INTERNATIONAL STANDARD

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Road vehicles — Automotive cables —

Part 1: Vocabulary and design guidelines

Véhicules routiers — Câbles automobiles —

Partie 1: Vocabulaire et lignes directrices pour la conception

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

This second edition cancels and replaces the first edition (ISO 19642-1:2019), which has been technically revised.

The main changes are as follows:

— new parts have been added to the ISO 19642 series (ISO 19642-11 and ISO 19642-12);

— reflecting these additions ISO 19642-2 had to be amended;

— some new terms and definitions for screened RF cables have been added for a new standard of the ISO 19642 series;

— Annex C has been added to give informative advice on how to address and manage requalification of cables already released against the older ISO standards ISO 6722-1 and ISO 6722-2.

A list of all parts in the ISO 19642 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document was prepared following a joint resolution to improve the general structure of the ISO automotive electric cable standards. This new structure adds more clarity and, by defining a new standard family, opens up the standard for future amendments.

Many other standards currently refer to ISO 6722-1, ISO 6722-2 and ISO 14572. These standards will stay valid at least until the next scheduled systematic review and will be replaced later by the ISO 19642 series.

For new automotive cable projects, customers and suppliers are advised to use the ISO 19642 series.

This document defines general terms used in cable engineering to lay a solid foundation for discussions and written information transfer in this field.

Annex A informally defines a calculation method for many important cable parameters (e.g. resistance limits, several cable dimension).

Annex B informally proposes preferred colour concentrations for automotive cables.

Annex C gives an expert opinion on how to address and manage requalification of single core cables already released against the old, but still active, ISO standards ISO 6722-1 and ISO 6722-2.

Road vehicles — Automotive cables —

Part 1:
Vocabulary and design guidelines

1 Scope

This document defines terms in the field of cables applied in road vehicle general purpose applications, for use in the other parts of the ISO 19642 series.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19642-7, *Road vehicles — Automotive cables — Part 7: Dimensions and requirements for 30 V a.c. or 60 V d.c. round, sheathed, screened or unscreened multi or single core copper conductor cables*

ISO 19642-8, *Road vehicles — Automotive cables — Part 8: Dimensions and requirements for 30 V a.c. or 60 V d.c. round, sheathed, screened or unscreened multi or single core aluminium conductor cables*

3 Terms and definitions

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms related to voltage rating

3.1.1
AC voltage
voltage in an alternating current circuit that also periodically reverses because the current has a periodic function of time

Note 1 to entry: Whenever AC voltage is specified in the ISO 19642 series, the AC root mean square (r.m.s.) value shall be used.

3.1.2
60 V cable
cable (3.3.7) intended for use in road vehicle applications where the *nominal system voltage* (3.1.6) is less than or equal to 30 V a.c. or 60 V d.c.

3.1.3
900 V cable
cable (3.3.7) intended for use in road vehicle applications where the *nominal system voltage* (3.1.6) is less than or equal to 600 V a.c. or 900 V d.c.

3.1.4
1 500 V cable
cable (3.3.7) intended for use in road vehicle applications where the *nominal system voltage* (3.1.6) is less than or equal to 1 000 V a.c. or 1 500 V d.c.

3.1.5
DC voltage
non-alternating constant or pulsed voltage

3.1.6
nominal system voltage
maximum continuous voltage of a *conductor* (3.3.13) to its system ground under normal conditions

3.2 Terms related to temperatures

3.2.1
temperature class rating
temperature range for safe operation of the *cable* (3.3.7) divided into eight temperature classes as defined in Table 1

Table 1 — Temperature class rating

Class	Is equivalent to Class	Temperature °C
A	T 1	−40 to 85
B	T 2	−40 to 100
C	T 3	−40 to 125
D	T 4	−40 to 150
E	T 5	−40 to 175
F	T 6	−40 to 200
G	T 7	−40 to 225
H	T 8	−40 to 250

3.2.2
room temperature
RT
situation with a temperature of (23 ± 3) °C and a relative humidity (RH) of 45 % to 75 %

3.3 Terms related to cables

3.3.1
bare conductor
metal *cable* (3.3.7) *conductor* (3.3.13) in which the strand or strands are not coated

3.3.2
bedding layer
non-metallic covering applied (normally extruded) around the assembly of the *cores* (3.3.14) (and *fillers* (3.3.18), if any) of a *multi-core cable* (3.3.29) to obtain a more circular outline

3.3.3
braid
covering formed from bare or plated metallic or non-metallic material

3.3.4
braid parameter
parameter of a *braid* (3.3.3) as defined in Table 2

Table 2 — Braid parameter formulae

Diameter over braid	Number of single strands in one direction	Angle of lay perpendicular to cable axis
$D_B = D_C + 4 \times D_S$	$n_d = n_S \times \frac{n_C}{2}$	$\theta = \arctan \frac{2 \times L_L}{\pi \times (D_B + D_C)}$
Coverage [2)]	Optical coverage, braid percentage	Lay length
$B = \begin{cases} \frac{n_d \times D_S}{L_L \times \cos(\theta)} & B < 1 \\ 1 & B \geq 1 \end{cases}$	$B_o = (2 \times B - B^2) \times 100$	$L_L = 25{,}4 \times \frac{n_S}{2 \times P}$

Key to braid parameters

D_S diameter of single strand, in mm

D_C diameter of core below the braid, in mm

D_B diameter over braid, in mm

n_S number of strands in one carrier

n_d number of single strands in one direction

n_c number of carriers

L_L lay length, in mm

θ angle of lay perpendicular to cable axis, in degrees

P picks per inch (number of braid crossover points in 1" = 25,4 mm)

B coverage, proportion of the covered surface by strands in one direction compared to the whole surface

B_o optical coverage, also called braid percentage; proportion of the covered surface by strands in both directions compared to the whole surface, in percentage

Note 1 to entry: For better accuracy the angle θ shall not be measured directly but be calculated from the measured dimensional parameters referenced in the formulae above.

