What you need to know about DC Resistance Unbalance testing for PoE

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Introduction to PoE Standardisation

When Power over Ethernet (PoE) was first introduced, it is doubtful that the creators could have imagined how far the technology would be pushed in terms of the amount of power it would supply. The very first implementations provided just four watts, enough to power a nightlight. Today, PoE can supply more than 90 watts, enough to power a 75” flat panel TV.

Standardisation of PoE took three steps over 15 years, beginning with IEEE 802.3af in 2003, 802.3at in 2009, and 802.3bt in 2018. Each step increased the amount of power that could be delivered to attached devices by increasing the number of pairs, voltage, and current used. The 802.3bt version was the most complicated for several reasons. The amount of power being delivered can create heat in both the cable and in the power supplies which can lead to signalling errors and shortened service life of the PSE (Power Sourcing Equipment).

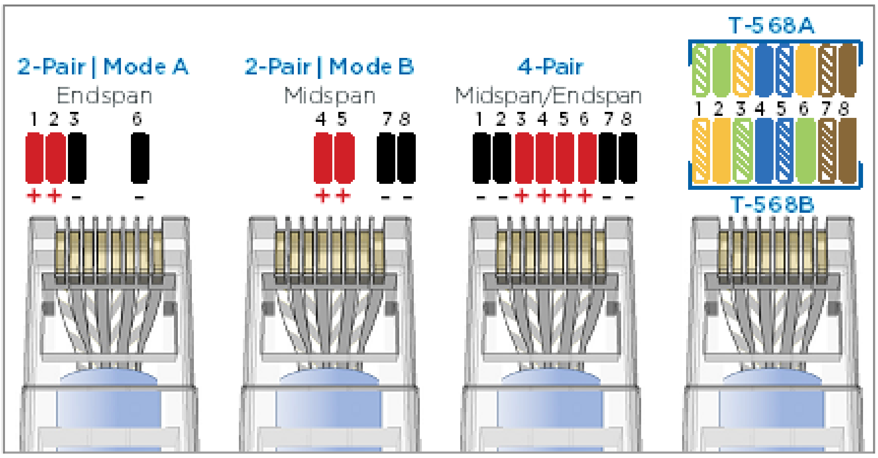

Figure 1: PoE Wiring Specifications

	Specifications at PSE/Switch/Injector		Specifications at PD/Device				
Class	Max power delivered	Voltage range	Power available	Voltage range	IEEE PoE standard		
0	15.4 W	44-57 V	12.94 W	37-57 V	802.3af	PoE	2 pr.
1	4 W		3.84 W				
2	7 W		6.49 W				
3	15.4 W		12.95 W				
4	30 W	50-57 V	25.5 W	42-57 V	802.3at	PoE+	2 pr.
5	45 W	50-57 V	40 W	42-57 V	802.3bt Type 3	“PoE++”	4 pr.
6	60 W		51 W				
7	75 W	52-57 V	62 W	51-57 V	802.3bt Type 4	“PoE++”	4 pr.
8	90 W		73 W				

Figure 2: PoE Classifications

What is Resistance Unbalance?

Throughout the PoE development process, both the ANSI/TIA's TR42.7 and the ISO/IEC's SC25/WG3 engineering committees worked on the standardisation process for the cabling that would be required to support 802.3bt PoE, also known as PoE++. Testing revealed that minor differences in the resistance between the pairs and within a pair of cable caused problems with PoE++ delivery.

The problem stems from the way power is applied to the twisted pairs for PoE use. Compared to data signals which are differential and apply opposite voltages to each conductor of a pair, PoE is a common-mode voltage where the same voltage is applied to both conductors in a pair. Two pairs are the positive voltage while the other two pairs are the negative voltage. If the resistance with a pair is different, or the resistance between two pairs differs, the wire acts as a resistive heating element. Think of it like the wires in an old electric heater, just on a much lower power level. In this case two problems arise, cable heating and PSE heating.

If the PSE encounters additional resistance while trying to force high levels of power through the cable, its internal circuitry will heat up. The additional heat may reduce the service life of the equipment, reduce efficiency, and increase the costs of operation from increased cooling needs in the data centre to compensate.

