Synopsis

Structured cabling standards were overhauled in 2002, with higher performance media plus new architectures and dimensioning rules defined in ISO/IEC 11801, CENELEC EN 50173 and TIA/EIA 568-B. These 2nd generation standards are significantly more complex than their predecessors and, while every effort was made to harmonise them, a number of technical differences exist. This white paper describes the key features of 2nd generation cabling standards and also highlights the main changes and differences.

1. 1st Generation Cabling Standards

TIA/EIA 568-A, ISO/IEC 11801 and EN 50173 were all published in 1995. They each define cabling as a system, from outlet-to-outlet. These design standards also define cabling components (cable and connecting hardware), either as formal specifications (by TIA/EIA) or as minimum performance requirements (by ISO/IEC and CENELEC).

1st generation standards specified copper cabling up to 100 MHz. ISO/IEC 11801 and EN 50173 were based on link performance and recognised 4 Classes of copper cabling performance; Class A, B, C and D. All 1st generation standards recognised copper component performance Categories 3, 4 and 5. TIA/EIA 568-A specified 100 ohm unscreened twisted pairs, terminated with an 8-pin modular connector (RJ-45) as a 4-pair cable. ISO/IEC 11801 and EN 50173 specified both 100 ohm and 120 ohm cables, which may be screened or unscreened twisted pairs or quad construction, terminated with an 8-pin modular connector as either a 2-pair or 4-pair cable. ISO/IEC 11801 and EN 50173 stated a preference for 4-pair terminated 100 ohm cables. 150 ohm screened (IBM Type 1) cable was also recognised by 1st generation standards, although its use was not preferred.

The key parameters specified for 1st generation copper cabling were Attenuation and Near-End Crosstalk (NEXT). Return Loss was also specified by ISO/IEC 11801 and EN 50173 however the limits were qualified "ffs" (for future study), which meant that compliance was not necessary in order to conform with the standard. Standards-makers use the "ffs" tag in cases where there is insufficient confidence in the limits or test methods being specified.

62.5/125 micron multimode fibre was also recognised by all 1st generation standards, whereas 50/125 micron multimode fibre was only recognised by ISO/IEC 11801 and EN 50173. Both 160/500 and 200/500 MHz.km modal bandwidth grades of 62.5/125 micron multimode fibre were specified, but only the 500/500 MHz.km modal bandwidth grade of 50/125 micron multimode fibre was recognised. Duplex ST and duplex SC optical connectors were both recognised, although use of the duplex ST connector was preferred.

All parameters were specified using spot frequency limits, with an additional "smoothing function" applied to create a continuous performance limit for compliance testing.

2. ISO/IEC 11801 and EN 50173 2nd Editions

The structure and content of ISO/IEC 11801 2nd edition is shown in figure 2. EN 50173 2nd edition is similar.

Clauses:

1. Scope
2. Normative References
3. Definitions & Abbreviations
4. Conformance
5. Structure
6. Balanced Cabling Performance
7. Balanced Cabling Ref Implementations
8. Optical Fibre Channel Performance
9. Cable Requirements
10. Connecting HW Requirements
11. Screening Practices
12. Administration
13. Modular Cords

Annexes:

A. Balanced Plink/CPlink Performance
B. Test Procedures
C. Connecting H/W Testing
D. Electromagnetic Characteristics
E. Acronyms for Balanced Cables
F. Supported Applications
G. Models for Balanced Cabling
H. Changes from Earlier Editions
I. Bibliographical References

Figure 2. ISO/IEC 11801 2nd Edition Structure and Content

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A review of ISO/IEC 11801 2nd edition follows, with commentary on the notable differences to both TIA/EIA 568-B and EN 50173 2nd edition.

Scope: The scope has been extended by deleting the existing population limits of 50 - 50,000 people plus the floor space limit of 1 million square metres. This now captures small-scale implementations such as residential or SOHO environments and also giant campuses, such as airports. The geographical span of 3,000 metres and life expectancy of "at least 10 years" remain unchanged.

