White Paper | etherCON®

Next generation ethernet – CAT6A

NEUTRIK®

Content

White Paper – etherCON CAT6A
Title: NWP05

1 SCOPE

The increasing need for a higher bandwidth for growing Ethernet applications led to new standards. More and more manufacturers advertise with Cat 6A / Cat 6A or Class EA products.

10 G-Ethernet over copper wires and the related higher bandwidth do have restrictions. This paper explains the difference of current standards and includes measuring results of Neutrik's latest product – the Cat6A series.

TERMINOLOGY

The requirement of multivendorcapable standardized wirings led to the international norm ISO/IEC 11801. This standard specifies a structured wiring and includes requirements on the single components as well as the entire link.

A structured wiring can be divided into primary, secondary and tertiary wiring. Primary wiring refers to the cabling between buildings. The linking of different hubs within a building is known as secondary wiring, whereas the tertiary wiring is responsible for the connection between a hub and the receptacles. There mostly twisted pair cables are used.

The American standard EIA/TIA 568 and the European norm EN50173 are derived from the global standard ISO/IEC 11801.

2.1 Category vs. Class

The terms **"category"** and **"class"** are often mixed up. Both determine the electrical transmission values, which have to be observed in a norm compliant installation.

According to DIN EN 50173 *"class"* applies to the entire wiring, i.e. the installed link. The *"category"* (CAT) as such applies only to one single component, for example the connector. The installed link is always tested according to classes. Only manufacturers and verification labs possess measurement instrumentation to evaluate single components according to the categories.

- Category specification for components – cables, patch panels, communication outlets, connectors
- Class specification for system applications on full channel

CAT describes, up to which operating frequency and transmission speed for example the cable is applicable. The higher the frequency range is, the higher the transmission speed gets on larger distances. That increases the performance of the network.

In contrast, the American standard EIA/TIA 568 only classifies according to categories and uses this term for the whole system as well as for the components.

For a detailed overview of the different classes and categories please refer to chapter 3.3.

2.2 Permanent Link vs. Channel Link

Concerning the term "link" it can be distinguished between:

Permanent Link – Permanent link defines the path between the data outlet and the patchbay excluding the patchcords. Which means that it includes the permanently installed wiring path.

Channel Link – Channel link defines the path between the data outlet and the patchbay including all patch cables. That is the complete signal path as it is in use.

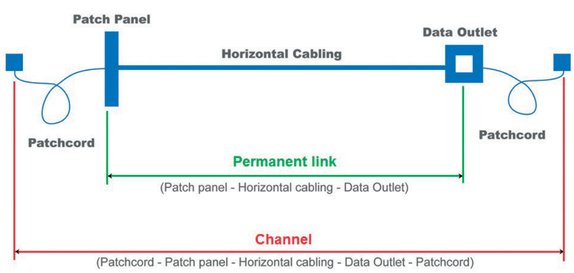


figure 1 – Permanent Link versus Channel Link (Source: Telegärtner)

TECHNOLOGY

3.1 Ethernet standards

Ethernet is a technology which specifies software (protocols, etc.) as well as hardware (cables, switches…) for wired networks. It enables the data transfer between devices which are connected to a local network (LAN). Ethernet protocols contain the specification of types of cables, connectors as well as the form of the transmission. Ethernet is the basis of other network protocols such as Apple Talk, DECnet or TCP/IP. IEEE developed an Ethernet standard known as IEEE Standard 802.3.

The previous Ethernet standard network was able to transmit data rates up to 10 Mbit/s for a distance of 100 m (max) and a frequency range of 20 MHz.

Fast Ethernet

For Ethernet networks, where a higher transmission speed is required, the Fast Ethernet (100BASE-TX) standard IEEE 802.3u has been established. With this the speed limit has been raised from 10 Mbit/s up to 100 Mbit/s for a distance of 100 m (max) and a frequency of 100 MHz.

Gigabit Ethernet

Applications such as multimedia and Voice over IP (VoIP) require even faster communication networks such as Gigabit Ethernet (1000BASE-T). In contrast to Fast Ethernet the Gigabit Ethernet is 10 times faster. For the transmission all 4 pairs of wires are used. The 1000 Mbit/s are subdivided into 250 Mbit/s for each pair. Regarding frequency limit, Class D allows up to 100 MHz whereas Class E specifies 250 MHz already.

