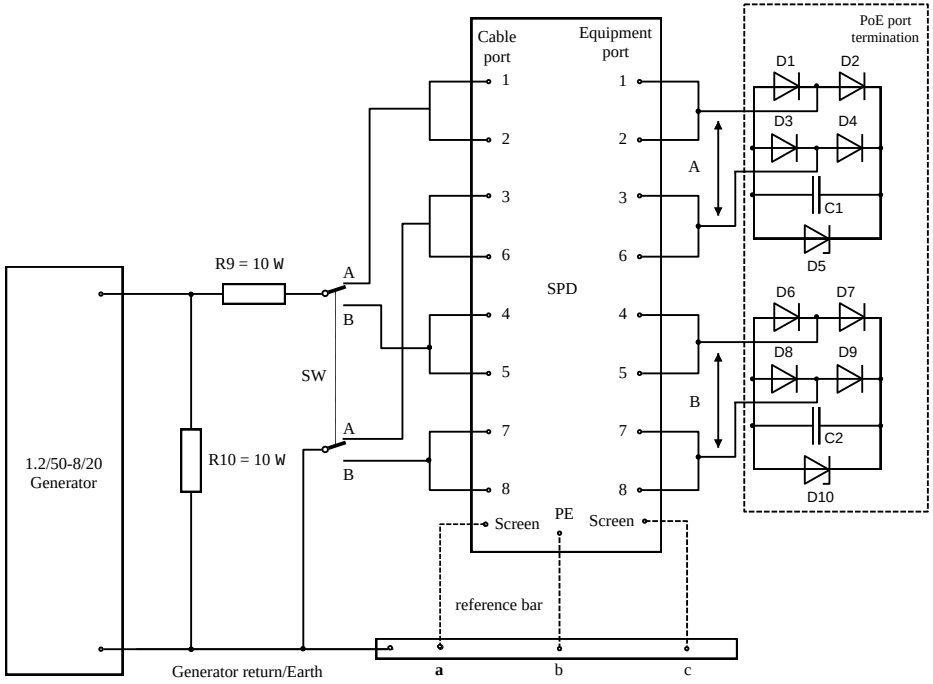
Surge tests - Differential-mode single pair



- Individual twisted pair tests
- Simulated Equipment port
- Simulated generator current division
- DC tested after impulses

Generator charge voltage kV	Preferred measured values for 1-2, 3-6, 4-5 & 7-8	
	Termination peak voltage V	Termination peak current A
2.5	100	50
6	200	100
12	300	150
Manufacturer defined	Manufacturer defined	Manufacturer defined

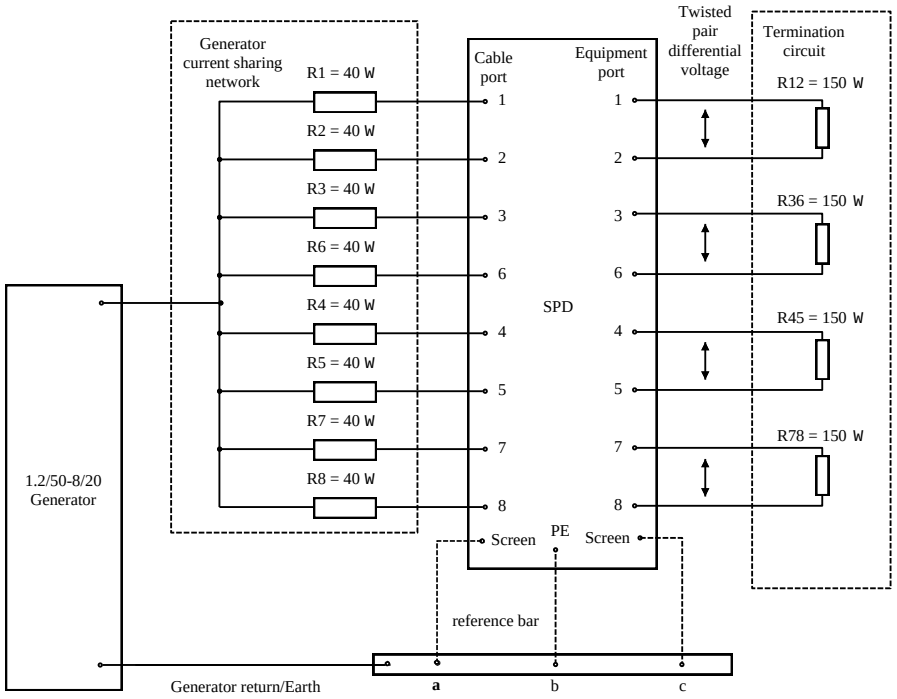
Surge tests - Differential-mode PoE pairs



