Eaton.com/wiringmanual
Moeller® series

Command and Signalling
Automation
Motor Applications
Power Management

Wiring Manual 2023

Powering Business Worldwide

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All the connections are designed according to our best expertise and have been carefully tested. They serve as practical examples. Eaton Industries GmbH does not accept any liability for any errors.

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Eaton Wiring Manual

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Eaton Wiring Manual

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What is the Wiring Manual?

An integral part for anyone working with electrical switchgear.

This Wiring Manual is intended to serve as an aid for trainees, as well as professionals in technical professions. The work includes detailed information on industrial switchgear, which is also offered by Eaton. The focus is on the presentation of the circuit diagrams in order to correctly connect the devices in a control cabinet, for example.

In addition to circuit diagrams for electrical switchgear, this Wiring Manual also contains suitable connection examples for Eaton devices. Along with the most important basics of the respective device series, information is provided on wiring, project planning and programming of the switchgear. The currently valid standards can be looked up here, which are supplemented by common formulas and tables.

Eaton Wiring Manual
Prolog

Where do I find some more information?

In this edition of the Wiring Manual, the content has been focused on the following topics:

- Automation
- Drives
- Pilot devices
- Switch devices and protection devices for motors
- Export

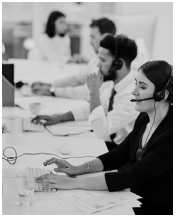
Should you require further technical information on the product ranges mentioned in this document, please feel free to visit our website at Eaton.com.

Here you will have access to data sheets, manuals, instruction leaflets, product information, technical essays and more.

How do I get technical support?

For technical support, please visit our support section at Eaton.com. After specifying your request, you will receive assistance from colleagues in our local sales organization.

You can also add your name to receive the Eaton newsletters. This way you will receive regular information about our products.



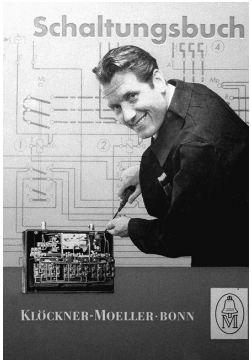
Online selection aids

Eaton configurators, selection aids and tools make your products selection easier and faster. The tools to choose from are, e.g.:

- Pushbutton configurator →page 1-32
- SL4/SL7 Signal tower configurator →page 1-33
- Selection aid for PowerXL variable frequency drives →page 5-73
- Selection aid for motor starter combinations →page 3-17

Visit our website:
Eaton.com/moem-tools

Eaton Wiring Manual
History of the Wiring Manual



German Edition 1958

German Edition 1986

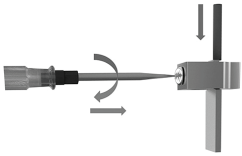
The first Wiring Manual was published in 1958 under Klöckner-Moeller and was continued under Moeller as well as Eaton. Since then, the manual has established itself as a proven source for future engineers. The Wiring Manual not only enjoys great popularity at German vocational schools, but the translated version is also highly regarded internationally as a work – in education as well as in professional life.

The contents of the Wiring Manual are available for download online:
Eaton.com/wiringmanual

Download the current version of the Wiring Manual as a digital version.

Screw terminals (traditional)

According to DIN VDE regulations, terminals are removable connections and connections that permanently connect electrical conductors to each other or to other equipment mechanically and electrically. Today, terminals exist in a wide variety of designs as screwless or screwless terminals.



The oldest connection technology is the screw terminal: In the past, device terminals usually consisted of screws with an exposed, wide head under which the conductor was clamped. To this day, this has resulted in many different designs, such as tunnel clamps, frame clamps or clamping combination screws.

Screw terminals cover a wide range of conductor clamping – the market offers screw terminals that can be used to connect conductor cross-sections up to 300 mm^2 and more. Especially with large cross-sections and the associated high powers, screw terminals offer a high level of safety due to a large contact support, a high contact force and a relatively low contact resistance. Another advantage is that the handling of the screw terminals is intuitive for most users.

The tightening torque is decisive for the safe clamping of the conductor with screw terminals: If the clamping force of the screw is too high, there is a risk that the soft copper of the conductor wire will be damaged.

In addition, the thread can tear, or the screw head can be damaged, so that the terminal is irreparably damaged, can no longer be opened and cannot be connected again.

If the torque is too low, the clamping force is not sufficient, and the conductor can come loose.