Conformance: The following mandatory requirements are stated by this clause:

1. structural requirements must be met (architecture and dimensioning rules)
2. connectors used at TOs must be as specified
3. administration must meet the stated requirements

The following routes to compliance are permitted:

1. either the channel or permanent link must comply with the performance requirements, or
2. links must comprise standard components when building reference implementations

Testing is recommended, not mandatory, in the following situations:

1. were the entire channel is not implemented
2. when building reference implementations
3. when using non-standard components
4. for performance verification (commissioning tests)

Guidance is also provided on compliance referencing and product marking to distinguish the different levels of performance specified by 1st edition standards, their amendments and 2nd edition standards. Publication date referencing is specified (e.g. ISO/IEC 11801: 2000).

Structure: Architecture and dimensioning rules for balanced cabling are specified by this clause.

The existing 3-level hierarchy has been retained but the following changes were made to dimensioning rules:

1. Horizontal cabling is no longer additional to a maximum 2,000m channel. Instead, it is an integral part of it. This is to support 2,000m applications (such as 100BASE-F) in a campus-centralised optical fibre architecture.

2. The existing 500m limit for a building backbone has been removed in the interests of architectural flexibility.

The Transition Point has also been removed due to the practical difficulty of *absorbing* its electrical contribution into the horizontal link design.

Open Office Cabling has been introduced to support the use of configurable cables for improved distribution in high-churn, open-plan office environments. The principles are based on TIA/EIA TSB-75. The key supporting component is the Consolidation Point (or CP), which facilitates easy reconfiguration of outlets, as shown in figure 3. A CP may be a punch-down facility or multiple connectors, typically installed in a ceiling space or beneath the floor.

A CP must be located at least 15m from the distributor in order to minimise interference caused by multiple nearby connections (e.g. compounded crosstalk). The total length of a horizontal channel will depend on the type of cable used for Outlet attachment (CP cable) and flexible cords. It is sometimes necessary to use thinner cables for CP attachment which, like flexible cords, will have higher attenuation than the Fixed Horizontal Cable.

A Multi-User Telecommunications Outlet assembly (MUTO) may be used to provide a local cluster of connections within system furniture or an open area. Longer work area cables are then supported by reducing the length of horizontal cable.

A MUTO may serve up to 12 work areas and must be marked with the maximum allowable work area cable length.

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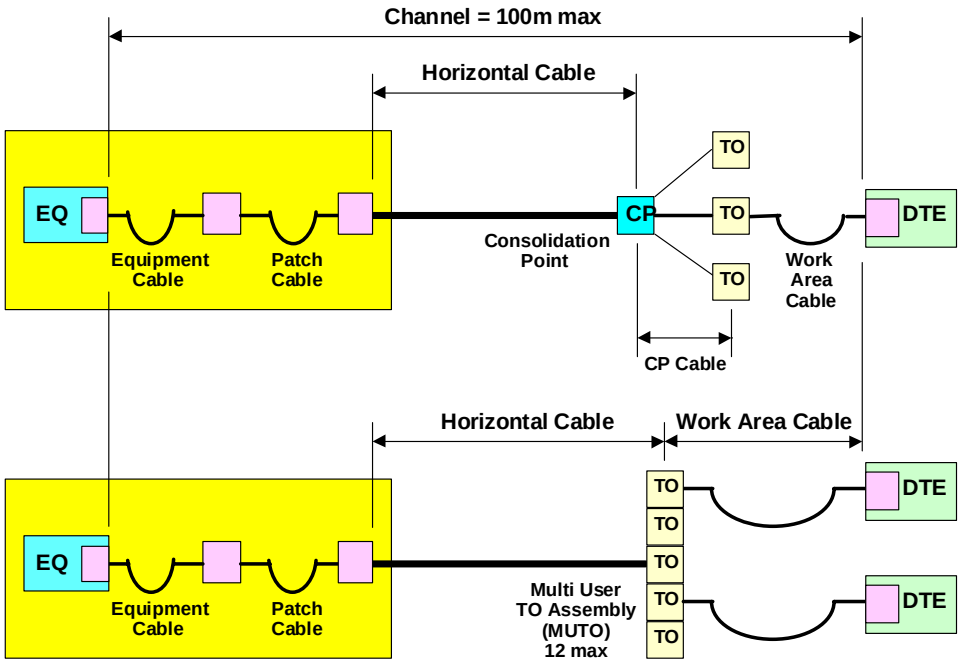

