Premises cabling system performance

Understanding the Options

A White Paper

Perspective

Whether you're an end user, consulting engineer, contractor or distributor; it is critical to consider the dynamics between network protocols, building/campus topology, cabling system performance and cabling system life expectancy. As it would be a waste of money to specify a cabling system that didn't satisfy the current and future performance requirements of a corporate or institutional information systems strategy, it would also be a waste to over-specify a cabling system because of a misunderstanding of the requirements or issues for each option.

To clarify the many cabling system transmission performance classifications, we review the history of the industry's efforts to define cabling systems, with particular emphasis on twisted pair (balanced) cable for horizontal cabling and optical fibre for backbone cabling and Fibre-to-the-Desk (FttD) plus provide an account of current industry designations and expectations and describe the AMP NETCONNECT systems showing how they satisfy these current industry designations. Although there are many differences between the various specifications written around premises cabling systems, we will focus on the issues related to performance.

History, Standards, Perceptions and Definitions

The first major attempt to define a generic commercial cabling standard was begun in the mid '80s. Although there were earlier efforts to classify cabling systems, they were predominately based on the specific requirements of a particular equipment vendor.

EIA/TIA-568

In July 1991, the Electronic Industries Association/Telecommunications Industry Association published ANSI/EIA/TIA-568, "Commercial Building Telecommunications Wiring Standard", to formally define the mechanical and electrical requirements for the cable and components that made up USA premises cabling systems. This standard formalised the maximum cable runs used in the industry; most importantly 100 metres maximum for horizontal cabling and 500 metres maximum for building backbone cabling.

The standard also included specifications for 100 Ohm UTP (unshielded twisted pair), 150 Ohm STP (shielded twisted pair), 50 ohm coax and 62.5/125μ optical fibre. Twisted pair cable and connecting hardware were specified electrically as components from 1 to 16 MHz. Although a cable performance programme had been proposed, time did not permit its inclusion in the standard.

TSB 36

In November 1991 Technical Systems Bulletin 36 (TSB 36), which further defined UTP cable performance by "categories", was published. TSB 36 included definitions for cables from Category 1 to Category 5 plus mechanical and electrical specifications for Categories 3, 4, and 5.

Note: TSB 36 also replaced the 150 Ohm STP *Level* 5 cable in industry terminology with 100 Ohm *Category* 5 cable, which had extended performance requirements for near end crosstalk (NEXT) and attenuation up to 100 MHz.

TSB 40

In order to specify connecting hardware to match the performance of the cable categories, TIA TR41.8.1 published Technical Systems Bulletin 40 (TSB 40). TSB 40 classified connecting hardware by Categories 3, 4 and 5 and listed NEXT and attenuation specifications up to 100 MHz. Recognising that installation practices could affect cable performance, TSB 40 also included recommendations for specific handling procedures, such as pair untwist and jacket removal when terminating Category 4 & 5 cables. The revision (TSB 40-A; January 1994) went further and included requirements for patch cables and jumpers.

ISO/IEC 11801

In May (corrected and reprinted in July) 1995 the International Organisation for Standardization (ISO) and the International Electrotechnical Commission (IEC) published the International Standard ISO/IEC 11801, "Generic Cabling for Customer Premises". ISO/IEC 11801 defined the channel as all the horizontal cabling including the patch cords but less the equipment plugs. ISO added a second definition called a link. The link was everything from the equipment panel to the workstation outlet and was considered to be what the contractor would leave in the wall. The link included patch cables (between two halves of the cross connect) but not equipment cables. The link model was used to determine minimum performance (Figure 1). Five link performance classifications were also established; Class A, B, C and D for 100, 120 and 150 ohm balanced cabling (shielded or unshielded) plus an optical class for 50/125μ, 62.5/125μ and singlemode optical fibres. Class D has the highest balanced cabling performance and is specified up to 100 MHz. This was the first time that a published standard provided performance parameters for something more inclusive than cabling system components. This work acknowledged the importance of cabling system performance and the fact that component specifications alone did not assure that result.