Spring-loaded terminals/Cage Clamp

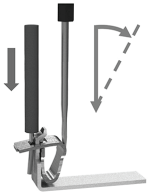
As an alternative and supplement to screw terminals, spring-loaded terminals have become established.

In them, the conductor is fixed in a retaining profile not by a screw, but by a spring. The spring is opened with the help of a tool that is inserted into an operating opening. This means that flexible conductors with or without ferrules as well as solid conductors can be connected.

The spring ensures the required contact pressure and prevents the conductor from slipping out. The connection uses the principle of self-locking and is thus mechanically durable and electrically safe. Even in the event of vibrations and shocks, spring-loaded clamps do not come loose on their own.

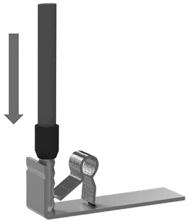
Regular maintenance, as with screw terminals, is not required. Incorrect operation due to too low or too high tightening torque is also excluded, since only the property of the spring determines the contact pressure.

Classic spring-loaded terminals are designed for cross-sections of up to 35 mm^2 and are available for smaller currents in a wide range.



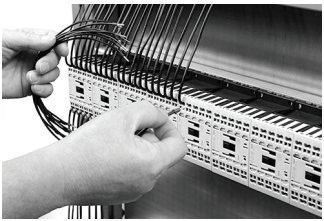
Push-In terminals

Push-in terminals are the next generation of spring-loaded terminals.



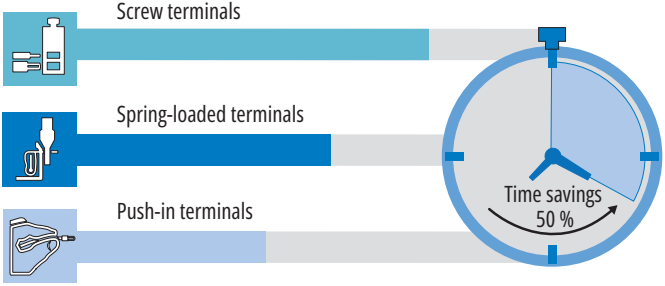
Again, the electrical contact is made by a spring and the conductor is fixed. However, with Push-in technology, the spring is opened by inserting the conductor itself: rigid conductors or conductors equipped with ferrules can thus be connected directly and without tools.

Due to the tool-free installation, the installer holds several cables in one hand and can plug in one cable after the other with the other hand. There is no need to tighten the screws (with the corresponding torque) or to open the spring-loaded terminal with tools.



Using the Push-in results in a time saving of 50 % compared to the screw clamp and 40 % compared to the spring-loaded terminals. There is also no need to retighten the screws.

The Push-in terminal is maintenance-free and offers future-proof wiring and enables automatic assembly via robots.



The Push-in clamp offers the same advantages as a spring-loaded clamp:

- The conductor clamping force is independent of the user, and operating errors are excluded.
- The terminals are very well suited for use with vibration and shock loads and always offer IP20 protection.
- Push-in terminals enable robot-controlled wiring.

Read more in our white paper
Eaton.com/push-in-whitepaper

Our approach to managing cybersecurity risks

Today's customers need cybersecurity addressed in order to minimize the threat of operational downtime, data loss, impacts on lifecycle costs and brand reputation. And because cybersecurity incidents can cripple an organization in minutes, customers need suppliers to provide evidence that the products they sell comply with industry cybersecurity standards.

Eaton's commitment to defending those environments comes to life at our Product Cybersecurity Center of Excellence, where our experts discover new ways to help protect products and systems against cyberattack, provide internal training and help customers deploy and maintain secure solutions.

In this regard, Eaton's "secure-by-design" philosophy assures that our products comply with rigorous cybersecurity process, requirements and testing standards. Our cybersecurity processes and secure development lifecycle are integrated into product development and guide our labs, procurement and design teams as the foundation of innovation. And our customized testing procedures help ensure our products comply with industry cybersecurity standards.

More information around cybersecurity is available on:

Eaton.com/cybersecurity

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Eaton charging technology portfolio for electric vehicles

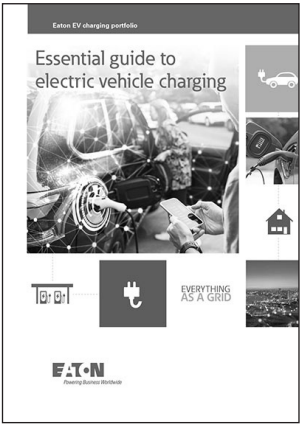
We offer you a comprehensive range of AC and DC chargers, energy management systems and advanced software that are suitable for both residential buildings as well as commercial buildings, public parking lots and fleet operations.

