TECHNOLOGY DISRUPTORS IN CABLE MARKETS

POE & POH TECHNOLOGIES
MESSAGE FROM THE ICF SECRETARIAT

ICF CONGRESS OMAN - PLEASE NOTE THE DATES

In order to avoid an overlap with the other events, which ICF members may wish to attend, it has been decided to schedule this year’s congress from the 15th to the 19th of October, 2018. This will also allow us to adapt to the working week structure in the Middle East, so please note that the starting day is a Monday instead of the usual Tuesday.

The organization is going according to schedule and a shortlist of venues for the Gala Dinner and suitable hotels has been prepared. For those of you, who have not had the opportunity to visit the country yet, you will be amazed by its natural beauty and historical culture.

The congress program development is going well and our gratitude goes to our Middle East Standing Commission members, who are supporting the Standing Commission Team.

ICF MEMBERSHIP

We welcome RR Kabel as a new member of ICF and are pleased to inform you that NKT Cables has rejoined our federation.

We are looking forward to seeing all of you in Oman.

Marija Vladic
ICF Executive Administrator
POE & POH TECHNOLOGIES

THE PROGRESS WITH TECHNOLOGIES FOR DELIVERING POWER OVER TWISTED-PAIR COMMUNICATIONS CABLE WILL SPUR DEMAND FOR CATEGORY CABLES IN KEY APPLICATIONS

In a June 2017 conference keynote talk, Southwire CEO Rich Stinson identified three “technology disruptors” that are poised to bring about profound changes in cable markets:

1. LED technology, 2. Power over Ethernet (PoE), 3. dc power distribution

Provided by CRU

The first two, LED technology and PoE are synergistic. Mr. Stinson said the global market for “smart lighting” will grow 25 times over the next five to six years. And of the various protocols and wiring technologies to be used for managing the smart lighting, PoE will have the fastest growth.

LED lighting is indeed a key application for PoE technologies, and it will help stimulate demand for cable to support PoE installations. Of course, there are other applications that will contribute to more systems and cable demand. Some, such as IP telephones, date back more than 15 years. Others, such as industrial automation, are just emerging along with LED lighting and other “intelligent” systems.

Power over Ethernet (PoE) technology has been used for almost 20 years, although early implementations were labeled “injected power,” “inline power” or other names. In the past 10 years, the technology has advanced with more products, higher power levels, and increasingly wide-spread adoption. The most recent work in this area has extended to higher power levels, above 70 W, and new cabling concepts, such as Power over HDBaseT (PoH). These advances, combined with the trends to smart buildings, industrial automation, and other Internet-of-Thing (IoT) applications, suggest strong promise for PoE implementations and associated category cable demand.

PoE: a Wide Family of Products
By 2017, the term “PoE” has come to represent several standards and families of products from many equipment vendors. Most of the connected devices installed in the past 10 to 15 years use Cat-5e or higher-rated twisted-pair cable, and most are associated with web-enabled devices, such as PCs, IP telephones, video cameras, and WiFi hotspots. These applications will continue, but an even broader array of devices will be connected in the future. Examples include indoor lighting, building controls, industrial sensors and controls, and wireless network “small-cell” equipment. With higher power levels and PoH technology, connected devices can now include PCs and television sets.

Market Demand is Ramping Up
In a statement issued in May of 2017, the Ethernet Alliance cited data from market research firm Dell’Oro Group, saying that more than 700 million Ethernet switch ports and 280 million PoE devices will be shipped in the five years from 2017 through 2021. The devices will include IP telephones, cameras, lighting systems, and wireless access points. The data from Dell’Oro also indicates that 35% of
Ethernet ports shipped for campus applications have PoE capabilities, and this percentage will increase to 50%. John D’Ambrosia, Ethernet Alliance chairman and Huawei senior principal engineer, said “The impact of PoE technologies cuts across multiple markets, from enterprise IT, to network operations, to home automation, and this trend looks to continue.”

In a December 2017 press release, CommScope announced new features in its automated infrastructure management software – new features for managing PoE devices. CommScope said, PoE growth trends are due to the ongoing explosion of IoT devices in the building – LED lighting systems, security cameras, wireless access points, etc., as well as the convergence of IT and building operations technology. CommScope also offered the following data points to characterize PoE market size and growth potential:

A report by Grand View Research projects the global PoE market to exceed $3.75 billion by 2025.

A Data Center Journal article estimates that the number of PoE ports installed globally is already over 100 million.

Approval of the 4-Pair PoE standard [an IEEE standard specifying power levels up to 90 W] is expected next year, leading the way for an additional 45 million devices to be powered by the network.