- Individual PoE pair tests
- Simulated Equipment port
- Simulated generator current division
- DC tested after impulses

Generator charge voltage kV	Preferred Peak mode A or mode B termination voltage V
2.5	90
6	95
12	100
Manufacturer defined	Manufacturer defined

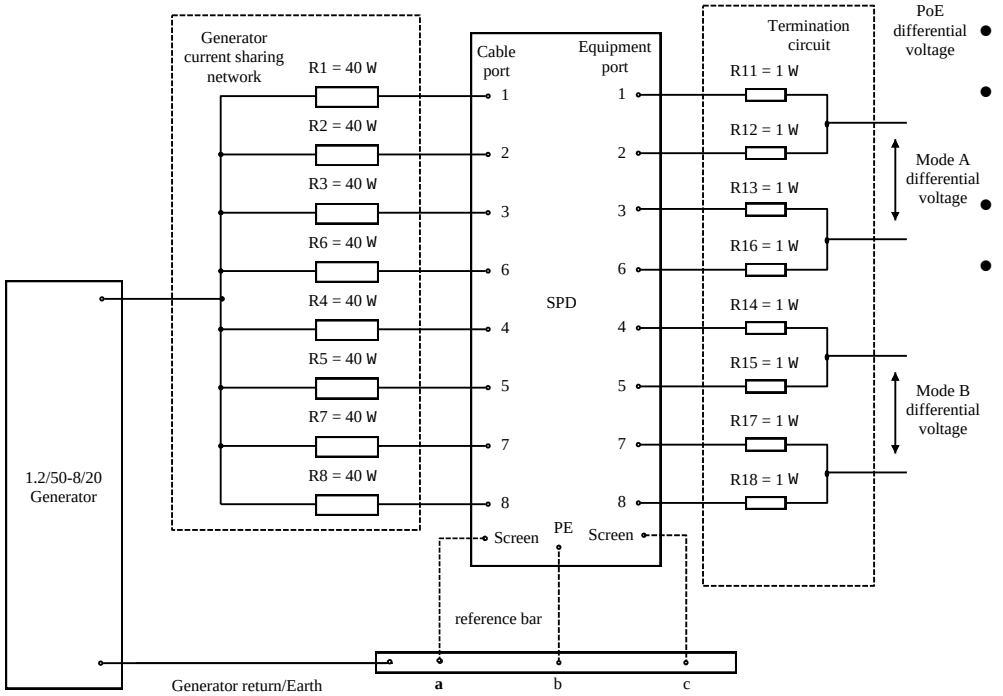
Surge tests - Common-mode to differential-mode conversion – single pair



- Individual twisted pair measurements
- High impedance equipment port to measure source voltage
- Equalised generator current division
- DC tested after impulses

Generator charge voltage kV	Preferred values of differential voltage V
2.5	100
6	200
12	300
Manufacturer defined	Manufacturer defined

Surge tests - Common-mode to differential-mode conversion – PoE pairs



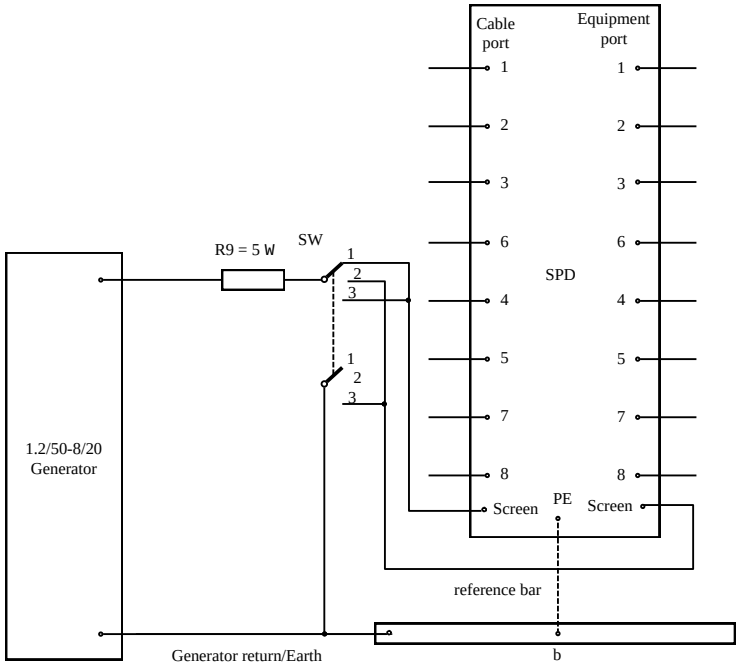
- Individual twisted pair measurements
- High impedance equipment port to measure source voltage
- Equalised generator current division
- DC tested after impulses

