What you should know about ferrules

Ferrules

Why ferrules?

An untreated shoelace end will fray over time and be difficult to insert into the eyelets of a shoe. Therefore, to protect against fraying and thus ensure easy threading, lace ends are fitted with metal caps or plastic film.

Flexible litz wires can also splice as a result of stripping, making it difficult to insert the wire into the terminal blocks.

Ferrules bundle the litz wires and prevent splicing. Crimping the sleeve around the conductor also creates a permanent, rigid connection that provides reliable protection against mechanical influences and facilitates (re)wiring.

The advantages of ferrules

- ☑ Process reliability and fast wiring
- ☑ Reliable connection, even with repeated rewiring
- ☑ Time and cost-saving processing with automatic devices
- ☑ Increased, long-term operational safety and contact reliability
- ☑ Permanently low contact resistances
- ☑ Easy cross-section detection
- ☑ Increased vibration resistance
- ☑ Individual litz wires are protected (particularly for screw terminal blocks)

Ferrule types

Non-insulated ferrules
In accordance with DIN 46228-1, UL 486F-A

Insulated ferrules
In accordance with DIN 46228-4, UL 486F-E

Insulated ferrules with extended plastic collar (GB)
For AWG, multinorm, and JIS conductors

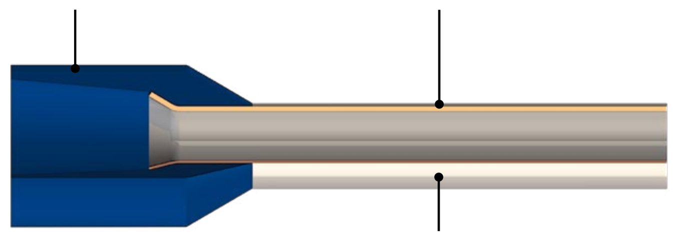
Insulated ferrules with greatly extended plastic collar (XL)
For short-circuit/ground-fault proof conductors and PV conductors

Insulated ferrules for 2-wire connection (TWIN)
In accordance with UL 486F-F, for crimping two conductors of the same cross-section

Materials

Insulation collar
Polypropylene (PP) with a heat resistance of up to +105°C is commonly used

Sleeve
Copper with a purity of >99.9% (preferably CU-DHP or CU-ETP) and a hardness of max. 105 HV*



Coating
Tin-plated, at least 3 µm

* Note: In the manufacturing process, the “pulling” action applied to the copper sleeve results in an increase in material hardness. To meet the specifications of DIN 46228, the sleeves must then be annealed. If the material hardness is too high, the crimping process would result in insufficient forming and/or cracks.

Coloring

The color of the plastic collar indicates the cross-section of the ferrule and thus facilitates assignment to the corresponding conductor. In addition to the standardized color series, however, there are also various color versions.

Cross-section	DIN 46228-4 UL 486F	NF C 63-023	Special color code
0.14 mm²	Gray*		Gray
0.25 mm²	Yellow*		Light blue
0.34 mm²	Turquoise*	Green	Turquoise
0.50 mm²	White	White	Orange
0.75 mm²	Gray	Blue	White
1.00 mm²	Red	Red	Yellow
1.50 mm²	Black	Black	Red
2.50 mm²	Blue	Gray	Blue
4.00 mm²	Gray	Orange	Gray
6.00 mm²	Yellow	Green	Black
10.00 mm²	Red	Brown	Ivory
16.00 mm²	Blue	Ivory	Green
25.00 mm²	Yellow	Black	Brown
35.00 mm²	Red	Red	Beige
50.00 mm²	Blue	Blue	Olive

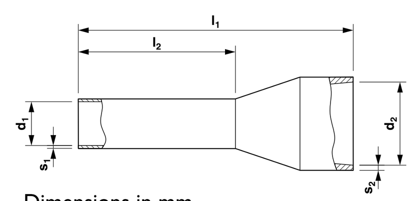
* Not present in the DIN standard

UL certification

Phoenix Contact has had ferrules certified in accordance with the UL 486F standard in combination with a selection of crimping tools and crimping devices (ZMLF.E488001). Together with conformity with the DIN 46228-1/-4 standard, it meets the global market requirements for quality, safety, and compatibility, offering a system that is accepted worldwide to export-oriented users.

Insulated ferrules in accordance with UL 486F-E

For additional information on ferrules, scan the QR code.