The standard also recommended that optical fibre should be used as backbone cabling for 'high-speed' data systems.

International Standard ISO/IEC 11801 provides a basis for global consistency and is now strongly considered during the preparation of all regional or national standards, including the American National Standard ANSI/TIA/EIA-568-A, European Standard CENELEC EN 50173 (issued August 1995), Canadian Standard CSA T 529, and Australian/New Zealand Standard AS/NZS 3080:1996.

	NEXT			ATTENUATION			ACR		
Frequency	11801	TSB 67		11801	TSB 67		11801	TSB 67	
	Class D	CAT 5	CAT 5	Class D	CAT 5	CAT 5	Class D	CAT 5	CAT 5

(MHz)	Link	Channel	Link	Link	Channel	Link	Link	Channel	Link
1	54	60	60	2.5	2.5	2.1		57.5	57.9
4	45	50.6	51.8	4.8	4.5	4	40	46.1	47.8
8		45.6	47.1		6.3	5.7		39.3	41.4
10	39	44	45.5	7.5	7	6.3	35	37.0	39.2
16	36	40.6	42.3	9.4	9.2	8.2	30	31.4	34.1
20	35	39	40.7	10.5	10.3	9.2	28	28.7	31.5
25		37.4	39.1		11.4	10.3		26.0	28.8
31.25	32	35.7	37.6	13.1	12.8	11.5	23	22.9	26.1
62.5	27	30.6	32.7	18.4	18.5	16.7	13	12.1	16.0
100	24	27.1	29.3	23.2	24	21.6	4	3.1	7.7

Figure 1

Shaded areas represent no listed specifications by the designated standard. Although ACR (attenuation to crosstalk ratio) is not specified by ANSI/TIA/EIA-568-A or TIA TSB-67, the derived values based on NEXT and attenuation are provided for comparison.

ANSI/TIA/EIA-568-A

In October 1995, TSB 36, TSB 40 and TSB 40A were incorporated into ANSI/TIA/EIA-568 Revision A along with worst case performance characteristics. The channel at this time was defined as everything from the NIC card to the LAN concentrator or hub.

Figure 2 illustrates the channel and link relationships defined in these standards.

