White Paper: DC Resistance Unbalance Testing: Easy, Low-Cost Insurance for Your PoE Systems

Originally ratified by IEEE in 1999 and 2003 respectively, gigabit Ethernet (1000BASE-T) and power over Ethernet (PoE) are two network technologies that today are considered the norm. With both technologies supported by an estimated 85 percent of the installed cabling base, they have proliferated in tandem over the past decade to the point where the many enterprise entities are deploying, or planning to deploy, gigabit Ethernet in the horizontal LAN environment and more PoE devices than ever before.

While 10/100BASE-T (i.e., 10 and 100 Mbps) applications required only two cable pairs for transmission, leaving two spare pairs of a four-pair twisted cable available for PoE, gigabit Ethernet requires all four cable pairs for bidirectional transmission. In this scenario, PoE is delivered over pairs that are simultaneously transmitting data.

Often referred to as phantom power and accomplished by applying a common-mode voltage between two pairs in a four-pair Ethernet cable, PoE is intended to not interfere with data transmission. However, DC resistance unbalance in a PoE connection has the potential to cause significant problems. While not required in TIA performance field testing, resistance unbalance is specified in the IEEE's PoE standards and making DC resistance unbalance testing a field test requirement will go a long way in ensuring that devices get the power and data they need.
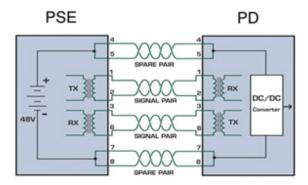
Understanding PoE and DC Resistance Unbalance

The IEEE 802.3af standard for PoE was developed to provide remote low-voltage power to devices over twisted-pair data cabling. Power is injected by power sourcing equipment (PSE), which is typically a PoE-enabled switch or a mid-span power device. The power can be used by a wide range of powered devices (PDs) at the other end, including VoIP phones, wireless access points (WAPs), wall clocks, sensors, cameras, access control panels and more.

The original IEEE 802.3af standards allows for delivering a maximum of 15.4 W (13 W available) of power over two pairs, while the latest IEEE 802.3at PoE Plus standard increases the allowed maximum power to 30 W (25.5 W available). PoE Plus was developed in response to more power-hungry devices such as higher power WAPs, pan-tilt-zoom cameras, LED display boards and more. In fact, the latest 802.11ac standard for gigabit WiFi has higher power requirements due to more sophisticated signal processing and a higher frame rate that requires PoE Plus.
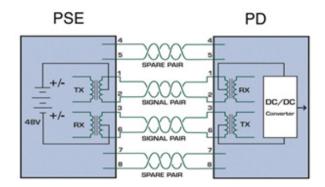
The IEEE standard specifies two methods for PSE to provide power using two pairs of a four-pair data cable—Alternative A and B. In Alternative B, power is delivered over spare pairs using Pairs 1 and 4. This is compatible with data signals that only use two pairs (Pairs 2 and 3), including 10/100BASE-T applications. In Alternative A, the power is delivered simultaneously with data over Pairs 2 and 3, which is compatible with both two- and four-pair applications, including 10/100BASE-T and 1000BASE-T.

In Alternative A, power is transmitted over the data pairs by applying a common-mode voltage. Power is received and returned using the center tap of a PD's transformer, which splits the current between each conductor of the pair. When the resistance of each wire in the pair is equal, the dc resistance unbalance (the difference in resistance between two conductors) is at zero, current is split evenly, and common-mode current is achieved.

Method B that takes advantage of the spare pairs in twisted-pair Ethernet cables is an easy approach but is only compatible with 10/100BASE-T applications.

Method A is compatible with 10/100/1000BASE-T and transmits power simultaneously with data using the center tap of the transformer.

While devices can tolerate some DC resistance unbalance, too much unbalance causes the potential for saturation of the transformer. This can ultimately distort the waveform of Ethernet data signals, causing bit errors, retransmits and even non-functioning data links.

What Causes DC Resistance Unbalance?

DC resistance unbalance can occur in a PoE data link for a variety of reasons. While problems with transformers such as an offset center tap can occur at both PSE and end devices, DC resistance unbalance is more often caused by poor workmanship, inconsistent terminations and subpar cable quality.

Poor installation practices have long been at the crux of network performance problems. Practices such as ensuring minimum bend radius and maintaining pair twist as close to the point of termination as possible are key to meeting performance parameters, especially in higher frequency applications like 1000BASE-T. While PoE relies more on the DC resistance of a specific length of cable rather than high-frequency transmission characteristics, there are some installation practices that matter.

Consistency in individual conductor terminations is important to preventing DC resistance unbalance. Punching down the individual conductors to the proper IDC tower of a network jack displaces the conductor's insulation to expose the copper and make the connection. Ensuring proper and consistent seating during this practice isn't always easy. A certain amount of force is required to seat the conductors, and inexperience, hand fatigue and larger conductor gauge sizes can all impact the ability to maintain consistency. When two conductors of a pair carrying PoE are terminated inconsistently, DC resistance unbalance can occur. Using the correct termination tool can help increase termination consistency and avoid DC resistance unbalance in PoE systems (see sidebar on termination tools).

Conscientious terminations must also be coupled with precision manufacturing processes as the overall quality of the cable and connectivity can also impact DC resistance unbalance. Manufacturing quality UTP cable requires careful selection of copper conductors and the use of stringent controls to maintain the proper physical geometry of the cable. When a poor quality cable exhibits variations in the diameter, concentricity (roundness), contour and smoothness of the copper conductors, there is a higher risk for DC resistance unbalance in PoE systems.

