NEMA WC 66

PERFORMANCE STANDARD FOR CATEGORY 6 AND CATEGORY 7 100 OHM SHIELDED AND UNSHIELDED TWISTED PAIR CABLES

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ANSI Approved

NEMA Standards Publication No. WC 66-2001

Performance Standard for Category 6 and Category 7
100 Ohm Shielded and Unshielded
Twisted Pair Cables

Published by

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Foreword

This standards publication is one of a series developed by NEMA on cables to be used for voice, data, video, and other high-frequency signal transmission. The other standards publications are NEMA WC 63.1, *Performance Standard for Twisted Pair Premise Voice and Data Communications Cable*, and ANSI/NEMA WC 63.2, *Performance Standard for Coaxial Premise Data Communications Cable*.

Compliance with these standards may require use of an invention covered by patent rights. By publication of this document, no position is taken with respect to the validity of this claim or of any patent rights in connection therewith. The patent holder has, however, filed a statement of willingness to grant a license under these rights on reasonable and non-discriminatory terms and conditions to applicants desiring to obtain such a license. Details may be obtained from the publisher.

This standards publication has been developed by the Premise Wiring Subcommittee (members as listed below) of the High Performance Wire and Cable Section of NEMA in close coordination between manufacturers, users, third party certifying agencies, and others having specialized experience. The Premise Wiring Subcommittee of the High Performance Wire and Cable Section of NEMA periodically reviews this standards publication for any revisions necessary to keep it up to date. Proposed revisions or comments should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
1300 North 17th Street
Rosslyn, Virginia 22209

Members of NEMA High Performance Wire and Cable Section that participated in the development of this standards publication were:

Alcatel Electronics Cable/a Nexans Company—Elm City, NC
Avaya—Norcross, GA
Belden Wire & Cable Company—Richmond, IN
Coleman Cable CCI—North Chicago, IL
General Cable Corporation—Highland Heights, KY
Harbour Industries—Shelburne, VT
Helix/Hi-Temp Cables, Inc.—Franklin, MA
Judd Wire Inc.—Turner Falls, MA
Montrose/CDT—Auburn, MA
Southwire Company—Carrollton, GA

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Scope

This standards publication primarily defines minimum electrical performance and allowable conductor sizes, stranding, and shielding for premise wiring cables for voice and data applications for 100 ohm shielded and unshielded twisted pair cables.

The cables included are intended to conform with the cabling system architecture and design, as specified in ANSI/TIA/EIA 568A, and to harmonize with international standards such as ISO/IEC 11801. These cables have improved return loss (RL) and crosstalk loss performance requirements beyond the Category 5e values in NEMA WC 63.1. These cables may be used for voice, data, and video applications whose spectral bandwidth extends up to 200 MHz for Category 6 and 600 MHz for Category 7. These cables are tested at a frequency 25% greater than the spectral bandwidth specified above: 250 MHz for Category 6 and 750 MHz for Category 7. Applicable definitions, test methods, and performance requirements are included. The material, mechanical, and physical characteristics for these cables are covered under UL 444/CSA 22.2 No. 214.

Unless otherwise specified, the constructions defined herein are 2 through 25 pair cables and 22 through 26 AWG including patch cables.

This document complements other specifications by including, for the first time, a part numbering system to assist in procurement of these types of cables.

The products covered in this standard shall conform to the requirements of Part 68 of the FCC rules and regulations as well as the applicable article(s) of the National Electrical Code and/or other national and local codes and safety standards.

The performance requirements contained in this document are for cables as manufactured. Link and channel requirements are beyond the scope of this document.

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Section 1
REFERENCED STANDARDS

Copies of referenced documents may be obtained from the appropriate sources as follows.

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ASTM B 3-95	*Soft or Annealed Copper Wire*
ASTM B 8-99	*Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft*
ASTM B 33-00	*Tinned Soft or Annealed Copper Wire for Electrical Purposes*
ASTM B 286-95	*Copper Conductors for Use in Hookup Wire for Electronic Equipment*
ASTM B 298-99	*Standard Specification for Silver-Coated Soft or Annealed Copper Wire*
ASTM D 4566-98	*Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire & Cable*

Federal Communications Commission (FCC)
1919 M Street N.W.
Washington, DC 20554

Code of Federal Regulations, Title 47, Telecommunications, Chapter 1-FCC, Part 68.

Insulated Cable Engineers Association (ICEA)
P.O. Box 440
South Yarmouth, Massachusetts 02644

ANSI/ICEA S-90-661-1997	*Standard for Individually Unshielded Twisted-Pair Indoor Cables for Use in Communication Wiring Systems*

International Electrotechnical Commission (IEC)
3 Rue de Varembé
Case Postal 131
CH-1211, Geneva 20
Switzerland

ISO/IEC 11801-1995	*Generic Cabling for Customer Premises*

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ANSI/NEMA WC 61-1992 *Standard for Transfer Impedance Testing*
NEMA WC 63.1-2000 *Performance Standard for Twisted Pair Premise Voice and Data Communications Cables*

National Fire Protection Association (NFPA)
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA-70-1999 *National Electrical Code (NEC)*

Telecommunications Industry Association (TIA)
2500 Wilson Blvd.
Arlington, VA 22201

Addendum No. 1 to
TIA/EIA-568-B.2 (draft) *Commercial Building Telecommunications Cabling Standard*[1]

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062

Canadian Standards Association (CSA)
178 Rexdale Boulevard
Etobicoke, ON M9W 1R3
Canada

UL 444-94/
CSA 22.2 No. 214 1994 *Communications Cables*

[1] As of the publication of this standard, Addendum No. 1 to TIA/EIA-568-B.2 was still in draft form. It is being utilized as an informative reference only.