Note 2 to entry: A value of $B > 1$ is physically impossible so, if due to measurement tolerances, a value of $B > 1$ is obtained, it shall be adjusted to 1.

Note 3 to entry: A braid is formed by a number of single strands which are grouped into carriers and applied to the *cable* (3.3.7) surface in two different directions (left and right or S and Z) in a form that each carrier of one direction is alternatively above and below the adjacent carrier of the other direction.

Note 4 to entry: See Figure 1.

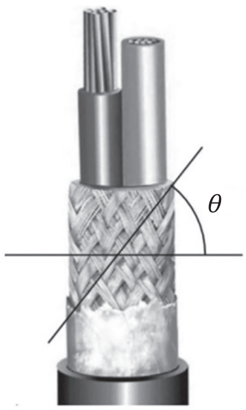


Figure 1 — Angle of lay

3.3.5
bunched conductor
conductor (3.3.13) in which individual strands are assembled together in helical formation, all in the same direction and with the same length of lay

3.3.6
bunching loss
$F_{x,b}$
ratio of *conductor* (3.3.13) resistance before and after the bunching process of *stranded conductors* (3.3.36)

Note 1 to entry: The factor, $F_{x,b}$, is derived by the formula:

$$F_{x,b} = \frac{m_{mean} \cdot R_{mean} \cdot \kappa}{1\ 000 \cdot \rho}$$

where

κ	is the conductivity of the used conductor material in Sm/mm^2;
ρ	is the density of the conductor material in kg/dm^3 = kg/l;
m_{mean}	is the mean of measured conductor mass in g/m;
R_{mean}	is the mean of measured conductor resistance at 20 °C in mΩ/m.

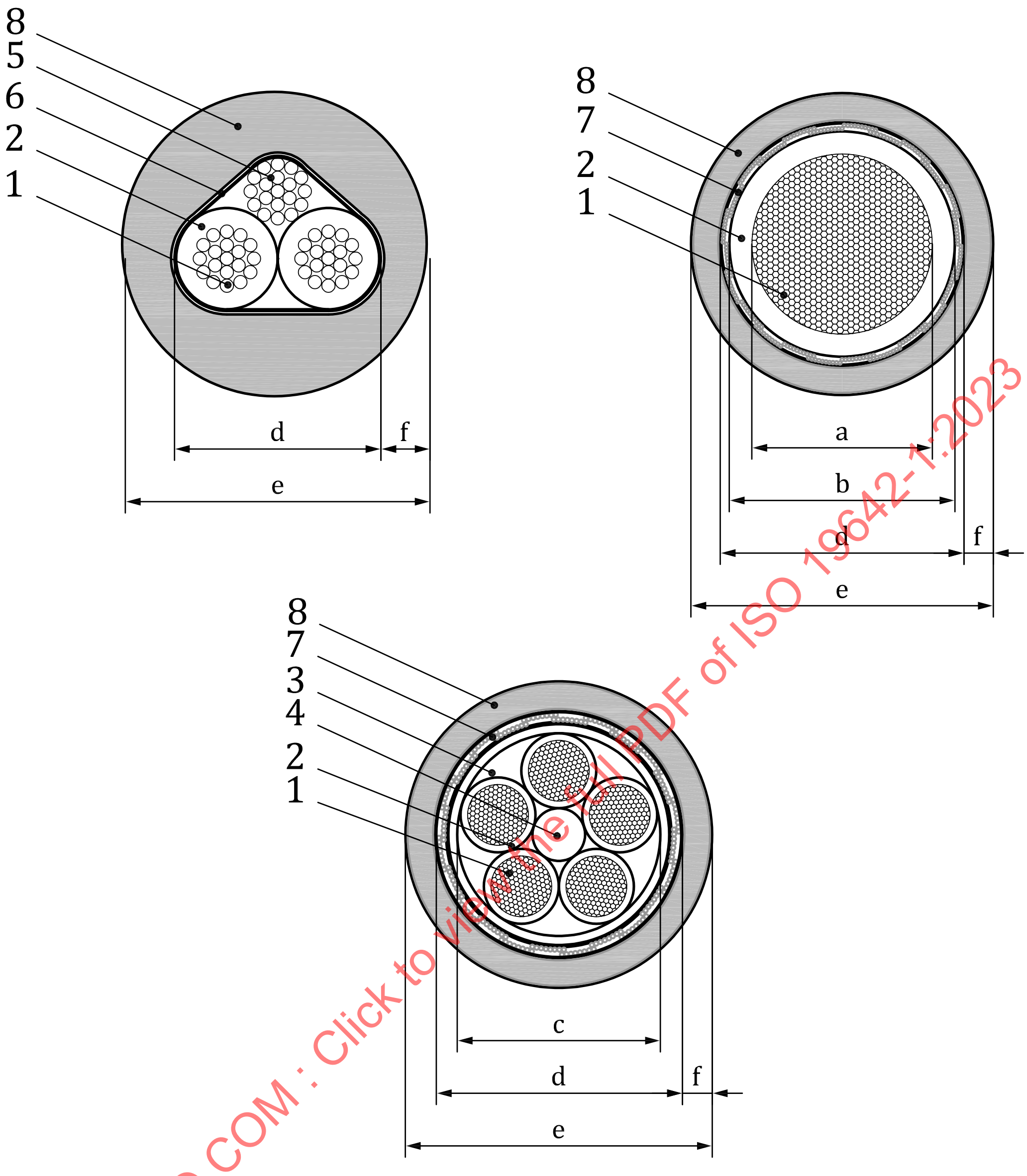
3.3.7
cable
single or multi-core *wire* (3.3.39)

Note 1 to entry: Cable dimension definitions are shown in Figure 2.