Secondly, using the electric heater analogy, the cable's temperature will increase as power is forced through it in an unbalanced manner. While it won't become glowing hot, the temperature increase can get high enough to cause signal transmission issues. Cable insertion loss (attenuation) is affected by three factors: length, signal frequency, and temperature. In cases where the installed length is near the 90-metre limit and the cable is installed in an already hot environment, an increase in temperature from PoE use can cause the insertion loss to exceed levels where packet errors occur.

How can we detect these problems?

The DC Resistance Unbalance (DCRU) is the measurement that is performed on the cabling after installation to test for differences in DC resistance. It is performed by cable certifiers in addition to the radio frequency (RF) measurements to test cable performance such as NEXT, insertion loss, and return loss. DCRU measures pair unbalance and pair-to-pair (P2P) unbalance. Testing DCRU ensures that the installed cabling meets the stringent unbalance requirements of the TIA and ISO standards. The requirements are a maximum pair unbalance of 7% or 0.20 ohms max and P2P unbalance 7% or 0.20 ohms max.

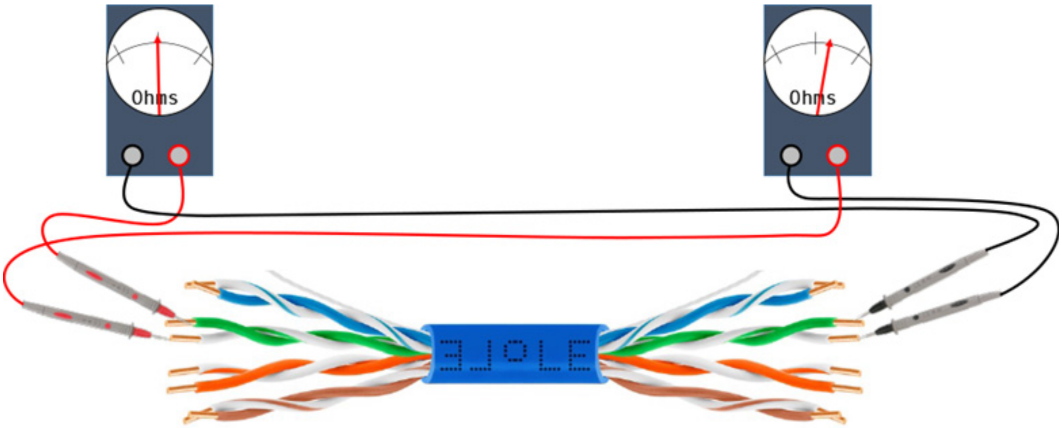

Figure 3: Pair unbalance measurement configuration

Think about measuring pair unbalance as comparing the resistance of two separate ohm meters while measuring the conductors in a pair. In the diagram (Figure 3) both positive leads are attached to the same side of the cable, each on a different conductor; and on the opposite end the negative leads are attached to the corresponding conductors. Each meter is measuring the resistance of its conductor and the two values are compared. Pair unbalance is measured for all four pairs. According to the specification they must be within 7% of each other or differ by no more than 0.20 ohms.