Figure 3. ISO/IEC 11801 2nd Edition Balanced Cabling Horizontal Channels

Centralised Optical Architecture (COA) has also been introduced to provide connections directly from outlets to a building or campus distributor and main equipment room. The principles of COA are taken from TIA/EIA TSB-72 however the length limit of 300 metres specified by TIA/EIA 568-B for within-building application has not been adopted by ISO/IEC 11801 or EN 50173 2nd editions.

Balanced Cabling Performance: This clause specifies minimum performance requirements for channels based on normative (i.e. mandatory) formulae. Spot frequency limits are provided for information only. Permanent Links and CP Links are specified in a normative annex.

The minimum performance of a horizontal link is now Class D. The original Class A to C requirements continue to be recognised and are unchanged. Class D Channel and Permanent Link specifications have been "upgraded" to Category 5e, as specified by TIA/EIA 568-B. This change elevates Class D NEXT and PS-NEXT limits by 3 dB.

ISO/IEC 11801 2nd edition introduces two new Classes of balanced cabling:

Class E (Category 6) is state-of-the-art unscreened or overall foil-screened cabling, specified to 250 MHz, with a positive PS-ACR at 200 MHz.

Class F (Category 7) is state-of-the-art cabling with individually screened pairs, specified to 600 MHz.

There is no longer a requirement for nominal impedance. Instead, this is characterised by return loss. In addition, insertion loss is now used in place of attenuation. Insertion loss is sometimes referred to as "operational attenuation", and is what is measured in practice. Attenuation is measured when the cabling is terminated into its own characteristic impedance. 100 ohm termination is specified for measurement.

New measurement rules have been introduced to overcome the effects of *short link resonance*, or perturbations in attenuation and return loss characteristics which is caused by mismatches in cords and connecting hardware and short reflection wavelengths:

1. NEXT values at frequencies where insertion loss is below 4dB are for information only
2. Return Loss values at frequencies where insertion loss is below 3dB are for information only

Channel specifications take account of the Insertion Loss Deviation (ILD) contribution to insertion loss, which has been evaluated for a 4-connector channel as 1dB @ 250 MHz and 2dB @ 600 MHz. The ILD contribution to Insertion Loss @ 100 MHz is judged to be insignificant and is ignored.

White Paper

The maximum DC loop resistance of a Class D channel has been reduced from 40 ohms to 25 ohms to more accurately reflect reality (at high temperature too!). This same limit has been applied to Class E and Class F channels. DC resistance unbalance of 3% has been introduced for each pair, and a current capacity of 175mA per cable conductor/connector pin has also been added to ISO/IEC 11801 1st and 2nd editions. DC loop resistance, resistance unbalance and current capacity are not specified by TIA/EIA 568-B.

The minimum performance requirements specified by ISO/IEC 11801 2nd edition for Class C, D, E and F insertion loss and NEXT are shown in figure 4. These limits apply to a 4-connector channel. Note the different NEXT limits for Class D specified by ISO/IEC 11801 1st and 2nd editions.

