Introduction to Cable Engineering

Continuous supply of electric power, or faultless data transfer respectively, provided mostly through wiring, are a primary requirement affecting virtually all areas of our life. This results in tough requirements for production, installation and operation of cables. To be able to design the cables suitably and to install them correctly, it is necessary to have good knowledge in various fields, e.g. physics, electrical engineering, mechanic and other applied engineering sciences.

Cable failure can be caused, for example, by mechanical action or electrically by overvoltage, by insulation ageing, corrosion, sneak currents, as well as by unqualified installation or by incorrectly or badly dimensioned design. What is also important is technically correct elaboration of a wiring project and proper crosscheck of all installation work. Then, in operation, it is necessary to observe relevant operating conditions, a cable was designed for.

Employees of the Lapp Group are prepared anytime to help you professionally in preventing any and all consequences, which may be caused by a wiring failure.

The Fundamentals of Cable Engineering

1. What cables and conductors are required for

- Electric power transmission – for power supply

- Transmission of data, signals or impulses – for data communication

Generally, the term of electric cable means a route for transmission of el. power, data or signals betweeen a source and an appliance (for data cables → transmitter and receiver).

2. Explanation of general terms

2.1 Conductor

Conductor (conductive core) represents a conductive route of electric power and together with insulation it forms a wire. Several wires form a core. A sheath protects a cable from external actions.

Metals are conductors of the 1st class. Conductance of metals is related to the number of electrons in their outer layer. The most often used conductor materials are as follows:

- Copper (Cu) (in more than 99 % of all applications)
- Aluminium (Al)
- Silver (Ag)

Conductors can be bare or treated (tinned, silver-coated, gold-coated).

Photographs are not to scale and do not represent detailed images of the respective products.

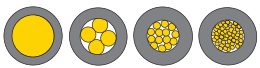
Classification according to design:

- Compact core: of a single wire (up to 16 mm²) or of multiple wires
- Stranded core: made of 7 to several hundreds of thin single wires (VDE 0295/ IEC 602258).

Classes of stranded cores are specified in VDE 0295, or from 0.5 mm² in compliance with IEC 60228 respectively. Max. diameter of a single wire and max. conductor resistance are critical for the core design. The larger cross-sectional area, the lower resistance; the larger length, the higher resistance (similarly as for water supply piping).

Stranded core classes

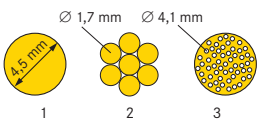
Class 1: compact
Class 2: made of multiple wires
Class 5: made of fine wires
Class 6: made of extra-fine wires



Example of a conductor with nominal cross-sectional area of 16 mm²

$A = \pi r^2$ or $A = \pi d^2/4$
A = geometric cross-sectional area
r = radius
d = diameter

1: solid wire (1 x 4.5 mm)
2: multiple wires (7 x 1.7 mm)
3: fine wires (122 x 0.41 mm)



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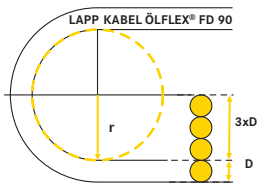
Minimum bending radius

It is a characteristic value, which gives you a degree of possible cable bending without its damaging. It is absolutely necessary to respect this value, when using a cable in tow chains („FD“ cables in the Lapp Group programme). Only maximum outside diameters are shown for highly flexible cables; tolerance is possible only downwards.



D = Cable outside diameter

2.2 Insulation

Insulation is electrically non-conducting protective layer around the conductor. Insulating materials are applied on conductors by extrusion. The mostly used insulating materials are compounds of organic elements.

C, H2, O2, N2, S, e.g.:

- Thermoplastics: PVC, PE, PP, PTFE
- Elastomers (rubber): CR, SR
- Thermoplastic elastomers: PUR, TPE-E

An insulated conductor is called a wire.

2.3 Twisting

While producing a multiwire cable the wires are twisted together.

A cable of wires, a bundle of wires or a twisted bundle (cable core) is created.

Reasons for twisting are:

- Lower need for space → smaller outer diameters
- Circular form
- Flexibility

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2.4 Identification of wires (wire identification code)

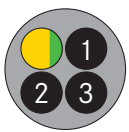
To be able to connect the wires correctly, they must be uniquely identified.

