Electrical Protection of 24 & 48 VDC Battery Strings and DC Plant Distribution Circuits

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Overview

- Telecom Battery Disconnects
  - Pros and Cons of Battery Disconnects in Telecom DC Plants
    - Single Point of Failure
      - Not Generally Used on Flooded
    - VRLA Maintenance
  - Disconnects vs. Protectors
    - Dual Power Source Problem
    - Reverse Polarity Protection?
    - Commercially Available Disconnects and Protectors
  - Proper Sizing
    - 125% of Maximum Recharge/Discharge Current
      - How to Predict the Maximum?
      - Special Case for UPS Disconnects (Hi-Rate Higher Voltages)
    - Short Circuit Ratings
- DC Circuit Surge Protection
  - Why?
    - Circuits Leaving the Building/Hut/Cabinet
  - Clamping Voltage Choices
  - Types of 48/24 VDC Protectors Commercially Available
  - Special Case of PoE Leaving the Building/Hut/Cabinet

Flooded Batteries w/o Disconnects

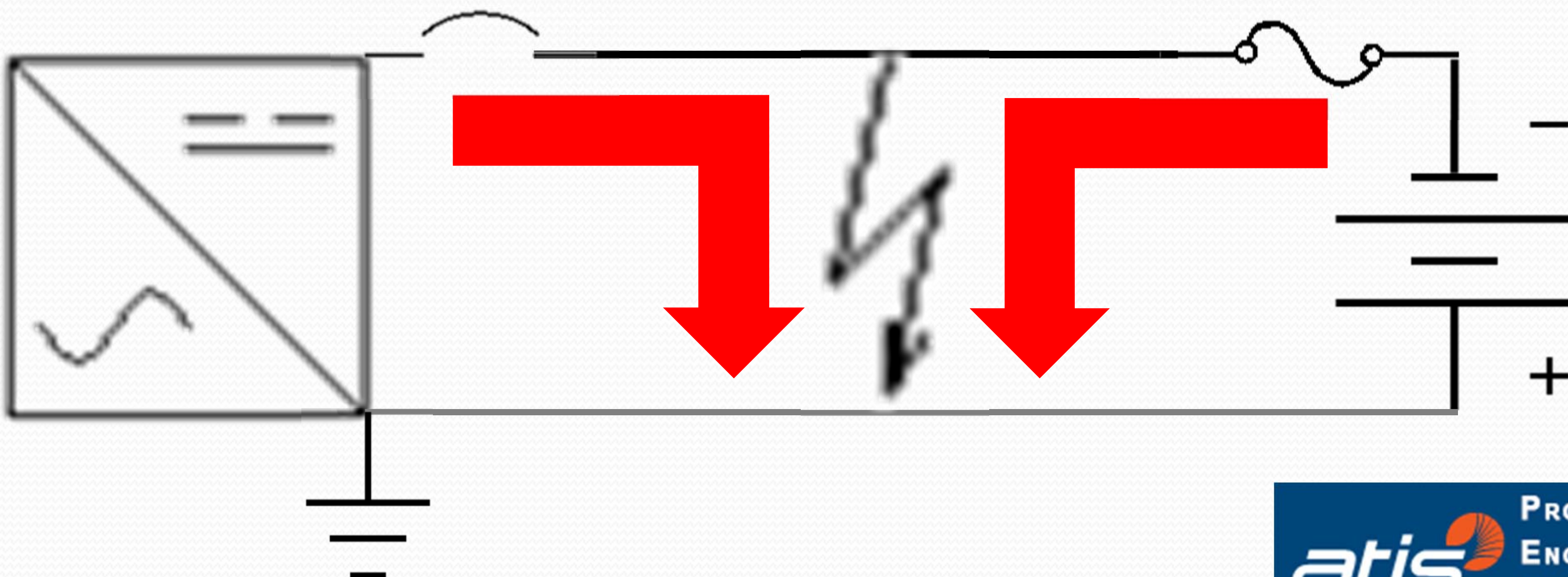
- Increases Reliability by Not Having a Failure Point
- Can Get Away With It Because Hot Connections Typically Only Have to Be Made/Removed Every 20 Yrs or So
- May Be Required in Buildings Not Owned by Telco by AHJ
  - May Be Required in Raised Floor Environments for EPO Switch