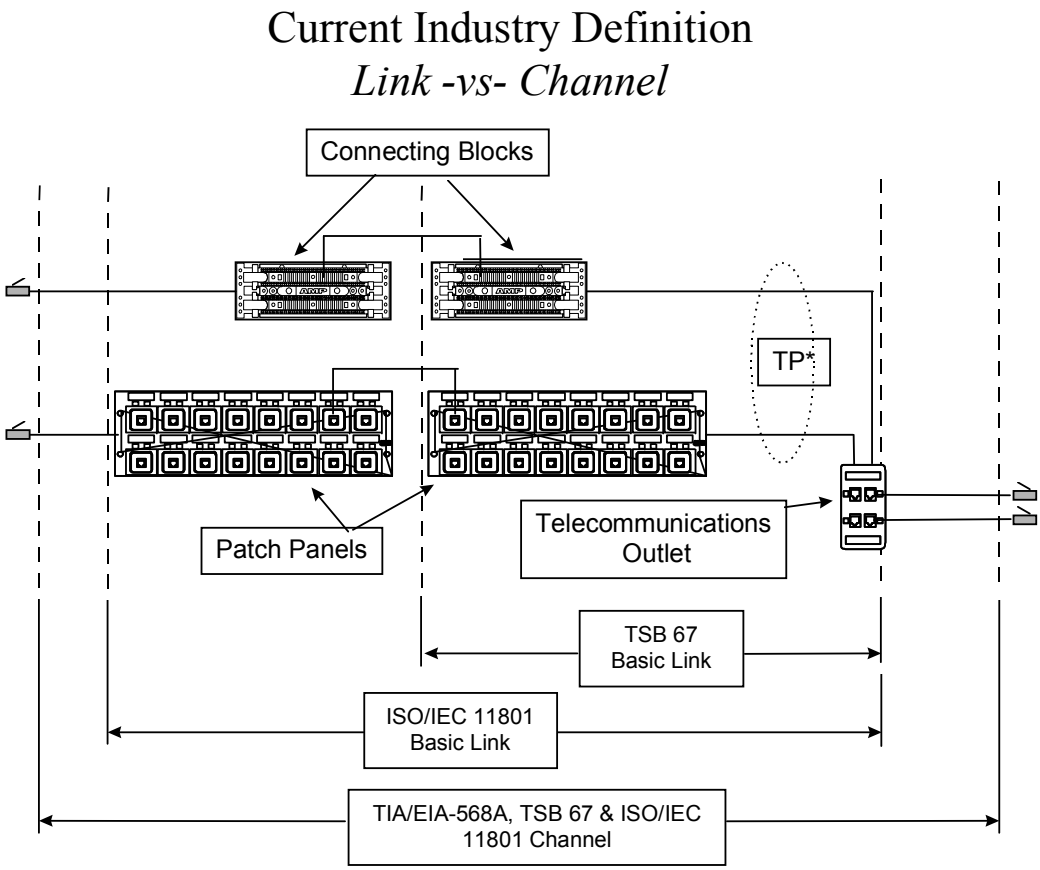


Figure 2

TSB 67

Directly following TIA/EIA-568-A in 1995 was Technical Systems Bulletin 67. The purpose of TSB 67 was to more clearly define performance requirements for premises cabling systems and how they should be measured in the field. This TSB included separate definitions for the “Channel” and the “Basic Link” (Figure 2) and specified different performance levels for each (Figure 1). The numbers specified for basic link were more strict to allow for the addition of patch cables at a later time and still maintain the channel performance requirements. TSB 67 also specified the measuring accuracy of hand held testers in order to control the variation in results.

Industry Stability?

At this time there appeared to be stability in the cabling system industry. Standards were now established that specified performance requirements for components and completely installed systems, providing guidelines to:

- manufacturers of cable and connecting hardware
- cabling system manufacturers who provide warranties on components or systems
- manufacturers of hand-held field testers
- contractors who install and verify complete cabling systems

Stability, however, is relative. As this brief summary of the premises cabling systems business has already shown, performance requirements are constantly changing. This first series of standards were written for cabling systems that supported network protocols like 10BASE-T, 4 or 16 Mbps token ring, 100 Mbps FDDI, 100 Mbps Fast Ethernet and even 155 Mbps ATM. It would seem that these applications, especially the latter, would be sufficient for most any application. Right? Guess again, because it's not unusual:

- to replace workstations or PCs every one or two years.
- to be three performance revisions behind on your PC six months after you purchased the 'fastest on the market'.
- to have 90 % of your memory resources used up on your PC or workstation.
- to have creative engineers or designers staring at their screens waiting for networks to respond when printing or saving files.
- to want new hardware and applications that allow you to be more efficient at your work.
- for software companies to come up with new applications that make you want them.
- for hardware companies to continue to come up with machines that are 'fastest on the market'.
- and it's not unusual for businesses, health care facilities, education providers, financial institutions or governments to want to install the highest performance cabling infrastructure they can afford in order to accommodate these things.

Based on the facts that hardware continues to get faster, application software continues to use more memory and require more bandwidth and end users continue to buy faster equipment, we know that network bandwidth requirements will continue to increase. It would also be reasonable to presume that requirements for cabling system performance will also change.

Cabling systems did begin to change. Terms like "enhanced", "headroom", "margin", "high-end Cat 5", "Cat 5+", "Level 6" "Level 7", "Category 6", "Category 7", "Class E and F" and phrases like "characterised to 350 MHz", "able to transmit 622 Mbps to the workstation area" and "able to transmit 1000 Mbps to the workstation area" began to accompany premises cabling systems that were designed with various amounts of added performance margin.

