De-Mystifying Cabling Specifications

– From 5e to 7_A

Structured cabling standards specify generic installation and design topologies that are characterized by a "category" or "class" of transmission performance. These cabling standards are subsequently referenced in applications standards, developed by committees such as IEEE and ATM, as a minimum level of performance necessary to ensure application operation. There are many advantages to be realized by specifying standards-compliant structured cabling. These include the assurance of applications operation, the flexibility of cable and connectivity choices that are backward compatible and interoperable, and a structured cabling design and topology that is universally recognized by cabling professionals responsible for managing cabling additions, upgrades, and changes.

The Telecommunications Industry Association (TIA) and International Standard for Organization (ISO) committees are the leaders in the development of structured cabling standards. Committee members work hand-in-hand with applications development committees to ensure that new grades of cabling will support the latest innovations in signal transmission technology. TIA Standards are often specified by North American end-users, while ISO Standards are more commonly referred to in the global marketplace. In addition to TIA and ISO, there are often regional cabling standards groups such as JSA/JSI (Japanese Standards Association), CSA (Canadian Standards Association), and CENELEC (European Committee for Electrotechnical Standardization) developing local specifications. These regional cabling standards groups contribute actively to their country's ISO technical advisory committees and the contents of their Standards are usually very much in harmony with TIA and ISO requirements.

While the technical requirements of TIA and ISO are very similar for various grades of cabling, the terminology for the level of performance within each committee's Standards can cause confusion. In TIA Standards, cabling components (e.g. cables, connecting hardware, and patch cords) are characterized by a performance "category" and are mated to form a permanent link or channel that is also described by a performance "category". In ISO, components are characterized by a performance "category" and permanent links and channels are described by a performance "class". TIA and ISO equivalent grades of performance are characterized by their frequency bandwidth and are shown in table 1.

TABLE 1: TIA AND ISO EQUIVALENT CLASSIFICATIONS

FREQUENCY BANDWIDTH	TIA COMPONENTS)	TIA (CABLING)	ISO (COMPONENTS)	ISO (CABLING)
1 – 100 MHz	Category 5e	Category 5e	Category 5e	Class D
1 – 250 MHz	Category 6	Category 6	Category 6	Class E
1 – 500 MHz	Category 6A	Category 6A	Category 6_A	Class E_A
1 – 600 MHz	n/s	n/s	Category 7	Class F
1 – 1,000 MHz	n/s	n/s	Category 7_A	Class F_A

When faced with the daunting task of upgrading an existing network or designing a new building facility, cabling experts are encouraged to look to the Standards for guidance on performance and lifecycle considerations. Both TIA and ISO state that the cabling systems specified in their Standards are intended to have a useful life in excess of 10 years. Since applications, such as Ethernet, typically have a useful life of 5 years, it is recommended practice to specify cabling systems that will support two generations of network applications. For most commercial building end-users, this means specifying a cabling plant that is capable of supporting 1000BASE-T (Gigabit Ethernet) today and a planned upgrade to 10GBASE-T in 5 years.

TIA categories and ISO classes of structured cabling that are recognized for the support of data-speed applications are specified in the Standards listed in Table 2.

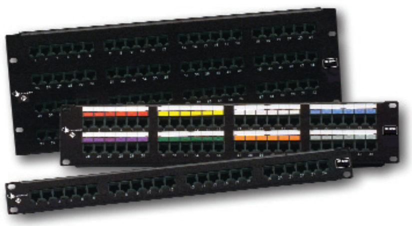
TABLE 2: TIA AND ISO STANDARDS REFERENCES