VRLA Batteries W/Disconnects

- Much Less Reliable than Flooded, So Replacements Are More Frequent
- Ohmic Test Readings Are More Accurate if Disconnected

Disconnects or Protectors?

- Dual Power Source Problem for Protection Theoretically Requires Protection at Both Ends
  - I've Never Seen This Done (Dual Protection)



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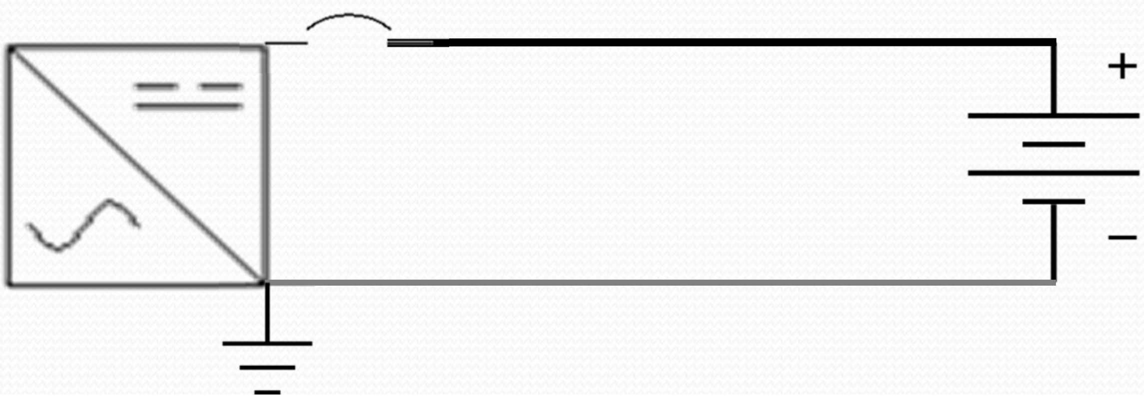
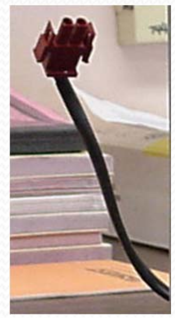
Reverse Polarity Protection

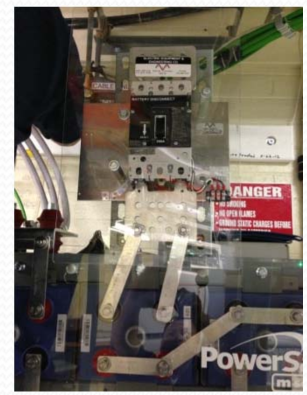
- Dual Source Problem Would Seem to Favor a Disconnect vs. a Protector If You're Only Putting One Disconnect/Protector In?
- However A Single Protector Can Protect Against Reverse Polarity Hookup
  - This is a Problem Sometimes in RTs and Prems
  - Breakers Can Double As Disconnects and Protectors



Examples of Commercially Available Disconnects and Protectors

- Anderson Disconnects
- AMP/SLC Connectors
- EEE Battery Disconnects
- Small Breakers
- Pull-Out Fuses
- Fused Switches





How Do You Size The Disconnect?

