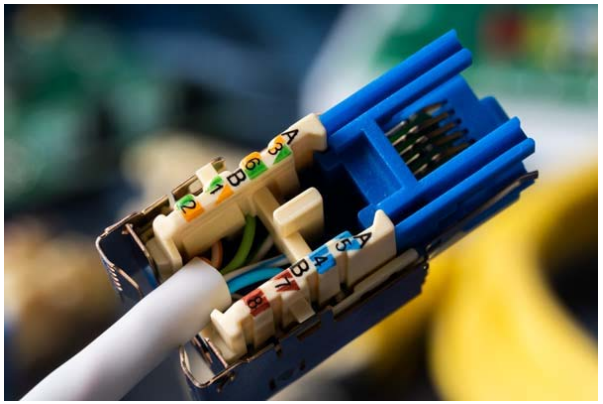
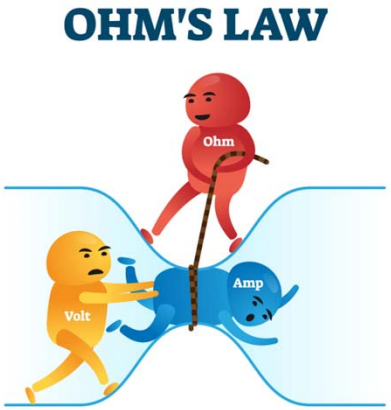
DCRU Measurement and Certification Testing for TIA 568.2-E





- **Tom Jallo RCDD**
- tom.jallo@softing.com

Why is Certification testing relevant ?

- ***Certification – guarantees cabling system compliance to industry standards***
  Certification instruments are the only tools that provide “Pass” or “Fail” information in accordance with industry standards. In the North America market, the prevalent industry standards organization dealing with the transmission capabilities of structured cabling, is the Telecommunications Industry Association (TIA). In the international markets, the Electro-technical commission of the International Organization for Standards (ISO/IEC) creates and maintains standards for telecommunication cabling.
- Certification test tools determine whether a link is compliant with a category (TIA) or class (ISO); for example, category 6 or class E. Certification is the final step required by many structured cabling manufacturers to grant their warranties for a new cabling installation but increasingly in moves add and changes or network upgrade instances.

Cable Certification to TIA Standards

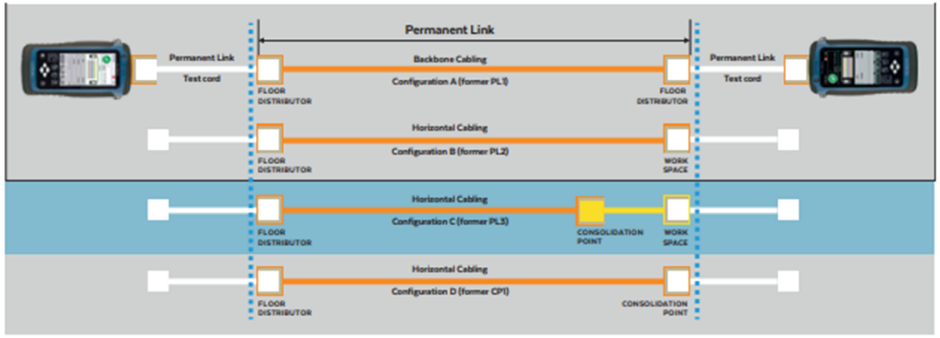


Figure 13b: Permanent link measurements according to ANSI/TIA 568.2.D; *Source: Softing IT Networks*

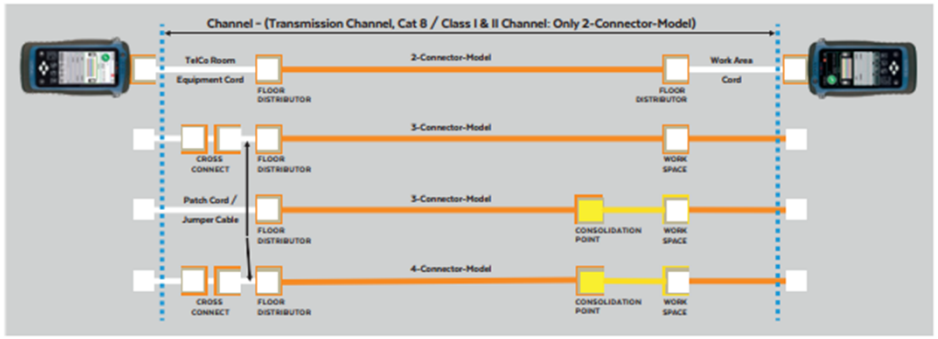
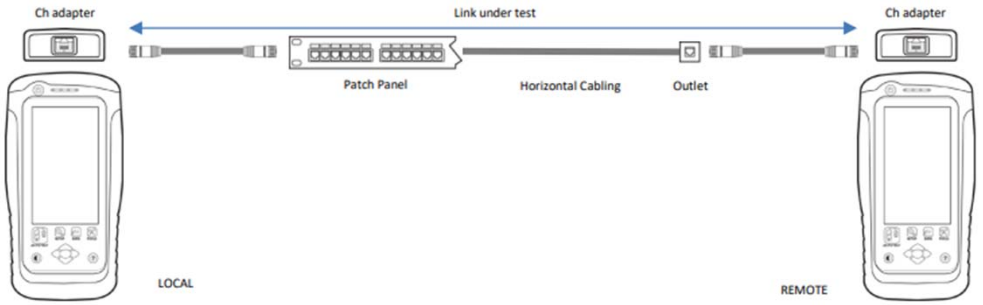
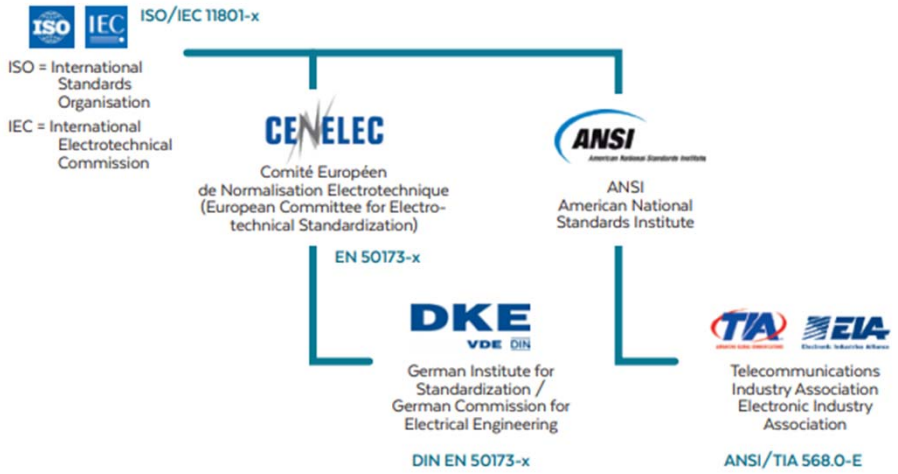