The latest work coming out of IEEE for 'Gigabit Ethernet' has even called into question the assumption that optical fibre can do anything.

To better explain these current terms and phrases we need to look specifically at where they came from and what they were describing.

E DIN-44312-5

The anticipation of increasing network bandwidth requirements, and the uncertainty that a Class D system would have good enough transmission and electro-magnetic emissions performance for an emerging 622 Mbps ATM application to operate properly, a need developed to generate a specification to ensure that high speed data could run over copper cable systems. A subcommittee of the Deutsches Institut für Normung (DIN), the German standards body, generated it's own standard for a 600 MHz cabling system. This draft specified cable requirements which a number of (mostly European) manufacturers produce. The only cable design that met this standard (so far) is referred to as PiMF (Pairs in Metal Foil) which describes a 4-pair, 100 Ohm cable where each twisted pair is wrapped in foil and then an overall shield surrounds the 4-pair assembly. The standard followed the requirements in EN 50173 but added a new 'link' which included the workstation area cable and only allowed one patch panel. In theory such a cabling system would support 622 Mbps ATM on two pairs using simple NRZ encoding.

Additional Requirements for Category 5 and Enhancements

In North America efforts were also made to put some boundaries around the numerous "enhanced" Category 5 cables that were being marketed as "enhanced performance" or "Cat 5+". One attempt to set boundaries came from a distributor of premises cabling components. They published a document based on a purchasing specification that required their suppliers to qualify their ***high performance*** unshielded twisted-pair cable by a series of "levels". Three levels of performance were defined:

- Level 5 – similar to Category 5 with the additional specifications of 10 dB pair-to-pair ACR (attenuation to crosstalk ratio) at 100 MHz and 10 dB power sum ACR at 80 MHz.
- Level 6 – a new 'level' that specifies cable with 10 dB pair-to-pair ACR at 155 MHz & 10 dB power sum ACR at 100 MHz.
- Level 7 – another new 'level' that specifies a cable with 10 dB pair-to-pair ACR at 200 MHz and 10 dB power sum ACR at 160 MHz.

The biggest concern with this approach was that it only specified ***cable*** performance. Network protocols run over a complete installation of cable, connecting hardware, patch and work area cables plus active devices. The draft Gigabit Ethernet standard for balanced cabling (1000BASE-T) seems to add more parameters at each revision. To cover this important issue the ANSI/TIA/EIA UTP System Task Group is in the process of releasing two addenda to ANSI/TIA/EIA-568-A. One is titled, "Additional Transmission Performance Specifications for 100Ω 4 -Pair Category 5 Cabling" (issued) and the second one is entitled, "Additional Transmission Performance Specifications for 100Ω 4 -Pair Enhanced Category 5 Cabling" The additional requirements are summarised below (Figure 3).

	Addendum	
Parameter (See glossary for definition)	Cat 5	E-Cat 5
Power Sum NEXT		√
Power Sum ELFEXT	√	√
Return Loss	√	√

Figure 3

These additional requirements are also being added into the International Standard ISO/IEC 11801 and it is expected that a second issue, to be called ISO/IEC 11801 (2000) will be released towards the end of the year 2000. This will be matched by a revised CENELEC EN 50173 (2000) and an ANSI/TIA/EIA 568-B standard. Other benefits to all will include common definitions for links, more help for fibre-to-the -desk installations etc.

'Category 6/Class E' and 'Category 7/Class F'

Additionally, the ISO/IEC Joint Technical Committee 1/SC 25 Working Group 3 (ISO/IEC JTC 1/SC 25/WG3) decided at the conclusion of the September 1997 meeting in Munich, Germany to proceed with new cabling categories and classes that will provide significant improvement over Category 5 and Class D. WG 3 is undertaking simultaneous development of these new balanced cabling categories and classes. 'Category 6/Class E' will specify cabling system positive channel performance to 200 MHz and 'Category 7/Class F' will specify cabling system positive channel performance to around 600 MHz. 'Category 6/Class E' also specifies that the modular jack interface shall be maintained for all user interfaces at the TO (telecommunications outlet). The 'Category 7/Class F' interface connector at the TO will be capable of 4-pair termination and performance. This interface connector will be internationally standardised. At this time the modular jack interface is the default connector.