- Simplifying the NEC Rule, Take 125% Minimum of Worst-Case Discharge or Recharge Current
  - What About Failed Parallel Strings Increasing That Current?
  - Take Into Account that Initially, Until Load Grows, the Recharge Currents for OverRectified Plants can be very High

Example Calculation Assumptions

- -48 VDC Plant with 1068 A Float Load at -54.48 V
- 5 Strings 1520 Ah VRLA Batteries Sized to 1.86 mvpc
- Fourteen 200 A Rectifiers

Worst-Case Discharge Current

- Constant Power Loads Cause Increasing Current During Discharge
  - End Voltage = 24 cells x 1.86 mvpc = 44.64 V
  - End-Of-Discharge Load = 1068 x (54.48 ÷ 44.64) = 1303 A
- Discharge Current/String = 1303 ÷ 5 = 261 A

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Worst-Case Charge Current

- During Recharge, All Rectifiers Will Come On Full Bore
  - While They Will Start to Back Off Once the Voltage Approaches Float, For Worst-Case Recharge Current Calculation, We Can Assume Float Load
- Worst Recharge Current = (14 x 200) – 1068 = 1732 A
- Recharge Current/String = 1732 ÷ 5 = 346 A

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Minimum Disconnect Sizing

- Recharge Current > Discharge Current in This Example
- 125 % x 346 A = 433 A
- Upsizing to Next Common Size of Disconnect Means 450 A or 500 A Disconnect
  - May Want to Go Larger To Ensure Breaker Doesn't Trip if One String Off-Line for Replacement/Maintenance, Etc.

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UPS Battery Disconnect Sizing Needs?

- While 48 and 24 VDC Plants Predominate, with the Merging of Telecom and IT, We Are Seeing More UPS and Potentially 380 VDC Plants in the Future
  - These Typically Use High-Rate Batteries
    - The Chargers Are Too Small To Need To Consider Recharge Current, So Only Discharge Current is Used in the Sizing
  - UPS Designed with Monobloc Cabinets Already Have Built-In Pre-Sized Battery Disconnects
    - If We Use Larger Individual Cell Batteries (Flooded May Be Monobloc, but Have Accessible Posts to Individual Cells), We May Have to Size the Disconnects

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UPS Battery Disconnect Formulas

- 125% of $I_{\max}$
- $$I_{\max} = \frac{R_{VA}}{(mvpc \times n_{c/s} \times \eta)}$$
  - $I_{\max}$ is the Current That Will Be Drawn From a Fully-Loaded UPS Battery String at Minimum Inverter Voltage
  - R_{VA} is the Rating of the UPS in Volt-Amps (most Units are Rated in kVA, so You Must Multiply the kVA Rating by 1000 to Get VA)
  - $mvpc$ is the Minimum Volts Per Cell Design Rating for the Battery, Based On the Inverter Minimum Operating Voltage and the Number of Cells per String; although Typically 1.67 V/cell is Used for most UPS
  - $n_{c/s}$ is the Number of Cells per String (Typically 180 or 240 For Medium-Large UPS); Noting that Monoblocs Have Multiple Cells Per Jar (For Example Forty 12 V Monoblocs is 240 Cells/String, Since There are 6 Cells in a Lead-Acid 12 V Monobloc
  - η is the Inverter DC-AC Conversion Efficiency, Typically at Least 0.95 (95%) For Modern UPS Inverters

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UPS Battery Breaker Size Example

- UPS Specs
  - 350 kVA UPS
  - Approximate 540 VDC Bus (240 Cells/String)
  - 2 Strings Hi-Gravity 6 V Flooded Jars Approx. 800 W/cell
    - Assume 1 String Being Maintained When Sizing Disconnect
  - Inverter Minimum Operating Voltage of 400 (1.67/Cell)
  - Inverter Efficiency of 97% at Full Load
- $$I_{\max} = \frac{350{,}000}{(1.67 \times 240 \times 0.97)} = 900A$$
- 125 % x I_{max} = 1125 A => 1200 A Breaker

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Watch IEC 61439 Short Circuit Test

- YouTube Video Showing Effects of Short Circuit Currents that Exceed the k.A.I.C. Ratings of the Devices