Figure 14: Channel (Transmission channel) measurement, Cross Connect – opt. additional distribution field i.e., in the Data Center; *Source: Softing IT Networks*



ANSI TIA 1152-A details

- ANSI/TIA-1152-A standard, published in November 2016 by the Telecommunications Industry Association (TIA), specifies requirements for field test instruments and measurements used to verify the performance of balanced twisted-pair cabling as defined in the ANSI/TIA-568 series of structured cabling standards



AN

Measurement parameters on cabling sections

- Wiring and shielding (Wiremap, Shield)
- Direct current resistance of the wire pairs (DC Resistance)
- Delay and delay difference (Delay and Delay Skew)
- Length of the measurement, informative for ISO/IEC 11801 & EN 50173-1, normative for ANSI/TIA 568.0-E

and the high-frequency measurements such as

- Attenuation of the wire pairs (Insertion Loss)
- Crosstalk attenuation between the wire pairs (NEXT Loss)
- Return Loss of the wire pairs
- Crosstalk of the wire pairs at the far end (FEXT Loss)

From this, further parameters are then calculated such as

- Attenuation to crosstalk ratio at near end (ACR-N) (not used in ANSI/TIA 568.2-D)
- Attenuation to crosstalk ratio at the far end (ACR-F – formerly known as ELFEXT)
- Power sum of the crosstalk attenuation (PSNEXT)
- Power sum of the attenuation to crosstalk ratio at the near end (PSACR-N)
- Power sum of the attenuation to crosstalk ratio at the far end (PSACR-F)

ANSI TIA 1152-A Key Testing Requirements 1

•**Wiremap (including shield connection, if present)**:

•Verifies correct pin assignments and continuity of each conductor, including the shield for shielded cables.

•Ensures proper connectivity from one end of the cable to the other.

•**Insertion Loss**:

•Measures signal power loss from the start to the end of the cabling, reported in decibels (dB).

•Assesses the cable's ability to transmit signals effectively.

•**Length**:

•Verifies the physical length of the cable installation to ensure it meets specified limits for the cabling category.

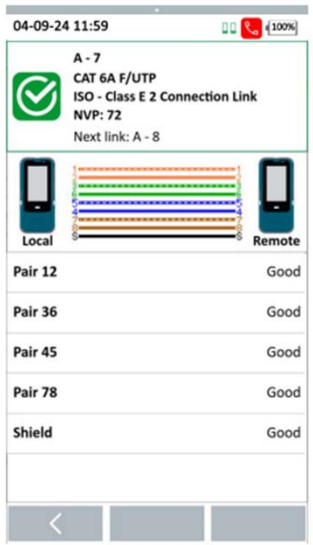
•**Propagation Delay**:

•Measures the time taken for a signal to travel from one end of the cabling to the other.

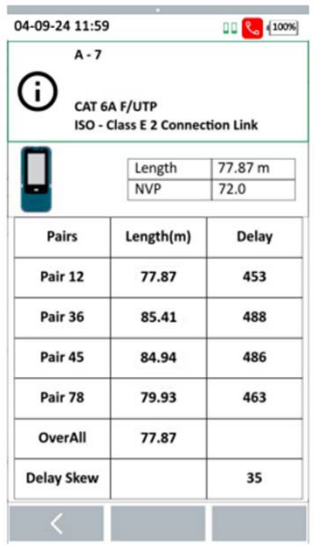
•**Delay Skew**:

•Calculates the difference in propagation delay between the four wire pairs, critical for high-speed applications.

- **DC Loop Resistance** assesses the cables ability to support basic PoE



Wiremap



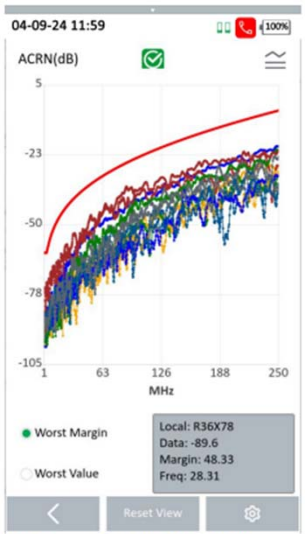
Length & Delay

DC Loop Resistance²

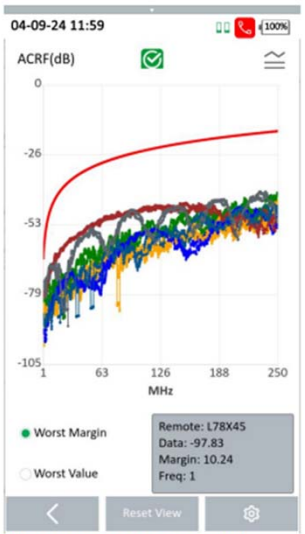
ANSI TIA 1152-A Key Testing Requirements 2

•**Near-End Crosstalk (NEXT) Loss (local and far end)**:
•Measures unwanted signal coupling between pairs at the near end of the cabling.
•NEXT is more significant in pairs with less twist, impacting signal quality.
•**Power-Sum Near-End Crosstalk (PSNEXT) Loss (local and far end)**:
•Evaluates cumulative crosstalk from multiple pairs at the ends of the cable due to their proximity.
•**Power Sum Attenuation to Crosstalk Ratio, Far End (PSACRF)**:
•Measures the difference (in dB) between the test signal and crosstalk from other pairs at the far end of the link.
•**Return Loss (local and far end)**:
•Measures signal reflections caused by impedance mismatches along the link, reported in dB.