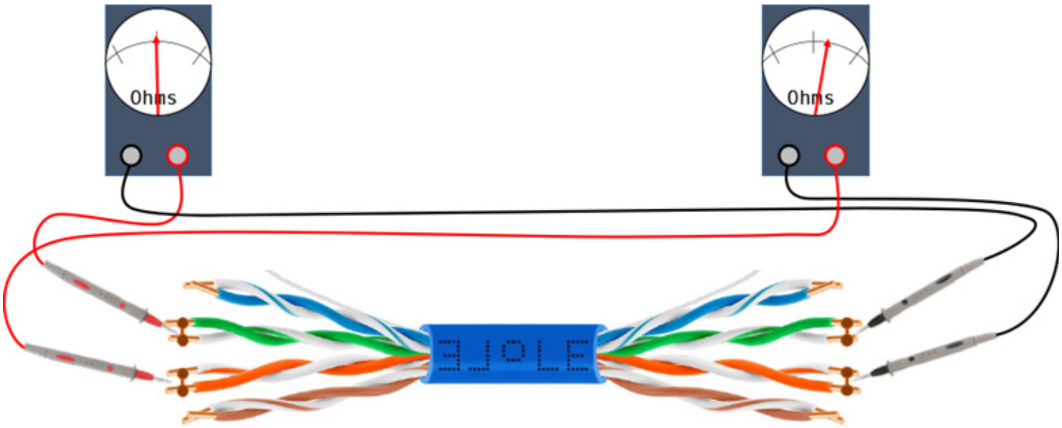

Figure 4: Pair-to-pair unbalance measurement configuration

Measuring P2P unbalance is a comparison of the parallel resistance of the pairs compared to one another. In the diagram, the green and orange pairs are compared for demonstration. For an actual DCRU test all four pairs are measured and the difference between the lowest and highest measured value cannot exceed 7% or 0.20 ohms.

Causes of Resistance Unbalance

Resistance unbalance can be inherent in the cable or can be a result of cable termination. Pair unbalance, the difference between conductors in the same pair, is unlikely in the cable. It is usually going to be the result of a poor termination of one of the conductors.

Pair-to-pair unbalance, the difference between pairs, can come from the cable when lengths exceed 90 metres. While the TIA limits links to 90 metres and channels to 100 metres, the ISO standards do not have a maximum length limit. The ISO 11801-1/IEC 61935-1 require only require that the length be reported and that the RF test parameters pass. Therefore, a link can be long enough where the different twist rates can lead one pair to be significantly longer than another which can cause the P2P unbalance to exceed specifications.

Termination of the cable to the connector is another common cause of resistance unbalance. Poor punch downs can cause high-resistance connections that pass RF certification tests. This is because the RF energy travels on the surface of the conductors and if a conductor is barely touching the IDC (insulation displacement connector) contacts, enough energy will pass through the connection that tests like insertion loss and return loss will be unaffected. The same connection will have a high DC resistance measurement causing a resistance unbalance.

Is DCRU Testing Mandatory?

The latest TIA, ISO and EN/CENELEC cabling standards do not require field testing DCRU. It is entirely optional. In 2020 the TIA produced an addendum to the 568.2-D, the 568.2-D-2 for power delivery that defines the DCRU requirements for all channels from category 5e through 8. Still, it is up to designers and specifiers to understand the importance of DCRU in how it impacts the ability of a cabling system to support PoE++. Best practice is to require DCRU testing in addition to the usual certification testing.

While any cabling from category 5e and up should pass DCRU testing, some companies are marketing cable specifically for PoE++ applications. This usually involves using a larger wire gauge (22 AWG typically) on cat 5e or cat 6 cable that might usually be constructed of 24 AWG conductors. The larger wire will reduce loop resistance to ensure 90+ watts can be delivered on 90-metre links.

Testing DCRU in the Field

While all cable certifiers can measure DC loop resistance (a requirement when they were designed), not all cable certifiers currently deployed in the field, or even some being sold today, can measure DCRU. Because it is a relatively new test, only certifiers designed within the last few years can measure DCRU. This means that you'll need a fairly new certifier, such as the TREND Networks LanTEK IV-S, to be able to test DCRU. Loop resistance should also be measured when certifying for PoE support because it is an important parameter in ensuring the full amount of power can be delivered to the PoE device.

Since none of the certification test standards require DCRU testing, your DCRU enabled certifier will have a setting to add DCRU to the regular Autotest for the category/class being certified. In the example below, the certifier has an option for Cat5e + PoE which adds DC loop resistance and DCRU to the required TIA tests to certify a link for cat5e performance.