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Section 2
PART IDENTIFICATION NUMBER (PIN)

2.1 PART IDENTIFICATION NUMBER (PIN)

The part numbers shall be as follows:

WC66-(Category)(NEC/CSA Type)(AWG/Stranding)(Coating)(Pairs)(Shield[2])(Drain Wire)

Where:

Category	=	Character for NEMA Category as determined in Table 2-1a.
NEC/CSA Type	=	Character for NEC/CSA Type as determined in Table 2-1b
AWG/Stranding	=	Character for conductor gauge size and stranding as determined from Table 2-2.
Coating	=	Character for conductor coating. "B" for Bare Copper ,"T" for Tin or "S" for Silver
Pairs	=	Number of pairs in cable (i.e.: 2, 4, 12, 25, etc.)
Shield	=	Character(s) for type of shield(s) as determined from Table 2-3.
Drain Wire	=	"D" if specified.

Table 2-1a
NEMA CATEGORY DESIGNATION

Category	Description
6	100 Ohm, Twisted-Pair Cables, for frequencies up to 250 MHz
7	100 Ohm, Twisted-Pair Cables, for frequencies up to 750 MHz

Table 2-1b
NEC/CSA TYPES

Character	Cable Types	Description
P	MPP, CMP	Plenum
R	MPR, CMR	Riser
G	MPG, MP, CMG, CM	General Purpose
X	CMX, CMH	Limited Use

[2]Shield also refers to screen

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Table 2-2a
ALLOWABLE AWG SIZES FOR SOLID CONDUCTORS IN HORIZONTAL AND BACKBONE CABLE

Character	AWG Size
A	22
B	24
C	23

Table 2-2b
ALLOWABLE AWG SIZES FOR STRANDED CONDUCTORS IN PATCH CABLES

Character	AWG Size	Stranding	Character	AWG Size	Stranding
D	22	7	G	24	19
E	22	19	H	26	7
F	24	7	J	26	19

Table 2-3
ALLOWABLE SHIELDING OPTIONS

Character	Description
S	Individually shielded Pair, Foil
K	Individually shielded Pair, Braid
F	Overall shield, Foil
B	Overall shield, Braid
U	Unshielded

The following are examples of possible part numbers:

WC66-7PAB4SB: Category 7, plenum, 22 AWG, solid bare copper, 4 pair, individually foil shielded pairs with an overall braid shield.
WC66-6GFT4F: Category 6, general purpose, 24 AWG, 7 strand, tinned copper, 4 pair, overall foil shield.
WC66-6RCB4U: Category 6, riser, 23 AWG, solid bare copper, 4 pair, unshielded.

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Section 3
MATERIALS AND MECHANICAL REQUIREMENTS

3.1 CONDUCTORS

Conductors shall conform to the requirements of the applicable ASTM document(s) with the exception that the requirements for “Dimensions and Permissible Variations” shall be waived. The minimum dimensions and maximum strand lay shall be in accordance with UL 444/CSA 22.2 No. 214. Minimum elongation of solid conductors from a finished cable shall be in accordance with ICEA S-90-661.

3.1.1 Bare Copper Wire

Bare copper wire shall conform to soft or annealed wire in accordance with ASTM B 3, except that the requirements for "Dimensions and Permissible Variations" shall not apply.

3.1.2 Tin-Coated Copper Wire

Tin-coated copper wire shall conform to soft or annealed wire in accordance with ASTM B 33, except that the requirements for "Dimensions and Permissible Variations" shall not apply.

3.1.3 Silver-Coated Copper Wire

Silver-coated copper wire shall conform to soft or annealed wire in accordance with ASTM B 298, except that the requirements for "Dimensions and Permissible Variations" shall not apply.

3.1.4 Stranded Copper Wire

Stranded bare, silver-coated, or tin-coated copper wire shall conform to ASTM B 8 or B 286 except the minimum dimensions and maximum strand lay shall be in accordance with UL 444/CSA 22.2 No. 214. Stranded conductors are used for patch cables, and as such are intended to be used in short lengths.

3.2 INSULATING MATERIALS

The copper conductors shall be insulated with one or more layers of solid or expanded material. The core consisting of two or more pairs and other construction components shall be protected with an overall covering generally referred to as an "outer jacket". The insulation, jacket, plus other components, such as core wrap, shield, and inner jackets, shall conform to the applicable requirements of UL 444/CSA 22.2 No. 214.

3.3 SHIELDS

When a type of shield is specified in the part identification number, that shield shall be constructed as described below.