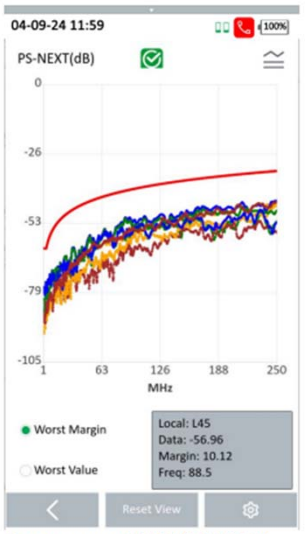
- **DC Resistance Unbalance (for Category 8)**: These are optional tests, though performance limits are specified. They assess the cabling's ability to support Power over Ethernet (PoE) applications (e.g., IEEE 802.3af, 802.3at, 802.3bt).
- Excessive resistance unbalance can disrupt data transmission and PoE functionality



[3] *Attenuation to Crosstalk Ratio (ACR-N)*



Attenuation to Crosstalk Ratio, Far-end (ACR-F)



Power-sum NEXT (PSNEXT)

6 Key Differences Between TIA-568.2-D and TIA-568.2-E

- 1. Publication and Status :
- - **TIA-568.2-D** : Published in 2018, this standard replaced TIA-568-C.2, consolidating requirements for balanced twisted-pair cabling (Categories 5e, 6, 6A, and 8) and introducing new configurations like Modular Plug Terminated Links (MPTL
- - **TIA-568.2-E** : Released on October 24, 2024, this standard revises TIA-568.2-D, incorporating updates, correcting errors, and aligning with modern networking demands. It became effective November 5, 2024

DC Resistance Unbalance (DCRU) Requirements

- 2. DC Resistance Unbalance (DCRU) Requirements**:
- - **TIA-568.2-D :** Introduced DC resistance unbalance specifications for Category 8 cabling, critical for Power over Ethernet (PoE) performance, but did not mandate DCRU testing for Categories 5e, 6, and 6A.
- - **TIA-568.2-E** : Extends DCRU measurement requirements to all permanent links and channels for Categories 5e, 6, and 6A, in addition to Category 8. This ensures reliable PoE delivery, especially for high-power applications up to 90W (IEEE 802.3bt Type 4). DCRU measures resistance differences within and between pairs, enhancing PoE reliability

Power Delivery Specifications

- 3. **Power Delivery Specifications****:
- - **TIA-568.2-D** : Included guidance for PoE, referencing TSB-184-A for four-pair PoE (up to 90W) and introduced DC resistance unbalance for Category 8. It also supported 28 AWG patch cords for high-density environments
- - **TIA-568.2-E** : Incorporates normative information from TIA-568.2-D-2 (Power Delivery Over Balanced Twisted-Pair Cabling) into Annex H. This annex provides detailed requirements and design guidance for power delivery across different cable categories, types, and operating conditions (e.g., pathways and bundling). It recommends Category 6A or higher for non-engineered channels to support high-power PoE.

Cabling Categories and Performance

- 5. Cabling Categories and Performance**:
- - **TIA-568.2-D** : Supports Categories 5e (100 MHz), 6 (250 MHz), 6A (500 MHz), and 8 (2,000 MHz), with Category 8 designed for 25G/40GBASE-T over short distances (up to 30 meters). It also formalized MPTL configurations for direct device connections
- - **TIA-568.2-E** : Maintains support for Categories 5e, 6, 6A, and 8 without introducing new categories. However, it updates performance metrics and testing methods to align with modern high-bandwidth and PoE demands. No specific additions for new cable categories or classes are included in the scope

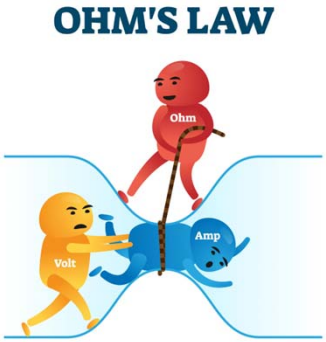
Testing and Compliance

- 6. Testing and Compliance :
- - **TIA-568.2-D** : Standardized testing for MPTL and direct attach configurations, with a focus on parameters like insertion loss, near-end crosstalk (NEXT), and far-end crosstalk (FEXT). DC resistance unbalance was specified only for Category 8.
- - **TIA-568.2-E** : Mandates DCRU testing as a pass/fail criterion for all categories (5e, 6, 6A, and 8), enhancing certification for PoE applications. This change means some cables compliant with TIA-568.2-D may not meet TIA-568.2-E requirements due to the new DCRU specifications. Specialized certification tools are likely required.

DC loop resistance and resistance unbalance

- ISO/IEC 11801 and TIA 568.2-D-2 and TIA 568.2-E have limit values for the DC loop resistance
  and DC resistance unbalanced
  - Channel Link:
    - DC loop resistance values must be <25
    - Permitted resistance unbalance
      - Between the pairs: 7% (200 mΩ min.)
      - Within a pair: 3% (200 mΩ min.)

- Exceeding the individual limit values causes various effects
  - DC loop resistance
    - High power dissipation
    - Excessive heating up, even in dangerous regions
    - Increased attenuation values, which in turn leads to a strong signal attenuation
  - DC resistance unbalance
    - Transformer saturation
    - Distortion of the waveform of Ethernet data signals (causes bit errors)
  - In a four-pair PoE system (4PPoE), a certain unbalance in DC resistances between the pairs can be tolerated, but if it is too large, PoE will not work properly

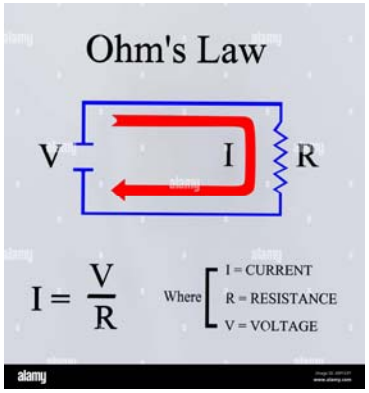


Details of the standards

- **Detailed PoE parameters**

Output voltage range at PSE	44-57 V	50-57 V	50-27 V
Input voltage range at PD	36–57 V	42.5–57 V	42.5–57 V
Maximum operating current	350 mA	600 mA	2× 960 mA
Maximum DC resistance of the cabling	20 Ω (per pair) (min. Category 3 cabling)	12.5 Ω (per pair) (min. Category 5 cabling)	6.25 Ω (per pair setrate) (min. Category 5 cabling)
Supported operating modes	Alternative/Mode A Alternative/Mode B	Alternative/Mode A Alternative/Mode B	4PPoE (combination of A and B)
power management	Performance Classes 1-3 negotiated during the activation process	Performance Classes 1-4 negotiated during the activation process, additional fine tuning via Data Link Layer (DLL) classification using LLDP	Performance Class 1-8 negotiated during activation process, additional fine tuning via Data Link Layer (DLL) classification using extended LLDP (Autoclass)