**BACKGROUND OF POE**

**Early History in the Late 1990s**

Cisco Systems is acknowledged as an early developer and strong promoter of PoE technology, referring to it as Inline Power in documents dating back to the late 1990s. Other companies involved in IP telephony also

| THREE STANDARDS COVER POE AND POH – A FOURTH WILL BE RATIFIED IN 2018 |
|---|---|---|---|---|---|---|
| Standard | Common name | Publ. date | Input power | Device power | Cable type | Reach | Conductors |
| IEEE 802.3af | PoE | 2003 | 15.4 W | 12.95 W | Cat-3 or higher | 100 m | 2 pairs |
| IEEE 802.3at | PoE+ | 2009 | 30 W | 25.5 W | Cat-53 or higher | 100 m | 2 pairs |
| Power over HDBaseT | PoH | 2011 | 100 W | 95 W | Cat-5e or higher | 100 m | 4 pairs |
| *IEEE 802.3bt | ** | 2018 | 60 & 90 W | * 51 & 71 W | Cat-5e or higher | 100 m | 4 pairs |

*IEEE 802.3bt standard will include two versions, also range sensing to maximize power at the device, depending on distance.
**IEEE 802.3bt technology has been referred to as PoE++, 4-pair PoE (4PPoE), or HPoE, but none of these names are standardized.
were working on proprietary powering schemes in the 1990s.

In 2000, Cisco published a report describing how it converted its San Jose, Calif. campus to an IP telephony system. Cisco used its Architecture for Voice, Video, and Integrated Data (AVVID) technology to connect 20,000 desktop telephones, located in 55 buildings in a two-mile (3.2-km) radius. The AVVID system’s Ethernet and voice switching units provided 7.5 W of “Inline Power” to the desktop units over CAT3 cable. This was an early large-scale implementation, using a “pre-standard” proprietary scheme.

Progress in Standards and Technology
In 1999, an IEEE standards working group issued a Call for Interest, and work on a PoE standard was underway in 2000. Early applications included VoIP private-branch-exchange (PBX) telephone systems.

- IEEE standards committees finalized two key standards and several updates
- equipment manufacturers developed new “powered devices” (PDs), including Internet-connected devices such as “webcams” and Wi-Fi hotspots
- technical advances included higher power levels and longer reach
- more electronics companies developed devices to operate with PoE power sources
- advances in high-brightness LEDs led to increasing interest in LED lighting
- building owners also pursued other “smart building” features that reduce energy consumption and provide lower operating costs
- the convenience and lower cost of using one “wire” for both power and communications spurred increasing acceptance in both consumer and commercial markets

POE PRODUCTS INCLUDE SWITCHES AND POWERED DEVICES
Electronic equipment manufacturers offer a wide array of commercial and consumer products to operate over category twisted-pair cables with PoE interfaces.
ADVANTAGES OUTWEIGHT DISADVANTAGES

The result of the progress in these areas is an increasing trend among electrical contractors, network designers, lighting contractors, and others to incorporate PoE systems when designing new or retrofit systems for commercial buildings. The advantages and disadvantages of PoE systems include the following characteristics:

ADVANTAGES:
1. No need for ac to dc converters for many powered devices
2. Elimination of building wiring and wall plugs
3. Installation does not require a licensed electrician for low-voltage network
4. Line voltage is typically 50 or 60 V, so safer for working in premises areas, and less risk of overloads damaging the equipment or powered devices
5. Control of lights and other devices through the Ethernet switch, eliminating the need for wiring a separate wall-plate or other switch
6. Greater energy efficiency, resulting from the power sources' power-management software
7. Cat-5e and Cat-6 cables and 8P8C (eight position eight contact) connectors are mature technologies with the following attributes:
   a.) specifications in well accepted, long-standing standards, for network design and installation methods
   b.) widespread availability from well-established manufacturers and distributors
   c.) excellent product uniformity
   d.) strong familiarity among network designers and installers
8. Reliability – Ethernet network equipment often is backed up with uninterruptible power supplies
9. Flexibility in locating powered devices, such as cameras, and in repositioning them, because there is no need to be near a wall-plug or power cable
10. No need for expensive equipment – four- or eight-port Ethernet switches can fall in a range of US$100 to US$300

DISADVANTAGES:
1. Heat dissipation, which limits the number of cables bundled in a cable tray or plenum area
2. Safety risks due to excess heat buildup
3. Degradation of performance – data or power transmission – due to heat buildup
4. Distance limitations
5. Failure risks associated with having multiple devices may be powered by a single multi-port Ethernet switch
6. Connector performance if arcing has occurred during un-mating and caused pitting on the connector contacts. (Note, this depends on the current levels and location of the pitting.)

SPLITTERS CAN BE USED TO POWER WITH NON-POE DEVICES

Electronic equipment manufacturers offer a wide array of commercial and consumer products to operate over category twisted-pair cables with PoE interfaces.

(Diagram courtesy: FS.COM, Shenzhen, China.)
LED LIGHTS

Evolving Since 2000

About 15 years ago, LED light sources were mainly cost-effective for exterior lighting and specialty lights, such as traffic lights. As LED brightness and color balance have improved, costs also have come down. As a result, LEDs are now practical for automotive lighting, interior building lights, and even residential lighting. Over this same 15-year span, PoE technologies also have advanced with the development of software control features and lower costs. And the specific features of LED lighting are well suited for use with the power levels and energy management features of PoE systems.