3.3.1 Individually Shielded Pairs, Foil

The individual pair shield shall be a polymeric/metallic laminated tape, such as polyester/aluminum, electrically continuous, and shall satisfy the criteria of UL 444/CSA 22.2 No. 214 and ICEA S-90-661. One or more drain wire(s) shall be provided per Paragraph 3.3.5.

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3.3.2 Individually Shielded Pairs, Braid

The individual pair shield shall be a braid, electrically continuous, and shall satisfy the criteria of UL 444/CSA 22.2 No. 214 and ICEA S-90-661.

3.3.3 Overall Shield, Foil

The foil overall shield shall be a polymeric/metallic laminated tape, such as polyester/aluminum, electrically continuous, and shall satisfy the criteria of UL 444/CSA 22.2 No. 214 and ICEA S-90-661. Drain wire(s), at the manufacturer's option, shall be provided per Paragraph 3.3.5.

3.3.4 Overall Shield, Braid

A braid overall shield shall be applied per Paragraph 3.3.6

3.3.5 Drain Wire(s)

One or more drain wire(s) shall be provided when foil shields are specified without a braid shield. Drain wire(s) may be provided when a braid shield is specified. The drain wire(s) shall:

a. consist of a solid tinned copper conductor(s) per ASTM B 33; or stranded tinned copper conductor(s) per ASTM B 286, except that the stranding lay may be 1" maximum;
b. be equivalent or larger in gauge size than the twisted pair conductors comprising the core;
c. be in contact with the metallic side of the foil tape; and
d. be electrically continuous.

3.3.6 Braid Shield

The braid shield shall:

a. be tinned copper wires in accordance with ASTM B 33 and
b. provide a minimum of 60% coverage.

3.4 MECHANICAL, PHYSICAL, DIMENSIONAL, AND SAFETY CONSIDERATIONS

The cable shall be in accordance with NFPA 70 (NEC) and conform to the applicable requirements of UL 444/CSA 22.2 No. 214. These will be determined primarily by the wide variety of insulation and jacket material choices. Additionally, the environmental, fire performance, and electrical characteristics as required by this standard will influence cable design parameters.

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Section 4
ELECTRICAL DEFINITIONS

4.1 RESISTANCE

4.1.1 DC Conductor Resistance

The DC resistance of any conductor is defined as:

$$R=V/I$$

Where:

R = DC conductor resistance (in ohms)
V = Applied DC voltage
I = Measured DC current

4.1.2 DC Resistance Unbalance

The DC resistance unbalance between the two conductors of any pair is defined as:

$$R_{ub} = \frac{(R_{max} - R_{min})}{R_{min}} \times 100$$

Where:

R_{ub} = Resistance unbalance (in percent)
R_{max} = The resistance of the conductor with higher resistance value in ohms
R_{min} = The resistance of the conductor with lower resistance value in ohms

4.1.3 Insulation Resistance

Insulation resistance is defined as the measured resistance between any single conductor and ground. All other conductors and shields, if present, in the cable are grounded.

4.2 INPUT IMPEDANCE

The input impedance of any pair is defined as:

$$Z_{in} = \sqrt{Z_{open} \times Z_{short}}$$

Where:

Z_{in} = Input impedance in ohms
Z_{open} = Measured open circuit impedance in ohms
Z_{short} = Measured short circuit impedance in ohms

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4.3 CHARACTERISTIC IMPEDANCE

The characteristic impedance is calculated by a least squares function fit of input impedance data as defined in ASTM D 4566 Section 44, Method 3

4.4 RETURN LOSS

The return loss of any pair relates the input impedance to 100 Ohms. It is defined as:

Where:

$$\mathrm{RL} = -20 \log_{10} \left| \frac{Z_{in} - 100}{Z_{in} + 100} \right|$$

RL = Return loss in decibels
Z_{in} = Input impedance (complex) in ohms

4.5.1 INSERTION LOSS (ATTENUATION)

The insertion loss (attenuation) of any pair is defined as:

$$a = \left| 10 \log_{10} \frac{P_2}{P_1} \right| = \left| 20 \log_{10} \frac{V_2}{V_1} \right|$$

Where:

α = The insertion loss (attenuation) in decibels
P_1 = The input power in watts
P_2 = The output power in watts
V_1 = The input voltage in volts
V_2 = The output voltage in volts

4.6 CROSSTALK LOSS

4.6.1 Near-End Crosstalk Loss (NEXT)

The near-end crosstalk loss of any pair combination is defined as:

$$\mathrm{NEXT} = \left| 10 \log_{10} \frac{P_{2N}}{P_{1N}} \right| = \left| 20 \log_{10} \frac{V_{2N}}{V_{1N}} \right|$$

Where:

NEXT = Near-end crosstalk loss in decibels
P_{1N} = The input power of the disturbing pair in watts
P_{2N} = The output power of the disturbed pair at the near-end of the cable in watts
V_{1N} = The input voltage of the disturbing pair in volts
V_{2N} = The output voltage of the disturbed pair at the near-end of the cable in volts

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4.6.2 Power Sum Near-End Crosstalk Loss (PSNEXT)

The power sum near-end crosstalk loss of any disturbed pair is defined as:

$$PSNEXT = \left| 10 \log_{10} \sum_{i=1}^{n} \left| 10^{\left(\frac{-x_i}{10}\right)} \right| \right|$$