Generator charge voltage kV	Preferred values of differential voltage V
2.5	90
6	95
12	100
Manufacturer defined	Manufacturer defined

Surge tests - Durability

- Little attention is given to impulse durability rather than big number single impulse ratings
- Over life SPDs may experience many thousands of surges not just one big one
- Further depending on the technology the single and multi-impulse ratings maybe the same (silicon junction) or require major rating reduction due to wear-out (MOVs)
- It makes sense to know what the SPD 100 impulse or more impulse rating is

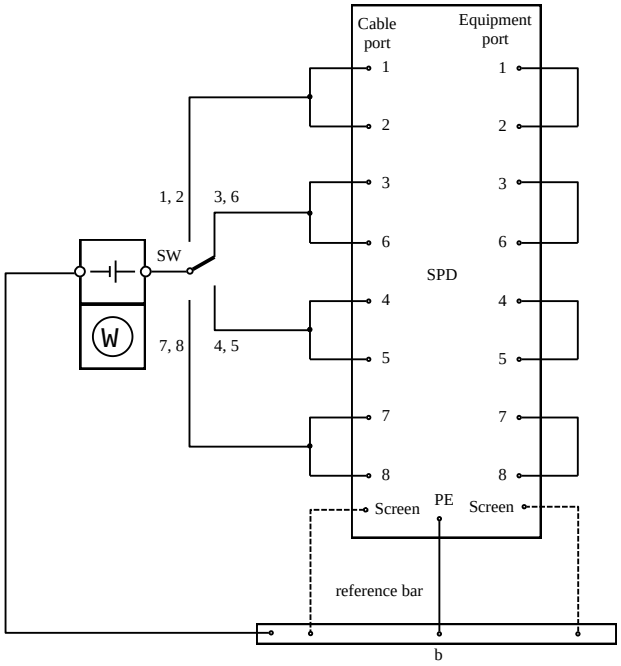
Surge tests - Cable screen terminal



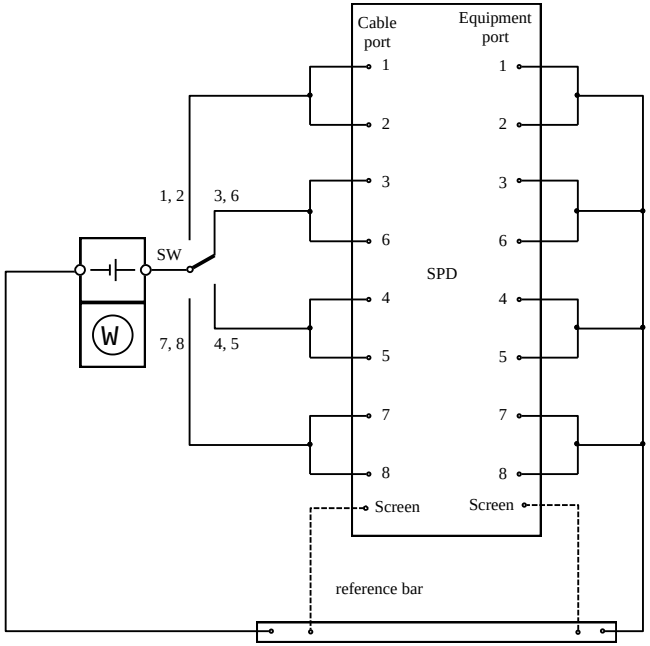
- Values based on IEC 60603-7-7
- SW position 1 checks cable port screen terminal to protective earth (PE) terminal bonding
- SW position 2 checks equipment port screen terminal to protective earth (PE) terminal bonding
- SW position 3 checks cable port screen terminal to the equipment port screen terminal.

Generator charge voltage kV	Maximum screen to PE voltage, SW positions 1 & 2 V	Maximum screen to screen voltage, SW position 3 V
2.5	40	80
6	90	180
12	180	360
Manufacturer defined	Manufacturer defined	Manufacturer defined