Working Together to Save Power

LED lights operate with low-voltage dc power. Mains power is ac, and depending on the country, delivered at 110 V to 230 V. Thus, most LED lights used with mains power in residential and commercial buildings must incorporate a converter. This is inefficient, and an extra cost. PoE systems, on the other hand typically provide 15 to 90 W of dc power at voltages typically below 60 V. The amount of money saved by avoiding the inefficient conversion can be substantial even for small buildings – thousands of euros per year. What’s more, the PoE power supply equipment can sense the power level needed and adjust accordingly.

When used with photodetectors, motion sensors, and other controls, the LED light and PoE delivery system form a smart-lighting hub. The Ethernet switch can turn lights up or down if rooms are unoccupied. Further, it can reduce artificial lighting to take advantage of sunlight, and it can balance the use of daylight with the need for air conditioning or heating as parts of the building become warmer than others.

Other Applications

Although LED lighting and PoE systems seem particularly well suited to work together, there are many other systems that can take advantage of PoE to reduce installation costs as well as power and other operating expenses.

USE OF UPS WITH SWITCHES CAN BOOST PD RELIABILITY

The PoE and PoH standards specify power sources at the hub or switch unit as well as mid-span units.
do not need to meet the requirements of the local power utility line voltages, such as 110 V, 230 V, etc. The power source equipment converts line voltages to the appropriate levels required by the devices, and all dc power (and data) connections are made through the category cables’ 8P8C terminations.

**Hub vs. Mid-span Power Sources**

The use of mid-span power sources also can provide greater flexibility in using existing Ethernet switches, upgrading the Ethernet equipment to faster bit rates, and in scaling the number of powered devices connected as needed. Mid-span sources are availability with different port counts, from one to 96, although lower counts, such as 4, 8, 12 and 24, are widely used. The use of mid-span sources also can optimize power efficiency by tailoring the number of ports with power sources to the number needed, and powering up and down as needed. High-port-count Ethernet switches, with say 48 or 96 ports, if fully enabled as PoE power supplies, will waste more power.

**Benefits of Centralized Control**

The power management and power efficiency is a big advantage of PoE systems compared with the use of traditional building wire for power delivery. In a September 2017 webinar organized by Leviton, Kirk Krahn, the company’s senior product manager, copper cable and assemblies, said that PoE can save energy costs for some buildings by up to 40%. The use of central control systems can allow some diagnostics and maintenance from a remote location and can reduce the time to effect repairs. The centralized control and the use of backup power or uninterruptible power supplies also can result in more “up time” or fewer outages. As for operating efficiency, Mr. Krahn discussed office lighting and other building functions, such as temperature and humidity controls. Lighting and other networked systems become part of the IT network, so the building operator can collect data and develop stronger management plans. The use of air conditioning, for example, can be carefully tailored to parts of the building that heat up more due to sunlight or other factors.

**PoE May Drive Cable Demand**

These intrinsic advantages suggest strong potential for PoE systems and category cabling. In addition, some of the applications are experiencing rapid growth. In the case of enterprise wireless devices, the CAGR for wireless traffic is progressing at growth rates of 50% or more. This means not only more data on the networks, but also more wireless access devices. Mr. Krahn said that POE lighting is expected to grow 42% annually, and use of sensors for controlling LED lighting in commercial buildings is expected to increase with a CAGR of 79% through 2020. Thus, LED lighting could prove to be a relatively new and high-growth market for category cables.

**STANDARDS**

**IEEE: the Key Standards Body**

The IEEE published its IEEE 802.3af standard in 2003. This document, known as the “PoE” standard, specifies power delivery up to 15.4 W for an Ethernet port using two pairs of Cat-5e cable. In 2009, the IEEE completed the IEEE 802.at standard, specifying power levels up to 25.5 W per port, again using two of the pairs in Cat-5e or Cat-6 cable. It is known as the “PoE+” standard.

**IEEE Standard for 15 W**

The IEEE 802.3af standard specifies the injection of DC power at 4, 7, 15.4

**EXAMPLES OF POE POWERED DEVICES (PDS) INCLUDE:**

- IP Telephones
- Video conferencing equipment
- IP cameras for security, surveillance, research, etc.
- WiFi Hotspots
- Point-of-sale equipment
- Card readers for security systems
- Biometric access controls
- RFID scanners
- HVAC controls
- Kiosks (e.g. airport flight-check-in equipment)
- Sensors and controls for industrial automation
- Microphones and speakers

**HOW POE WORKS**

**Using the Datacom Cable Plant**

Powering in PoE networks can originate from two sources – the Ethernet switch (hub) unit, or a mid-span injection point. The latter can be used with an Ethernet switch that does not incorporate the power electronics for PoE connections. The dc power can be supplied over two or four pairs, depending on which type of PoE technology is used – that is, which standard. All versions operate over distances up to 100 meters using standard category cabling, such as Cat-3, Cat-5e, Cat-6, or Cat-6a. In PoE systems, the powered devices
W. Devices that operate at other power levels, such as 6-W IP telephones, can be operated with power sources that detect the required power level and also comply with IEEE 802.3af.