Battery Short Circuit Currents

- Battery Short Circuit Currents Are Very High (Often Over the 10 kA of Typical Breakers)
- Short Circuit Currents Available From Battery Mfg
  - Sometimes on the Data Sheet, Sometimes Requires Call
  - Can Be Estimated As:
    - 7 x the 8-h 1.75 V Ah Rating for Long Duration Flooded & 2 V VRLA
    - 5 x the 15-min 1.67 V W/cell Rating for UPS Flooded
    - 35 x the Ah Rating for VRLA Long-Duration Monobloc
    - 10 x the 15-min 1.67 V W/cell Rating for UPS Monobloc
- Actual Short Circuit Current At Fault Will Be Less Due to Intercell Connector and Cable Impedances, But Plan for Published Mfg Worst Case

Protector k.A.I.C. Ratings

- DC-Rated Fuses Typically 100,000 A
- Breakers Typically 10, 22, 42 and 65 k.A.I.C.
  - DC Breakers at Higher Voltages (Such as for 405 or 540 VDC UPS Buses or 380 VDC Systems) Are Much Larger Than AC Breakers of Equivalent Ampere Rating Because DC Has No Zero Crossing 120 Times/Second, So it is Much Harder to Break the Arc
    - Breaking a Fuse DC Arc is Simpler Due To Sand in the Fuse

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Why/When do DC Circuits Need SPDs?

- All Copper/Entering Leaving a Building or Electronics Cabinet Historically Has Had Surge Protection
  - TVSS for AC
  - 5-pin Protectors for Twisted Pairs
  - Coax Arrestors for GPS Sync
- Historically DC Never Left the Building / Cabinet
  - It Sometimes Does Now!
    - RRH
    - PoE
    - Backhaul Provider Powering

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Clamping Voltage(s) for DC SPDs

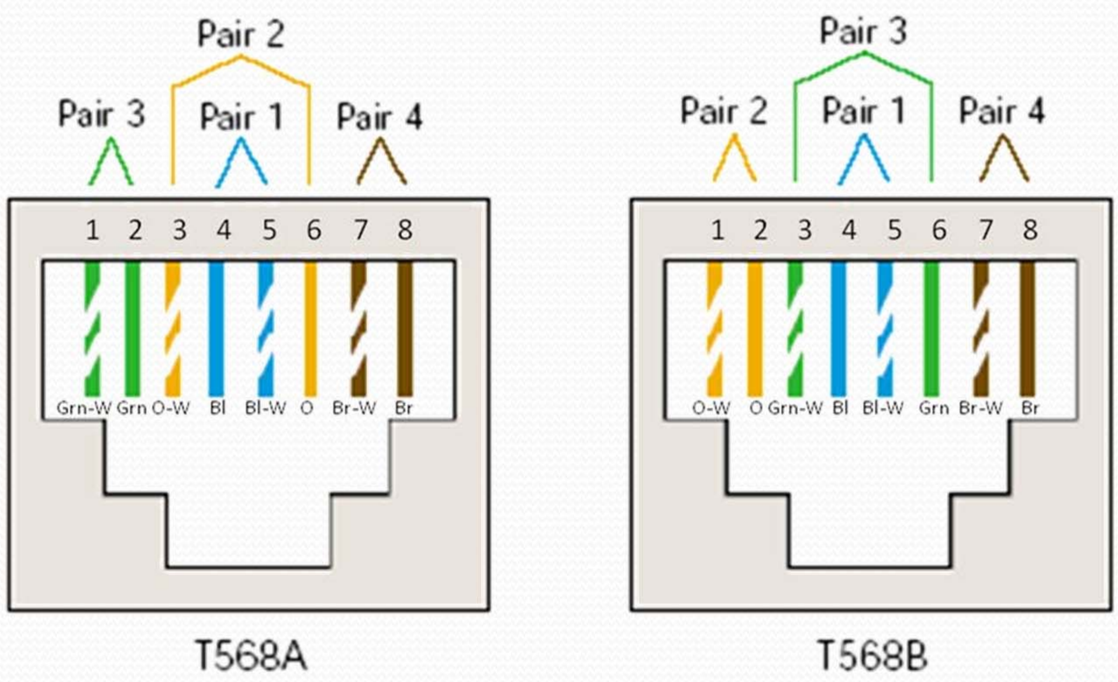
- Choose it Pretty Close to DC Plant Voltages
  - 60-90 V DC for Nominal -48 VDC Plant (Which Normally Operates from -52.08 to -55.2 V)
    - NEBS GR-1089 Pulls from ATIS-0600315, Which Allows Momentary (50 μs) Transients from 75-100 V, and < 10 ms Transients from 62.5 – 75 VDC
  - 30-45VDC for Nominal 24 VDC Plant (Which Normally Operates from 26.4 to 27.25 V)
    - ATIS-0600315 Has Not Yet Recommended Transient Testing/Levels for Nominal 24 VDC-Powered Equipment
  - Too High of a Clamping Voltage Will Allow Damage to All the Other Electronics Connected to the DC Plant
  - Highly Capacitive Nature of Batteries on DC Plants with them Prevents Most Initial Surges From Being Very Large