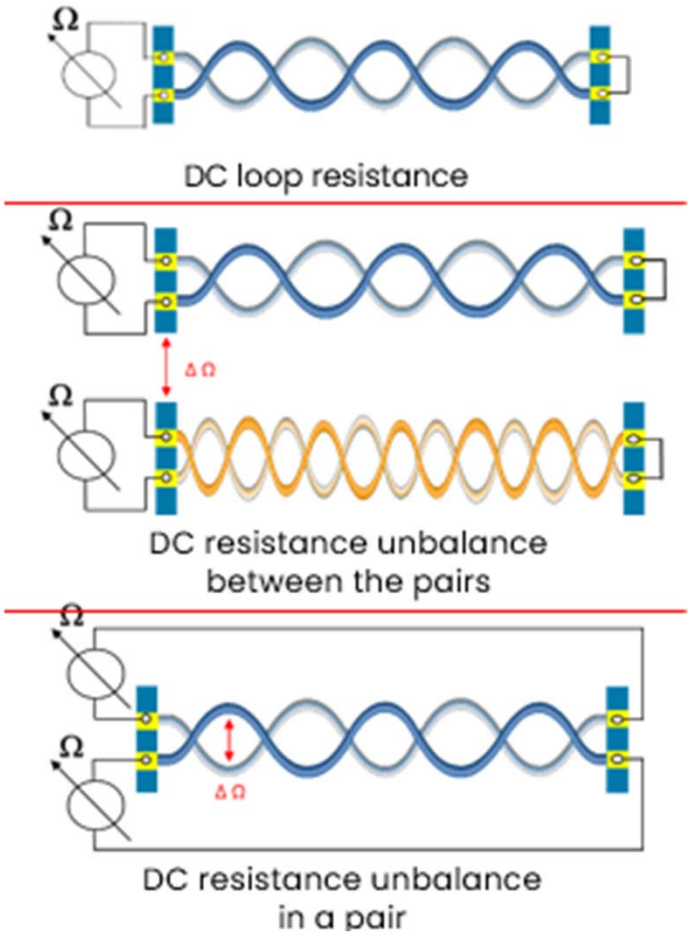
What is DCRU?



- - **Definition** : DC Resistance Unbalance refers to the difference in DC resistance (measured in ohms) either within a single twisted pair (wire-to-wire unbalance) or between different pairs (pair-to-pair unbalance) in a balanced twisted pair cable.
- - **Purpose** : Ensures cables can handle PoE, especially high-power applications (e.g., IEEE 802.3bt Type 4, up to 90W), without excessive heat generation, power loss, or signal degradation. Unbalanced resistance can lead to uneven current flow, reducing PoE efficiency and potentially damaging devices.

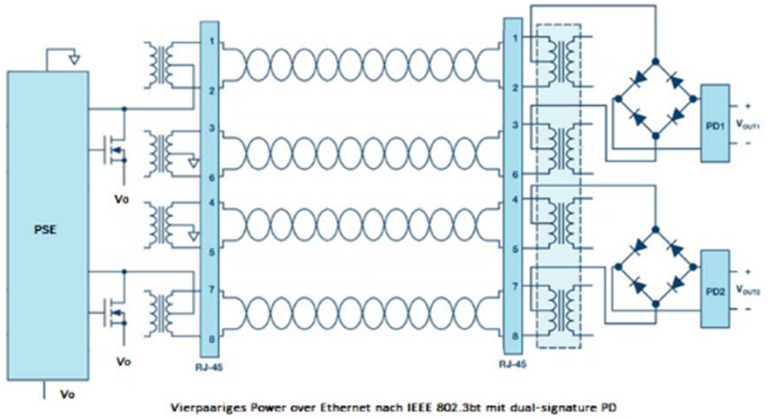
DC loop resistance and resistance unbalance

- Operating High Power PoE with up to 60 or 90 W requires cabling with very good DC resistance performance
  - To ensure that the cabling does not overheat in high-power PoE applications, all 8 connection paths must have a low and very similar DC resistance value and performance
  - Cabling here means: cables, outlets AND patch cords
  - Measurement of the DC loop resistance is not sufficient
  - Additional measurements are required:
    - DC resistance unbalance between pairs
    - DC resistance unbalance within a pair

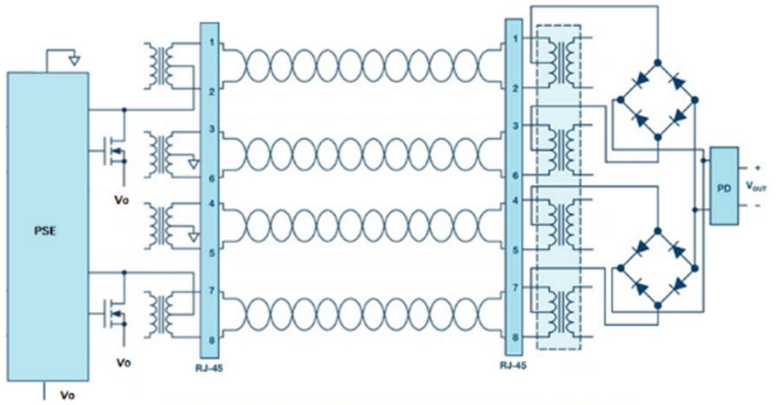


Types of DCRU

- 1. Within-Pair Unbalance**:
- - Measures the resistance difference between the two conductors (wires) in a single twisted pair.
- - Example: If one wire in a pair has a resistance of 10 ohms and the other has 10.5 ohms, the unbalance is 0.5 ohms.
- - High within-pair unbalance can cause current to flow unevenly, leading to heat buildup or PoE instability.
- 2. Pair-to-Pair Unbalance**:
- - Measures the resistance difference between the average resistances of different pairs in a four-pair cable.
- - Example: If Pair 1 has an average resistance of 10 ohms and Pair 2 has 11 ohms, the pair-to-pair unbalance is 1 ohm.
- - This affects PoE systems using all four pairs, as uneven resistance across pairs can disrupt power delivery.