Eaton also offers a wide range of products for protection, switching and operation and will advise you on the selection of products and further questions.

Our portfolio ranges from Bussmann fuses and VDE certified contactors for input or output sides switching and contacting HMI panels for user-friendly operation to emergency stop switches for safe shutdown.

Under the following link you will find more information:

Eaton.com/ev-charging



Eaton Wiring Manual
Owl – safety lighting

How to do it!

Planning and operating safety lighting in compliance with standards

With a free registration the brochure with over 100 pages on the topic of safety lighting "Basics, requirements, installation and lighting technology" is available.

German regulations and presentation on safety lighting for download under:

Eaton.com/notlicht-vorschriften

Eaton Wiring Manual
The way to a safe machine

Safety Manual

The manual contains examples for how functional safety can be implemented using electrical, electronic and programmable components and systems in safety applications.

The Safety Manual was created for machine builders and system integrators, as well as trainers, students and customers interested in the topic of machine and system safety.

→Section "Electrical equipment of machines", page 10-21

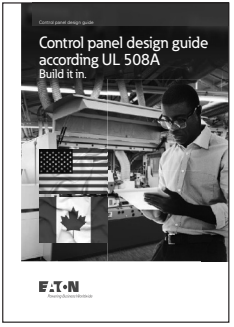
Download Safety Manual:

Eaton.com/shb

UL 508A

The right components for your next control cabinet. Once the key data of the new control system, the right components have to be selected. With the new manual for the design of switchgear according to UL 508A, this task is child's play. All the necessary switchgear with the corresponding technical data are clearly listed.

→Section "Special characteristics for the export to North America (USA, Canada)", page 9-3



Eaton Wiring Manual
The way to a safe machine

Engineering Guide

This Consulting Application Guide has been drawn up by a group of experienced experts, with respect to standards for electrical installations (IEC 60364 series) and other product standards.

The main areas of application are

- Low voltage distribution equipment
- Protective devices
- Overcurrent protection
- Protection against electric shock
- Low voltage switchboards
- Safety management

Download Safety Manual:

Eaton.com/applicationguidelv

Ex Protection

Global reference guide on the marking of electrical equipment for use in explosive atmospheres according to the latest guidelines and standards.

→Section "Use of electrical equipment in explosive atmospheres", page 10-34

A comprehensive overview of:

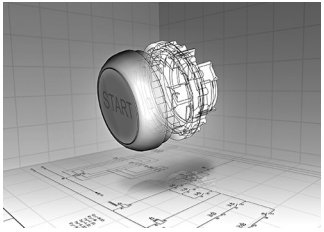
- Explosion groups
- Electrical types of protection for explosive atmospheres due to flammable gases, vapours and mists
- Zone classification/Equipment protection level
- Classification of explosion-protected equipment into equipment groups and categories in accordance with directive 2014/34/EU
- Example of type label

Further information

- Global reference guide
  Publication No. 300 8000 2153
- →Chapter 10 „Standards, formulae, tables"
- Principles of Ex-Protection BR1213:
  Eaton.com/ex-protection

eCAD and mCAD data

For electrical and mechanical design data for project planning of control cabinets, systems or machines – Eaton provides the corresponding CAD data.



Data for more than 22,000 Eaton parts is available on the EPLAN data portal.

The part data and macros can be downloaded from there.

In addition, Eaton provides 2D and 3D data for about 20,000 products. The models can either be obtained from the Partcommunity portal on the Internet or integrated directly into the planning software via the CADENAS Partsolution software.

Visit our website:
Eaton.com/moem-tools

Technical documentation

Visit the Eaton Download Center to obtain all the technical information you require, such as instruction leaflets or manuals. Uncomplicated and quick way of finding the information you need in the language you need.

Download at:

Eaton.com/documentation

Eaton Wiring Manual
After Sales Service

Eaton offers After Sales Support for all low voltage switchgear, controlgear and services. Detailed information and the general terms and conditions can be accessed at:

Eaton.com/aftersales

Service Specialists

Gain the benefit of our service personnel. Comprehensive expertise linked with long term experience and modern equipment help you find the solution to your tasks.

Material characteristic

Components, cards and spare parts of our product range are available for your use.

Service products

After Sales Service offers service products to match Eaton's products.