Where:

PSNEXT	=	Power sum near-end crosstalk loss in decibels
x_i	=	Measured near-end crosstalk loss in decibels of the pair combination consisting of the disturbed pair, and the i-th disturbing pair
n	=	Number of disturbing pairs (the number of pairs in the cable minus one)
i	=	Disturbing pair number

4.6.3 Far-End Crosstalk Loss (FEXT)/Equal Level Far-End Crosstalk (ELFEXT)

4.6.3.1 Far-End Crosstalk Loss (FEXT)

The FEXT loss is defined as an input to output crosstalk loss (the power input to the disturbing pair as compared to the output power coupled into the disturbed pair at the opposite end of the cable from the disturbing source). For a 4 pair cable, there will be 12 combinations as indicated in the following example:

Example: FEXT (1-2) Near-end pair 1 to Far-end pair 2
FEXT (2-1) Near-end pair 2 to Far-end pair 1
FEXT (1-3) Near-end pair 1 to Far-end pair 3
FEXT (3-1) Near-end pair 3 to Far-end pair 1, etc.

The first pair is the "Disturbing Pair," and the second pair is the "Disturbed Pair."

Far-end crosstalk loss is defined as:

$$FEXT = \left| 20 \log \frac{V_{2F}}{V_{1N}} \right|$$

Where:

FEXT	=	Far-end crosstalk loss measured in decibels
V_{1N}	=	Disturbing pair input voltage at the near-end
V_{2F}	=	Disturbed pair output voltage at the far-end

4.6.3.2 Equal Level Far-End Crosstalk (ELFEXT)

The ELFEXT is FEXT loss with the cable insertion loss (attenuation) removed to achieve equal-level comparisons (i.e., voltages are compared at the end of the cable opposite the power input).

The ELFEXT is calculated from the 12 FEXT combinations for a 4 pair cable in 4.6.3.1 minus the insertion loss (attenuation) of the "Disturbed Pair."

Example: ELFEXT (1-2) = FEXT (1-2) – Insertion Loss (Attenuation) (2)
ELFEXT (2-1) = FEXT (2-1) – Insertion Loss (Attenuation) (1) etc.

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4.6.4 Power Sum Equal Level Far-End Crosstalk (PSELFEXT)

The power sum equal level far-end crosstalk of any pair is defined as the power sum of the ELFEXT as

$$PSELFEXT = \left| 10 \log_{10} \sum_{i=1}^{n} \left| 10^{\left(\frac{-x_i}{10}\right)} \right| \right|$$

Where:

PSELFEXT	=	Power sum equal level far-end crosstalk in decibels
x_i	=	Calculated equal level far-end crosstalk in decibels
n	=	Number of disturbing pairs (the number of pairs in the cable minus one)
i	=	Disturbing pair number

4.7 TRANSFER IMPEDANCE

The transfer impedance (Z_t) of the shield in an electrically short, longitudinally uniform cable is defined as the ratio of the longitudinal electromotive force induced in the disturbed circuit to the current flowing in the interfering circuit.

4.8 VELOCITY OF PROPAGATION

The velocity of propagation is the ratio of the phase velocity to the speed of light in a vacuum, expressed as a percentage. Phase velocity of any pair is defined as:

$$v = \frac{\omega}{\beta}$$

Where:

v	=	Phase velocity in meters/second
ω	=	Angular frequency in radians/second
β	=	Phase constant in accordance Section 39 of ASTM D 4566

4.9 PHASE DELAY

Phase delay is the reciprocal of the phase velocity.

4.10 PHASE DELAY SKEW

Phase delay skew is defined as the difference in phase delay between any two pairs.

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4.11 BALANCE

4.11.1 Longitudinal Conversion Loss (LCL)

LCL is defined in ASTM D 4566, Section 46.

4.11.2 Longitudinal Conversion Transfer Loss (LCTL)

LCTL is defined in ASTM D 4566, Section 46.

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Section 5
TEST METHODS

5.1 GENERAL

Unless otherwise specified below, measurements shall be in accordance with ASTM D 4566.

Measurements shall be performed on a cable sample that is a minimum of 100 m (328 ft) in length.

The measurements of input impedance, return loss, insertion loss (attenuation), near-end crosstalk, equal level far-end crosstalk, and phase velocity shall be performed on a cable sample of 100 m (328 ft) or greater removed from the reel or package. The test sample shall be laid along a non-conducting surface, loosely coiled, or supported in aerial spans. On reel or packaged cable measurements that satisfy the performance requirements are acceptable. In case of conflict, the aerial span procedure shall be used as the referee method.

For swept frequency testing, the maximum test frequency shall be 25% greater than the maximum rated frequency as stated in the scope. A minimum of 100 points per decade shall be sampled. Logarithmic spacing shall be used for referee testing to ensure uniform weighting across the applicable frequency range.

5.2 INPUT IMPEDANCE

Input impedance shall be determined using Section 43, Method 2, Option 1 or Option 2 in ASTM D 4566. Option 1 is the referee method.

5.3 CHARACTERISTIC IMPEDANCE

Characteristic impedance shall be calculated using Section 44, Method 3, in ASTM D 4566.