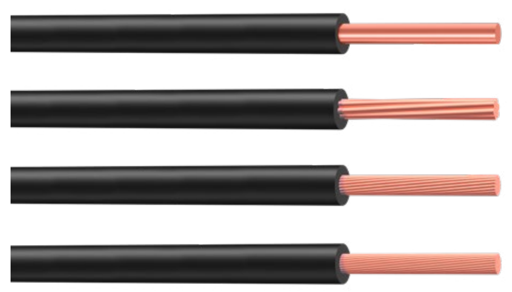
mm²	AWG	d_1	d_2	l_1	l_2	s_1	s_2
0.14*	26	0.8	1.9	10.5	6	0.15	0.25
				12.5	8		
0.25*	24	0.8	1.9	10.5	6	0.15	0.25
				12.5	8		
0.34*	22	0.8	1.9	10.5	6	0.15	0.25
				12.5	8		
				14.5	10		
				16.5	12		
0.5	20	1	2.6	12	6	0.15	0.25
				14	8		
				16	10		
0.75	18	1.2	2.8	12	6	0.15	0.25
				14	8		
				16	10		
				18	12		
1	–	1.4	3	12	6	0.15	0.25
				14	8		
				16	10		
				18	12		
1.5	16	1.7	3.5	14	8	0.15	0.25
				16	10		
				18	12		
				24	18		
2.5	14	2.2	4.2	14	8	0.15	0.25
				18	12		
				24	18		
4	12	2.8	4.8	17	10	0.2	0.3
				20	12		
				26	18		
6	10	3.5	6.3	20	12	0.2	0.3
				26	18		
10	8	4.5	7.6	22	12	0.2	0.4
				28	18		
16	6	5.8	8.8	24	12	0.2	0.4
				28	18		
25	4	7.3	11.2	30	16	0.2	0.4
				30	18		
				36	22		
35	2	8.3	12.7	30	16	0.2	0.4
				30	18		
				39	25		
50	1/0	10.3	15	36	20	0.3	0.5
				40	25		

* Not present in the DIN standard

Conductors

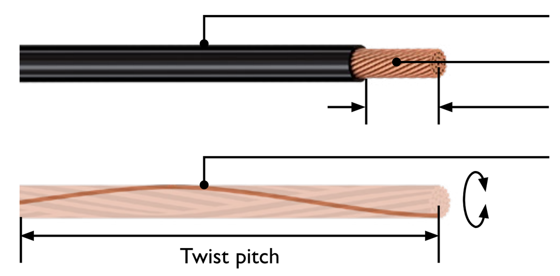
Conductor definition

The DIN EN IEC 60228 standard lays out the definition of a conductor. In addition to the insulation, it consists of a conductive aluminum or copper core, which is divided into four common conductor classes.



Ferrules in accordance with DIN 46228 part 1, 4 and UL 486F-A, E, F are designed to accommodate class 2, 5, and 6 conductors. Class 1 conductors, also called rigid conductors, are generally not crimped with ferrules. NOTE: Aluminum conductors may not be crimped with copper ferrules!

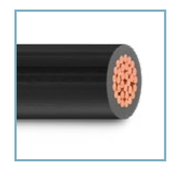
In accordance with DIN EN IEC 60228, the conductor cross-section is defined by the electrical conductance and not by its dimensions. This means, for example, a 10 mm² conductor can have a measured cross-section between 8 and 9 mm².



The twist pitch is a measure of the inherent stability of the conductor. The lower the twist pitch, the more rigid and compact the conductor is. This also increases the external diameter.

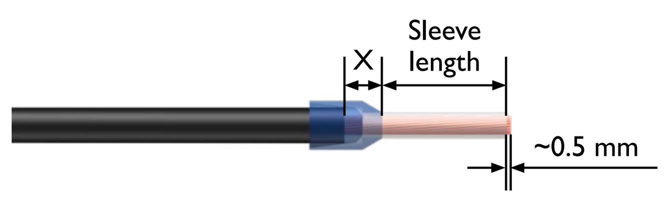
Cutting

A right-angled and clean cut is the foundation for successful further processing. Cable cutters ensure optimum, crush-free work results.



Stripping

The conductor must be stripped as cleanly as possible, with a right-angled cut, without damage to the inner litz wires or to the insulation, and the original twist must be retained. The stripping length depends on the sleeve length and the conductor outside diameter. For standard conductors up to 10 mm², the rule of thumb is: stripping length = sleeve length + ~3 mm (x). The aim is that the copper conductor protrudes approx. 0.5 mm through the front.



For uninsulated ferrules, the stripping length is approximately the same as the total length of the sleeve.

DIN EN IEC 60352-2 lists the possible error patterns, which may be due to worn stripping tools, incorrect settings, or incorrect handling, for example.

Crimping

Crimping tools

Various types of tools are available for processing ferrules. The tools should be equipped with a pressure lock that ensures that the crimping cycle is completed in full.

This widely used and universal type of crimping pliers is based on the scissors principle and is available with dies for different types of contact. With these tools, each cross-section has its own die cavity. This means that careful attention must be paid to correct positioning.

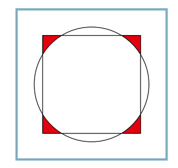
The self-adjusting crimping tools have just one insertion shaft, which adjusts itself automatically to the cross-section to be processed when actuated. Based on this, they are also ideally suited for other conductor standards (JIS/AWG) and for TWIN ferrules. The special mechanism enables square and hexagonal crimp forms.

A subgroup of self-adjusting crimping pliers is equipped with a rotating die. The conductor can be inserted from the front or the side. This enables conductors to be crimped conveniently even in confined work areas.