3.3.8
cable family
group with multiple *conductor* (3.3.13) sizes having the same conductor, strand coating, *insulation* (3.3.23) formulation, and wall thickness type

3.3.9
cable dimension
property of a *cable* (3.3.7) with physical unit (mm)

Note 1 to entry: Cable dimension definitions are shown in Figure 2.



Key

a	*conductor* (3.3.13) diameter	2	core *insulation* (3.3.23)
b	*core* (3.3.14) diameter	3	*inner covering* (3.3.22)
c	twisted core diameter	4	*filler* (3.3.18)
d	diameter under sheath	5	*drain wire* (3.3.17)
e	outside cable diameter	6	foil
f	wall thickness sheath	7	*screen* (3.3.32)
1	conductor	8	*sheath* (3.3.34)

Figure 2 — Cable dimension definitions

3.3.10
coaxial cable
cable (3.3.7) with one single inner *conductor* (3.3.13), an *insulation* (3.3.23) also called *dielectric* (3.3.16), a concentric cylindrical *screen* (3.3.32) as an outer conductor and a *sheath* (3.3.34)

3.3.11
colour code
code of a *cable* (3.3.7) colour to make it visually distinguishable from the others

Note 1 to entry: The recommended colours are listed in Table 3.

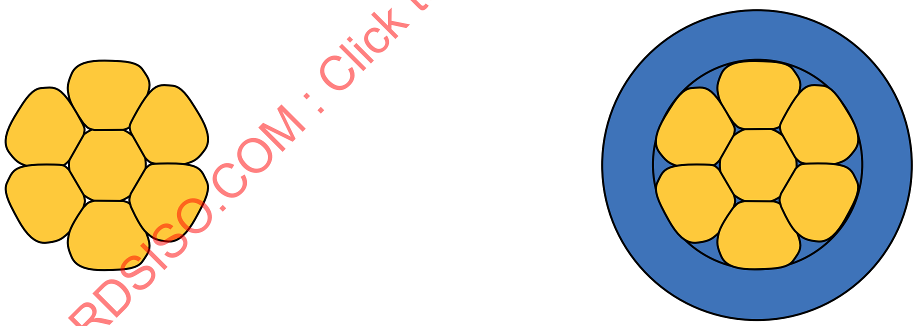
Note 2 to entry: Annex B indicates recommended colour concentrations for the colours listed in Table 3.

Table 3 — Recommended colours and colour codes

Colour	Colour code
Black	BK
Blue	BU
Brown	BN
Green	GN
Orange	OG
Red	RD
Violet (purple)	VT
White	WH
Yellow	YE
NOTE Other colours can be used based on agreement between customer and supplier (see IEC 60757).	

3.3.12
compressed conductor
stranded conductor (3.3.36) in which the interstices between the strands have been reduced by mechanical compression into a circular shape with reduced outside diameter

Note 1 to entry: See Figure 3.



a) Compressed conductor **b) Compressed conductor with *insulation* (3.3.23) only**

Figure 3 — Compressed conductor

3.3.13
conductor
one or multitude of bare, coated or cladded electrically conductive strands

3.3.14
core
insulated *conductor* (3.3.13) assembly comprising a conductor with its own *insulation* (3.3.23) (and *screens* (3.3.32), if any)

3.3.15
cross-sectional area
CSA
calculated or measured area of the *conductor* (3.3.13)

3.3.16
dielectric
insulation (3.3.23) of the inner *core* (3.3.14) of a *coaxial cable* (3.3.10)

3.3.17
drain wire
uninsulated or conductive coated *conductor* (3.3.13) laid in contact with a *screen* (3.3.32) or a *shield* (3.3.32)

3.3.18
filler
component used to fill the interstices between the *cores* (3.3.14) or fill a void for roundness of a *multi-core cable* (3.3.29)

3.3.19
flexibility
property of a *cable* (3.3.7) that allows for bending under the influence of an outside force

3.3.20
flex life
property of a *cable* (3.3.7) to withstand repeated bending

3.3.21
general purpose cable
cable (3.3.7) meeting basic requirements for standard automotive applications

3.3.22
inner covering
non-metallic covering which surrounds the assembly of the *cores* (3.3.14) (and *fillers* (3.3.18), if any) of a *multi-core cable* (3.3.29) and over which the protective covering is applied

3.3.23
insulation
set of insulating materials incorporated on a *conductor* (3.3.13) or *screen* (3.3.32) with a specific function of insulating and/or protecting the conductive elements

3.3.24
ISO conductor size
nominal value (3.3.30) / denomination of the ISO *wire* (3.3.39) used as a reference in this document

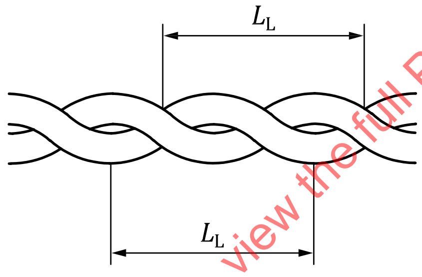
3.3.25
lay direction
direction of rotation of a component of a *cable* (3.3.7) in relation to the longitudinal axis of the *cable* (3.3.7)

Note 1 to entry: The lay is said to be right-hand when the visible portion of the helix, together with the two cross-sections limiting it, form the shape of a letter Z, and left-hand when they form the shape of a letter S. See Figure 4.