5.4 RETURN LOSS

Return loss shall be determined per Section 45.3 of ASTM D 4566.

5.5 INSERTION LOSS (ATTENUATION)

The sample length shall exhibit no less than 3 decibels at the lowest frequency tested and no more than 50 decibels for applicable frequencies. More than one length may be required to test a full range of frequencies.

5.6 NEAR-END CROSSTALK LOSS (NEXT) AND POWER SUM NEAR-END CROSSTALK LOSS (PSNEXT)

NEXT loss shall be measured and PSNEXT loss shall be calculated per Section 24 of ASTM D 4566.

5.7 FAR-END CROSSTALK LOSS (FEXT), EQUAL LEVEL FAR-END CROSSTALK (ELFEXT) AND POWER SUM EQUAL LEVEL FAR-END CROSSTALK (PSELFEXT)

FEXT loss shall be measured with a network analyzer per section 4.6.3.1. ELFEXT and PSELFEXT shall be calculated per section 4.6.3.2 and 4.6.4 respectively.

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5.8 TRANSFER IMPEDANCE

The transfer impedance of a shielded cable shall be measured using the method in NEMA WC 61. Note that this test method is only valid to a maximum frequency of 100 MHz.

5.9 VELOCITY OF PROPAGATION

The phase velocity shall be determined over the frequency range from 1 MHz to the highest referenced frequency using the method in Section 41 of ASTM D 4566. The velocity of velocity of propagation shall be calculated from the phase velocity using the following equation:

$$VP = \frac{100v}{C}$$

Where:

VP = Velocity of velocity of propagation (%)
v = Phase velocity
C = Speed of light in a vacuum (0.3 m/ns)

5.10 PHASE DELAY

Phase delay shall be determined from the phase velocity using the following equation:

$$t_d = \frac{100\,L}{V_p C}$$

Where:

t_d = Phase delay in nanoseconds
L = Reference length in meters (usually 100m).
V_p = Phase velocity as a percent of the speed of light in free space
C = Speed of light in a vacuum (0.3 m/ns)

5.11 PHASE DELAY SKEW

The phase delay skew shall be calculated by determining the maximum difference in phase delay between all pairs in a four pair cable. For cables greater than four pair, the phase delay skew shall be calculated by determining the maximum difference in phase delay between any four consecutive pairs.

5.12 BALANCE

5.12.1 Longitudinal Conversion Loss (LCL)

LCL shall be measured per Section 46 of ASTM 4566.

5.12.2 Longitudinal Conversion Transfer Loss (LCTL)

LCTL shall be measured per Section 46 of ASTM 4566.

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Section 6
ELECTRICAL REQUIREMENTS

6.1 GENERAL

This is a performance standard, and conductor sizes are not specified for given levels of performance. (Note: Values in Tables A-1a and A-2a are requirements. Values in Tables A-1b and A-2b are included for reference only.)

6.2 RESISTANCE

6.2.1 DC Resistance

The DC resistance at or corrected to 20°C shall not be greater than the following:

Table 6-1
DC RESISTANCE

AWG	DC Resistance Ω/100 m(328 ft.)
26	14.8
24	9.38
23	7.39
22	5.91

6.2.2 DC Resistance Unbalance

The DC resistance unbalance of any pair shall not be greater than 2%.

6.2.3 Insulation Resistance

The insulation resistance of any insulated conductor shall not be less than 1500 MΩ - 100 m (328 ft).

6.3 IMPEDANCE

6.3.1 Input Impedance

For Category 6 and 7 cables, the input impedance shall be as follows:

Table 6-2
INPUT IMPEDANCE

Category	Frequency (MHz)	Input Impedance (Ohms)
6 and 7	1 - 100	100 ± 15
6 and 7	> 100 - 200	100 ± 22
6 and 7	> 200 - 250	100 ± 25
7	> 250 - 750	100 ± 25

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6.3.2 Characteristic Impedance

For Category 6 and Category 7 cables, the characteristic impedance shall be as follows:

Table 6-3
CHARACTERISTIC IMPEDANCE

Category	Frequency (MHz)	Characteristic Impedance (Ohms)
6	1 – 250	100 ± 6
7	1 – 750	100 ± 6

6.4 RETURN LOSS

For Category 6 and 7 cables, the return loss shall not be less than the values listed below.

Table 6-4
RETURN LOSS

Frequency (MHz)	Return Loss (dB)			
	Horizontal & Backbone		Patch	
	Category 6	Category 7	Category 6	Category 7
1 to 10	$20+5 \log_{10}(f)$	$20+5 \log_{10}(f)$	$20+5 \log_{10}(f)$	$20+5 \log_{10}(f)$
> 10 to 20	25	25	25	25
> 20 to 250	$25-7 \log_{10}(f/20)$	$25-7 \log_{10}(f/20)$	$25-8.6 \log_{10}(f/20)$	$25-8.6 \log_{10}(f/20)$
>250 - 750	–	$25-7 \log_{10}(f/20)$	–	$25-8.6 \log_{10}(f/20)$