Commercially Available DC Circuit SPDs

- Lower-Current (e.g., 5-20 A) SAD and/or MOV Series Arrestors
- Higher Current SAD and/or MOV Parallel Arrestors
- Large MOVs

Ethernet Pinouts and Pairs

- T568B for Straight-Through Ethernet
- T568B to T568A for Cross-Over Ethernet

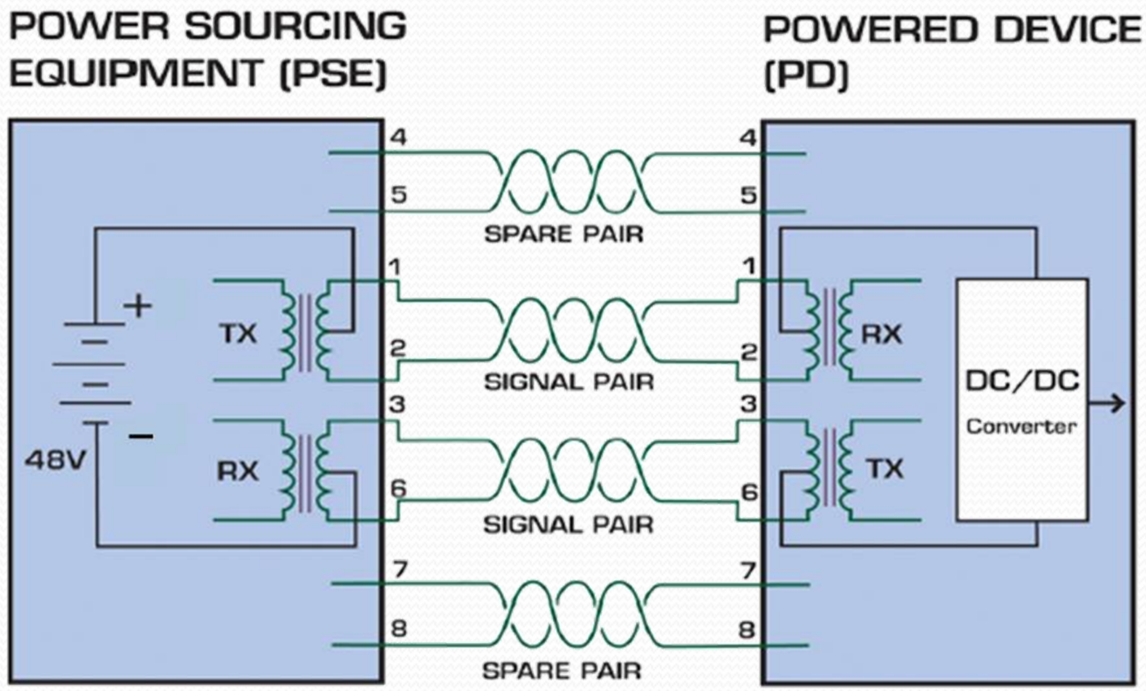


Types of PoE

- PoE (IEEE 802.3af)
  - 15 W Source max at Nominal 48 V (57 VDC max) up to 100 m on Cat 3 or Cat 5 Cable Using Either the Data Pairs 2 and 3 (Mode A) or the Spare Pairs 1 and 4 (Mode B)