Numbering

- All wires are identified by numbers in ascending order from 1 to ...
- Mostly by white digits on black background (insulation)
- The only exception is a protective conductor, which is always green-yellow

Numbered wires

Protective green-yellow wire
Colour ratio 70:30

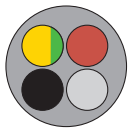


Colour code

- All wires are differentiated by different colours of insulation
- Individual colours are specified in the „Wire Identification Code“
- e.g. according to DIN VDE 0293-308/HD 308 S2

Coloured wires

Protective green-yellow wire
Colour ratio 70:30



2.5 Protection, screening, armouring

It has 2 main functions:

- Mechanical protection by braiding made of steel wires protected from „S“ oxidation, e.g. ÖLFLEX® CLASSIC 100 SY

- Electromagnetic protection (EMC) by braiding made of tinned copper „C“ wires, e.g. ÖLFLEX® CLASSIC 110 CY black 0.6/1 kV

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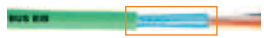
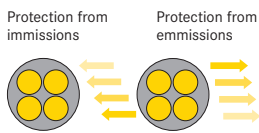
- or by braiding made of copper „D“ wires, e.g. ÖLFLEX® ROBOT 900 DP

- or by braiding made of metallized foil (e.g. aluminium bonded (steamed) polyester sheet), e.g. UNITRONIC® BUS EIB



2.6 Sheath

The sheath is a closed cover protecting elements laying under the sheath from external actions (mechanical, thermal, chemical or physical damages). Correct selection of sheath material is decisive.



Mechanical actions:
abrasion, impact, bending, tension, twisting (torsional swinging)...
Examples of protections:
braiding of steel wires, bearing members, supporting braiding, protective hoses

Chemical actions:
acids, caustics, oils, solvents, water (from 50 °C)
Examples of protections:
sheath materials, such as TEFLON, ROBUST, PUR; protective hoses

Thermal actions:
cold, heat
Examples of protections:
mixture with thermal stabilisers, teflon, silicone

Physical actions:
UV radiation, radioactive radiation
Examples of protections:
mixture with UV stabilisers

The mostly used sheath materials are as follows: PVC, PUR, SR, CR.

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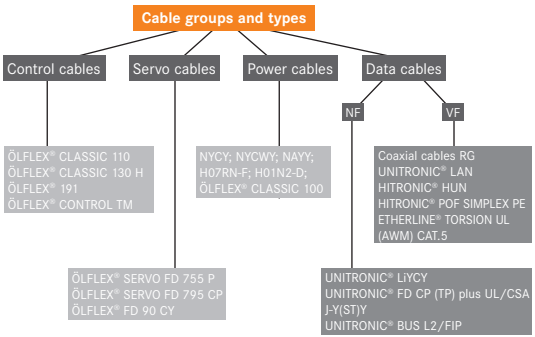
3. Labelling products of the Lapp Group programme

ÖLFLEX® CLASSIC 110 4 G 1.5 mm²

1 2 3 4

1. Brand, identification
2. Number of wires
3. G with a protective conductor or X without a protective conductor (green-yellow)
4. Cross-sectional area or diameter (J-Y(St)Y 4 x 2 x 0.6 mm) ... and relevant quantity



4. Selection criteria

Which criteria are important?

1. What is the purpose of use?
   Description of application
2. What nominal voltage is required?
   U_o/U
   300 V, 500 V,
   600/1000 V ...
3. Where the cable will be used?
   Environment
   Indoor or outdoor
   - Thermal resistance
   - UV radiation resistance
   - Weather resistance
4. How the cable will be laid?
   Way of laying
   Fixed or movable, in a tow chain, positively guided (pulleys...)
   - minimum bending radius, reversed bending cycles, tensile forces

   In open or closed cable systems (troughs, pipes...)
   - Current-carrying capacity, reduction factors

   In the vicinity of interference fields (EMC)
   - Screening by copper braid
5. What requirements for norms should be fulfilled?
   National norms, e.g. VDE, HAR, UL, CSA, NOM...
6. Other requirements
   Behaviour in case of fire/ Non-halogenity
   Chemical actions:
   free of compounds harming varnish wettability, free of lead, resistance to oils, acids, water
   Mechanical actions:
   resistance to torsional strain, to abrasion, to extension strain

5. Standards, approbations, norms

Approbation is a defined special standard for cables issued by an authorised body including description of design (compositions, materials, diameters, etc.) and the use. (see Table T6 and T18).