10 Gigabit Ethernet

10 GBASE-T offers already a nominal rate of 10 Gbit/s. The standard in terms of copper is IEEE 802.3an. The used connector is still RJ45, to be compatible with previous Ethernet types. The biggest challenge for setting up a 10G-Ethernet infrastructure is the duplication of the frequency bandwidth. Cat5e or Cat6 cables are therefore not sufficient for a 10 G-Ethernet transmission for a length of 100 m. 10 G-Ethernet requires a maximum frequency of 500 MHz in contrast to 250 MHz for 1 GbE.

Power over Ethernet (PoE/PoE Plus)

Power over Ethernet was developed to reduce costs when planning and installing networks. The standard of PoE is **IEEE 802.3af**. The power supply is provided by a data cable. Therefore the network setup gets independent of any switch case and electrical socket.

In a network the devices in use are classified into:
- Power Sourcing Units (PSE)
- Powered Devices (PD)

IEEE 802.3af defines a maximum power of **12,95 W** at the PD if a cable length of 100 m is in use. 802.3af distinguishes between two meth-ods: **Spare pairs** method refers to a separation between data and power. Pair 4/5 and 7/8 are responsible for power supply whereas pair 1/2 and 3/6 are in charge of the data transfer. In the **Phantom Power** method power and data are transmitted together using the pairs 1/2 and 3/6.

Since the introduction of Power over Ethernet the demand for more power increased. A new standard was developed and released in 2009 known as Power over Ethernet Plus (PoE Plus) **or IEEE 802.3at**. PoE Plus delivers more power to enable a new breed of Ethernet devices and continues to support IEEE 802.3af. The defined limit is **25,50 W**. In contrast to 802.af the current increased from 350 mA to 720 mA with a feeding voltage of 50 V. With 1000BASE-T cables only the Phantom Power method can be used, since all 4 pairs are necessary for the data transmission.

There is a new standard on its way but not released yet. **IEEE 802.3bt** should supply powered devices with 70 W. In this case all 4 pairs of a twisted pair cable must be used for phantom power.

When using Power over Ethernet it is important to take the heat buildup into consideration. Therefore you have to use proper cross sections of the conductors.

Besides the heating up of the conductors there is another critical issue which has to be considered: Damage of the contacts due to sparking.

During the insertion process the contact spot between the connector and the chassis moves along the surface of the contacts.

The area between the first contact spot until the nominal contact spot is known as grinding zone. (fig 2)

At a proper design of the contacts the nominal contact spot (green) and the connection / disconnection area (red) are separated as shown in fig 3.

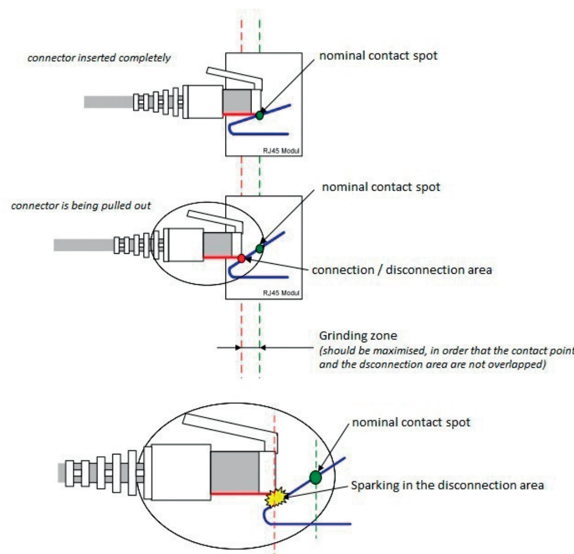


figure 2 – insertion process and contact spots

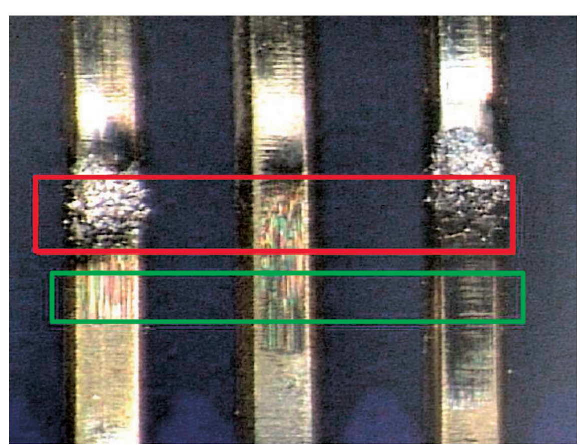


figure 3 – proper contact design

A bad contact design (fig 4), when the above mentioned areas overlap, result into damaged contacts in the nominal contact spot due to sparking during insertion.