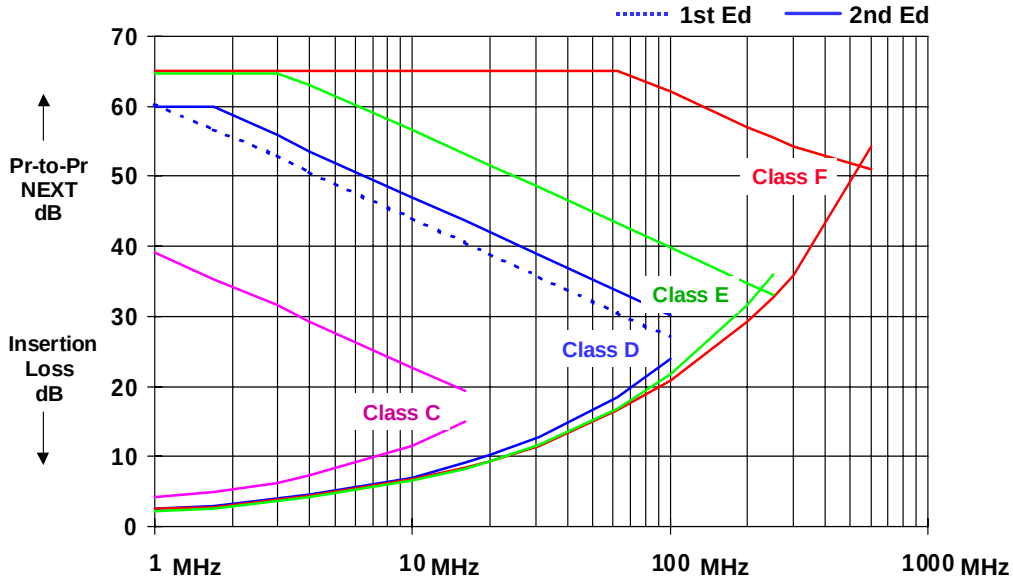

Figure 4. ISO/IEC 11801 2nd Edition Channel Insertion Loss & NEXT

The minimum performance requirements specified by ISO/IEC 11801 2nd edition for Class C, D, E and F return loss are shown in figure 5. These limits apply to a 4-connector channel. Class E and Class F limits are identical. It is worth noting that the most significant margin compared with Class D is below 10 MHz and above 40 MHz. Patch cord mismatches make return loss improvements very difficult to accomplish in the 10-40 MHz spectrum.