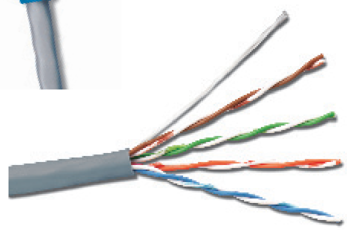
TIA CABLING STANDARDS	
Category 5e	ANSI/TIA-568-C.2, Balanced Twisted-Pair Telecommunications Cabling and Components Standard, 2009
Category 6	ANSI/TIA-568-C.2, Balanced Twisted-Pair Telecommunications Cabling and Components Standard, 2009
Category 6A	ANSI/TIA-568-C.2, Balanced Twisted-Pair Telecommunications Cabling and Components Standard, 2009
ISO CABLING STANDARDS	
Class D	ISO/IEC 11801, 2nd Ed., Information technology – Generic Cabling for Customer Premises, 2002
Class E	ISO/IEC 11801, 2nd Ed., Information technology – Generic Cabling for Customer Premises, 2002
Class E_A	Amendment 1 to ISO/IEC 11801, 2nd Ed., Information technology – Generic Cabling for Customer Premises, 2008
Class F	ISO/IEC 11801, 2nd Ed., Information technology – Generic Cabling for Customer Premises, 2002
Class F_A	Amendment 1 to ISO/IEC 11801, 2nd Ed., Information technology – Generic Cabling for Customer Premises, 2008

CATEGORY 5E/CLASS D

Category 5e/class D cabling requirements were first published in 2000 in order to address the additional transmission performance characterization required by applications such as 1000BASE-T that utilize bi-directional and full four-pair transmission schemes. The Standard added headroom to category 5 performance limits and characterized several new transmission criteria that were required for support of Gigabit Ethernet over a worst case four-connector channel (the 1000BASE-T application was originally targeted for operation over category 5 channels having just two-connectors). To ensure that additional performance margins were satisfied, category 5e/class D specifications added headroom to the parameters of NEXT loss, ELFEXT loss, and return loss and introduced the characterization of crosstalk using power summation, which approximates the total crosstalk present when all pairs are energized as in a four-pair transmission scheme.

Although no longer recognized by the Standards for new installations, a substantial number of installed category 5 channels are likely to support the 1000BASE-T application. Information on the qualification of legacy category 5 installations for this application can be found in annex M of ANSI/TIA-568-C.2.





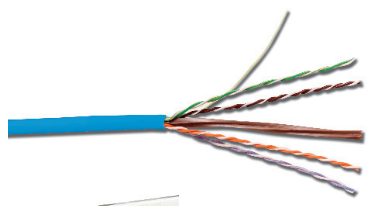
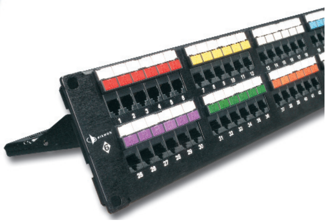
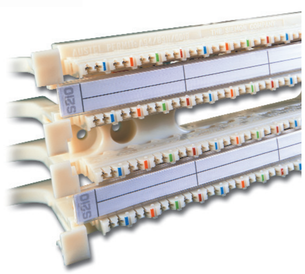
CATEGORY 6/CLASS E

Category 6/class E cabling delivers double the signal-to noise margin (attenuation-to-crosstalk margin is positive to 200 MHz) of category 5e/class D cabling and provides the performance headroom desired by end-users to ensure that their cabling plant can withstand the rigors of the cabling environment and still support 1000BASE-T when it comes time for an application upgrade. The category 6/class E cabling specification development process also brought to light the need to limit the conversion of differential mode signals to common mode signals and vice versa through the characterization of component balance, resulting in cabling systems with improved electromagnetic compatibility (EMC) performance.

Although, category 6/class E cabling was primarily targeted to support 100BASE-T and 1000BASE-T applications, the good news is that some of the installed base of category 6/class E cabling can support the 10GBASE-T application. The TIA TSB-155-A and ISO/IEC 24750 technical bulletins identify the additional performance headroom, as well as applicable field qualification test requirements and procedures, which must be satisfied by the installed base of category 6/class E cabling in order to support the 10GBASE-T application.