Cisco Systems, for example supplies powered devices that can communicate their power requirement to the Ethernet switch or power source. Cisco’s Ethernet switches incorporate “Intelligent Power Management” software to sense the power requirements and adjust the power level at each port to operate most efficiently.

The Market Needed More Power
The 15-W power level in IEEE 802.3af proved adequate for IP telephones, Wi-Fi antenna units, and fixed-lens cameras. But some devices require the higher power levels of PoE+. Examples include cameras with motors for pan, tilt, and zoom, or cameras with heating systems to prevent moisture from freezing on the lens, and new higher-power Wi-Fi standard (IEEE 802.11n). The 2009 IEEE 802.3at standard met the power requirements for many of these devices. It also allowed two devices to be powered with a single Cat-5e cable.

...And Even More Power
At the same time, it was apparent that there was interest in higher power levels. New classes of powered devices were envisioned, such as wireless-network small cells and distributed antenna systems. Several equipment companies had R&D programs to investigate higher power levels using all four pairs for power delivery.

Over the years, there also have been companies offering devices that incorporate non-standard power levels, and proprietary technologies for power over TWP cabling. Some of these have aimed to deliver higher power levels. Starting in 2014, the IEEE 802.3 Working Group began work on a standard for power levels up to 71 W using all four pairs. As of late 2017, there was a version of the new standard in draft form, with a final draft and approval expected in 2018. In a December 2017 statement, the Ethernet Alliance said final ratification is expected in September of 2018. The standard will be known as IEEE 802.3bt.

POE SWITCHES WITH 8, 24, AND 48 PORTS
Compact PoE switches with power supplies are available in a range of port counts, up to 96. The switches contain chips made in high volumes, so costs are reasonable. The RJ45 ports give an indication of the switch units’ size.
IEEE Standard for 90 W

The IEEE 802.3bt standard will have two versions – two power levels. One specifies the source power maximum at 60 W, and the other will be at 90 W. This standard contains protocols for communication between the power source equipment and the powered devices, so that the source unit can adjust the injected power level to meet the powered device’s requirement.

For short distances, with minimal resistance and less power dissipation, the protocol allows for measurement of the actual cable resistance. For short distances, the power received by the powered device can be higher. Thus, the IEEE 802.3bt standard specifies the power received at the power device as a range. In the first version, the input at the powered devices will range from 51W to 60 W. In the second version, it will range from 71W to 90W. The IEEE 802.3af and IEEE 802.3at standards do not incorporate this power-range capability. The powered device’s received power therefore is less than the injected power, to allow for the power dissipation.

Four Types, from 4 to 90 W

When the IEEE 802.3bt standard is ratified, the three IEEE standards as a group will specify four power levels. Thus, PoE is referred to as having four “types:”

- Type 1 is the 15-W power level of IEEE 802.3af.
- Type 2 is the 30-W power level of IEEE 802.3at.
- Type 3 is the 60-W power level of IEEE 802.3bt.
- Type 4 is the 90-W power level of IEEE 802.3bt.

LAN “CATEGORY” CABLES ARE UBICUITOUS

PoE applications take advantage of mature, standardized cable and connector technology.
**HDBaseT: More Power for Video**

Part of the interest in higher PoE power levels is the potential powering of laptop and desktop PCs, video-conference equipment, and other electronics with screens and speakers. The work on power over HDBaseT cables has been motivated by interest in connecting audio, video, and multi-media equipment – both consumer and commercial products.

**HDMI vs HDBaseT**

HDMI and HDBaseT are distinct digital transmission technologies. HDMI was introduced in 2002 for point-to-point links between HD video displays and signal-source equipment. The HDMI cables and connectors are not compatible with the LAN category cables in the TIA-568 structured cabling standard or in the IEEE 802.3 family of Ethernet standards. The HDMI technology is mainly intended for short-distance transport of high-end audio and video signals. HDMI cables are usually sold in 25-foot lengths, and are available in lengths up to 50 feet (15 meters) at most.

**HDBaseT Offers 5Play**

HDBaseT was introduced in 2010 to provide a data transmission standard supporting five functions: HDTV, audio, Ethernet, controls, and power delivery, all over single four-pair cable. The HDBaseT Alliance refers to this capability as “5Play.” The Alliance promotes the technology for applications in consumer electronics, corporate networks, industrial PCs, automotive networks, medical imaging, and other industries.

**Gbps over 100 Meters**

As currently supported by equipment manufacturers, the HDBaseT cable system can transport up 10.2 Gbps of uncompressed high-definition video and audio, 100BaseT Ethernet, control signals, and power in the same cable over distances of 100 meters. Recent versions of HDBaseT equipment also are capable of transporting USB2.0 and 4K video, and the technology will allow multi-stream video and higher resolution video in the future.