    - Some Lower Power PoE Applications Use Nominal 24 V
- PoE+ (IEEE 802.3at)
  - 30 W on Cat 6 or Cat 7 Cable (and Sometimes on Cat 5e Dependent on Wire Gauge and Distance)
- PoE++ (Presently some Proprietary Schemes [UPoE, LTPoE++, etc.], But IEEE 802.3bt Will Standardize in 2016)
  - Will Be 60 or 90 W Using All 4 Pairs

Mode A PoE and PoE+

- Polarity May be Reversed From What is Shown



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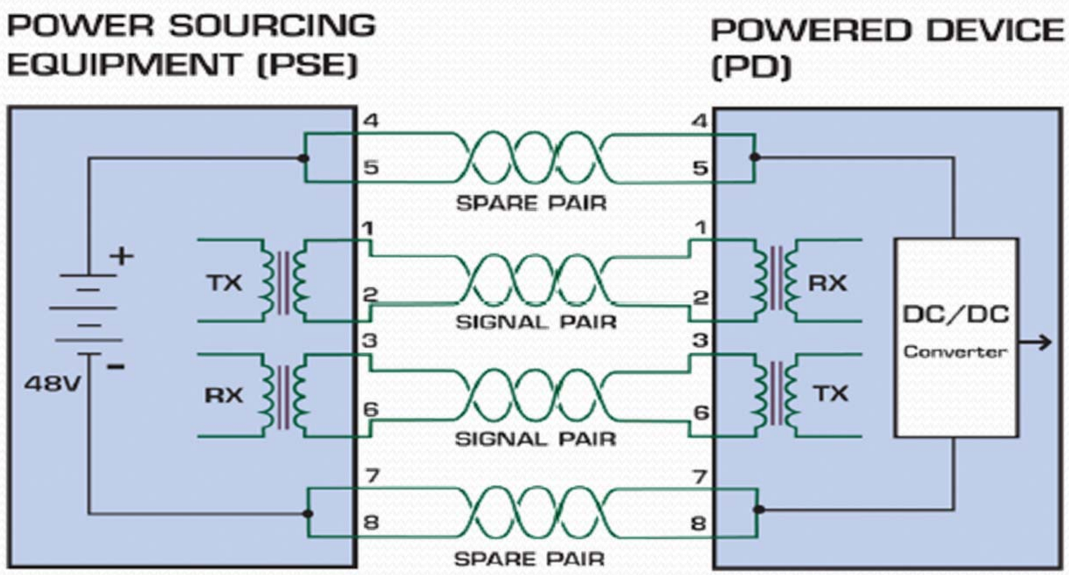
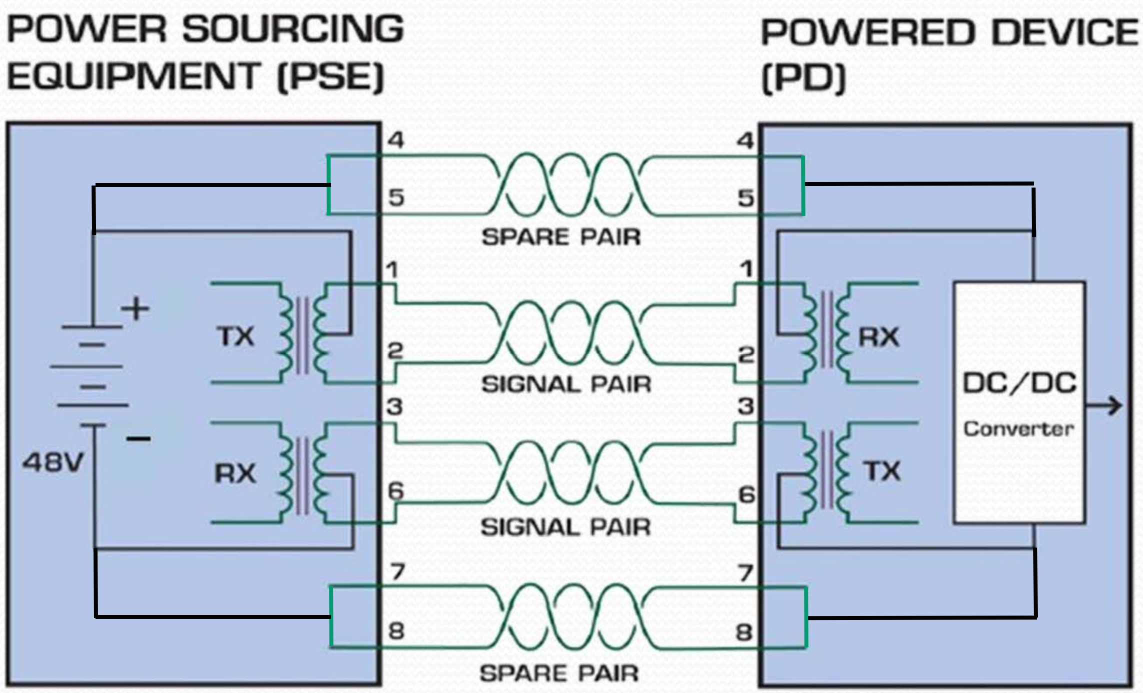
Mode B PoE and PoE+