Vierpaariges Power over Ethernet nach IEEE 802.3bt mit dual-signature PD



Vierpaariges Power over Ethernet nach IEEE 802.3bt mit single-signature PD

DC loop resistance and resistance unbalance

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  - In a four-pair PoE system (4PPoE), a certain unbalance in DC resistances between the pairs can be tolerated, but if it is too large, PoE will not work properly

DC loop resistance and resistance unbalance

- The "Measurement Standards" IEC 61935 and ANSI/TIA 1152A define the test procedures
- Field measurements of DC loop resistance and resistance unbalance are mandatory or optional, depending on the respective cabling standard
  - Normative
    - Measurement must be performed and is considered a pass/fail criterion
  - Optional
    - Measurement can be performed, if performed, then pass/fail criterion

Parameter	ISO/IEC and EN/DIN EN	ANSI/TIA
Direct current loop resistance	Normative	Normative
Direct current resistance unbalance	Optional	Normative

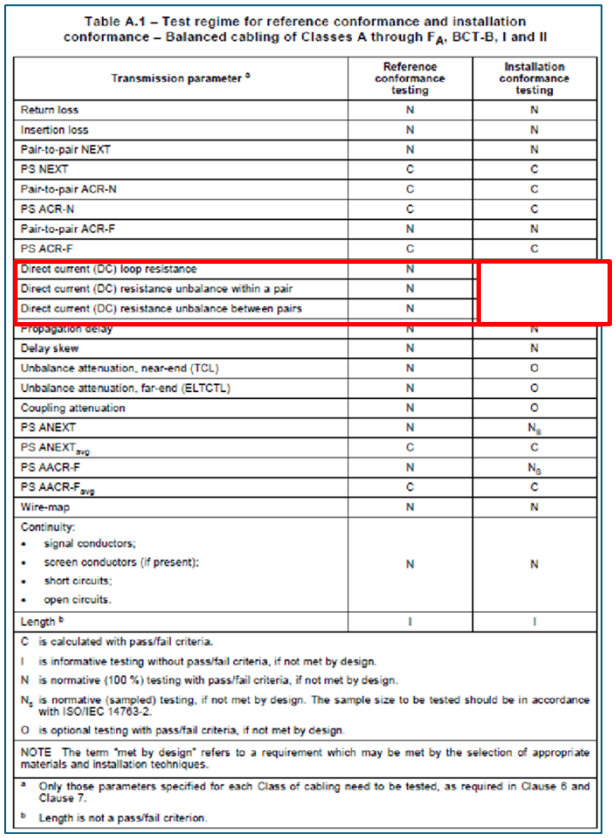

Table A.1 – Test regime for reference conformance and installation conformance – Balanced cabling of Classes A through F_A, BCT-B, I and II

Transmission parameter [a]	Reference conformance testing	Installation conformance testing
Return loss	N	N
Insertion loss	N	N
Pair-to-pair NEXT	N	N
PS NEXT	C	C
Pair-to-pair ACR-N	C	C
PS ACR-N	C	C
Pair-to-pair ACR-F	N	N
PS ACR-F	C	C
Direct current (DC) loop resistance	N	
Direct current (DC) resistance unbalance within a pair	N	
Direct current (DC) resistance unbalance between pairs	N	
Propagation delay	N	N
Delay skew	N	N
Unbalance attenuation, near-end (TCL)	N	O
Unbalance attenuation, far-end (ELTCTL)	N	O
Coupling attenuation	N	O
PS ANEXT	N	N_s
PS $ANEXT_{avg}$	C	C
PS AACR-F	N	N_s
PS $AACR\text{-}F_{avg}$	C	C
Wire-map	N	N
Continuity: • signal conductors; • screen conductors (if present); • short circuits; • open circuits.	N	N
Length [b]	I	I

C is calculated with pass/fail criteria.

I is informative testing without pass/fail criteria, if not met by design.

N is normative (100 %) testing with pass/fail criteria, if not met by design.

N_s is normative (sampled) testing, if not met by design. The sample size to be tested should be in accordance with ISO/IEC 14763-2.

O is optional testing with pass/fail criteria, if not met by design.

NOTE The term "met by design" refers to a requirement which may be met by the selection of appropriate materials and installation techniques.

[a] Only those parameters specified for each Class of cabling need to be tested, as required in Clause 6 and Clause 7.

[b] Length is not a pass/fail criterion.

Practical Implications of 568.2 E

- Practical Implications
- - **Backward Compatibility** : TIA-568.2-E builds on TIA-568.2-D, maintaining compatibility with existing installations but introducing stricter DCRU requirements. Cables certified under TIA-568.2-D (especially Categories 5e, 6, and 6A) may need retesting to comply with TIA-568.2-E's PoE standards
- - **PoE Focus** : The emphasis on DCRU and Annex H in TIA-568.2-E reflects the growing importance of high-power PoE in applications like IoT devices, security cameras, and wireless access points
- - **Future-Proofing** : TIA-568.2-E ensures cabling infrastructure supports modern networking demands, particularly for high-power PoE and high-speed data in data centers and commercial buildings, without introducing new cable categories)
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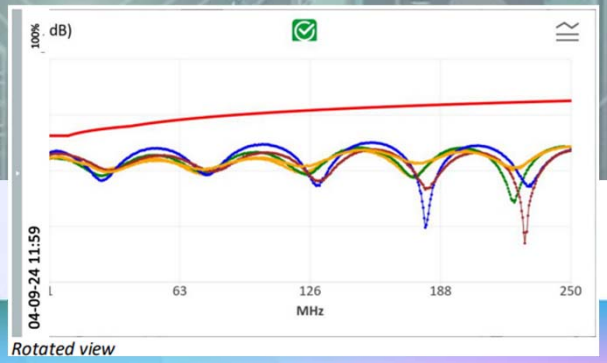
Best Practices in Testing