HDBaseT technology also supports multiple “hops” to achieve distances longer than 100 meters. There also are single-mode and multimode versions available for distances greater than 100 meters. Single-mode versions are available for distances up to 10 km.

**HDBaseT Mainly Relies on Cat-6a**

Some early implementations of HDBaseT systems using Cat-5e cable encountered problems with the cable’s 100-MHz bandwidth specification. Cat-6a cable, which is rated at 500 MHz, has proved successful in meeting the high frequency applications.

**PoH Standard in 2011**

Power over HDBaseT (PoH) was introduced in September 2011. In a publication introducing the new standard, the HDBaseT alliance said it “is based on the IEEE 802.3at standard with the appropriate modifications to enable safe delivery of 100 W over the four pairs of an Ethernet cable.” The statement also said the standard includes detection and protection mechanisms to ensure safe and reliable power deliver.

**PoH: Also Serving Consumers**

Use of HDBaseT for in-home transport of television programs is considered a key consumer application. PoH technology has been standardized to provide the power levels required by most television sets – up to 100 W. At the same time, TV energy requirements are decreasing with improvements in display technology. PoH also is promoted for television applications because it eliminates the need for ac-to-dc converter, which some customers may consider to be cumbersome with the thinner wall-mounted sets. PoH, however, also means that consumers must bear the additional cost of RJ45 interfaces and Cat-6a cabling. For low-end TV sets and video players, this cost may not be justified.

In the commercial world, PoH is generating interest for video-conferencing equipment and some PCs. Like PoE, the standard can offer energy efficiency and simplified network design and installation.
Heat is the Main Problem
Organizations involved in wiring standards, electrical codes, and safety issues have expressed concern about PoE or PoH installations in which many twisted pair cables carrying power are bundled into the same tray or plenum space. The bundling and packing of cables in such spaces may reduce the potential for heat dissipation into the surrounding air and therefore increase the risk of cable degradation or fire hazards.

UL Offers a Further Specification
In an October 2017 IWCS presentation on PoH cable testing, UL’s Anthony Tassone said that temperatures greater than 100°C have been observed. The UL recently has developed a new specification, UL4299, which describes procedures for measuring and qualifying cables for PoH. Also in 2017, the HDBaseT Alliance and UL announced a certification program for PoH cables that will test cables against the UL4299 specification. The program is for cable manufacturers, and it will evaluate their cables’ ability to 100 W at certain current levels.

Safety Organizations Are Involved
The UL’s specification defines a “-LP” power level that can be safely used in bundles without risk of overheating. The UL’s research on this subject also is the basis of a new table in the 2017 publication of the US National Electrical Code (NEC). The table shows the relationship between cable conductor ampacity, ambient temperature, and cable temperature rating for wire sized between 22 and 26 AWG and for different bundle sizes (number of four-pair cables in the bundle).

Vendors Also Studying the Heat
In a November 2017 webinar organized by the IWCS, Thibaut Lanoe, senior product development engineer for Superior Essex, described his company’s work to analyze twisted-pair performance under the pending four-pair PoE (4PPoE) standard — also known as IEEE 802.3bt. Mr. Lanoe said main concerns of the standard will include temperature and safety of installation. Other concerns will be power efficiency, operating cost, lifetime of cable components — lifetime when exposed to higher temperatures.

Bundles at Higher Power Levels
Concerning safety, the main issue is injecting power up to 100 W. The issue is that dc resistance generates heat (the Joule effect). This results in lower voltage and power loss, and the components are exposed to higher temperatures. To study this, Superior Essex ran tests with 100 cables in a bundle. Mr. Lanoe said, “we think this is a typical number,” but he noted that UL runs tests with larger bundles.

Optimizing AWG and Materials
Superior Essex ran the tests with different category cable types, different conductor sizes (AWG), and different cable materials. Among the conclusions, power efficiency is affected more by gauge than temperature; and aluminium foil shielding can help with heat dissipation. The most effective combination appeared to be Cat-5e cable with 22 AWG and plenum materials. However, this is not the least expensive selection of AWG and cable materials.

Beyond 100 W? Too Soon To Say
Mr. Lanoe noted that the IEEE standard work was aiming to stay under 100 W, although he was aware of some studies to test the performance up to 200 W. He commented that he was not aware of any concrete plans for 200 W equipment. In general, his presentation indicated that work on applications using the IEEE 802.3bt standard or higher powers will require cable manufacturers to undertake studies to balance the AWG, materials costs, and other factors.