Since the digital signal processing (DSP) capabilities of the 10GBASE-T application result in full internal pair-to-pair crosstalk cancellation, this application is particularly sensitive to undesired signal coupling between adjacent components and cabling. This coupling is called alien crosstalk and the characterization of alien crosstalk in the installed category 6/class E cabling plant is the main focus of the TIA TSB-155-A and ISO/IEC 24750 technical bulletins. Because the alien crosstalk in category 6/class E UTP cabling is extremely dependent upon installation practices (e.g. bundling, the use of tie-wraps, and pathway fill), performance values were developed based upon a “typical” worst case environment meaning that 10GBASE-T should operate over category 6/class E UTP channel lengths of up to 37 meters and may operate over channel lengths of 37 to 55 meters of category 6/class E UTP cabling depending upon the actual alien crosstalk levels present. Since the overall foil in category 6/class E F/UTP cabling designs significantly reduces alien crosstalk, these length limitations are not applicable to F/UTP cabling.



TIA TSB-155-A and ISO/IEC 24750 also specify recommended mitigation practices in the event that an installed category 6/class E channel does not satisfy the minimum alien crosstalk levels. Mitigation techniques include using non-adjacent patch panel ports to support the 10GBASE-T application, separating or using improved equipment cords, using F/UTP equipment cords, unbundling cables, reconfiguring cross-connects as interconnects, and replacing category 6/class E components with category 6A/class E_A components.

Category 6/class E cabling is not recommended for new installations targeted for support of the 10GBASE-T application. The reason for this is that, while field test devices for determining compliance to the new PSANEXT loss and PSAACRF (previously known as PSAELFEXT loss) parameters are just now being introduced to the market, the test methodology remains extremely time-consuming, overly onerous to implement, and may not be fully conclusive. Furthermore, in a majority of installations, alien crosstalk mitigation will be required. Often, the recognized mitigation methods cannot be easily implemented due to existing pathway fill restrictions and the potential need to replace components. In addition, there is no guidance on qualification procedures for large installations or future MAC work.

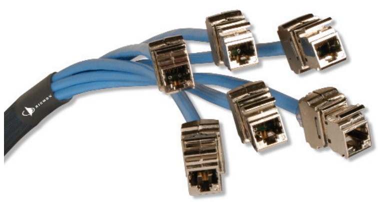
Since the category 6/class E Standard was published in 2002, it is more than halfway through its targeted 10-year lifecycle. Today's cabling specifiers are looking to even higher performing grades of cabling to ensure maximum performance and return-on-investment.

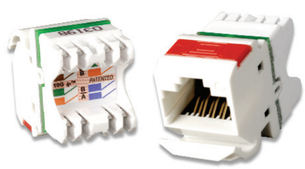
CATEGORY 6A/CLASS E_A

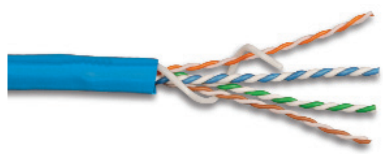
Category 6A/class E_A cabling requirements were developed to address the extended frequency bandwidth and alien crosstalk headroom required to support 10GBASE-T over 100 meters of cabling containing up to four-connectors. Category 6A/class E_A cabling delivers positive signal-to-alien crosstalk margin up to 500 MHz and is recommended as the minimum grade of cabling capable of withstanding the rigors of the cabling environment and supporting 10GBASE-T when it is time for an application upgrade. Balance requirements for channels and permanent links are also specified for the first time, thereby ensuring better electromagnetic compatibility (EMC) performance than any previous generation of cabling.

Performance headroom has been incorporated into all transmission parameters, including power sum alien crosstalk, and both laboratory and field test qualification methods are specified for category 6A/class E_A cabling. Average power sum alien crosstalk across all four-pairs is specified for use by the IEEE committee in their channel capacity modeling. It is interesting to note that the term "equal level far-end crosstalk loss" (or ELFEXT loss) previously used in TIA specifications has been replaced by "attenuation to crosstalk ratio, far-end" (or ACRF). The intent of this change is for TIA to harmonize with the ISO terminology and more accurately describe the actual test measurement configuration.