Rotated view

Best Practices in Testing

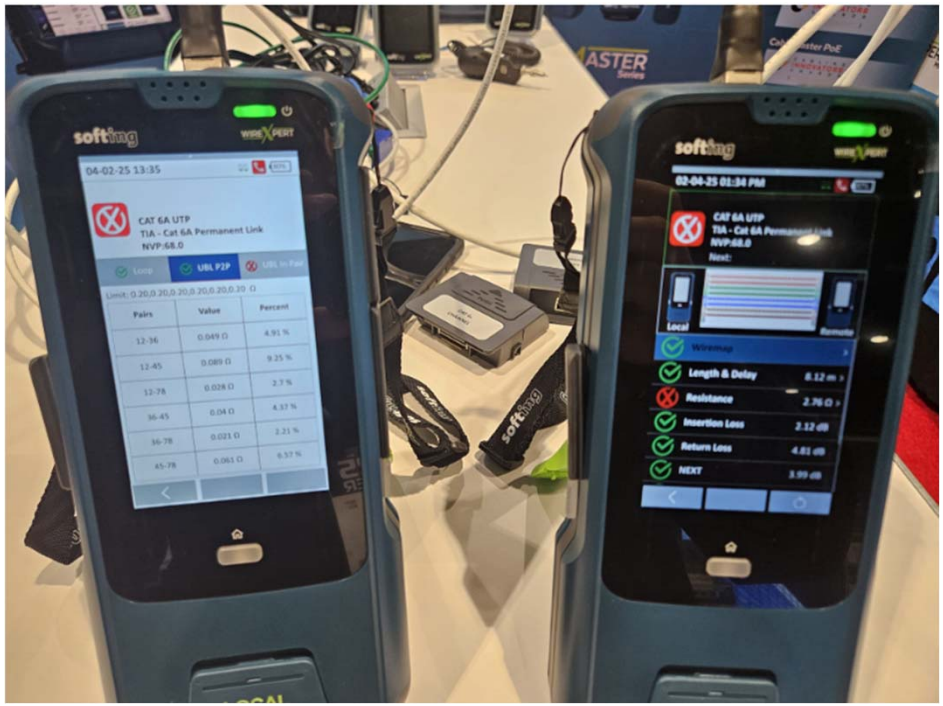
- **Maintenance, cleanliness, and calibration of testing equipment**
  - **Testing Equipment that is Calibrated and well-kept ensures proper operating functions.**
    - **Calibration configures and verifies your test equipment's accuracy and ensures its readings are correct according to your selected standard.**
    - **Maintaining the cleanliness of your test equipment promotes repeatability in measurements; without it, your equipment can provide inaccurate measurements, and threaten equipment longevity.**
    - **Test equipment should be inspected daily and stored in a manufacturer-approved manner.**
    - **For more information on Calibration and Testing Quality management, consult ISO and NIST.**

Why DCRU Testing Matters

- - **PoE Performance** : High-power PoE (e.g., 90W for Type 4) requires low resistance unbalance to prevent excessive heat, which can degrade cable performance or pose safety risks.
- - **Data Integrity** : Unbalanced resistance can introduce noise or crosstalk, impacting high-speed data transmission (e.g., 10GBASE-T or 40GBASE-T).
- - **Compliance with TIA-568.2-E** : Unlike TIA-568.2-D, which required DCRU testing only for Category 8, TIA-568.2-E mandates it for all categories (5e, 6, 6A, and 8) for both permanent links and channels, making it a pass/fail criterion for certification.
- - **Applications** : Critical for PoE-powered devices like IP cameras, wireless access points, and IoT sensors, where reliable power and data delivery are essential.
-

How DCRU Testing is Performed 1

- 1. **Test Equipment** :
- - Specialized cable testers, are used. These devices are designed to measure DCRU alongside other parameters like insertion loss and crosstalk.
- - Testers must comply with TIA-568.2-E requirements for accuracy.
-
- 2. **Test Setup** :
- - Permanent Link : Tests the fixed cabling from the patch panel to the outlet (excluding patch cords).
- - Channel : Tests the entire link, including patch cords and equipment cords.
- - The cable is connected to the tester at both ends, ensuring proper termination.



How DCRU Testing is Performed ?

- 3. **Measurement Process** :
- - The tester applies a DC current to each wire and pair, measuring the resistance of each conductor and calculating:
- - Within-Pair Unbalance**: Difference in resistance between the two wires in a pair.
- - Pair-to-Pair Unbalance**: Difference in average resistance between pairs.
- - Results are compared against TIA-568.2-E limits (e.g., maximum allowable unbalance for each category).
-
- 4. **Pass/Fail Criteria** :
- - TIA-568.2-E specifies maximum allowable DCRU values, which vary by cable category (5e, 6, 6A, 8). For example, Category 6A may have stricter limits than Category 5e due to its use in higher-performance applications.
- - A cable fails if the measured unbalance exceeds the standard's threshold, indicating potential issues with PoE or data performance.
-
- 5. **Testing Time** :
- - Modern testers can complete a full Category 6A autotest, including DCRU, in about 8 seconds, making it efficient for field use. some certification testers are incapable of these measurements outright or require add on equipment for the measurement
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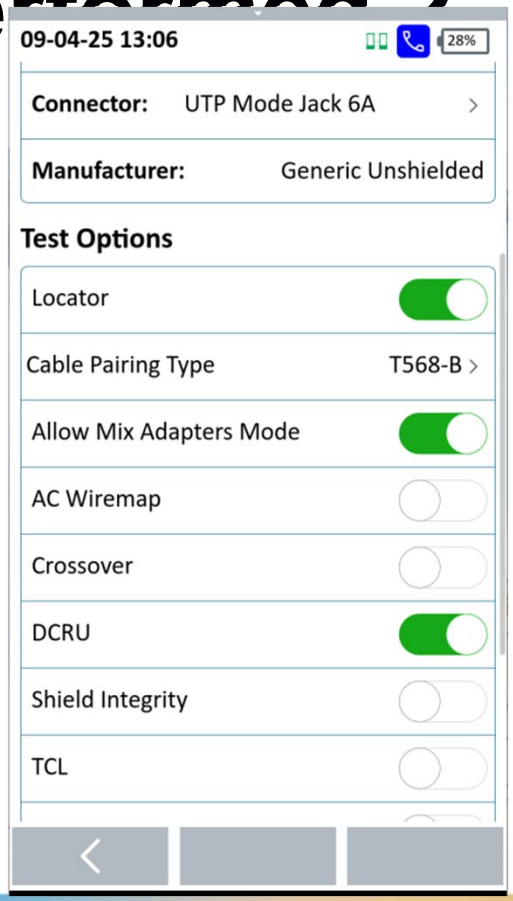