PoE has Distance Limitations
All of the standards specify 100-meter spans, although there are possible ways to extend this with mid-span power sources and repeaters. In 2014, TE Connectivity, now part of CommScope, developed a hybrid fiber-plus-power cable to substitute for PoE installations over spans up to 3 km. When TE officials...
presented the concept during sessions of the IWCS 2014 annual conference, they described it as a “PoE extension cord.” CommScope now refers to this system as its “Powered Fiber Cable System.” The design can support either single-mode or multimode fibres in a central tube. For the power, TE has versions with 12 or 16 AWG conductors to provide -48V dc power over different distance ranges. The result is a compact flat cable that incorporates fibre and conductors to deliver PoE functions over longer distance.

**PoE and PoE+ Can Be Extended**

CommScope offers this system with a mix of optical power (distance) and conductor sizes (power levels). The system is supplied with the cable, power supply, connection accessories, and a unit containing the fiber-to-TWP data interface, the DC power management, and electrical protection circuits. TE supplies the system with options for conductor size and DC-to-DC converters to cover a range of power requirements, or distances from 0.4 to 3.0 km.

**Certifying the Equipment Too**

In May of 2017, the Ethernet Alliance launched a PoE Certification Program. The goal is to assure that power devices and power sources from different equipment manufacturers are interoperable. The program also will allow users to rapidly distinguish between proprietary and standards-based equipment. The products are tested against the Ethernet Alliance PoE certification specification, which is based on the current IEEE PoE standards. Tests may be performed at the University of New Hampshire InterOperability Laboratory, or vendors can conduct their own tests using approved equipment. After successful tests, equipment vendors can use the Ethernet Alliance’s certification logo and can be listed to a registry of PoE products.

In December of 2017, the Ethernet Alliance said it would include pre-standard testing of products against the draft of the new IEEE 802.3bt standard. This will further help the expansion of commercial markets and stimulate demand for Cat-5e, 6, and 6A.

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**POE AND POH CAN USE ALL CATEGORY CABLE TYPES**

Market demands have led to development of higher-bandwidth category-cable types, and PoE equipment is able to operate with all types.

<table>
<thead>
<tr>
<th>Cable type</th>
<th>AWG</th>
<th># pairs</th>
<th>shielding</th>
<th>Maximum frequency</th>
<th>Application, other comment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level-1</td>
<td>2</td>
<td>2</td>
<td>UTP</td>
<td>1 MHz</td>
<td>&quot;telephone wire&quot;</td>
</tr>
<tr>
<td>Level-2</td>
<td>4</td>
<td>4</td>
<td>UTP</td>
<td>4 MHz</td>
<td>&quot;telephone wire&quot; and Token Ring</td>
</tr>
<tr>
<td>Cat-3</td>
<td>24-26</td>
<td>2-4</td>
<td>UTP</td>
<td>16 MHz</td>
<td>&quot;station wire,&quot; early 10 BaseT Eth. cable, obsolete</td>
</tr>
<tr>
<td>Cat-4</td>
<td>26</td>
<td>4</td>
<td>UTP</td>
<td>20 MHz</td>
<td>telephone and data up to 16 Mbps, obsolete</td>
</tr>
<tr>
<td>Cat-5</td>
<td>24</td>
<td>4</td>
<td>UTP</td>
<td>100 MHz</td>
<td>10 BaseT or 100 BaseT, also obsolete</td>
</tr>
<tr>
<td>Cat-5e</td>
<td>22-26</td>
<td>4</td>
<td>STP or STP</td>
<td>100 MHz</td>
<td>10 Base T, 100 Base T, 1G BaseT</td>
</tr>
<tr>
<td>Cat-6</td>
<td>23**</td>
<td>4</td>
<td>STP</td>
<td>250 MHz</td>
<td>10G BaseT up to 55 m</td>
</tr>
<tr>
<td>Cat-6a</td>
<td>23</td>
<td>4</td>
<td>STP</td>
<td>500 MHz</td>
<td>10G BaseT up to 100 m</td>
</tr>
<tr>
<td>Cat-7</td>
<td>23</td>
<td>4</td>
<td>STP</td>
<td>600 MHz</td>
<td>ISO std, but not a TIA/EIA std., 10 Gbps Eth., plus 25 and 40 Gbps over shorter distances</td>
</tr>
<tr>
<td>Cat-7a</td>
<td>23</td>
<td>4</td>
<td>STP</td>
<td>1 GHz</td>
<td>ISO std, but not a TIA/EIA std., 10G over 100 meters, 40G over 50 m, and 100G over 15 m.</td>
</tr>
<tr>
<td>Cat-8</td>
<td>22</td>
<td>4</td>
<td>STP</td>
<td>2 GHz</td>
<td>ISO and TIA/EIA std., 25 and 40G over 30 m</td>
</tr>
</tbody>
</table>

*TIA 568 standard specifies Cat-5e with solid core “thermoplastic insulated solid conductors” of 22 to 24 AWG. The standard also includes an annex specifying a screened variant with cores of 26 AWG. The STP version can incorporate 26 AWG tin-coated copper conductors.