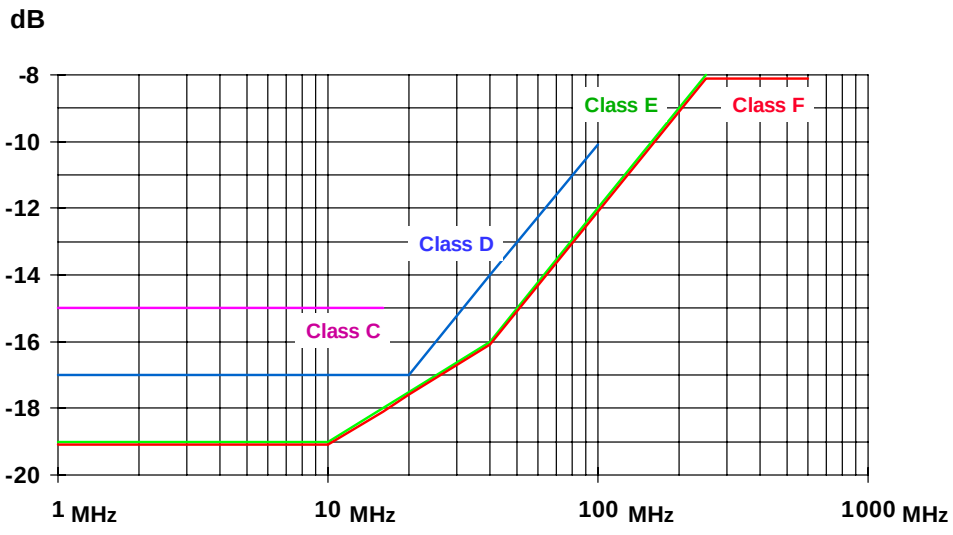

Figure 5. ISO/IEC 11801 2nd Edition Channel Return Loss

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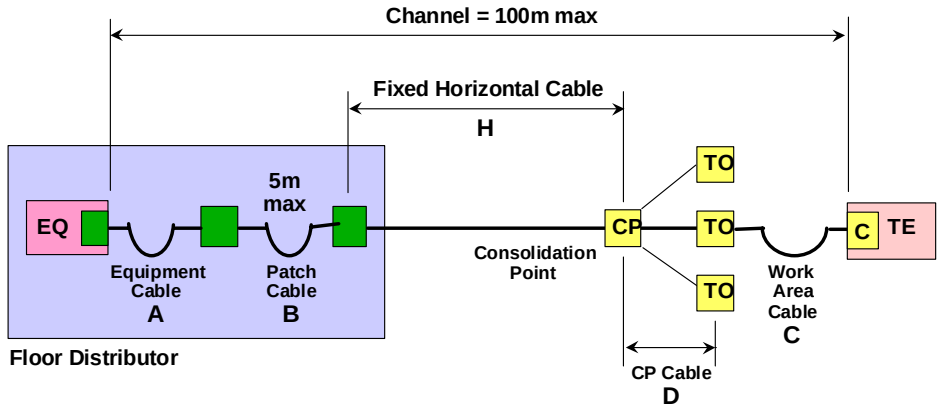
Balanced Cabling Reference Implementations: This clause defines popular implementations of generic cabling that use standard components and are structurally compliant. Dimensioning rules are based on "component-up" design principles and use insertion loss values throughout (refer to figure 6). Dimensioning rules accommodate channels with 2, 3 or 4 connectors and may be used for different elements of horizontal cabling. The formula accommodates CP cables and flexible cords with different attenuation factors.

The ILD contribution to insertion loss is compensated by offsetting the maximum length of horizontal cabling. This is 3m for Category 6/Class E or Category 7/Class F and 0m for Category 5/Class D.

Temperature effects are also taken into account by de-rating the maximum length of horizontal cabling, as follows:

- 0.2% per degC (20-60degC) for screened cables
- 0.4% per degC (20-40degC) for unscreened cables
- 0.6% per degC (40-60degC) for unscreened cables



$H_{max} = 105 - Z - (A+B+C)X - DY$ **where; X = attenuation premium of cords**
Y = attenuation premium CP cable
Z = ILD offset distance (0m or 3m)

Figure 6. ISO/IEC 11801 2nd Edition Reference Implementations

Optical Fibre Channel Performance: ISO/IEC 11801 2nd edition specifies optical fibre cabling in terms of channel transmission characteristics for maximum link lengths of 300m, 500m and 2000m; classified generically as OF-300, OF-500 and OF-2000 respectively.

Cable Requirements: ISO/IEC 11801 2nd edition references IEC 61156-series standards for Category 5, 6 and 7 cables. However, in order to apply the same dimensioning rules for all Categories of cable, more stringent requirements for Category 5 cable insertion loss are specified by ISO/IEC 11801 2nd edition.

IEC has introduced a number of changes to cable specifications, in particular with regard to impedance tolerance, which has been tightened significantly due to the need to meet channel return loss and ILD performance requirements. The mean characteristic impedance for Category 5, 6 and 7 cables is now 100 ± 5 ohms at 100 MHz (1st edition standards specified 100 ± 15 ohms measured from 1 MHz to the upper frequency limit of the cable).

Category 3, Category 4, 120 ohm and 150 ohm cables have been withdrawn.

CENELEC EN 50173 2nd edition references EN 50288-series cable standards without any additional requirements.

TIA/EIA 568-B contains cable specifications as an integral part of the standard and still recognises Category 3 cable. The original Category 5 cable specification has been modified by TSB-95 (additional requirements for 1000BASE-T) and made informative. Category 5e and Category 6 cables are normative specifications.