DC loop resistance and resistance unbalance

- **Result screen for Certification tester**
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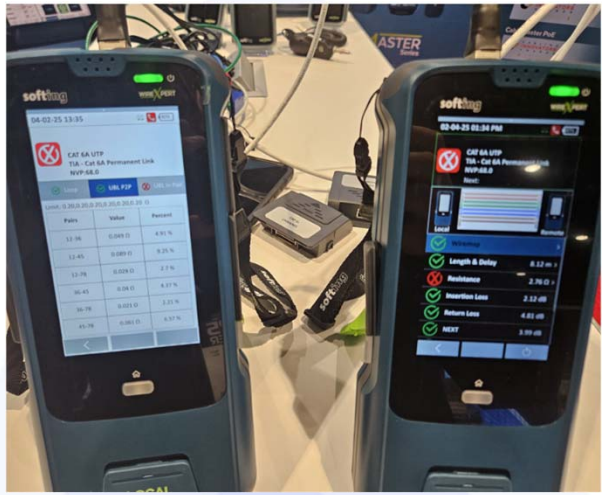
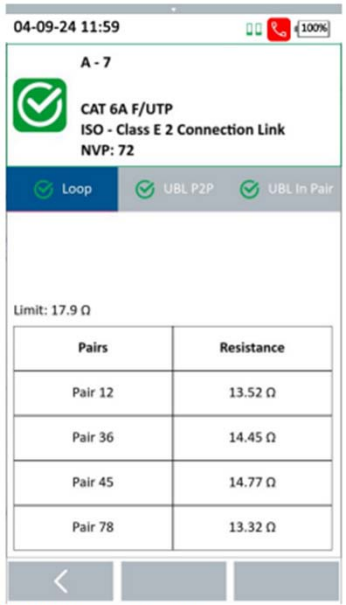
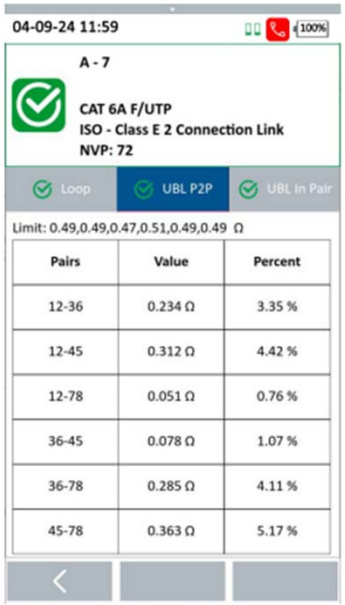
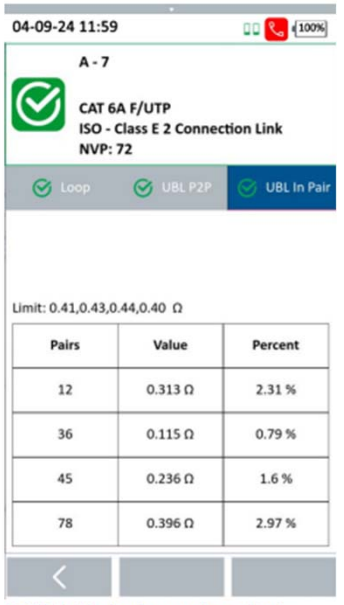




DCRU Loop Resistance



DCRU Unbalance between Pairs

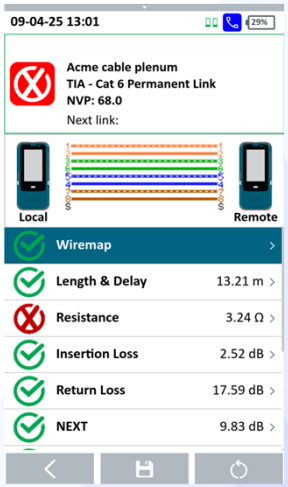


DCRU Unbalance in a Pair

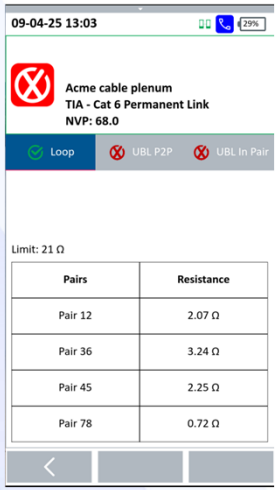
DC loop resistance and resistance unbalance