**Standards specify Cat-6 through Cat-8 with AWG 22-24, but 23 is commonly produced. 22 AWG is clearly the maximum.
BACKGROUND ON CABLE TYPES

Cable Standards
A key standards body working on standards for structured wiring systems is the TIA’s TR-42 committee, with its various sub-committees and working groups. The resulting standards are published as TIA-568. There have been numerous addenda and revisions since the first 568 standard publication in 1991. The latest, as of 2015, is referred to as revision D.

The US has an umbrella organization, ANSI, that sanctions standards in many industries. Thus, the American standard for building writing is often referred to as ANS / TIA 568-D.

The corresponding standard for Europe and other regions is the IEC 11801. IEC standards are sanctioned by the ISO, hence the name ISO / IEC 11801. This standard also has updates as well as variants for different types of buildings, such as residential, office, industrial, etc. The latest version for office buildings is ISO / IEC 11801-2:2017.

A Note About Connector Types
The TIA/EIA 568 standard that governs structured cabling systems for communication networks specifies the pinouts and spacing of the four-pair category cables. The connector specification is referred to as 8P8C - “eight position eight contact.” The well-known RJ45 “registered jack” technology is a version of 8P8C connectors, but the terms “8P8C” and “RJ45” are not strictly synonymous. The RJ45 plug’s molded body contains an alignment key not specified in the TIA 568 standards.

In practice, however, the equipment and connector manufacturers generally refer to their TIA-568-compliant 8P8C connectors informally as RJ45s, and this name has become widespread. More importantly, the TIA-568 network

8P8C CONNECTOR, KNOWN AS RJ45

The term “RJ45” is widely used to describe the 8P8C connectors of the TIA-568 standards, and the connectors are widely used with four-pair category cables.
cables and equipment used in PoE and PoH systems have full compatibility and intermateability.

**Connector Standardization**
For the purposes of PoE product compatibility, the connector interface is identical to that specified in the TIA 568 cabling standards. Category cables used in standard PoE systems can work with equipment and devices made by any manufacturer, in any country. The PoE switches and devices have been developed to simplify installation in terms of physical-layer interconnection, as well as in the upper layers that manage the power levels. Some equipment manufacturers describe the products as “plug and play,” and many, such as web cameras, can readily be installed by consumers.

**Cable category nomenclature**
The various categories have different bandwidth capabilities, resulting from the cable’s design. The main design features aim to reduce electromagnetic interference from external sources and to reduce cross talk from other wires in the same cable. The design variables affecting bandwidth include insulation materials, use of shielding, type of shielding, and twist characteristics – the number of twists per meter.

The higher the cable type or “category” number, the higher the bandwidth performance. Because bandwidth and distance trade-off against each other, the higher-performing cables generally are specified for higher bit rates over a commonly used distance of 100 meters. In some cases, the higher-performing cables are specified with options for bit rates and distance, or a combination of higher bit rates and longer reach.

**Cable Names in the Standards**
Low-speed versions of unshielded twisted-pair cable have been used over many decades for internal telephone wiring. Versions rated at 1 and 4 MHz are sometimes referred to as Cat-1 and Cat-2, but these names are not defined in ANSI / TIA standards. Anixter has used a “Level” numbering scheme with 1 and 2 for these products. These cables often were called “telephone wire” or “station wire.” Categories 3 through 7a are defined in ISO / IEC standards and ANSI / TIA standards. Categories 3 through 5e were unshielded, and the standards defined Cat-6 with both shielded and unshielded versions.

Early local-area-network (LAN) installations, dating back to the 1970s and early 1980s used coaxial cable. One early IBM LAN used shielded twisted pair. In the mid-1980s, 16-MHz unshielded twisted pair, later known as Category-3, was used for a 1 Mbps LANs. Cat-3 UTP also was first used for in-line power, starting in the mid-to-late 1990s, for early VoIP systems.

As the technology has progressed, Cat-3, Cat-4, and Cat-5 cable types have become obsolete. That is, they no longer are in production. Cat-5e cable is still in production, but its use is being superseded by Cat-6 and Cat-6a. Systems operating with Cat-3 or Cat-5 cable, of course, can continue to operate. The owners or operators can use higher rate cables for any maintenance, extensions, additions, etc.

**Faster LANs and Better Cables**
The general trend since the 1990s has been for computer users to need more network bandwidth as processors, memory, software, displays, printers, storage systems, and other technologies have improved. Computer files became larger, and users needed transmission faster rates. The IEEE 802.3 sub-committees are continually working on standards addenda or on new versions. The standards organizations involved in physical-layer networking are also working on new cable specifications to keep up with requirements for faster bit rates. There is also a change in the mix of cable types being sold as the networking standards and transmission rates scale up.

**Market Preferences Shifted Up**
In the 1990s, Cat-5e cable had the largest share of the premises cable market. This was superseded by Cat-6, which was developed in the late 1990s and widely deployed in the last 15 years. Cat-6 sales have levelled off, and Cat-6a, which was developed to support 10-Gbps networking, is showing stronger market acceptance.