Category 6A/class $E_A$cabling provides the maximum return-on-investment when the calculations are performed using a 10-year lifecycle.







CLASS F

Class F requirements were published in 2002 and describe performance criteria for a fully shielded media type (i.e. cabling with an overall shield and individually shielded pairs). Category F cabling delivers positive attenuation-to-crosstalk margin up to 600 MHz and offers unsurpassed electromagnetic capability (EMC) performance because of its shielded construction.

Due to its ease of use, performance headroom, ability to support multiple applications under one sheath, and its specification as the recommended category 7 interface in the ISO 15018 Standard, the non-RJ style plug and socket interface specified in IEC 61076-3-104:2002 is the most commonly specified category 7 connector. This interface is commercially available from multiple manufacturers whose products are interoperable. There is significant evidence that the cabling industry and applications developers are ready to adopt fully-shielded cabling. For example, class F cabling was identified as the copper media of choice in one IEEE new application call-for-interest and the published ISO/IEC 14165-114 application Standard, entitled, "A Full Duplex Ethernet Physical Layer Specification for 1000 Mbit/s operating over balanced channels Class F (Category 7 twisted pair cabling)", specifies operation over a minimally rated class F channel.

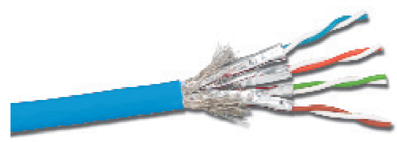
It is interesting to note that, although TIA is not actively developing a standard for category 7 at this time, it is acceptable to specify class F cabling in North American markets. The rationale for this is that, in addition to being recognized by BICSI, NEMA, IEEE, and other standards organizations, class F is simply a superset of TIA category 6A requirements. Field test requirements and adapters for class F cabling qualification have been commercially available since 2002.

The advantage that class F has over other grades of cabling is that it is targeted for support of next generation applications beyond 10GBASE-T. Class F cabling is the only media to have a 15-year lifecycle and class F cabling provides the maximum return-on-investment when calculations are performed using a 15-year lifecycle.

CLASS F_A

Class F_A requirements are based upon the existing class F cabling requirements and category 7 non-RJ style plug and socket interface. The significant enhancement in class F_A specifications is the extension of the frequency bandwidth of characterization from 600 MHz to 1,000 MHz. This enhancement allows class F_A cabling to be uniquely capable of supporting all channels of broadband video (e.g. CATV) that operate up to 862 MHz. Today, nearly all fully-shielded cabling solutions specified are class F_A.




APPLICATIONS SUPPORT

Table 3 summarizes cabling types capable of supporting commonly specified applications over 100-meter, four-connector topologies.

TABLE 3: APPLICATIONS CHART

	CATEGORY/5E CLASS D	CATEGORY 6/CLASS E	CATEGORY 6A/CLASS E_A	CLASS F	CLASS F_A
4/16 MBPS TOKEN RING	√	√	√	√	√
10BASE-T	√	√	√	√	√
100BASE-T4	√	√	√	√	√
155 MBPS ATM	√	√	√	√	√
1000BASE-T	√	√	√	√	√
TIA/EIA-854		√	√	√	√
10GBASE-T			√	√	√
ISO/IEC 14165-144				√	√
BROADBAND CATV					√

PERFORMANCE COMPARISON CHART:

Table 4 provides comparative channel performance data at 100 MHz for category 5e/class D, category 6/class E, category 6A/class E_A, class F, and class F_A channels. Where there is a slight difference between TIA and ISO performance limits, ISO performance limits are indicated in parenthesis.