Category 5 cable insertion loss specified by TIA/EIA 568-B is slightly higher than that specified by ISO/IEC 11801 and EN 50173 2nd editions and only supports a channel comprising 90m horizontal + 10m cordage using cordage with an attenuation premium of up to 20% (i.e. unscreened cords). ISO/IEC 11801 and EN 50173 2nd editions support a channel comprising 90m horizontal + 10m cordage using cordage with an attenuation premium of up to 50% (i.e. either screened or unscreened cords).

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Four optical fibre types are specified; these are referenced by ISO/IEC 11801 and EN 50173 2nd editions as "OM" (Optical Multimode) and "OS" (Optical Singlemode). OM1 and OM2 are specified with modal bandwidths of 200/500 MHz.km and 500/500 MHz.km respectively, measured in terms of LED/LED bandwidth (or overfilled launch). OM3 is specified with a modal bandwidth of 2000[1500]/500 MHz.km, measured as both [LED] and laser bandwidth in the 1st window and LED bandwidth only in the 2nd window. OM3 fibre is 50 micron core diameter, while OM1 and OM2 may be either 50 or 62.5 micron core diameter.

Connecting Hardware Requirements: International IEC 60603-7-series standards have been developed for 8-pin modular connectors. Two types of Category 7 connector are specified by ISO/IEC 11801 and EN 50173 2nd edition standards; one with an 8-pin modular connector interface, another with a non-RJ-45 interface, as defined by IEC 61076-3-104. The 8-pin modular connector interface is preferred when backwards-compatibility is required with other Categories of connector.

Two types of optical connector are specified by 2nd edition cabling standards:

- the duplex SC connector (IEC 60874-19-1) is specified for use at an outlet by ISO/IEC 11801 and EN 50173.
- either the duplex SC or any Small Form Factor (SFF) connector are permitted at distributors by ISO/IEC 11801 and EN 50173.
- either the duplex SC or any SFF connector is permitted at an outlet or patch panel by TIA/EIA 568-B.

The duplex ST connector plus the connector originally specified for Token Ring (IEC 807-8) have been withdrawn.

ISO/IEC 11801 and EN 50173 2nd edition standards contain the backwards-compatibility matrix show in figure 7. This requires any combination of TO connector and modular plug/cord to have a minimum electrical performance equivalent to the lowest Category component. In other words, the minimum performance when mating a Category 5 plug/cord into a Category 6 jack/socket will be Category 5.

Due to the complexity of mixing modular connectors, each with electrical compensation applied, ISO/IEC 11801 and EN 50173 2nd edition standards also contain a caveat stating that backwards-compatibility should be underwritten by connector manufacturers.

		Category of modular connector at TO		
		Cat 5	Cat 6	Cat 7
Modular plug & cord performance	Cat 5	Cat 5	Cat 5	Cat 5
	Cat 6	Cat 5	Cat 6	Cat 6
	Cat 7	Cat 5	Cat 6	Cat 7

Figure 7. ISO/IEC 11801 2nd Edition Modular Connector Compatibility Matrix

Modular Cords: Specifications for modular cords are also being developed by IEC however published standards are not available. In the meantime, ISO/IEC 11801 and EN 50173 2nd edition standards will specify requirements for Category 5, 6, 7 modular cords plus optical cords.

Work area cords must comprise stranded conductors to achieve the desired flexibility and robustness. All other types of cord may use either stranded or solid conductors. Cords may have attenuation up to 50% higher than the horizontal cable (attenuation premium), in order to accommodate thinner conductors within screened cables.

Return loss and NEXT limits are specified for all Categories. Insertion loss is achieved by design.

Test Procedures: The following test schedules for channels and permanent links are specified by ISO/IEC 11801 and EN 50173 2nd edition standards:

1. *Acceptance Testing:* As a means of validating installed cabling which is known to comply with implementation requirements and is constructed from standard referenced cables, connector hardware and cords.