Figure 4 — Lay direction

3.3.26
lay length
axial length of one complete rotation of the helix formed by one *cable* (3.3.7) component, for example an individual strand or *core* (3.3.14)

Note 1 to entry: See Figure 5.



Key

L_L length where a core in the outermost layer of the bunching/twisting fulfils a full 360° turn

Figure 5 — Lay length

3.3.27
metal-coated conductor

3.3.27.1
cladded conductor
conductor (3.3.13) in which each individual strand is bonded with a thin layer of another different metal or metal alloy

3.3.27.2
plated conductor
conductor (3.3.13) in which each individual strand is electroplated with a thin layer of another different metal or metal alloy

3.3.28
percentage of International Annealed Copper Standard
percentage of the volume resistivity of a metal when compared to 100 % of pure annealed copper having a volume resistivity of 0,017 24 Ω × mm^2/m at 20 °C as defined in IEC 60028

3.3.29
multi-core cable
cable (3.3.7) having more than one *core* (3.3.14), some of which can be un-insulated (e.g. *drain wire* (3.3.17))

Note 1 to entry: See Figure 6.

Note 2 to entry: Annex A provides design guidelines for calculating dimensions in multi-core cables.

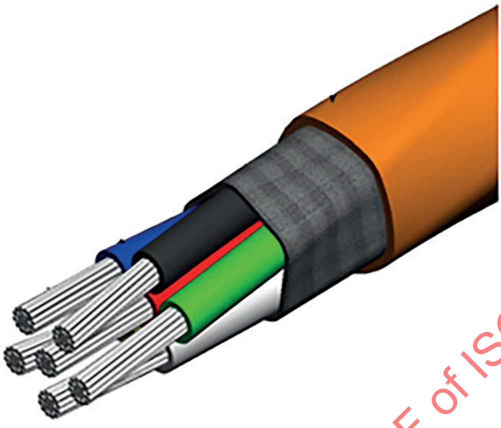


Figure 6 — Multi-core cable with screen and sheath

3.3.30
nominal value
suitable approximate value used to designate or identify an attribute of a component

3.3.31
rope-stranded conductor
stranded conductor (3.3.36) consisting of a number of groups of strands assembled together in one or more helical layers, the *wires* (3.3.39) in each group being either bunched or stranded

Note 1 to entry: See examples in Figure 7.

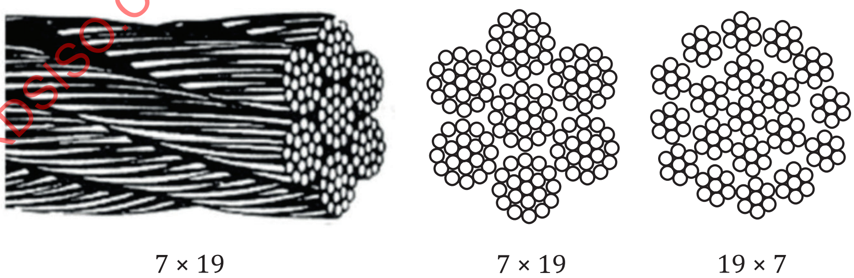


Figure 7 — Rope-stranded conductors

3.3.32
screen
shield
conductive material intended to reduce the penetration and/or radiation of a varying electromagnetic field

Note 1 to entry: Metallic *sheaths* (3.3.35), foils, *braids* (3.3.3), armours and earthed concentric *conductors* (3.3.13) may also serve as shields.

3.3.33
separator
thin layer used to facilitate the separation of, or as a barrier to prevent mutually detrimental effects between different components of a *cable* (3.3.7), such as between the *conductor* (3.3.13) and the *insulation* (3.3.23) or between the insulation and the *sheath* (3.3.34)

3.3.34
sheath
jacket
non-conductive, uniform and continuous covering of material, generally extruded

3.3.35
special purpose cable
cable (3.3.7) meeting basic requirements plus additional or enhanced performance requirements for unique applications

Note 1 to entry: Unique requirements are as defined by the customer.

3.3.36
stranded conductor
conductor (3.3.13) consisting of a number of individual strands, all or some of which are wound in a helix

3.3.37
strip force
force needed to remove or displace an outer layer of a *cable* (3.3.7) from the subjacent cable elements

Note 1 to entry: For a single inner conductor *coaxial cable* (3.3.10) three different strip forces and the corresponding test procedures are defined in ISO 19642-2.

Note 2 to entry: The following strip forces are defined:

Strip force a) between inner conductor and dielectric cable insulation;

Strip force b) between dielectric cable core and the screen together with the sheath (screen + sheath composite);

Strip force c) between screen and sheath.

3.3.38
twisting loss
ratio of *conductor* (3.3.13) resistance before and after the twisting process of *cores* (3.3.14)

3.3.39
wire
stranded or solid cylindrical *conductor* (3.3.13), with or without an insulating covering

3.4 Terms related to RF systems and properties

3.4.1
100BASE-T1 Ethernet
standardized in IEEE 8802.3, physical layer which applies to a single balanced twisted pair cable capable of transmitting 100 Mbit/s up to 15 m in total length

3.4.2
1000BASE-T1 Ethernet
standardized in IEEE 8802.3, physical layer which applies to a single balanced twisted pair cable capable of transmitting 1 000 Mbit/s up to 15 m (segment A) or 40 m (segment B) in total length

3.4.3
alien crosstalk
exogenous crosstalk
unwanted disturbing signal, stated in dB, coupling from one balanced pair cable to another

3.4.4
balanced cable
data transmission cable consisting of two *cores* (3.3.14) which have uniform differential *impedance* (3.4.17) along their length

Note 1 to entry: Common forms of balanced cables are twisted pair, parallel pair and twin lead cables.