Onsite Service

Troubleshooting, inspection, testing, maintenance, commissioning.

Repairs

Replacement devices and spare parts for actual and phased-out products, direct exchange and exchange under warranty for selective products, repair.

Online Services

FAQ (frequently asked questions), Downloads and interactive troubleshooting.

Contact

Email

AfterSalesEGBonn@eaton.com

Internet

Eaton.com/aftersales

Notes

Pilot devices

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Pilot devices
RMQ-Titan® – System M22/M30

Commands and signals are the fundamental functions for controlling machines and processes. The required control signals are produced either manually by pilot devices or mechanically by position switches. The respective application governs the protection type, the shape and color. As with almost all devices, global certification and an international distribution system are important criteria in this sector.

Basically, the devices in the RMQ system can be divided into two categories:

- Modular pilot devices (M22/M30)
- Compact pilot devices (C22)

Modular pilot devices (M22/M30)

The modular devices meet the requirements of demanding customers in terms of flexibility, variety and performance. Here, for example, up to 6 contact elements can be attached behind a front element. You can also choose between particularly powerful, very flat contact elements and between different connection types (screw connection, cage clamp connection, Push-in terminal).

A wide range of Emergency-stop devices is important for many customers. The devices should be tested in accordance with all current standards and specifications. The same applies to the contact elements so that the Emergency-stop devices can be operated without restriction.

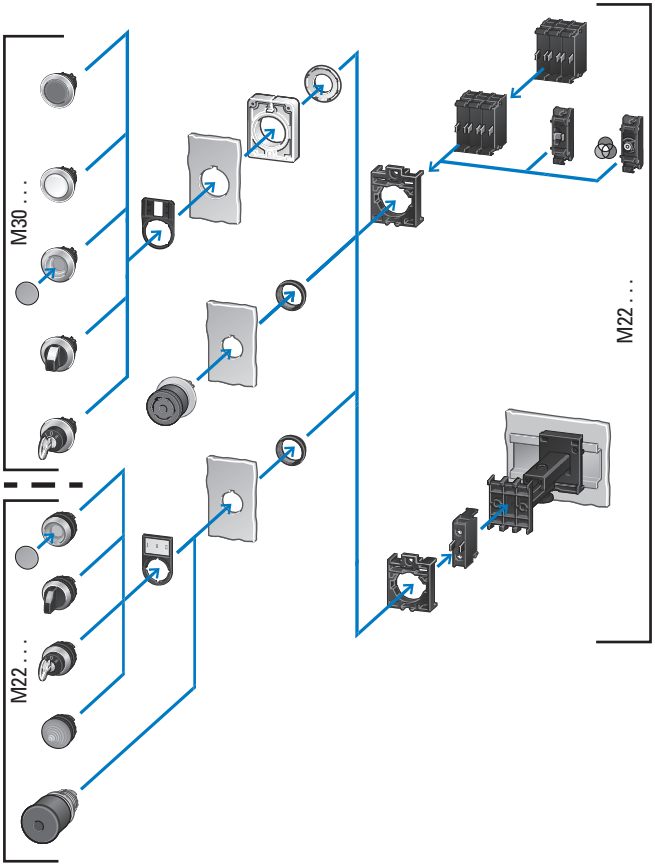
Compact Devices (C22)

The compact devices differed from the modular devices in particular in their design behind the front element. Compact devices are already equipped with a maximum of two contacts at the factory and can therefore be used immediately by the customer. The advantage of the compact devices over the modular range is their easy handling and quick installation.

Another special feature are devices with an integrated cable connection (C22 compact solution). These are sealed at the rear (IP65) and can therefore be used without the need for an additional housing.

Pilot devices
RMQ-Titan® – System M22/M30

System overview M22/M30



Pilot devices
RMQ-Titan® – System M22/M30

Advanced technology has been used consistently in control circuit devices "RMQ-Titan®". The use of LED elements and laser inscription throughout offer maximum reliability, efficiency and flexibility. In detail, this means:

- High-quality optics for a uniform appearance,
- Highest degree of protection up to IP67 and IP69K (suitable for steam-jet cleaning),
- Clear contrast using LED element lighting, even in daylight,
- Up to 100,000 h, i.e. machine lifespan,
- Impact and vibration resistant,
- LED operating voltage from 12 to 500 V,
- Expanded operating temperature range-25 to +70 °C,
- Light testing circuit,
- Built-in safety circuits for highest operational reliability and accessibility,
- Wear-resistant and clearly contrasting laser inscription,
- Customer-specific symbols and inscriptions from 1 off,
- Text and symbols can be freely combined,
- Terminal type using screws and Cage Clamp1) throughout,
- Spring-loaded Cage Clamp connections for reliable and maintenance free contact,
- Switching contacts suitable for use with electronic devices to EN 61131-2: 5 V/1 mA,
- User-programmable switching performance on all selector switch actuators: momentary/maintained,
- All actuators in illuminated and non-illuminated version,
- Emergency switching off pushbuttons with pull-to-release function and turn-to-release function,
- Emergency switching off pushbuttons with lighting option for active safety,
- Mushroom shape or palm-tree shape,
- Four different head diameters,
- Contacts switch differing potentials,
- For use also in safety-related circuits using positive operation and positive opening contacts,
- Complying with industry Standard IEC/EN 60947.

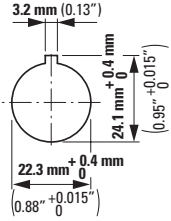
1) Cage Clamp is a registered trade mark of WAGO GmbH & Co. KG, Minden.

Pilot devices
RMQ-Titan® – Assortment M22

Product features

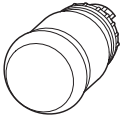
- Two different bezels: Titan (silver) or black

- Mounting hole diameter 22.3 mm



Front elements

- Emergency-stop



- Pushbutton

- Illuminated pushbutton actuator

- Mushroom actuator

- Double actuator pushbutton

- Indicator lights flush and extended

- Selector switches

- Illuminated selector switches

- Key-operated pushbuttons

- Joystick

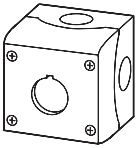
- Potentiometer

- USB sockets

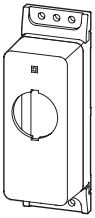
- RJ45 sockets

Pilot devices
RMQ-Titan® – Assortment M22

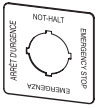
- Surface mounting enclosure



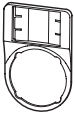
- Surface mounting enclosure



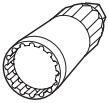
- Accessories
  – Legend plates



– Add-on legend plates

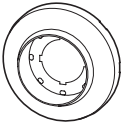


– Mounting ring tool



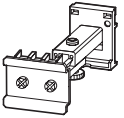
– Emergency-stop guard ring

– Illuminated ring



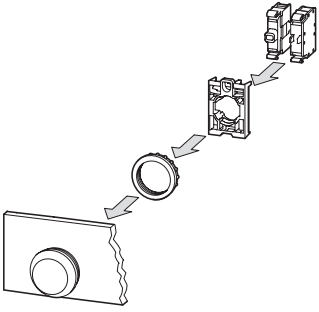
– Protective diaphragm silicone

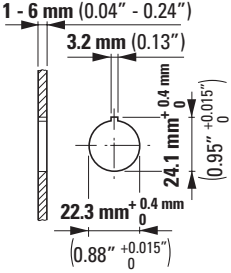
– Telescopic clip for top-hat rail



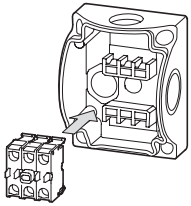
Pilot devices
RMQ-Titan® – Assortment M22

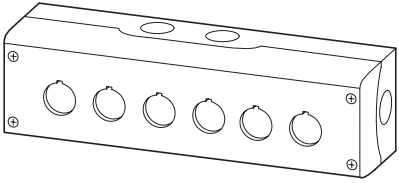
Front mounting

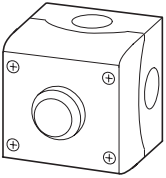


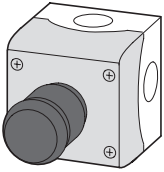


Base fixing in surface mounting enclosure





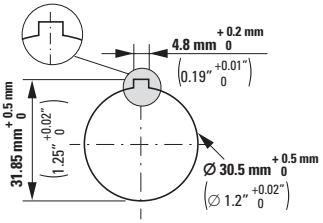


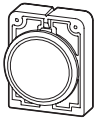


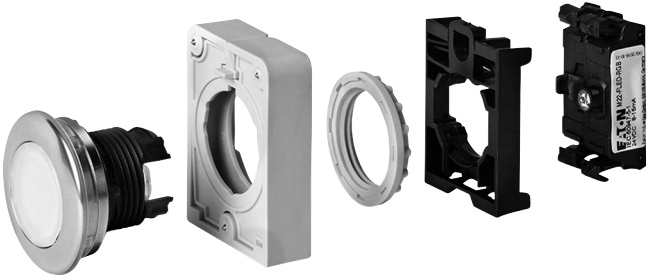
Pilot devices
RMQ-Titan® – Assortment M30 Flat Front