- Note That Spare Pairs May Also be Transformer-Isolated
  - In Which Case the Power Connections Would Be on The Secondary Side of the PSE End Transformers, and the Primary Side of the PD End Transformers



PoE++

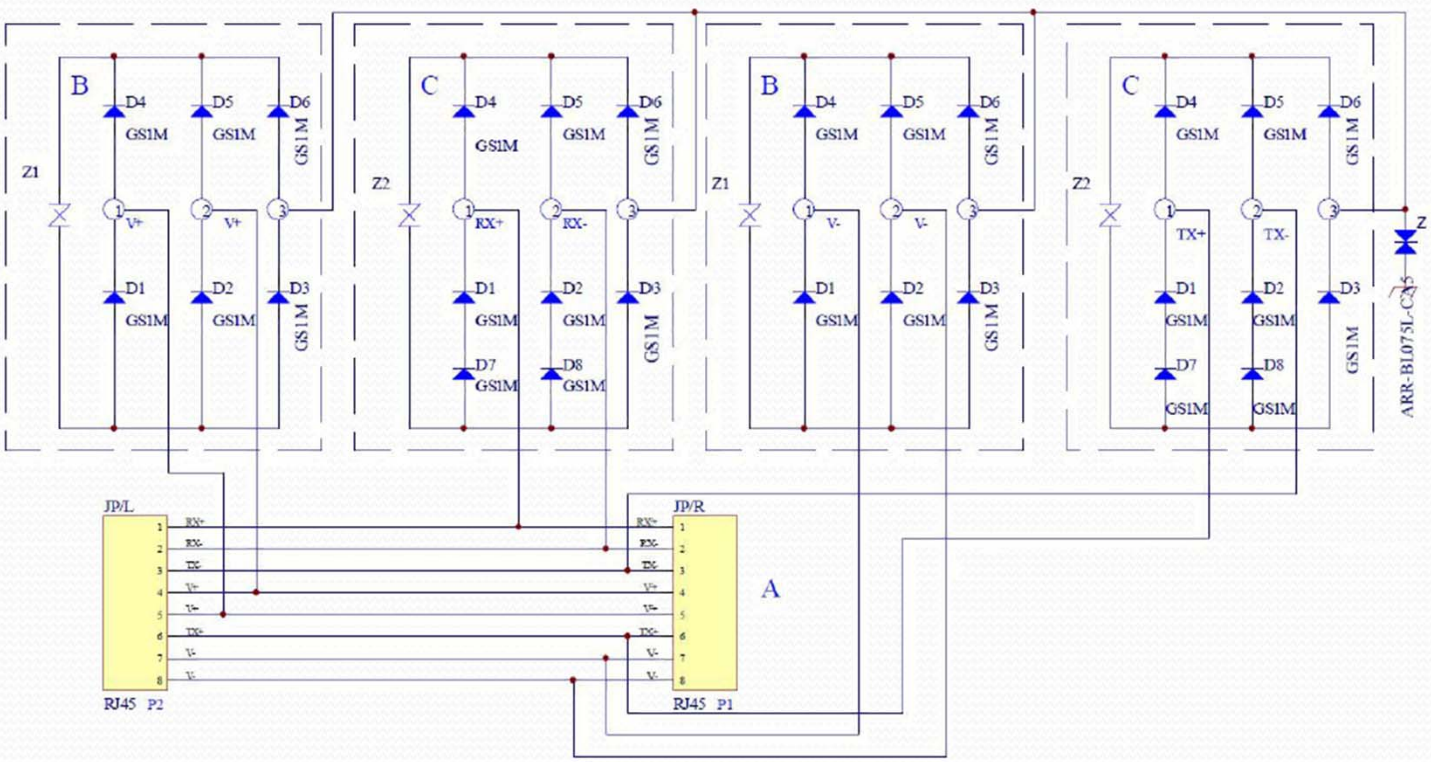


POWER SOURCING EQUIPMENT (PSE)
POWERED DEVICE (PD)
4
5
SPARE PAIR
1
2
SIGNAL PAIR
3
6
SIGNAL PAIR
7
8
SPARE PAIR
+
−
48V
TX
RX
RX
TX
DC/DC
Converter

PoE Power Pairs Protection

- Similar to Other 48 V Devices, Protect Power Pairs on Spare Pairs With 60-90 VDC Clamping Devices
  - Half the Voltage For Devices Designed for 24 V PoE
- If Mode B PoE or PoE+, Data Pairs Can Be Protected At a Lower Voltage