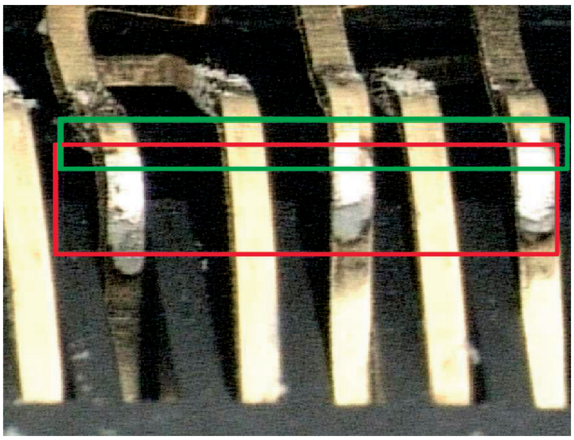


figure 4 – bad contact design

3.2 NEXT, FEXT, AXT and RL

The higher the data rates get, the faster a system has to switch between different voltage levels. That's the reason for decreasing voltage values. Fast Ethernet (100 Mbit/s) had a level range of 1 V, whereas 20 Gigabit Ethernet operates with 130 mV only.

Since the electronics get more sensitive with increasing data rate, even small disturbances are now noticeable. With higher frequencies interference due to crosstalk is increasing. Crosstalk appears because of an electromagnetic field of adjacent signal transporting wire. This generates interference currents and voltages. Modern transmission methods offer high line impedance and low currents. That's why the capacitive crosstalk is stronger than the inductive crosstalk.

Most modern Ethernet networks therefore use twisted pair cables. A pair of wires forms a circuit that can transmit data. The twist of the paired wires is necessary to provide protection against crosstalk – the noise generated by adjacent pairs. As soon as electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. The two magnetic fields cancel each other out. If the wires are twisted the cancellation effect is even stronger.

If this twist is not tight enough or the connecting hardware is not proper designed, the result is **near end crosstalk (NEXT)**. The NEXT level is the signal level, which occurs in a pair of wires if an adjacent pair is transmitting a signal. A transmitter disturbs the nearby receiver. The NEXT level is that high because the emission is high at the beginning of the wire. **Far end crosstalk (FEXT)** occurs on signals which run parallel. The FEXT level is occurring on the total length but is also getting attenuated over the distance. That's why the FEXT level is lower than the NEXT level.

With higher transmission rates additional effects occur such as coupling effects between adjoining twisted pair cables. Crosstalk between cables is known as **Alien Crosstalk (AXT)**. Alien Crosstalk can't be calculated and compensated. Proper shielding and proper installation are the key factors to avoid this.

Another important factor is the return loss. It determines whether the used components of a channel are well designed regarding the characteristic impedance. The more properly the setup is matched, the lower the reflected signal will be.

3.3 Current twisted pair standards

As stated in the beginning of this paper, twisted pair cables are standardised and divided up into classes and categories according to their bandwidth. Each class or category covers different applications with specific quality demands.

This table gives an overview about current standards:

EIA/TIA 568-C.2	ISO/IEC 11801	EN 50173	Max. Frequency	Application
CAT 5	CAT 5	Class D	100 MHz	100 Base-TX, SONET, SOH
CAT 5e	CAT 5e	Class D	100 MHz	1 GBase-T
CAT 6	CAT 6	Class E	250 MHz	1 GBase-T, 155-MBit-ATM, 622-MBit-ATM
CAT 6A	CAT 6_A	Class E_A	500 MHz	10 GBase-T
–	CAT 7	Class F	600 MHz	10 GBase-T
–	CAT 7_A	Class F_A	1000 MHz	10 GBase-T, 40 GBase-T, 100 GBase-T, (limited)

figure 5 – Twisted pair standards – Overview

3.4 10 G-Ethernet / Category 6A

Cat 6A derived from the need for a higher bandwidth due to 10 G-Ethernet applications. Thus frequencies up to 500 MHz and a distance of 100 m are possible.