Product features

- Fully compatible with the existing M22 products
- Elegant and high-quality metal design
- Bezel in titanium design M30C or stainless steel M30I
- Easy cleaning of the machine
- Extensive portfolio
- Mounting optional with or without groove Anti-rotation by standard adapter
- Mounting hole diameter 30.5 mm



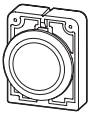




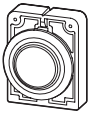
Pilot devices
RMQ-Titan® – Assortment M30 Flat Front

Front elements

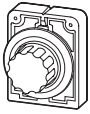
- Pushbutton, Illuminated pushbutton actuator



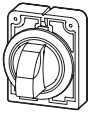
- Indicator lights



- Selector switches

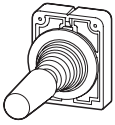


- Illuminated selector switches

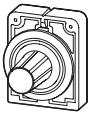


- Key-operated pushbuttons

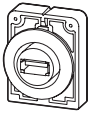
- Joystick



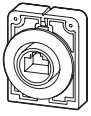
- Potentiometer



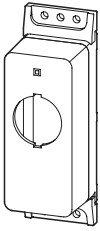
- USB sockets



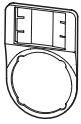
- RJ45 sockets



- Surface mounting enclosure



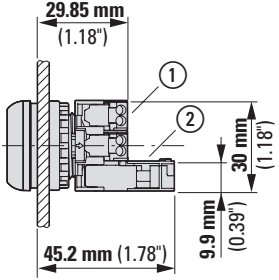
- Accessories
  – Add-on legend plate

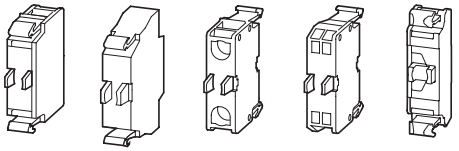


Pilot devices
RMQ-Titan® – Function elements

Contact elements

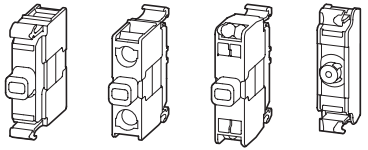
- Front-/base fixing
- Normally closed contact/ Normally open contact
- Positive opening NC contacts ⊕
- Screw terminals, Cage Clamp terminals, Push-In terminals
- Various contact sequences
- Double contact elements
- Self-monitoring contact elements
- Standard ② or Flat Rear contacts ①





LED elements

- Front-/base fixing
- Screw terminals, Cage Clamp terminals, Push-In terminals
- 24 V/230 V
- 4 light colors
- Standard or Flat Rear design
- Flat Rear with High Performance LED
- Flat Rear with Multicolor RGB-LED



Pilot devices
RMQ-Titan® – Function elements

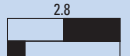
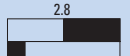
Contact versions

Screw terminals	Spring-loaded terminals (Cage Clamp)	Front fixing	Base fixing	Contact	Contact travel diagram[1]
M22/M30 standard contact elements					
x	x	x	x		M22-(C)K(C)10
x	x	x	x		M22-(C)K(C)01
x	x	x	-		M22-(C)K01D2)
x	-	x	-		M22-K10P

1) Stroke in connection with front element.

2) N/C: Positive opening safety function according to IEC/EN 60947-5-1.

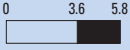
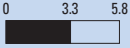
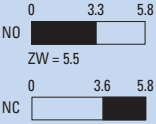
Pilot devices
RMQ-Titan® – Function elements

Screw terminals	Spring-loaded terminals (Cage Clamp)	Front fixing	Base fixing	Contact	Contact travel diagram[1]
M22/M30 double contact elements					
–	x	x	–		M22-CK20
–	x	x	–		M22-CK02
–	x	x	–		M22-CK11[2]
M22/M30 standard self-monitoring contact elements					
x	–	x	x		 M22-K(C)01SMC10
x	–	x	x		 M22-K(C)02SMC10

1) Stroke in connection with front element.

2) N/C: Positive opening safety function according to IEC/EN 60947-5-1.