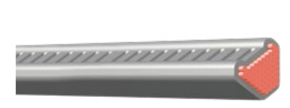
Crimp forms

Which crimp form is the best? There is no clear answer to this question. In principle, all the forms shown are permissible and they work in all clamping spaces.

However, at the maximum cross-section the form can become problematic. A square crimp, for example, will not necessarily fit into a round clamping space with the same cross-section specification.



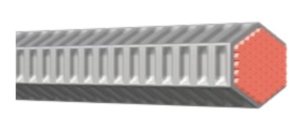
The rather flat, oval crimp form is common for small cross-sections of 0.14 to 1 mm².



The trapezoidal form is the classic for crimping up to 10 mm². On the other hand, it is also common for large cross-sections up to 120 mm². Depending on the height-width ratio, this form offers high compatibility with square and rectangular clamping spaces.

For conductors from 6 mm² as well as the corresponding TWIN ferrules, the almost rectangular WM crimp form is common.

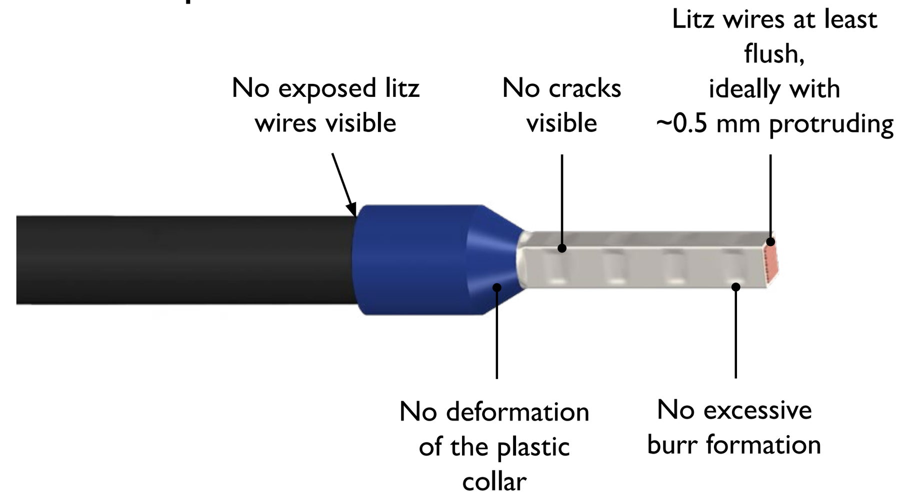
The square crimp form has become established as a standard for cross-sections from 0.14 to 16 mm². It offers optimum compatibility and large contact areas in rectangular and square clamping spaces.



The hexagonal crimp form is also considered universal. It also offers optimum compatibility with round clamping spaces, as is the case in drilled distribution blocks and also in screw terminal blocks with conductor centering. The cross-section range is usually between 0.14 and 10 mm².

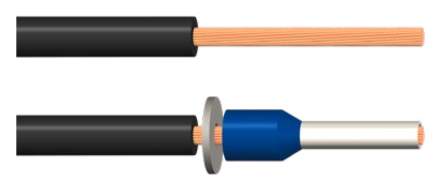
Quality

Visual inspection

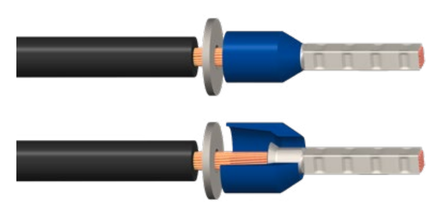


Conductor pull-out test

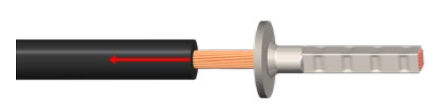
The pull-out test is a relatively simple, yet destructive, method of evaluating the quality of a crimping. The requirements and basic principles can be found in the UL 486F and DIN 46228/ 60999-1 standards.



Remove the insulation to a length sufficient to enable you to place a steel washer suitable for the cross-section behind the sleeve. Make sure that no litz wires are damaged or broken off.



After crimping the ferrule correctly, the plastic collar must be removed carefully using a micro wire cutter, for example, without the copper sleeve being affected.



Place the test object properly in a suitable pull-out testing machine (such as a Schleuniger PullTester 26T).

The machine travels at a constant speed of 25 mm/min until the preset cross-section-dependent minimum tensile force is reached and then maintains this force for one minute. The test is considered passed if the sleeve remains exactly in position. The device then continues to travel until the conductor detaches from the ferrule, absorbing the maximum tensile force in the process.

Conductor pull-out values

IEC 60999-1 N	Conductor size mm²	Conductor size AWG	UL 486F N
–	0.14	26	7
10	0.2	–	–
–	0.25	24	10
15	0.34	22	15
20	0.5	20	20
30	0.75	18	30
35	1	–	35
40	1.5	16	40
50	2.5	14	50
60	4	12	60
80	6	10	80
90	10	8	90
100	16	6	100
135	25	4	135
190	35	2	190
–	50	1/0	190

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