Let's have a look at 10 Gigabit Ethernet according to the different standards:

Standard-body	Configuration	Cat 6 / ClassE (500 MHz)	Cat 6A/ ClassEA (500 MHz)
ISO/IEC	Channel Permanent Link Component	Class E Class E Cat 6	Class E_A Class E_A Cat 6_A
EN (CENELEC)	Channel Permanent Link Component	Class E Class E Cat 6	Class E_A Class E_A Cat 6_A
EIA/TIA	Channel Permanent Link Component	Cat 6 Cat 6 Cat 6	Cat 6A Cat 6A Cat 6A

figure 6 – Class E / E_A Overview (Source: Tyco Electronics)

The requirements of the US specification (EIA/TIA) differ from the international (ISO/IEC) as well as from the European (EN) standard. The latter have higher power reserve and thus allow better planning and installing reliability.

The international and European standards define cable networks from 100 MHz up to 1000 MHz:

Class D: to 100 MHz
Class E: to 250 MHz
Class EA: to 500 MHz
Class F: to 600 MHz
Class FA: to 1000 MHz

Class EA fits for applications up to 10 Gbit/s. Class F and class FA have considerably more headroom and are specified for further Ethernet generations such as 40 GBase and 100 GBase.

The US standard EIA/TIA 568-C.2 is limited for networks up to 500 MHz.

It is essential that Category 6A is not the same as Category 6A!

3.5 Cat6A vs Cat6A – ISO/IEC vs EIA/TIA

The introduction of 10 G-Ethernet over twisted pair cables led to new standards. In February 2008 the EIA/TIA published the Cat6A standard. Almost at the same time the ISO/IEC came up with class EA. Those specifications define different performances.

For the frequency range from 250 MHz up to 500 MHz the prescribed threshold value for the “Near End Crosstalk” is significantly higher within the international ISO/IEC and European EN standard than in the US EIA/TIA counterpart.

Frequency	NEXT Connectors	
MHz	ISO/IEC 11801 AM2	EIA/TIA 568-C.2
	Category 6_A	Category 6A
1	75	75
100	54	54
250	46	46
500	**37**	**34**

figure 7 – Requirements NEXT (Connectors)

For the connectors for example the requirement at 500 MHz is 3 dB higher. This corresponds to a performance increase of 30 % at 500 MHz.

The same is valid for the channel as well as the permanent link:

Frequency	NEXT Permanent Link	
MHz	ISO/IEC 11801 AM2	EIA/TIA 568-C.2
	Class E_A	Category 6A
1	65	65
100	41,8	41,8
250	35,3	35,3
500	29,2	26,7

figure 8 – Requirements NEXT (Permanent Link)

Frequency	NEXT Channel	
MHz	ISO/IEC 11801 AM1	EIA/TIA 568-C.2
	Class E_A	Category 6A
1	65	65
100	39,9	39,9
250	33,1	33,1
500	**27,9**	**26,1**

figure 9 – Requirements NEXT (Channel)

The EIA/TIA CAT 6A channel requirements show a steady decrease of the attenuation from 330 MHz upwards, whereas the channel according to the ISO/IEC Class EA defines a straight curve.

At 500 MHz the difference of the NEXT performance is 1,8 dB between the Class EA and the CAT 6A channel.

ISO/IEC CAT6A vs. TIA Cat 6A
Connecting Hardware Next Values

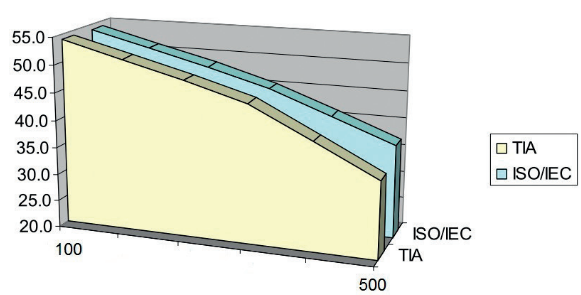


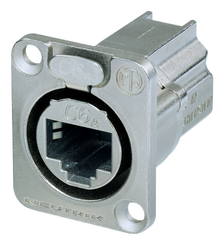
figure 10 – Connecting Hardware NEXT values for different standards

Thus the best performance according to the predominantly available RJ45 technology can be reached by a class EA channel. Since Cat6A components according to the EIA/TIA can’t meet the strong performance of a class EA channel, it is advisable to apply Cat 6A components. This leads to a higher operating reliability of the network and fewer transmission errors.

MEASURING RESULTS

To meet the increasing market demands of higher bandwidth links even in harsh environments Neutrik launches a new product series – the ruggedized CAT6A connector range. These connectors and chassis are component compliant as well as PoE+ compliant.

NE8MX6



NE8FDX-Y6

Below there are measuring results of Neutrik's new CAT6A series regarding NEXT and Power over Ethernet performance.