At their subsequent January 1998 Orlando meeting they added more performance details to the evolving drafts e.g. 'Category 6/Class E' channel test requirements at 250 MHz.

'Gigabit Ethernet' and optical fibre.

The IEEE committee has identified that most multimode optical transceivers use LED, digital (on - off) technology, and their operating limit is about 622 Mbps. A new transceiver technology -VCSEL (Vertical Cavity Surface Emitting Laser) - has been developed to bring 'Gigabit' capability to multimode optical fibre networks. VCSELs also operate at the same wavelength ('short' - 850nm) as the most common LEDs.

The performance implications for large-building horizontal networks and backbone applications can be critical. 50/125μ and 62.5/125μ optical fibres can provide 'Gigabit' short wavelength system performance in the horizontal (100 metre) cabling but only the right 50/125μ optical fibre can give this performance in the building backbone (500 metres).

For this distance, 62.5/125μ optical fibre requires optical transceivers working at the 'long' (1300nm) wavelength and these transceivers need high performance (and price) lasers. In addition, special 'launch conditioning' adapter leads are needed.

When the campus backbone is longer than around 550 metres only singlemode cabling and transceivers will handle 'Gigabit Ethernet'.

Summary of Industry/Standard Performance Designations

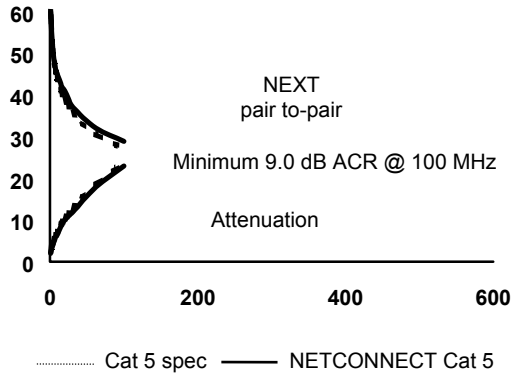
Performance Designation	Current Status	Performance Characteristics
Class D/ Category 5 Cabling Systems	• Original Industry Performance Spec for Cat 5 – TIA/EIA-568-A, Category 5 – ISO/IEC 11801, Class D – CENELEC EN 50173, Class D – AS/NZS 3080:1996, Class D • TIA/EIA-568-A is currently being amended to include ELFEXT and return loss as additional requirements Considered a minimum performance requirement for cabling technology	• Performance bandwidth: 1 to 100 MHz • Worst case link performance requirements at 100 MHz per EN 50173* – NEXT (loss)..... 24 dB – Attenuation ..... 23.2 dB – ACR..... 4 dB *See Figure 3 for other specifications
Class D (2000)/Category 5 (2000) - Enhanced Category 5 Cabling Systems	• TIA/EIA-568-A Draft Addendum, "Additional Transmission Performance Specifications for 4-pair 100Ω *Enhanced* Category 5 Cabling" – TIA/EIA 568-B, enhanced Category 5 – ISO/IEC 11801 (2000), Class D (2000) – CENELEC EN 50173 (2000), Class D (2000) – Needed for applications using all 4 cable pairs and full duplex transmission – Provides margin above Class D/Cat 5 – Recognises advances in cabling technology – Includes power sum NEXT, power sum ELFEXT, return loss, insertion loss deviation and balance as additional requirements of Category 5 Minimum for Gigabit Ethernet	• Performance bandwidth: 1 to 100 MHz • Worst case link performance requirements at 100 MHz per ANSI/TIA/EIA-568-A Draft Addendum 10a – Power sum NEXT (loss) ..... 29.3 dB – Attenuation ..... 21.6 dB – Power sum ACR* ..... 7.7 dB – ELFEXT..... 20.0 dB – Return Loss..... 12.1 dB – Skew ..... 45 ns – Balance ..... TBD *Derived