6.5 INSERTION LOSS (ATTENUATION)

6.5.1 Horizontal and Backbone Cables

The maximum insertion loss (attenuation) of any pair at or corrected to a temperature of 20°C shall be less than or equal to the value determined using the following formula for all frequencies from 0.772 to 250 MHz for Category 6 and 0.772 to 750 MHz for Category 7.

$$\alpha(f) \le k_1\sqrt{f} + k_2 f + \frac{k_3}{\sqrt{f}}$$

Where:

α = Insertion Loss (Attenuation) in dB/100m (328 ft)
f = Frequency in MHz
$K_{1,2,3}$ = See Table 6-5

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Table 6-5
COEFFICIENTS FOR INSERTION LOSS (ATTENUATION) FORMULA[3]

Coefficient	k_1	k_2	k_3
Category 6	1.808	0.017	0.200
Category 7	1.800	0.010	0.200

The cable insertion loss (attenuation) shall be verified at a temperature of 40 degrees Celsius and 60 degrees Celsius and shall meet the requirements of the formula above after adjusting the formula for temperature. The maximum insertion loss (attenuation) determined using the above formula shall be adjusted at elevated temperatures using a factor of 0.4% increase per degree Celsius for unshielded cables and 0.2% per degree Celsius for cables containing a shield(s).

6.5.2 Patch (Stranded) Cables

The requirements for insertion loss (attenuation) for cables employing 22 and 24 AWG stranded conductors shall be 20% higher than the values determined by the formula in 6.5.1. For 26 AWG stranded conductors, the requirements shall be 50% higher than the values determined by the formula in 6.5.1.

6.6 CROSSTALK LOSS

6.6.1 Near-End Crosstalk Loss (NEXT)

The minimum near-end crosstalk loss of any pair combination shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 to 250 MHz for Category 6.

Category 6

$$NEXT(f) \geq 44.3 - 15\log_{10}\left(\frac{f}{100}\right)$$

Category 7

for frequencies $\leq$ 62.5 MHz

$$NEXT(f) \geq 75$$

for frequencies > 62.5 MHz

$$NEXT(f) \geq 102.4 - 15\log_{10}(f)$$

Where:

NEXT = Near-end crosstalk loss in dB
f = Frequency in MHz

[3] Secretary's Note: Category 7 values came from IEC JTC 1/SC 25 WG3 5/2000

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6.6.2 Power Sum Near-End Crosstalk Loss (PSNEXT)

The minimum power sum near-end crosstalk loss of any pair, in cables employing more than two pairs, shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 to 250 MHz for Category 6 cables and from 0.772 to 750 MHz for Category 7 cables.

Category 6

$$PSNEXT(f) \geq 42.3 - 15\log_{10}\left(\frac{f}{100}\right)$$

Category 7

for frequencies $\leq$ 31.25 MHz

$$PSNEXT(f) \geq 75$$

for frequencies > 31.25 MHz

$$PSNEXT(f) \geq 99.4 - 15\log_{10}(f)$$

Where:

PSNEXT = Power sum near-end crosstalk loss in dB
f = Frequency in MHz

6.6.3 Equal Level Far-End Crosstalk (ELFEXT)

The minimum equal level far-end crosstalk of any pair combination shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 to 250 MHz for Category 6 cables. The PSELFEXT requirements for Category 7 establish the level of ELFEXT for Category 7.

Category 6

$$ELFEXT(f) \geq 27.8 - 20\log_{10}\left(\frac{f}{100}\right)$$

Category 7 (for all frequencies[4])

$$ELFEXT(f) \geq 94 - 20\log_{10}(f)$$

Where:

ELFEXT = Equal level far-end crosstalk in dB
f = Frequency in MHz

[4] Calculations that result in ELFEXT loss values greater than 75 dB shall revert to a requirement of 75 dB minimum.

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6.6.4 Power Sum Equal Level Far-End Crosstalk (PSELFEXT)

The minimum power sum equal level far-end crosstalk of any pair, in cables employing more than two pairs, shall be greater than or equal to the value determined using the following formula for all frequencies from 0.772 to 250 MHz for Category 6 cables and from 0.772 to 750 MHz for Category 7 cables.

Category 6

$$PSELFEXT(f) \geq 65.8 - 20\log_{10}(f)$$

Category 7 (for all frequencies[5])

$$PSELFEXT(f) \geq 91 - 20\log_{10}(f)$$

Where:

PSELFEXT = Power sum equal level far-end crosstalk in dB
f = Frequency in MHz

6.6.5 TRANSFER IMPEDANCE

The maximum common mode transfer impedance for shielded cables shall be less than or equal to the value determined using the following formula for all frequencies from 1 MHz to 100 MHz. Refer back to 5.9 for frequency limitations:

$$Z_t(f) \leq 37 + 4f + 4\sqrt{f} + 5\sqrt[3]{f}$$

Where:

Z_t = Transfer impedance, in mΩ/m
f = Frequency in MHz

6.6.6 VELOCITY OF PROPAGATION

The velocity of propagation of any pair of Category 6 and 7 cable shall not be less than 62% for all frequencies from 1 MHz to the highest referenced frequency.