Pilot devices
RMQ-Titan® – Function elements

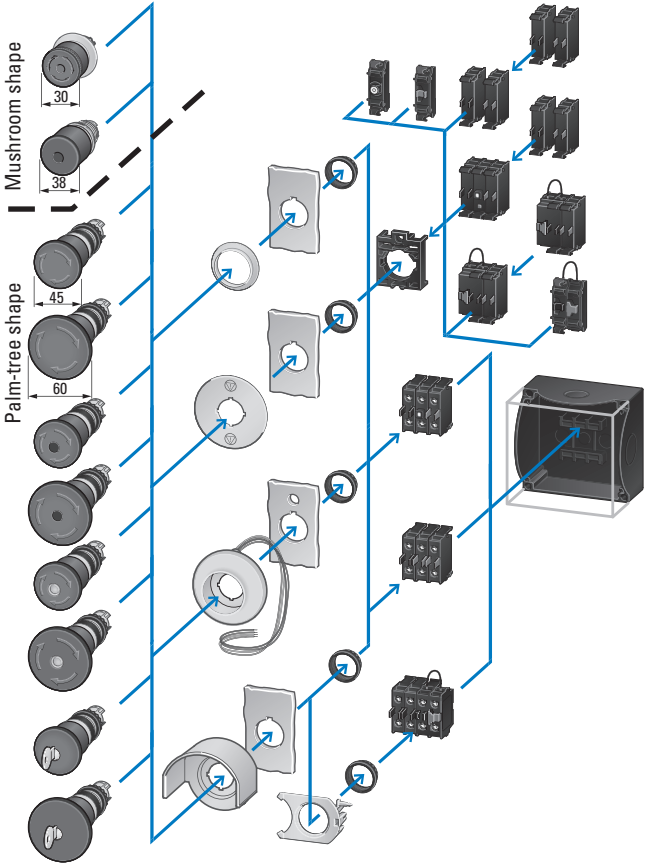
Push-In	Front fixing	Contact	Contact travel diagram[1)]
M22/M30 Flat Rear Contact elements			
x	x		 M22-FK10
x	x		 ZW = 5.5 M22-CK11[2)]
M22/M30 Flat Rear Self-monitoring contact elements			
x	x		 M22-K(C)02SMC10

1) Stroke in connection with front element.

2) N/C: Positive opening safety function according to IEC/EN 60947-5-1.

Pilot devices
RMQ-Titan® – Emergency-stop/off pushbuttons

System overview

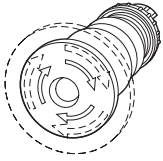


Pilot devices
RMQ-Titan® – Emergency-stop/off pushbuttons

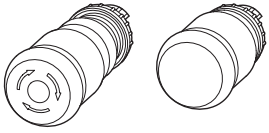
Product features

- 30/38/45/60 mm head diameter
- Mushroom shape or palm-tree shape
- Pull-to-release function or turn-to-release function
- Key-to-release function
- Illuminated versions
- Mechanical switching position indicator
- Surface mounting enclosure
- Legend plates
- Accessories
- EN ISO 13850
- EN 60947-5-5
- Machinery Safety Directive 2006/42/EC

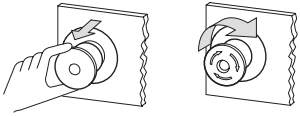
- Palm-tree shape



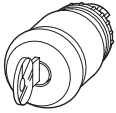
- Mushroom shape



- Pull-to-release or turn-to-release function



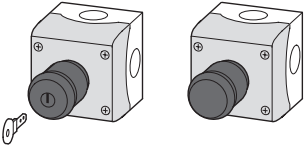
- Key-to-release function



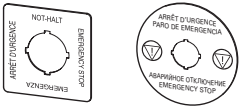
- Illuminated versions

- Small E-Stop 30 mm

- Surface mounting enclosure



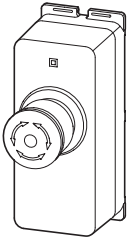
- Legend plates

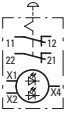


Pilot devices
RMQ-Titan® – Emergency-stop/off pushbuttons

Example for Emergency-stop complete device

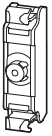
- Flat surface mounting enclosure
- Small Emergency-stop with mushroom diameter 30 mm
- Positive opening flat contact elements
- Pull-to-release function or turn-to-release function
- Illuminated with two-color LED red/green
- Tamper-proof according to ISO 13850/EN 418
- Degree of protection IP66, IP69