'Class E/ Category 6' Cabling Systems (Proposed)	• Originally a European de facto standard developed for 300 MHz shielded cabling to be fully compliant with EN 50173 and show a positive ACR at 300 MHz • Recently proposed for ISO/IEC 11801-A as 'Class E/ Category 6' specifying system (UTP or shielded) channel performance, testable to 250 MHz.	• Original de facto link performance bandwidth: 1 to 300 MHz • ISO/IEC 11801 positive channel performance bandwidth: 1 to 200 MHz (proposed) • Worst case channel performance (at 200 MHz) requirements proposed by ISO/IEC JTC 1/SC 25/WG3 – Power sum NEXT (loss) ..... 31.9 dB – Attenuation ..... 31.8 dB – Power sum ACR ..... 0.0 dB • ISO/IEC will be issuing additional clarification for this performance Category
'Class F/ Category 7' Cabling Systems (Proposed)	• Originally defined by E DIN 44312-5, Class E (Germany's effort to establish a next generation Copper performance category) • Recently proposed for ISO/IEC 11801-A as 'Class F/ Category 7' specifying system channel performance, testable to 600 MHz.	• Performance bandwidth: 1 to 600 MHz • Worst case link positive performance requirements at 600 MHz per E DIN 44312-5 – NEXT (loss)..... 54.0 dB – Attenuation ..... 50.0 dB – ACR..... >4.0. dB • ISO/IEC will be issuing additional clarification for this performance Category
'Gigabit Ethernet' and optical fibre.	• Results of IEEE 802.3 work on the behaviour of multimode cable subjected to short (VCSEL) and long (laser) wavelength 'Gigabit' transmissions • Only 50/125μ fibre can handle building cabling distances over 270 m at short wavelength; 62.5/125μ fibre needs long wavelength equipment • Launching laser light into multimode fibre requires special adapter leads • Singlemode cable needed for long distances	• Multimode cable size: 50/125μ • Bandwidth: 500 MHz.km @ 850nm; 500 MHz.km @ 1300nm • Cable size supported by ISO/IEC 11801 and EN 50173 but with 200 and 500 Mhz.km minimum bandwidth. • Cable size not covered by EIA/TIA 568-A

Figure 4

AMP *NETCONNECT* Systems and Link Performance

NETCONNECT Momentum Category 5/Class D System

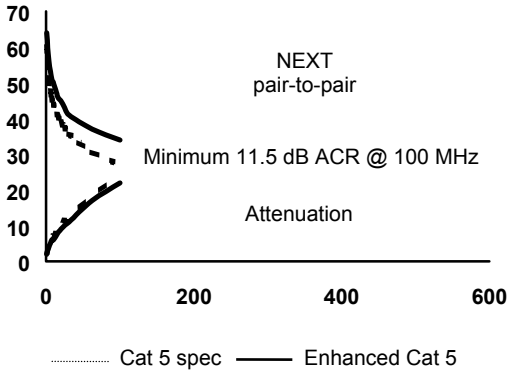
- Cable: NETCONNECT Category 5 UTP, FTP or S-FTP
- Connecting Hardware:
  - 110Connect Modular System
  - 110Connect XC Cross Connect System
  - EconoLink System
  - EMT Modular System
  - AMP Communications Outlet
  - Category 5 Patch Cord Assemblies
- Description: The NETCONNECT Class D System provides complete flexibility through modular and cross connect components as well as the AMP Communications Outlet that uses interchangeable inserts at the patch panel and outlet. The system exceeds the requirements of the original Class D specification.