- **Result screen and documentation of measurement with Certification tester**

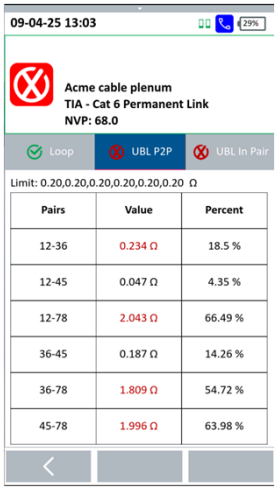
Overview



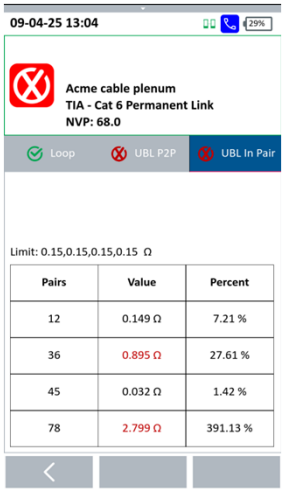
Direct current loop resistance

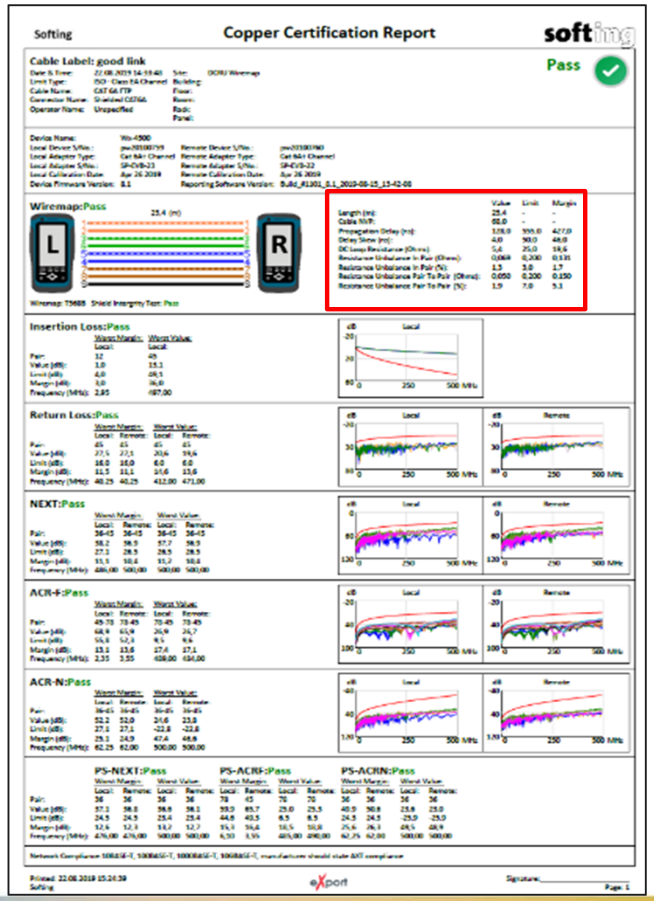


Direct current resistance unbalance between the pairs



Direct current resistance unbalance within a pair





Factors Affecting DCRU performance

- - **Cable Quality** : Poor manufacturing (e.g., inconsistent conductor thickness) can increase resistance unbalance.
- - **Connector Quality** : poor manufacturing or selection of connector style and quality can increase the resistance unbalance of the measurement
- - **Installation Practices** : Improper termination, tight bends, or excessive untwisting of pairs can degrade DCRU performance.
- - **Cable Length and Gauge** : Longer cables or thinner conductors (e.g., 28 AWG patch cords) may exhibit higher resistance, increasing unbalance risk.
- - **Environmental Conditions** : Temperature affects resistance, so testing accounts for ambient conditions, especially for PoE applications where heat dissipation is critical.
-

DIRECT CURRENT (DC) RESISTANCE ERRORS

In terms of measurement technology, these faults can usually be limited to affected pair of wires. The reasons for this can be:

- A poor connection due to insufficient cutting of the IDCs (Insulation Displacement Contacts) into the wires. This occurs less frequently today, as connection techniques have improved considerably over the last few years.
- A bad connection due to external contamination of the connectors. This cause can usually be easily identified and eliminated by cleaning the connectors.
- An overlength of the cabling route, this error can only be corrected by a shorter installation route, but this should not happen with good planning and execution.

However, if a DC resistance error is present, the cause can usually also be determined during the attenuation and return loss measurement and localized with a Time Domain Return Loss (TDRL) measurement.

Practical Implications

- - **TIA-568.2-E Compliance** : DCRU testing is now mandatory for all cable categories, meaning cables certified under TIA-568.2-D may need retesting to meet TIA-568.2-E standards, particularly for PoE-heavy installations.
- - **Installer Impact** : Technicians must use updated testers and follow precise termination practices to ensure compliance. Poorly terminated cables are a common cause of DCRU failures.
- - **End-User Benefits** : Ensures reliable performance for high-power PoE devices and high-speed networks, reducing downtime and maintenance costs.

Spec requirement explicit

Compliance with TIA-568.2-E Standards:

- All **horizontal cabling** (including **Cat 6 cables**) must be tested to meet **TIA-568.2 -E** standards for **Category 6 and Category 6A** performance.
- The tests include:
  - **Wiremap testing** to ensure that each conductor is correctly connected.
  - **Length testing** to ensure that each cable does not exceed the specified maximum length (100 meters for Cat 6).
  - **Insertion loss (attenuation)** testing to ensure that signal degradation does not exceed the acceptable limits.
  - **Near-end crosstalk (NEXT)**, **Power sum NEXT**, and **Return Loss** testing to ensure the integrity of the signal and minimize interference.
  - **DC resistance unbalanced measurements**

Testing Requirements

- **ISO/IEC 11801-1:2017 Class D, E, EA Permanent Link and Channel**
- **EN 50173-1:2018 Class D, E, EA Permanent Link and Channel**
- **IEC 61935-1-2:2019**
- **TIA568.2-E CAT 3, 5, 5e, 6, 6A Permanent Link and Channel**
- **ANSI/TIA 1152-A**

Spec requirement explicit

- **Testing Requirements:**

DC Resistance Unbalanced Testing:

- The **DC resistance unbalanced measurement** must be taken for each individual conductor pair to ensure that the resistance between pairs does not exceed the manufacturer's limits.
- The project specifications would often call for measurements to confirm that the **unbalanced resistance** between conductors (within a pair or across pairs) does not exceed the TIA-568 standard's maximums. For **Cat 6**, this value is typically **≤ 100 ohms per 100 meters** for each pair.
- This measurement is crucial for ensuring that the wires are not subject to significant **signal loss** or **interference** due to uneven current flow or resistance differences across the wire pairs.

Spec Requirement Implicit

Implicit DCRU measurement in a spec

- **Example POE 60 watt technology in spec and there are no DCRU requirements**
- **POE 90 watt technology in spec and there are no DCRU requirements**
- **4 pair POE in spec and there are no DCRU requirements**
- **28 gauge patch cords in a spec where there are no DCRU requirements**

- **CAT 6 performance is markedly less for balanced resistance than 6a**

Thank you very much!

Tom Jallo RCDD
tom.jallo@softing.com

Director of Business Development
2332 News Sentinel Drive Suite 120
Knoxville TN 37921

Content Credits

Alfred Huber Softing GMBH

Matt Apfel RCDD TECH

Konstantin Hudepohl Softing GMBH