DC tests - Insulation resistance 500 V >2 MΩ

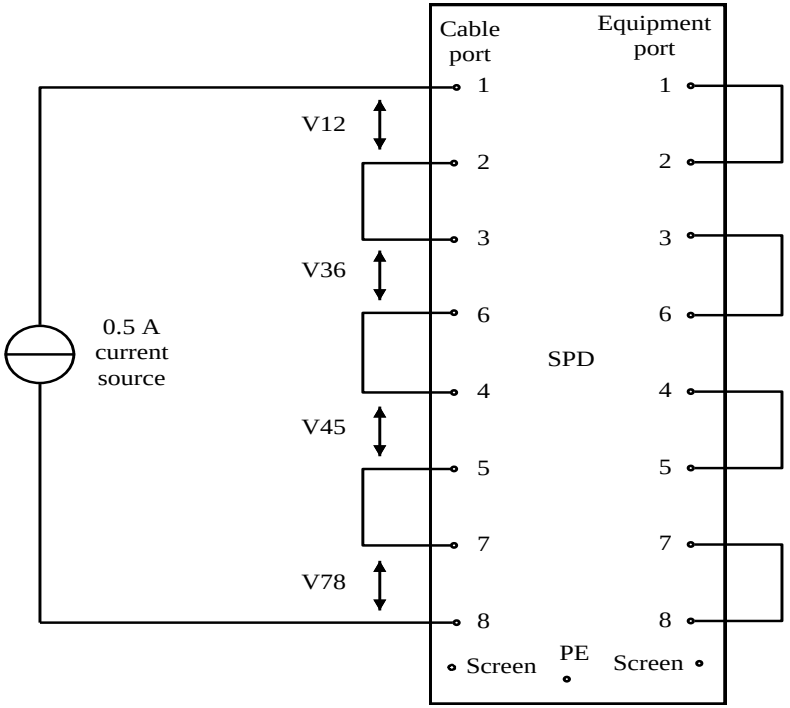


Voltage limiting SPD



Isolating transformer SPD

DC tests - Voltage drop



- Important for PoE
- Preferred value < 0.5 V
- Then total d.c. power feed mode A or B series resistance of the SPD < 0.5 Ω

References 1 of 3

Ethernet differential surge testing - di/dt
Differential surge stress reduction by Ethernet magnetics
Surges and their mitigation
Modes of PROTECTION and SURGE
Voltages and currents in Ethernet cables due to lightning strokes
ETHERNET port surge testing – Test levels and configurations
Ethernet Surge Protective Device (SPD) design considerations
Recommendation ITU-T K.117 : Primary protector parameters for the surge protection of equipment Ethernet ports

References 2 of 3

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CD currently available of all 1999-2012 papers

ATIS PEG Conference 1999 Papers
10Base-T Surge Protection: Nisar Chaudhry
ATIS PEG Conference 2007 Papers
Power Over Ethernet (POE) – What is it? How to Protect it?: Mick Maytum
ATIS PEG Conference 2008 Papers
Ethernet Protection (Once it has Left the Building; Inside the Cell Site): Nisar Chaudhry
ATIS PEG Conference 2009 Papers
Electrical Protection Considerations for the Deployment of Ethernet Services in the Outside Plant: Larry Payne
ATIS PEG Conference 2010 Papers
Evolving Ethernet Applications and Protection: Jim Wiese
Ethernet Protection: Nisar Chaudhry
ATIS PEG Conference 2011 Papers
A Comparison of Various Ethernet Protection Solutions: Ben Huang
Lightning Damage of the Home Network Ports: Mick Maytum
IEEE Std. 802.3 Ethernet ports — Types, Surge Capability and Applications: Mick Maytum
ATIS PEG Conference 2012 Papers
ONT Damage: Jim Wiese

References 3 of 3

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Currently downloadable at the PEG Library

ATIS PEG Conference 2013 Papers
Ground or Not to Ground Ethernet Protection, Part 2: Nisar Chaudhry
Optical Network Terminations (ONTs): Lightning Damage and Standards – What's the Latest Information?: Jim Weise
The Ethernet Port Maze, Part 1: Michael (Mick) Maytum
The Ethernet Port Maze, Part 2: Michael (Mick) Maytum
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Ethernet Protection-Latest Standards Work: Jim Wiese
GbE Port Protection in Exposed Environments: Len Stencel
ATIS PEG Conference 2015 Papers
Power Over Ethernet (PoE) Part 1- What Is It, How It Is Used, and Lightning Field Failure Analysis: Jim Wiese
Power Over Ethernet (PoE) Part 2 – Protecting PoE Against Intra-Building and OSP Environments: Tim Ardley
Latest ITU-T Surge Protection K Recommendations: Michael "Mick" Maytum
Direct Lightning Strike Surge Propagation in Customer Premises Wiring: Michael "Mick" Maytum
Lightning Surge Damage to Ethernet and POTS Ports Connected to Inside Wiring: Joe Randolph
ATIS PEG Conference 2016 Papers
Protecting PoE PSE and Ethernet to the Latest International OSP Standards: Tim Ardley