NETCONNECT Momentum Enhanced *Category 5*/*Class D (2000) System*

- Cable: *Enhanced* Category 5 UTP, FTP or S-FTP
- Connecting Hardware:
  - 110 Connect Modular System
  - 110 Connect XC Cross Connect System
  - AMP Communications Outlet
  - Enhanced Category 5 Patch Cord Assemblies

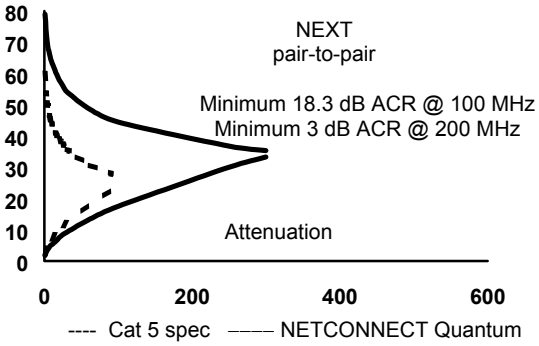
Description: The NETCONNECT *Enhanced* Category 5/Class D (2000) system provides all the same flexibility as the Class D/Category 5 system but with the addition of power sum *enhanced* performance. The system utilises modular connectivity as well as the AMP Communications Outlet that uses interchangeable inserts at the patch panel and outlet. It exceeds the Enhanced Category 5 cabling requirements currently under development by the TIA.



NETCONNECT Quantum 'Class E/Category 6' System

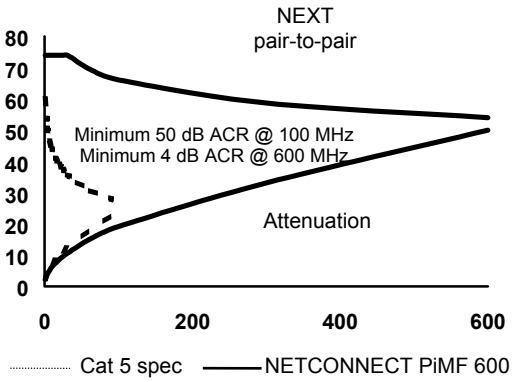
- Cable: Quantum UTP or PiMF 300
- Connecting Hardware:
  - Quantum Modular Jack Outlet System
  - Quantum Modular Patch Panels
  - EMT Modular System
  - AMP Communications Outlet
  - Quantum Patch Cord Assemblies

Description: The Quantum System provides performance above 'Class E/Category 6' with UTP or PiMF cable and modular connectivity as well as the AMP Communications Outlet that uses interchangeable inserts at the patch panel and outlet.



NETCONNECT Platinum 'Class F/Category 7' System

- Cable: PiMF 600
- Connecting Hardware:
  - AMP Communications Outlet
  - Platinum Patch Cord Assemblies
- Description: The Platinum System is a high performance shielded cabling system using PiMF 600 cable and the AMP Communications Outlet. This system satisfies the requirements for the link specified in the German E DIN 44312-5 standard and the proposed ISO/IEC 11801 specifications for 'Category 7/Class F' cabling.



NETCONNECT Solarum Optical Class System

- Cable size: multimode 50/125μ, singlemode cable size 9/125μ
- Connecting Hardware
  - MT-RJ, SC type or ST style outlets and enclosures
  - Solarum multimode and singlemode Patch Cord Assemblies
- Description: The Solarum System is a high performance optical fibre cabling system using Solarum optical fibre cable and MT-RJ, SC type or ST style connectivity. This system specifically satisfies the draft IEEE 802.3 requirements to run 'Gigabit Ethernet' for the full building standards cabling distances using short wavelength devices.

Conclusion

Our first objective was to clarify the industry's definitions of premises cabling systems performance and their relationship to end user requirements. The second objective was to provide the reader with the understanding necessary to recommend, specify or buy a cabling system that satisfied their requirements. The third objective was to show the AMP NETCONNECT Systems that exceed those requirements. AMP has continually provided the industry with high performance components and systems. Our mission is to stay ahead of your requirements in order to provide you with the exact cabling system you need when you need it.