2. *Compliance Testing:* As a means of validating installed cabling comprising unknown cables, connector hardware and cords.

3. *Reference Testing:* As a means of testing cabling models in a laboratory environment and for comparing results of measurements performed with laboratory and field test instruments. Reference testing in laboratory on cabling models is also used for verifying compliance for properties that cannot be tested in the field.

Figure 8 shows the status of each parameter for copper and optical fibre cabling. Procedures identify whether a test parameter is Mandatory (M), Voluntary (V) or Calculated (C). ffs means "for future study".

Characteristic	Acceptance testing	Compliance testing	Reference testing
insertion loss	V	M	M
return loss	V	M	M
LCL			M
coupling attenuation			ffs
propagation delay	V	M	M
skew	V	M	M
NEXT	V	M	M
PS NEXT	C	C	C
ACR	V	M	M
PS ACR	V	C	C
ELFEXT	V	M	M
PS ELFEXT	C	C	C
dc loop resistance	V	M	M
length	V	V	M
wiremap	M	M	M
continuity/shorts	M	M	M
optical attenuation	M	M	M
return loss		M	
MMF modal bandwidth			M
propagation delay	V	M	M
length	C	C	C
polarity test	M	M	M

Figure 8. ISO/IEC 11801 2nd Edition Test Procedures for Copper and Optical Cabling

Supported Applications: ISO/IEC 11801 and EN 50173 2nd edition standards map network applications specified by IEEE 802, ANSI, ATM Forum and ITU to different performance classes of generic balanced cabling and optical fibre cabling. A detailed listing of optical fibre network applications also contains channel flux budgets and maximum operating distances for each major fibre type. The latest developments on 10 Gigabit Ethernet are also captured in this mapping. The recently published ATM Forum specification for 1.2 Gbit/s operation over Class E cabling (af-phy-0162.000) has also been added.

3. TIA/EIA 568-B

TIA/EIA 568-B has been published in 3 parts:

TIA/EIA 568-B-1: General Requirements.

TIA/EIA 568-B-2: Copper Components.

TIA/EIA 568-B-3: Optical Components.

This major revision specifies Category 3 and Category 5e cabling channels, permanent links, components and test methods. The original specification for Category 5 has been redefined by the content of TSB-95 (additional requirements for 1000BASE-T cabling), however this specification is only contained in an informative annex.

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TIA/EIA 568-B has adopted the Permanent Link, as defined by ISO/IEC 11801 and EN 50173. This has now replaced the existing Basic Link, which included special 2m cords at each end of the link under test.

A specification for Screened Twisted Pair (ScTP) has been added. ScTP construction is “overall foil” (or FTP).

TIA/EIA 568-B incorporates TSB-67 (Field Testing), TSB-72 (Centralised Optical Architecture) and TSB-75 (Open Office Cabling). 568-A addenda 1 through 5 have also been incorporated. The fore-mentioned TSBs and addenda no longer exist.

The minimum bend radius for 4-pair UTP or ScTP patch cords was later specified as TIA/EIA 568-B-1.1, and a specification for grounding and bonding was added as TIA/EIA 568-B-1.2.

The specification of Category 6 was approved in June 2002 and published as addendum TIA/EIA 568-B-2.1.

A specification for next generation multimode fibre has also been added. This has a core diameter of 50 microns and a modal bandwidth of 2000/500 MHz.km (laser/LED bandwidth). This specification was approved in April 2002 and published as TIA/EIA 568-B.3-1.

About Brand-Rex

Brand-Rex is a designer and manufacturer of copper and fibre based cabling systems, headquartered in Glenrothes, Scotland with facilities across Europe. Brand-Rex has two primary businesses: Connectivity and Speciality. Its Connectivity division designs and manufactures cabling systems (both copper and fibre) for data communications and is the No.2 player in Europe. The Speciality division exclusively produces cables that are used for control, communications, power and instrumentation within hostile environments.

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