One of the growing concerns in the industry today is the significant amount of cables containing copper coated aluminum (CCA), copper coated steel and other non-standard conductors masquerading as Category 5e or even Category 6 cables. While these cables can be appealing to those looking for inexpensive networking solutions, CCA cables are not compliant with industry standards and do not support PoE applications due to their increased DC resistance, which can be 55% greater than for a solid copper cable of the same diameter. The greater resistance results in greater heating of the cable and lower voltage available at the powered device.
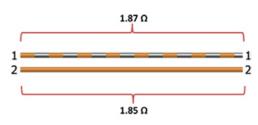
Unfortunately, testing for dc resistance is not always enough to determine support for PoE as some CCA cables will pass DC loop resistance testing for shorter links. However, regardless of link length, CCA cable will typically feature DC resistance unbalance on pairs due to lack of consistency across conductors (see sidebar on DC loop resistance vs. DC resistance unbalance). There are also other more serious concerns surrounding CCA cables—they cannot legally be installed to meet National Electric Code fire safety ratings, resulting in code violations and increased risk of fire.

Testing for DC Resistance Unbalance

IEEE Std 802.3-2012 specifies a maximum DC resistance unbalance of 3% between conductors, meaning that the difference in DC resistance between two conductors is no more than 3% of the total DC loop resistance of a pair. However, both TIA and IECs standards do not require DC resistance unbalance testing as a field measurement. The lack of field test requirement has been in part due to no field tester that was capable of testing for DC resistance unbalance, so it was left as a laboratory measurement only. That is no longer the case with the DSX-5000 CableAnalyzer.

DC resistance unbalance testing verifies that both conductors in a pair have equal resistance and will therefore enable the common-mode current needed to effectively support PoE and avoid distortion of the data signals transmitting on the same pair. Unlike other field testers that only test DC loop resistance, the DSX-5000 measures both DC loop resistance and DC resistance unbalance.

As shown in Figure 1 below, the DSX-5000 measures DC loop resistance as a sum of the resistance of two conductors in a pair, while DC resistance unbalance is a measure of the difference in resistance between the two conductors.

Figure 1

While not required in field testing, TIA and ISO/IEC standards both include resistance unbalance test limits, but TIA standards only provide these limits for a channel as shown in Table 1 below.

DSX CableAnalyzer Test Limit Name	DC Resistance Unbalanced	
	Channel	Permanent Link
TIA Cat 5e Perm. Link (+PoE)	0.20 or 3.0%	
TIA Cat 6 Perm. Link (+PoE)	0.20 or 3.0%	
TIA Cat 6A Perm. Link (+PoE)	0.20 or 3.0%	
ISO11801 PL Class D (+PoE)	0.20 or 3.0%	0.15 or 3.0%
ISO11801 PL Class E (+PoE)	0.20 or 3.0%	0.15 or 3.0%
ISO11801 PL2 Class Ea (+PoE)	0.20 or 3.0%	0.15 or 3.0%

If you are making a permanent link measurement, the measurement is still made by the DSX-5000 but no PASS/FAIL is applied for TIA testing as shown in Figure 2. This is still useful information if you observe PoE issues and want to rule out the cabling as a potential cause.

Figure 2

With TIA field testing standards now open for review, there might be just cause for defining DC resistance unbalance testing as a field test requirement to help deal with issues surrounding CCA cable and to provide greater assurance for meeting IEEE-mandated PoE requirements.

DC resistance unbalance testing will become an even greater concern as more enterprise entities deploy gigabit Ethernet and more PoE devices using the IEEE's Alternative A method of delivering power simultaneously with data. As the deployment of PoE Plus continues to grow, especially with the introduction of 802.11ac WAPs that require it, DC resistance unbalance will become an even greater concern as more current flowing through a conductor makes PoE even more susceptible to DC resistance and resistance unbalance. Furthermore, even higher power PoE is being considered for the future to power devices that require 30 to 50 Watts.

Don't let your PoE systems hang in the balance. Requiring DC resistance unbalance testing via the DSX-5000 is an easy, low-cost insurance for today's and tomorrow's PoE systems.

Increase Termination Consistency with the Right Termination Tool

Using the correct termination tool can help increase termination consistency and avoid DC resistance unbalance in PoE systems. There are three types of punchdown tools for terminating telecommunications cables—manual, impact and multi-wire. Manual punchdown tools require the bulk of the force to come from human power, which has the potential for higher inconsistency across two conductors of a pair. It's very difficult to use the exact amount of force for each conductor every time, especially once hand fatigue sets in.

Impact tools that require less force on the part of the installer are a better option, but these tools can still result in termination inconsistency from conductor to conductor. The best option for ensuring termination consistency are multi-wire tools such as JackRapid that terminate all pairs with one squeeze, providing an equivalent amount of force on all conductors. Multi-wire tools also ease hand fatigue and significantly cut installation time by terminating jacks up to eight time faster compared to using single-wire termination tools. The combination of faster, more reliable and consistent terminations reduces rework and cost by as much as 80%.

DC Loop Resistance vs. DC Resistance Unbalance

There is often some confusion over the difference between DC loop resistance and DC resistance unbalance. The ability to deliver a certain amount of power is dependent on the total DC loop resistance of a specific length of cable. DC loop resistance is calculated as the sum of the dc resistance of two conductors in a pair. According to IEEE standards, the channel DC loop resistance of a pair shall be 25 Ω or less while permanent DC loop resistance shall be 21 Ω or less.