4.1 NEXT Value

The picture below shows measuring results in terms of NEXT of a 90 m Permanent Link Class EA using Neutrik's NE8MX6 and NE8FDX-Y6. The results are within the limitation of the strict ISO/IES standard 11801.

The diagram reflects enough headroom for future applications. As stated before the class EA channel corresponds to a performance increase of 30 % at 500 MHz in contrast to CAT 6A. Using Neutrik's CAT 6A will provide you enough headroom for possible losses in the real installation environment due to cable bend, deformation, etc…

4.2 Mating durability test etherCON CAT6A with PoE

Neutrik performed a mating cycle test under load (PoE) to evaluate if mating cycle in combination with constant power has any effect to the contact resistance.

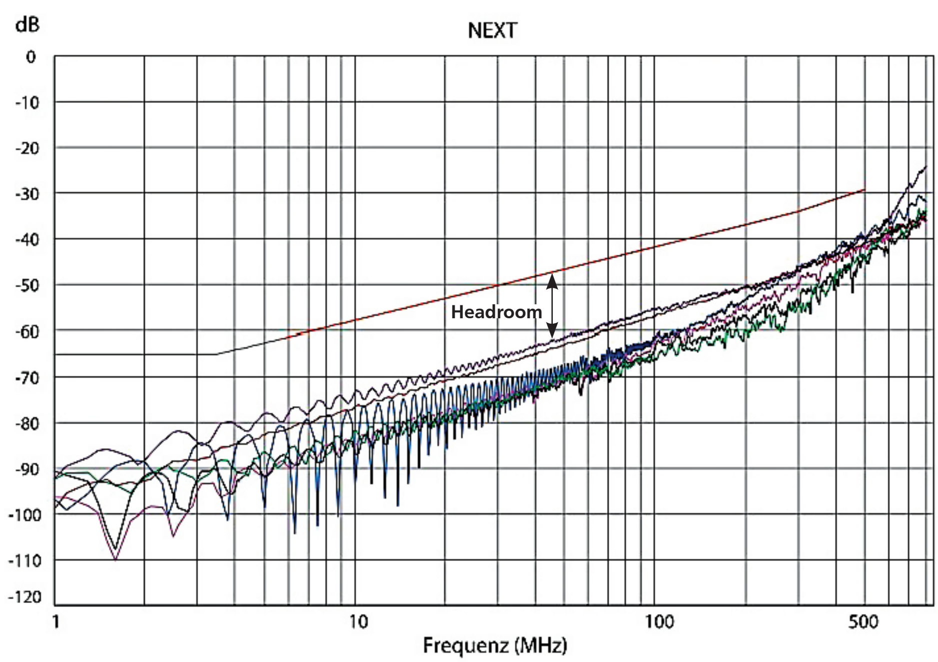


figure 11 – NEXT value of a 90 m Permanent Link Class EA according to ISO/IEC 11801

Test Setup:
The mating cycles have been carried out by a fully automatically mating cycle machine. Current load was simulated by a selfmade current sink (2 different tests with different settings). The cycle consisted of a 4 seconds mated period and a 9 seconds unmated duration.

Measuring was done after:

0 cycles	first initial measurement
250 cycles	resistance measurement with power source
500 cycles	polarity reversal and resistance measurement with power source
750 cycles	resistance measurement with power source
1000 cycles	polarity reversal and resistance measurement with power source

Resistance Measurement has been carried out using a HIOKI milliohm meter. The applied cable was a „Belden 1303E-CATSNAKE S/FTP CAT6A 4PR AWG 24". (2 x 70 cm)

Test Conditions:
Temperature: 21,2 – 24,2 °C
Duration / cycles: 0 to 1000 cycles

Standard measurements according to IEC 60512-99-001 prescribe 100 cycles under load. Neutrik increased this test up to 1000 cycles as it is usual with other Neutrik products.

Test Settings:
Test 1:
56.6 VDC, 0.6 A per pin / 30 W application
Test 2:
47.8 VDC, 1.03 A per pin / 100 W application

Test 1 refers to a PoE+ application (IEEE 802.3at). Test 2 was adapted according to preliminary information about the upcoming new standard 802.3bt, which is as mentioned before not released yet.