3.4.5
bus capacitance
C_{bus}
capacitive load of differential data cores in *multi-core cables* (3.3.29) stated in pF/m

3.4.6
capacitance
C
ability to store electric charge between *conductors* (3.3.13) or conductor to ground, measured in pF/m

3.4.7
controller area network
CAN
serial data communication protocol

Note 1 to entry: See the ISO 11898 series.

3.4.8
CAN-FD
flexible data rate
extension to *CAN* (3.4.7) that is able to transmit data at a higher rate

3.4.9
characteristic impedance
ratio of the electric [V/m] and magnetic field [A/m] strengths of a single wave, the physical unit is (Ω)

Note 1 to entry: See Table 4 for a list of characteristic impedance modes:

Table 4 — Characteristic impedance modes

CICMF	characteristic impedance common mode frequency domain
CICMT	characteristic impedance common mode time domain
CIDMF	characteristic impedance differential mode frequency domain
CIDMT	characteristic impedance differential mode time domain

3.4.10
common mode
CM
mode of transmission where the signal is propagated in reference to the ground level

3.4.11
crosstalk
phenomenon of the unwanted signal transmitted from one aggressor circuit or channel of a transmission system to the victim circuit or channel (for two or more channels in the same bundle)

3.4.11.1
far-end crosstalk
FEXT
level of interference that occurs between one pair and another within the same *cable* (3.3.7) measured at the far end of the cable, stated in dB

3.4.11.2
near-end crosstalk
NEXT
level of interference that occurs between one pair and another within the same *cable* (3.3.7) measured at the near end of the cable, stated in dB

3.4.11.3
alien near-end crosstalk
ANEXT
level of interference that occurs between one pair of a *cable* (3.3.7) and an exogenous source measured at the near end of the cable, stated in dB

3.4.11.4
powersum attenuation to alien crosstalk ratio
PS-AACR-F
ANEXT ratio of the sum of the total power coupled to a *wire* (3.3.39) pair from exogenous sources measured at the far-end minus the *insertion loss* (3.4.18) compared to the input power, stated in dB

3.4.12
de-embedding
mathematical method to remove the influence of connector and connecting hardware properties from *frequency domain (F)* (3.4.15) cable measurement data

3.4.13
differential mode
DM
mode of transmission where the signal is propagated symmetrically to the reference voltage

3.4.14
FlexRay
automotive network communications protocol

Note 1 to entry: See the ISO 17458 series.

3.4.15
frequency domain
F
representation of a signal with respect to variable frequencies

3.4.16
gating
mathematical method to remove the influence of connector and connecting hardware properties from *time domain (T)* (3.4.26) cable measurement data

3.4.17
impedance
Z
ratio of the voltage between the *conductors* (3.3.13) and the current in the conductors, described as a complex number

3.4.18
insertion loss
IL
attenuation
loss of signal power resulting in a transmission line and is stated in dB/m

Note 1 to entry: For unbalanced systems IL can be calculated from S-parameters S_{21} or S_{12}, for balanced systems IL can be calculated from S-parameters S_{dd21} or S_{dd12}.

3.4.19
in-pair skew
intra-pair skew
difference of *propagation delay* (3.4.23) between the two primary *wires* (3.3.39) of a single pair

3.4.20
inter-pair skew
difference of *propagation delay* (3.4.23) between two pairs

3.4.21
JUTP
acronym for jacketed (sheathed) un-shielded twisted pair cable

3.4.22
mutual capacitance
capacitance (3.4.6) between two insulated *wires* (3.3.39) in a twisted pair, stated in (pF/m)

3.4.23
propagation delay
amount of time it takes for the head of a signal to travel from the sender to the receiver

3.4.24
resistance unbalance
difference in DC resistance between two *conductors* (3.3.13), usually in a twisted pair

3.4.25
return loss
RL
ratio stated in decibels (dB) of the power of the outgoing signal to the power of the reflected or returned signal

Note 1 to entry: For unbalanced systems this is defined as S-parameter S_{11} or S_{22}, for balanced system S_{dd11} or S_{dd22}.

3.4.26
time domain
representation of a signal with respect to a variable time

3.4.27
unbalance attenuation
combinations of *common mode* (3.4.10) versus *differential mode* (3.4.13) measurements

Note 1 to entry: For definitions of possible combinations see Table 5 and IEC TR 61156-1-2.

Table 5 — Unbalance measurement modes

Definition		Related S -parameter	Measured output		Stimulus input	
Acronym	Name		Mode	End	Mode	End
TCL	transverse conversion loss	S_{cd11}	c common	1 near	d differential	1 near
LCL	longitudinal conversion loss	S_{dc11}	d differential	1 near	c common	1 near
TCTL	transverse conversion transfer loss	S_{cd21}	c common	2 far	d differential	1 near
EL TCTL [a]	equal level transverse conversion transfer loss	S_{cd21}	c common	2 far	d differential	1 near
LCTL	longitudinal conversion transfer loss	S_{dc21}	d differential	2 far	c common	1 near
EL LCTL [b]	equal level longitudinal conversion transfer loss	S_{dc21}	d differential	2 far	c common	1 near

[a] It is the same as TCTL but *attenuation* (3.4.18) is taken into account in the power ratio calculation.