TABLE 4: INDUSTRY STANDARDS PERFORMANCE COMPARISON AT 100 MHZ FOR CHANNELS

	Category 5e/Class D	Category 6/Class E	Category 6A/Class E_A	Class F	Class F_A
Frequency Range (MHz)	1 – 100	1 - 250	1 - 500	1 - 600	1 – 1,000
Insertion Loss (dB)	24.0	21.3 (21.7)	20.9	20.8	20.3
NEXT Loss (dB)	30.1	39.9	39.9[1]	62.9	65.0
PSNEXT Loss (dB)	27.1	37.1	37.1[1]	59.9	62.0
ACR (dB)	6.1	18.6	18.6	42.1	46.1
PSACR (dB)	3.1	15.8	15.8	39.1	41.7
ACRF (dB)	17.4	23.3	23.3	44.4	47.4
PSACRF (dB)	14.4	20.3	20.3	41.4	44.4
Return Loss (dB)	10.0	12.0	12.0	12.0	12.0
PSANEXT Loss (dB)	n/s	n/s	60.0	n/s	67.0
PSAACRF (dB)	n/s	n/s	37.0	n/s	52.0
TCL (dB)	n/s	n/s	20.3	20.3	20.3
ELTCTL [3] (dB)	n/s	n/s	0.5/0	0	0
Propagation Delay (ns)	548	548	548	548	548
Delay Skew (ns)	50	50	50	30	30

[1] ISO/IEC class E_A NEXT loss and PSNEXT loss requirements are more stringent than TIA category 6A limits above 330 MHz.

CONCLUSION:
When designing and installing structured cabling systems, chose the strongest foundation to support your present and future network applications needs. To ensure support of emerging technologies that utilize the latest advances in signaling schemes, it is critical to be as informed as possible. Trust the TIA and ISO standards developmental groups to specify complete cabling criteria capable of providing applications assurance for tomorrow's technologies today.

IMPORTANT DEFINITIONS

Alien Crosstalk
Unwanted signal coupling from one component, channel, or permanent link to another is defined as alien crosstalk. Since alien crosstalk is an indicator of differential (or balanced) signal coupling, alien crosstalk cannot be adversely impacted by common mode noise (e.g. noise from motors or florescent lights) that is present in the environment. Alien crosstalk is only specified by the Standards as a power sum parameter for components and cabling to approximate the energy present when all pairs are energized. Power sum alien crosstalk measured at the near-end is called power sum alien near-end crosstalk loss (PSANEXT loss) and power sum alien crosstalk measured at the far-end is called power sum alien attenuation to crosstalk ratio, far-end (PSAACRF). High power sum alien crosstalk levels can compromise the operation of the 10GBASE-T application.

Attenuation to Crosstalk Ratio, Far-End (ACRF) (previously know as ELEFXT loss)
Pair-to-pair far-end crosstalk (FEXT) loss quantifies undesired signal coupling between adjacent pairs at the far-end (the opposite end of the transmit-end) of cabling or a component. ACRF is calculated by subtracting the measured insertion loss from the measured far-end crosstalk loss and yields a normalized value that can be used to compare cable and cabling performance independent of length. Poor ACRF levels can result in increased bit error rates and/or undeliverable signal packets. Note that NEXT loss margin alone is not sufficient to ensure proper ACRF performance.

Attenuation to Crosstalk Ratio (ACR)
A critical consideration in determining the capability of a cabling system is the difference between insertion loss and near-end crosstalk (NEXT) loss. This difference is known as the attenuation to crosstalk ratio (ACR). Positive ACR calculations mean that transmitted signal strength is stronger than that of near-end crosstalk. ACR can be used to define a signal bandwidth (i.e. 200 MHz for category 6) where signal to noise ratios are sufficient to support certain applications. It is interesting to note that digital signal processing (DSP) technology can perform crosstalk cancellation allowing some applications to expand useable bandwidth up to and beyond the point at which calculated ACR equals zero. Even so, the maximum frequency for which positive ACR is assured provides a benchmark to assess the useable bandwidth of twisted-pair cabling systems.