6.7 PHASE DELAY SKEW

The phase delay skew for Category 6 four pair cables shall not be greater than 45 ns/100m for all frequencies at 20°C. The phase delay skew for Category 7 four pair cables shall not be greater than 15 ns/100m for all frequencies at 20°C. The phase delay skew for Category 6 cables greater than four pair shall not be greater than 48 ns/100m for all frequencies at 20°C.

For cables greater than four pairs, the maximum phase delay skew shall be as specified above between any four consecutive pairs.

For Category 6 cables, the phase delay skew as specified above shall not vary more than 10 ns from the

[5] Calculations that result in PSELFEXT loss values greater than 72 dB shall revert to a requirement of 72 dB minimum.

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20°C measurement at each frequency when measured at 0°C, 40°C, and 60°C.

6.8 BALANCE

6.8.1 Longitudinal Conversion Loss (LCL)

The minimum longitudinal conversion loss of any pair, in cables employing two pairs or more, shall be greater than or equal to the value determined using the following formula for all frequencies from 1 to 250 MHz for Category 6 and 1 to 750 MHz for Category 7 cables.

$$40 - 10\log_{10}(f)$$

6.8.2 Longitudinal Conversion Transfer Loss (LCTL)

Requirements are under study.

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Appendix A
ELECTRICAL PERFORMANCE REQUIREMENTS AND REFERENCES FOR CATEGORY 6 AND CATEGORY 7 CABLES

Table A-1a
ELECTRICAL PERFORMANCE REQUIREMENTS FOR CATEGORY 6 CABLES

Electrical Parameters	Category 6			
	22 AWG	23 AWG	24 AWG	26 AWG
Maximum DC Resistance (Ohms/100 m [328 ft]) at 20°C	5.91	7.39	9.38	14.8
Maximum DC Resistance Unbalance (%)	2			
Minimum Insulation Resistance (MΩ-100 m [328 ft])	1500			
Minimum Velocity of Propagation 1 MHz and above (%)	62.0			
Maximum Phase Delay Skew at 1 MHz and above (ns/100 m [328 ft]) for a four-pair cable	45			
Maximum Phase Delay Skew at 1 MHz and above (ns/100m [328 ft]) for greater than four-pair cable	48			

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Table A-1b
ELECTRICAL PERFORMANCE REFERENCE FOR CATEGORY 6 CABLES

			Horizontal Category 6							
Frequency MHz	**Input Impedance (Ohms)**	**Characteristic Impedance (Ohms)**	**Return Loss* (dB) Minimum**	**Insertion Loss (Attenuation)* (dB/100m) Maximum**	**NEXT (dB) Minimum**	**PSNEXT (dB/100m) Minimum**	**ELFEXT (dB/100m) Minimum**	**PSELFEXT (dB/100m) Minimum**	**Transfer Impedance** (dB/100m)**	**LCL dB Minimum**
0.772	100 ± 15	100 ± 6	19.4	1.8	76.0	74.0	70	68	48	-
1	100 ± 15	100 ± 6	20.0	2.0	74.3	72.3	67.8	65.8	50	40.0
4	100 ± 15	100 ± 6	23.0	3.8	65.3	63.3	55.8	53.8	69	34.0
8	100 ± 15	100 ± 6	24.5	5.3	60.8	58.8	49.7	47.7	90	31.0
10	100 ± 15	100 ± 6	25.0	6.0	59.3	57.3	47.8	45.8	100	30.0
16	100 ± 15	100 ± 6	25.0	7.6	56.2	54.2	43.7	41.7	130	28.0
20	100 ± 15	100 ± 6	25.0	8.5	54.8	52.8	41.8	39.8	148	27.0
25	100 ± 15	100 ± 6	24.3	9.5	53.3	51.3	39.8	37.8	172	26.0
31.25	100 ± 15	100 ± 6	23.6	10.7	51.9	49.9	37.9	35.9	200	25.1
62.5	100 ± 15	100 ± 6	21.5	15.4	47.4	45.4	31.9	29.9	338	22.0
100	100 ± 15	100 ± 6	20.1	19.8	44.3	42.3	27.8	25.8	500	20.0
125	100 ± 22	100 ± 6	19.4	22.4	42.8	40.8	25.9	23.9	-	19.0
155.52	100 ± 22	100 ± 6	18.8	25.2	41.4	39.4	24.0	22.0	-	18.1
175	100 ± 22	100 ± 6	18.4	26.9	40.7	38.7	22.9	20.9	-	17.6
200	100 ± 22	100 ± 6	18.0	29.0	39.8	37.8	21.8	19.8	-	17.0
250	100 ± 32	100 ± 6	17.3	32.8	38.3	36.3	19.8	17.8	-	16.0

* Applicable for horizontal and backbone cables only
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Table A-1c
RETURN LOSS & INSERTION LOSS PERFORMANCE REFERENCE FOR CATEGORY 6 PATCH CABLES