figure 12 – NE8FDX-Y6 before test

figure 13 – NE8MX6 before test

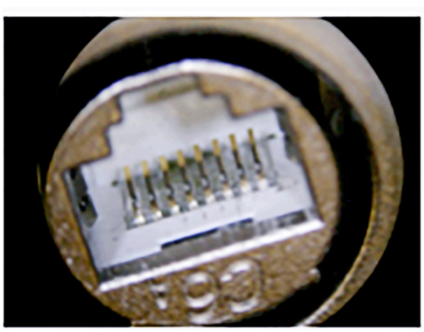


figure 14 – NE8FDX-Y6 after 1000 mating cycles

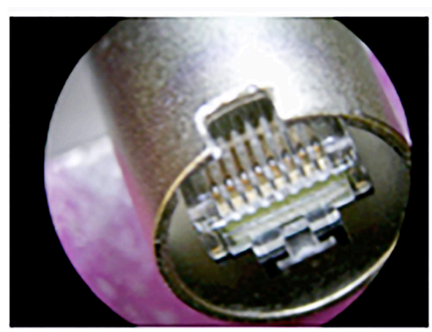


figure 15 – NE8FDX-Y6 after 1000 mating cycles

Results[1]

Test 1:

Pin	0 cycles	Temp.	250 cycles	Temp.	500 cycles	Temp.	750 cycles	Temp.	1000 cycles	Temp.
OR	224	Room temp. 22,6 °C	227	Room temp. 22,6 °C Contact temp. 22,9 °C	241	Room temp. 23,1 °C Contact temp. 23,6 °C	231	Room temp. 23,3 °C Contact temp. 23,6 °C	241	Room temp. 23,2 °C Contact temp. 23,5 °C
OR/WS	230		232		240		243		255	
GN	197		197		198		207		215	
GN/WS	206		209		212		212		212	
BR	206		205		207		216		218	
BR/WS	208		215		230		239		243	
BL	241		239		237		241		249	
BL/WS	240		228		227		229		242	

Measurements in mOhm

Test 2:

Pin	0 cycles	Temp.	250 cycles	Temp.	500 cycles	Temp.	750 cycles	Temp.	1000 cycles	Temp.
OR	224	Room temp. 23,7 °C	226	Room temp. 23,7 °C Contact temp. 24,2 °C	229	Room temp. 21,2 °C Contact temp. 21,8 °C	229	Room temp. 21,7 °C Contact temp. 22,6 °C	230	Room temp. 22,5° C Contact temp. 23,1 °C
OR/WS	235		237		238		239		243	
GN	193		195		194		197		197	
GN/WS	201		204		204		204		205	
BR	200		200		201		203		204	
BR/WS	204		205		205		207		210	
BL	236		237		237		237		237	
BL/WS	218		221		222		222		223	

Measurements in mOhm

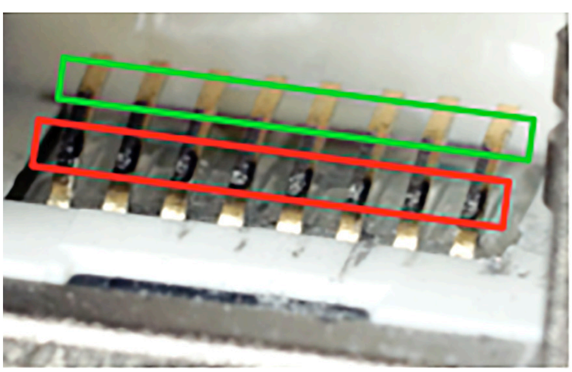


figure 16 – proper contact design of Neutrik's NE8FDX-Y6

Observations:

Typical abrasions of material at the contacts of the chassis as well as of the cable connector without noticeable resistance change. This proves the proper design of the contacts. As shown in fig.16 the contact spot (green) and the nominal spot (red) do not overlap. Further there are no big differences between the results of the two tests (Test 1 30 W; Test 2 100 W). According to the results Neutrik's new CAT 6A series is future proof for upcoming Power over Ethernet standards.

References / Literature

1 Connections 9/2009-37 „CAT 6A vs. CAT 6A", 2009
2 R&M „Cat. 6A vs. Cat. 6A", 2010
3 R&M „Power over Ethernet plus", 2009
4 Schnabel Patrik „Netzwerktechnik-Fibel", 2009
5 Telegärtner „Hintergrundwissen zu 10 G-Ethernet", 2010
6 Telegärtner „Daten-/Netzwerktechnik Basiswissen", 2011
7 Tyco Electronics „Where Cat.6A meets 600 MHz", 2009

[1] **Measuring results consist of:**
- Contact resistance inclusive bulk resistances of connector and chassis: ~ 90 mOhm
- Cable with a length of 1,4 m: ~ 63 mOhm

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