[b] It is the same as LCTL but attenuation is taken into account in the power ratio calculation.

3.4.28
unbalanced cable
cable (3.3.7), often a *coaxial cable* (3.3.10), where the signal is transmitted in *common mode* (3.4.10)

3.4.29
UTP
acronym for unshielded twisted pair cable without *jacket* (3.3.34)

3.4.30
velocity of propagation
speed of a wave along a transmission line stated as a percentage of the speed of light

Annex A
(informative)

Design guidelines for calculation of dimensions in multi-core cables

A.1 General

Due to geometric principles and the effect of subsequent production processes like twisting, braiding and sheath extrusion, the properties of the single cores in a multi-core cable are changed.

This annex provides guidelines on how these effects can be calculated.

It also gives guidelines on how to calculate the wall thicknesses of sheath and bedding layers and which tolerances should be guaranteed.

A.2 Outside diameter of twisted cores

The maximum outside diameter of twisted cores, $D_{t,max}$, is calculated using the stranding factors in Table A.1.

For certain numbers of cores (for example 5 or 6), filler cores may be used to get a stable bunching/twisting. The outside diameter of the twisted cores and the diameter of filler cores are calculated according to the following formulae:

$$D_{t,max} = F_{x,S} \times D_{max}$$

$$D_D = F_{x,D} \times D_{max}$$

where

$D_{t,max}$ is the maximum outside diameter of twisted cores;

$F_{x,S}$ is the stranding factor;

$F_{x,D}$ is the filler core factor;

D_{max} is the maximum outside diameter of single core;

D_D is the outside diameter of the filler core.

Table A.1 — Stranding factors for bunching/twisting

Number of cores	Stranding factor $F_{x,S}$	Filler core factor $F_{x,D}$	Filler core needed
2	2,000	—	no
3	2,155	—	no
4	2,414	0,414	optional
5	2,701	0,701	mandatory
6	3,000	1,000	mandatory

Table A.1 *(continued)*

Number of cores	Stranding factor $F_{x,S}$	Filler core factor $F_{x,D}$	Filler core needed
7	3,000	—	no

EXAMPLE For 5 thin wall cores with *ISO conductor size* (3.3.24) of 1,0 mm^2:

— D_{max} = 2,10 mm, maximum outside diameter of single core;

— $F_{x,D}$ = 0,701, filler core factor;

— D_D = 1,47 mm, outside diameter of the filler core;

— $F_{x,S}$ = 2,701, stranding factor;

— $D_{t,max}$ = 2,10 mm × 2,701 = 5,67 mm, maximum outside diameter of twisted cores.

Although in the centre of this bunching/twisting a filler core is needed, the stranding factor already takes the dimension of the filler core into account.

No extra measurement of the diameter of the twisted cores is performed. For data sheets, the calculated value with two decimals is used.

A.3 Maximum diameter under sheath

The maximum diameter of the bunched cores and the screen is derived with the following formulae:

For an unscreened multi-core cable:

$$D_{bsmax} = D_{t,max}$$

For a screened single core cable:

$$D_{bsmax} = D_{t,max} + 4 \times D_{smax} + 3 \times D_F$$

For a screened multi-core cable:

$$D_{bsmax} = D_{t,max} + 2 \times w_{bmax} + 4 \times D_{smax} + 3 \times D_F$$

where

D_{bsmax} is the maximum diameter under sheath;

$D_{t,max}$ is the maximum diameter of twisted cores for multi-core cables, maximum core diameter for single core cables;

w_{bmax} is the maximum wall thickness of bedding layer;

D_{smax} is the maximum diameter of screen strands;

D_F is the thickness of optional foil.

A.4 Minimum insulation wall thickness in multi-core cables

During core bunching/twisting and sheath extrusion, a certain deformation of the cores is unavoidable. This fact is taken into account when the minimum insulation wall thickness is determined.

The specified minimum insulation wall thickness of a single-core cable is reduced according Tables A.2 and A.3, which take into account the nominal cross-sectional area of the core, the nominal wall thickness (thick, thin) and the maximum stranded core diameter.

Table A.2 — Minimum insulation wall thickness of twisted cores with thick wall insulation

ISO conductor size mm²	D_{max} mm	Minimum wall thickness at lay length, ($w_{min,LL}$) mm			
		$L_L > 24 \times D_{max}$	$L_L > 12 \times D_{max}$	$L_L > 6 \times D_{max}$	$L_L \leq 6 \times D_{max}$
0,5	2,3	0,43	0,41	0,39	0,32
0,75	2,5	0,43	0,41	0,39	0,32
1	2,7	0,43	0,41	0,39	0,32
1,25	2,95	0,43	0,41	0,39	0,32
1,5	3	0,43	0,41	0,39	0,32
2	3,3	0,43	0,41	0,39	0,32
2,5	3,6	0,50	0,48	0,46	0,38

Table A.3 — Minimum insulation wall thickness of twisted cores with thin wall insulation

ISO conductor size mm²	D_{max} mm	Minimum wall thickness at lay length, ($w_{min,LL}$) mm			
		$L_L > 24 \times D_{max}$	$L_L > 12 \times D_{max}$	$L_L > 6 \times D_{max}$	$L_L \leq 6 \times D_{max}$
0,13	1,05	0,18	0,17	0,16	0,13
0,22	1,2	0,18	0,17	0,16	0,13
0,35	1,4	0,18	0,17	0,16	0,13
0,5	1,6	0,20	0,19	0,18	0,15
0,75	1,9	0,22	0,20	0,20	0,16
1	2,1	0,22	0,20	0,20	0,16
1,25	2,3	0,22	0,20	0,20	0,16
1,5	2,4	0,22	0,20	0,20	0,16
2	2,8	0,25	0,24	0,23	0,19
2,5	3	0,25	0,24	0,23	0,19

A.5 Conductor resistance increase due to bunching/twisting

A.5.1 General

The conductor resistance of cores in a multi-core cable is bigger than the resistance of a single-core cable. This effect is caused by two independent reasons and needs to be taken into account in the specified values.