**Cat-7 and 7a Connector Issues**
Cat-7 and Cat-7A are not covered in the TIA standards that are mainly used in the US. These two cable types are recognized in the ISO / IEC standards used outside the US. Cat-7 and Cat-7A cables cannot use the same “RJ45” connector as lower-rate category cables. The Cat-7 and Cat-7A cables require a special shielded 8P8C connect with additional contacts. As a result, Cat-7 and Cat-7A cables are mainly serving smaller market niches as of 2017.

**Cat-8 is the latest standard**
What is the status of Cat-8 in standards committees? The TIA standards group moved from Cat-6a to Cat-8, essentially ignoring Cat-7 and Cat-7A due to the connector and bandwidth issues. In July of 2016, the TIA released document TIA-568-C.2-1, which specifies minimum requirements for shielded Cat-8 cable and components, including connectors, connecting hardware, and equipment cords. The TIA also will incorporate the
Cat-8 specifications into the updated TIA-568-D standard.

The IEEE 802.3bq standard was completed in September 2016. It specifies 25GBaseT and 40GBaseT (25 Gbps and 40 Gbps) transmission over 30 meters of Cat-8 cable. The standard is mainly focused on shorter runs inside data centers, so the 30-meter specification includes a 24-meter link and 6 meters of patch cords.

**Cat-8 Equipment Not Ready Yet**

Although the standards groups have published standards with Cat-8 cable and with 25GBaseT and 40GBaseT transmission, the equipment manufacturers are still in development phases. Equipment products using 8G are not expected to be widely available until 2019, so adoption of Cat-8 cable is not expected to ramp up until 2020. Although the standards specify compatible connectors, it is not clear whether this cable type will be used with PoE equipment. With its design focused on short spans in data centers, Cat 8 probably is not cost-effective for PoE.

**Cable types and market trends**

There are countless magazine articles, web publications, and conference presentations about the relative merits of different cable types for different datacom applications. The three main factors for deciding among cable types are bit rate, distance, and cost. Several other factors indirectly are related to cost: energy and cooling requirements, energy efficiency, density, availability of space in ducts, trays, and rack hardware, etc. In addition, less readily quantified factors come up, such as customer preference or comfort and expectations as to when system upgrades will be needed.

**Data Centers have Specific Needs**

In the data center market, fiber may be capturing a larger share of the overall cable demand due to its distance and bit-rate capabilities. Fiber is clearly advantageous in the very large “hyper-scale” data centers. Gigabit-rate copper links, using Cat 6A and higher-rate cables will have a strong niche in shorter inside spans, such as links at the end of rows, links at the middle of rows, such as on the top of the racks. Within the data center market, the more interesting segment for copper cables may be smaller localized data centers. As of 2017, it is not clear whether data centers will be a high-growth application for copper cabling.

### American Wire Gauge in Metric Sizes, with Resistance and Ampacity Ratings.

Future work on higher power levels and heat dissipation may focus on wire gauge, shielding, and cable materials.

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<th>AWG</th>
<th>Dia., inch</th>
<th>Dia., mm</th>
<th>Area, mm²</th>
<th>Resistance (Ohm/km)</th>
<th>Resistance (Ohm/kft)</th>
<th>Ampacity at 20 deg. C</th>
<th>Ampacity at 75 deg. C</th>
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Data: ASTM and NFPA
PoE technology has developing for about 20 years. It has progressed through several standards, with the general trend to specify higher power levels.

PoE technology also has proven well suited for the main category-cable types used in structured cabling systems. Now, at the outset of 2018, PoE appears poised for a surge in port shipments.

The technology is particularly well-suited for LED lighting, which also has shown strong technical progress. However, the higher power levels, and the standardized cable and connector interfaces will help PoE and PoH in a large number of applications. The technology offers attractive benefits in energy management, ease of deployment, and low installation costs. As a result, the surge in ports shipped likely is to be accompanied by a surge in category cable demand.

**Where PoE Can Spur Cable Demand**

The bright spot in the copper data-com cable market outlook, however, may prove to be premises applications that will take advantage of PoE or PoH technologies. Fiber cable is not a factor in these applications. Also, for many PoE applications, such as IP telephones, LED lighting, web cameras, and building controls, gigabit transfer rates are not the deciding factor among cable types. Thus, PoE and PoH could prove to be key market drivers for Cat-6 and Cat 6A cable sales in the coming years. Plus, the attractiveness of efficient, easily managed power delivery may prove attractive with some of the emerging Internet of Things (IoT) applications – operating sensors and cameras, collecting data, running point-of-sale terminals, signs and information displays in public places.

For structured cabling in other building and campuses, fiber’s role is more likely to be identified with backbone installations, not horizontal runs or connections to individual devices. To the extent that many of these devices may benefit from PoE, campus and building networks might also offer better growth prospects for TWP cable now that PoE technologies are proliferating and maturing.

**CONCLUSION**