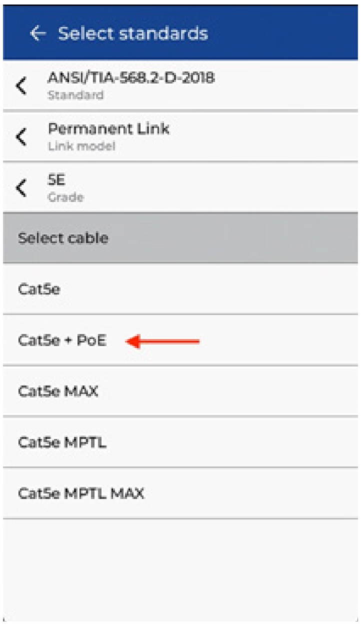

Figure 5: Selecting a +PoE test standard

The following series of screens show the results from the loop resistance and DCRU tests.

Figure 6: DC loop resistance

Loop resistance is the total resistance of both conductors in a pair. The limit is a fixed value regardless of cable length.

← Unbalanced P2P Resistance

Pair	Value Ω	Margin Ω	Limit Ω	
1,2-3,6	0.15	0.38	0.52	✓
1,2-4,5	0.09	0.43	0.52	✓
1,2-7,8	0.04	0.49	0.52	✓
3,6-4,5	0.05	0.47	0.52	✓
3,6-7,8	0.19	0.34	0.52	✓
4,5-7,8	0.13	0.39	0.52	✓

NVP:68

Figure 7: Pair-to-pair resistance, Pass

Pair-to-pair resistance (above) is the parallel resistance of each pair compared with the other three pairs in the cable. There are six combinations that need to be compared when measuring P2P resistance. In this example the worst case is between pairs 12-36 with a value of 0.15 ohms.

← Unbalanced Pair Resistance

Pair	Value Ω	Margin Ω	Limit Ω	
1-2	0.24	0.21	0.45	✓
3-6	0.16	0.29	0.45	✓
4-5	0.05	0.40	0.45	✓
7-8	0.22	0.23	0.45	✓

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Figure 8: Pair resistance, Pass

Pair resistance (above) is the difference between the conductors in each pair. In this example all four pairs pass with pair 1-2 having the highest unbalance of 0.24 ohms.

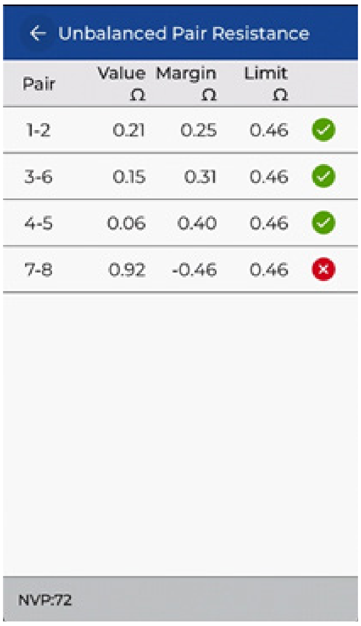

Figure 9: Pair resistance, Fail

Figure 10: Autotest result

In this example pair 7-8 (in Figure 9) failed the unbalance test with a value of 0.92 ohms which is 0.46 ohms over the limit. The first step in troubleshooting should be to re-terminate the connector. The Autotest results for the same cable (Figure 10) shows that NEXT, insertion loss, and return loss all pass. Meaning that this cable will support data transmission. The poor termination would go unnoticed if the DCRU test was not enabled.

In Summary

As PoE becomes a necessary part of every network, field testing should be performed to ensure the materials and the installation will support high power PoE without generating excess heat. The result can cause data transmission issues, shorten the service life of the power supplies, and reduce overall electrical efficiency. Even though DCRU testing is not required by the cabling standards, a best practice is to test it anyway. This will ensure the cabling and the installation workmanship is up to the task of supporting PoE to its fullest capability.

Can your cable certifier be upgraded to support DCRU testing? Some manufacturers such as TREND Networks offer DCRU adapters for previous generation certifiers that extend their useful life by allowing them to test DCRU with a permanent link and channel adapters that have the precision resistance measurement circuitry built in. The new adapters and a software update allow the LanTEK III certifier to measure DCRU along with the LanTEK IV which has integrated DCRU measurement capability.

Check with your certifier manufacturer to see what options are available for DCRU testing as it becomes a common requirement and PoE++ capability is increasingly a necessity for new cabling installations.

Learn more at www.trend-networks.com