A.5.2 Geometric lengthening

Due to the bunching/twisting, the conductor resistance in the finished cable is increased because the straight length of the cores is longer than the length of the finished cable.

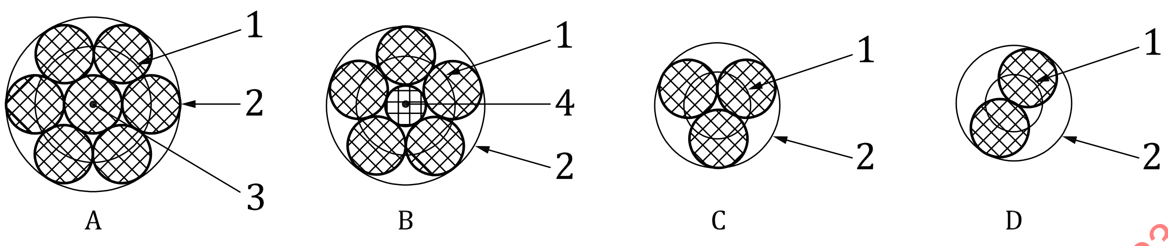
The resulting individual strand lengths are longer for shorter conductor lay lengths.

The amount of lengthening is determined by the distance of the cores to the centre of the bunching/twisting and the lay length:

A core in the centre of the bunching/twisting undergoes no lengthening.

Cores farther off the centre of the bunching/twisting suffer higher lengthening.

For the calculation, the diameter, c_L, of the circle through the centres of the cores in a layer is needed. See Figure A.1.



Key

A 7 cores
B 5 cores
C 3 cores
D 2 cores
1 D_L
2 $D_{t,max}$
3 straight core
4 filler

Figure A.1 — Example of core configurations

The geometric lengthening factor, *v*, is calculated according to the following formulae:

$$D_L = D_{t,max} - D_{max} = D_{max} \times (F_{x,S} - 1)$$

$$v = \sqrt{\left[\left(\frac{D_L \times \pi}{L_L}\right)^2 + 1\right]}$$

where

D_L is the diameter of a circle through the middle points of cores;

$D_{t,max}$ is the maximum diameter of twisted cores;

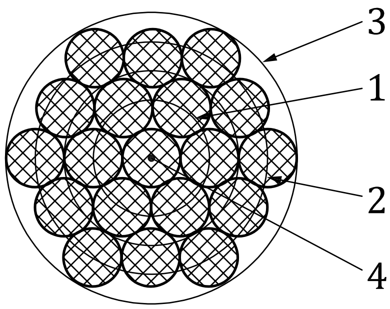
v is the geometric lengthening factor;

L_L is the lay length;

$F_{x,S}$ is the stranding factor;

D_{max} is the maximum diameter of single core.

For bunching/twisting with more than one layer, the lengthening of each layer needs to be calculated separately. See Figure A.2.



Key

1 D_{L1}

2 D_{L2}

3 $D_{t,max}$

4 straight core

Figure A.2 — Example of a complicated core configuration (19 cores)

A.5.3 Stress induced lengthening

Due to the unavoidable stress during the bunching/twisting process, an additional lengthening occurs. This additional lengthening is taken into account by the factor *z*. See Table A.4 for values.

Table A.4 — Stress induced lengthening factor, *z*, for cable conductors

ISO conductor size mm^2	Factor *z* Copper conductor	Factor *z* Aluminium conductor
≤ 0,35	1,020	[a]
0,5	1,015	1,020
0,75	1,010	1,015
≥ 1,0	1,005	1,010

[a] The cable construction does not exist.

A.5.4 Maximum conductor resistance in multi-core cables

The maximum permissible conductor resistance for multi-core cables is derived from the maximum values in the single core specification ISO 19642-3 to ISO 19642-6, using the following formula:

$$R_{max\_multi} = R_{max\_single} \times v \times z$$

where

R_{max_multi}	is the maximum permissible conductor resistance in multi-core cables;
R_{max_single}	is the maximum permissible conductor resistance in single core cables;
v	is the geometric lengthening factor;
z	is the stress induced lengthening factor.