  - e.g., 6-13 V?
  - Can't Protect Data Pairs At Lower Voltage When There is Both Power and Data on Same Pairs?
    - PoE or PoE+ Mode A, or Pairs 2 and 3 of PoE++

Schematic of Sample PoE Protector



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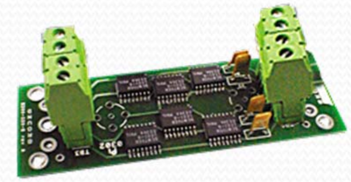
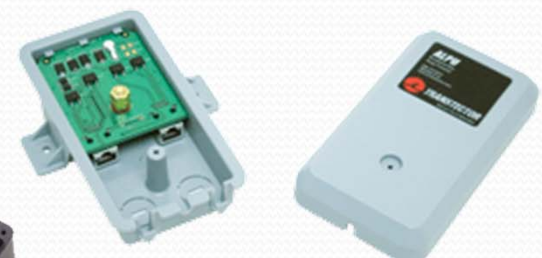
Commercially-Available PoE Protectors


- Some Have RJ-45 Ports and Some Don't
  - Those That Don't Probably Can't Be Used For Much Distance at Higher Data Rates (e.g., GigE or 10GigE) Because of the Untwisting Needed to Terminate
- Some Can Mount Outdoors







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