Frequency MHz	Return Loss (dB) Minimum	22 to 24 AWG Insertion Loss (Attenuation) (dB/100m) Maximum	<24 AWG Insertion Loss (Attenuation) (dB/100m) Maximum
0.772	19.4	2.2	2.7
1	20.0	2.4	3.0
4	23.0	4.6	5.7
8	24.5	6.4	8.0
10	25.0	7.2	9.0
16	25.0	9.1	11.4
20	25.0	10.2	12.8
25	24.2	11.4	14.3
31.25	23.3	12.8	16.1
62.5	20.7	18.5	23.1
100	19.0	23.8	29.7
125	18.2	26.9	33.6
155.52	17.6	30.2	37.8
175	16.9	32.3	40.4
200	16.4	34.8	43.5
250	15.6	39.4	49.2

Table A-2a
ELECTRICAL PERFORMANCE REQUIREMENTS FOR CATEGORY 7 CABLES

Electrical Parameters	Category 7			
	22 AWG	23 AWG	24 AWG	26 AWG
Maximum DC Resistance (Ohms/100 m [328 ft]) at 20°C	5.91	7.39	9.38	14.8
Maximum DC Resistance Unbalance (%)	2			
Minimum Insulation Resistance (MΩ-100 m [328 ft])	1500			
Minimum Velocity of Propagation at 1 MHz and above (%)	62.0			
Maximum Phase Delay Skew at 1 MHz and above (ns/100 m [328 ft]) for a four-pair cable	15			

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Table A-2b
ELECTRICAL PERFORMANCE REFERENCE FOR CATEGORY 7 CABLES*

					Horizontal Category 7					
Frequency MHz	**Input Impedance (Ohms)**	**Characteristic Impedance (Ohms)**	**Return Loss* (dB) Minimum**	**Insertion Loss (Attenuation)* (dB/100m) Maximum**	**NEXT (dB) Minimum**	**PSNEXT (dB/100m) Minimum**	**ELFEXT (dB/100m) Minimum**	**PSELFEXT (dB/100m) Minimum**	**Transfer Impedance** (dB/100m) Minimum**	**LCL dB Minimum**
1	100 ± 15	100 ± 6	20.0	2.0	75.0	75.0	75.0	72.0	50	40.0
4	100 ± 15	100 ± 6	23.0	3.7	75.0	75.0	75.0	72.0	69	34.0
8	100 ± 15	100 ± 6	24.5	5.2	75.0	75.0	75.0	72.0	90	31.0
10	100 ± 15	100 ± 6	25.0	5.9	75.0	75.0	74.0	71.0	100	30.0
16	100 ± 15	100 ± 6	25.0	7.4	75.0	75.0	69.9	66.9	130	28.0
20	100 ± 15	100 ± 6	25.0	8.3	75.0	75.0	68.0	65.0	148	27.0
25	100 ± 15	100 ± 6	24.3	9.3	75.0	75.0	66.0	63.0	172	26.0
31.25	100 ± 15	100 ± 6	23.6	10.4	75.0	75.0	64.1	61.1	200	25.1
62.5	100 ± 15	100 ± 6	21.5	14.9	75.0	72.5	58.1	55.1	338	22.0
100	100 ± 15	100 ± 6	20.1	19.0	72.4	69.4	54.0	51.0	500	20.0
125	100 ± 22	100 ± 6	19.4	21.4	70.9	67.9	52.1	49.1	-	19.0
155.52	100 ± 22	100 ± 6	18.8	24.0	69.5	66.5	50.2	47.2	-	18.1
175	100 ± 22	100 ± 6	18.4	25.6	68.8	65.8	49.1	46.1	-	17.6
200	100 ± 22	100 ± 6	18.0	27.5	67.9	64.9	48.0	45.0	-	17.0
250	100 ± 25	100 ± 6	17.3	31.0	66.4	63.4	46.0	43.0	-	16.0
300	100 ± 25	100 ± 6	16.8	34.2	65.2	62.2	44.5	41.5	-	
350	100 ± 25	100 ± 6	16.3	37.2	64.2	61.2	43.1	40.1	-	
400	100 ± 25	100 ± 6	15.9	40.0	63.4	60.4	42.0	39.0	-	
600	100 ± 25	100 ± 6	14.7	50.1	60.7	57.7	38.4	35.4	-	
750	100 ± 25	100 ± 6	14.0	56.8	59.3	56.3	36.5	33.5	-	

* Applicable for horizontal and backbone cables only
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Table A-2c
RETURN LOSS & INSERTION LOSS PERFORMANCE REFERENCE FOR CATEGORY 7 PATCH CABLES

Frequency MHz	Return Loss (dB) Minimum	22 to 24 AWG Insertion Loss (Attenuation) (dB/100m) Maximum	<24 AWG Insertion Loss (Attenuation) (dB/100m) Maximum
1	20.0	2.4	3.0
4	23.0	4.4	5.6
8	24.5	6.2	7.8
10	25.0	7.1	8.9
16	25.0	8.9	11.1
20	25.0	10.0	12.5
25	24.2	11.2	14.0
31.25	23.3	12.5	15.6
62.5	20.7	17.9	22.4
100	19.0	22.8	28.5
125	18.2	25.7	32.1
155.52	17.3	28.8	36.0
175	16.9	30.7	38.4
200	16.4	33.0	41.3
250	15.6	37.2	46.5
300	14.9	41.0	51.3
350	14.3	44.6	55.8
400	13.8	48.0	60.0
600	12.3	60.1	75.2
750	11.5	68.2	85.2

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