Balance
Twisted-pair transmission relies on signal symmetry or "balance" between the two conductors in a pair. Maintaining proper balance ensures that cabling systems and components do not emit unwanted electromagnetic radiation and are not susceptible to electrical noise. Component balance requirements are specified for category 6/class E cabling. Component and cabling balance requirements are specified for category 6A/class E_A and higher grades of cabling. Balance may be characterized by longitudinal conversion loss (LCL), longitudinal conversion transfer loss (LCTL), transverse conversion loss (TCL), or equal level transverse converse transfer loss (ELTCTL).

Equal Level Far-End Crosstalk (ELFEXT) Loss
See definition for Attenuation to Crosstalk Ratio, Far-End.

Insertion Loss (Attenuation)
Insertion loss is a measure of the decrease in signal strength along the length of a transmission line. Ensuring minimal signal attenuation is critical because digital signal processing (DSP) technology can not compensate for excessive signal loss.

Near-End Crosstalk (NEXT) Loss
Pair-to-pair near-end crosstalk (NEXT) loss quantifies undesired signal coupling between adjacent pairs at the near-end (the same end as the transmit-end) of cabling or a component. Excessive NEXT loss can be detrimental to applications that do not employ crosstalk cancellation digital signal processing (DSP) technology.

Power Sum
All pair-to-pair crosstalk parameters can be expressed as a power summation, which approximates the level of undesired internal signal coupling present when all pairs are energized. Power sum NEXT loss, ACRF, ANEXT loss, and AACRF characterization confirms that the cabling is significantly robust to minimize crosstalk from multiple disturbers. This type of characterization is necessary to ensure cabling compatibility with applications that utilize all four pairs for transmitting and receiving signals simultaneously such as 1000BASE-T and applications that are sensitive to alien crosstalk such as 10GBASE-T.

Propagation Delay & Delay Skew
Propagation delay is the amount of time that passes between when a signal is transmitted and when it is received at the opposite end of a cabling channel. The effect is akin to the delay in time between when lightning strikes and thunder is heard - except that electrical signals travel much faster than sound. Delay skew is the difference between the arrival times of the pair with the least delay and the pair with the most delay. Transmission errors that are associated with excessive delay and delay skew include increased jitter and bit error rates.

Return Loss
Return loss is a measure of the signal reflections occurring along a transmission line and is related to impedance mismatches that are present throughout a cabling channel. Because emerging applications such as 1000BASE-T and 10GBASE-T rely on full duplex transmission encoding schemes (transmit and receive signals are superimposed over the same conductor pair), they are sensitive to errors that may result from marginal return loss performance.

Transfer Impedance
Shield effectiveness characterizes the ability of screened (F/UTP) and fully shielded (S/FTP) cables and connecting hardware to maximize immunity from outside noise sources and minimize radiated emissions. Transfer impedance is a measure of shield effectiveness; lower transfer impedance values correlate to better shield effectiveness

ABOUT THE AUTHOR

Valerie Maguire holds the position of Global Sales Engineer at The Siemon Company. Valerie received her B.S.E.E. degree from the University of Connecticut and actively participates in the development and publication of IEEE 802.3 Ethernet and ANSI/TIA telecommunications standards. She has edited many TIA Standards, including ANSI/TIA-568-B.2-10 (category 6A) and newly published ANSI/TIA-568-C.2 (copper cabling). Valerie is Vice Chair of the TIA TR-42 Telecommunications Cabling Systems Engineering Committee, Vice Chair of the TIA TR-42.7 Copper Cabling Subcommittee, TIA TR-42 appointed liaison to IEEE 802.3, Treasurer of IEEE 802.3, and Secretary of the IEEE 802.3 Maintenance Task Force. In addition, Valerie is a frequent speaker at industry conferences. She has authored over 45 technical articles and engineering papers, holds one U.S. Patent, and received the 2008 Harry J. Pfister Award for Excellence in Telecommunications.

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