A.6 Wall thickness of sheath and bedding layer

Two different wall thicknesses for the sheath are recommended:

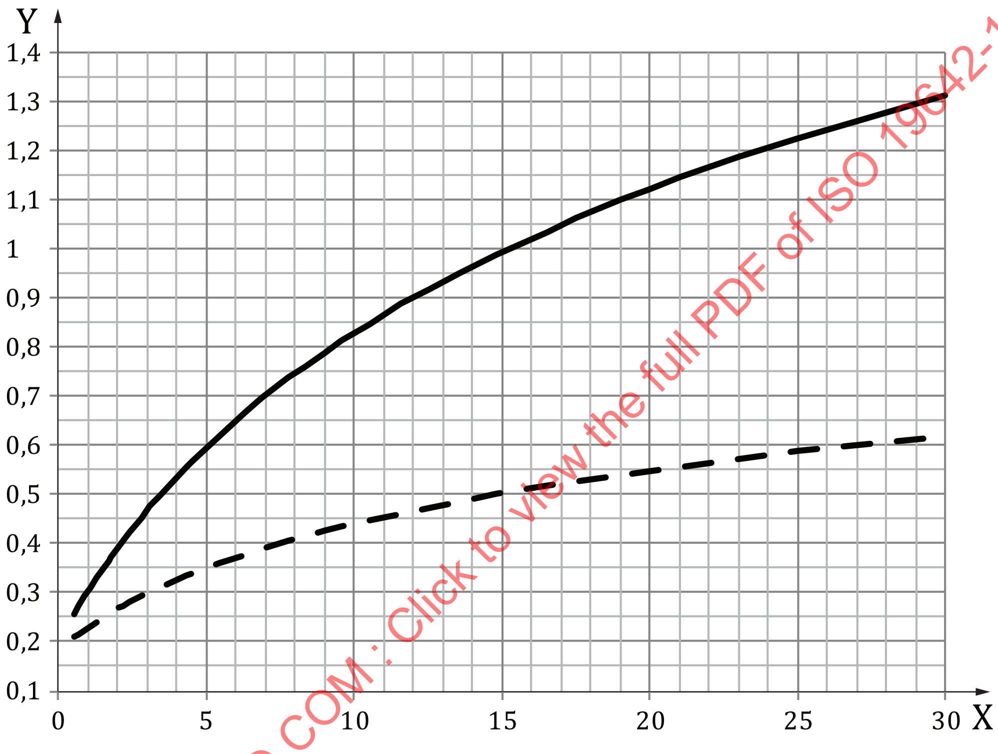
— thick wall sheath for thick wall cores;

— thin wall sheath for thin wall cores.

Other possible combinations are not recommended.

For screened multi-core cables a bedding layer is recommended below the screen.

The wall thickness requirements are derived from the diameter of the elements below the sheath or bedding, following Figures A.3 and A.4:



Key

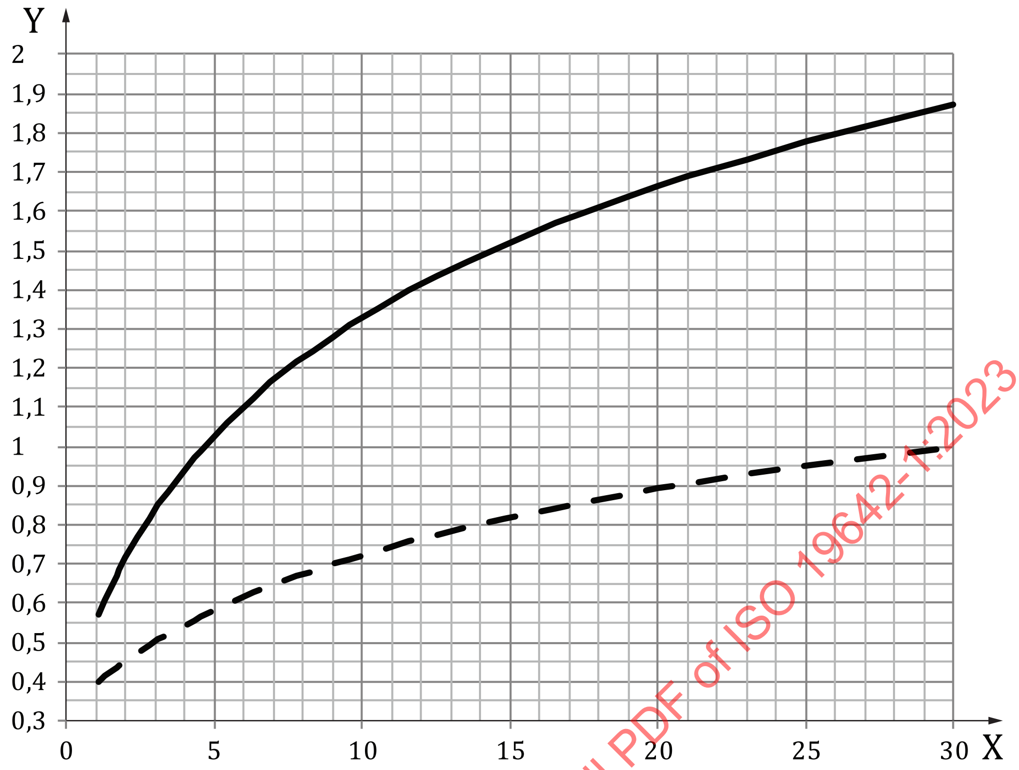
X diameter below wall

Y nominal wall thickness

—— thin wall sheath

– – thin wall bedding layer

Figure A.3 — Wall thicknesses for thin wall constructions



Key

X diameter below wall

Y nominal wall thickness

——— thick wall sheath

— — thick wall bedding layer

Figure A.4 — Wall thicknesses for thick wall constructions

A.7 Minimum wall thickness

The minimum wall thickness for sheath and bedding layer is derived from the nominal wall thickness from the following formula:

$$w_{min} = 0,8 \times w_{nom}$$

where

w_{nom} is the nominal wall thickness of sheath or bedding layer;

w_{min} is the minimum wall thickness of sheath or bedding layer.

A.8 Screen

The braid is made up of single strands.

The diameter of the single strands should fulfil the requirements given in the applicable parts of the ISO 19642 series.

The optical coverage should be greater than or equal to 80 %.

The use of a separator or a foil below and/or above the braid is permissible.