Multicolor LED-RGB element

- Flat Rear, minimal mounting depth
- Cage Clamp terminals, Push-In terminals
- 24 V DC



Colors	Connection X1	+R	X2	+G	X3	+B	X4	GND
M22-FLED-RG								
red	X						X	
green			X				X	
yellow	X		X				X	
M22-FLED-RGB								
red	X						X	
green			X				X	
yellow	X		X				X	
white	X		X		X		X	
blue					X		X	
violet	X				X		X	
turquoise			X		X		X	

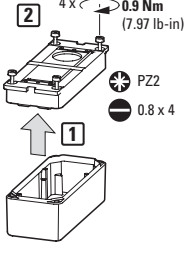
Pilot devices
RMQ-Titan® – Emergency-stop/off pushbuttons

Flat surface mounting enclosure

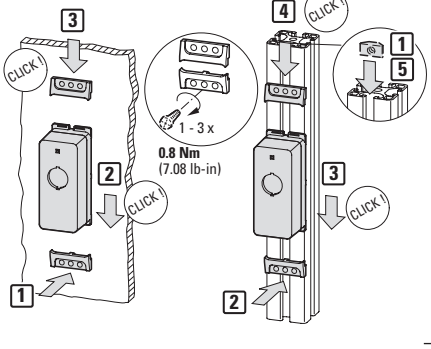
- Modular system with 1 - 4 mounting locations for M22 Standard or M30 Flat Front
- Grey or yellow enclosure cover
- Degree of protection IP66, IP67
- Mounting of flat contacts and flat LED elements
- Mounting on 40 mm profile rail or on the wall

M22 front elements

Wall mounting



40 mm profile rail

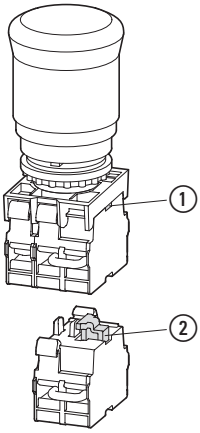


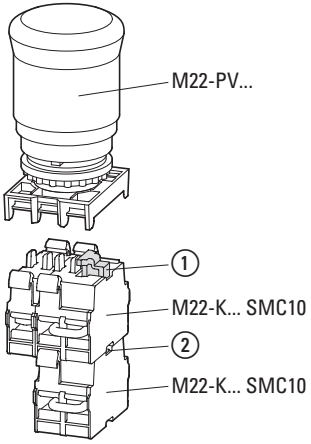
Pilot devices
RMQ-Titan® – Engineering

Assembly and function

1

M22...SMC10





① The self-monitoring contact mechanically monitors the connection on the M22-PV...

② The self-monitoring contact mechanically monitors the interface on the M22-K...SMC10 safety contact above it; but NOT the connection on the M22-PV...

M22-K01SMC10
M22-KC01SMC10

M22-K02SMC10
M22-KC02SMC10

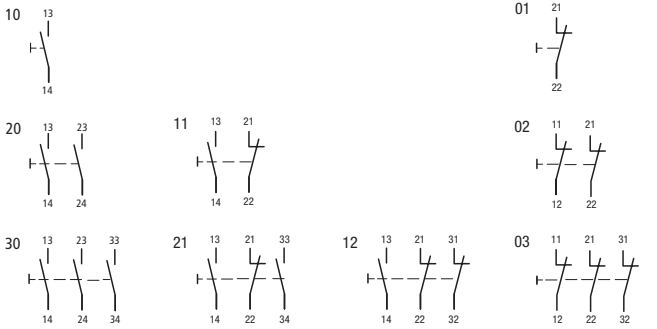
When the self-monitoring contact is mounted correctly, the N/O contact is closed.

The emergency switching off/stop circuit is activated via series connection of N/C and N/Os if

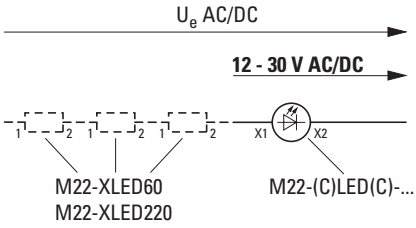
- the emergency switching off/stop pushbutton is actuated or
- the self-monitoring contact is isolated mechanically from the pushbutton

Pilot devices
RMQ-Titan® – Engineering

Terminal markings and function numbers (distinctive number/contact sequence), EN 50013

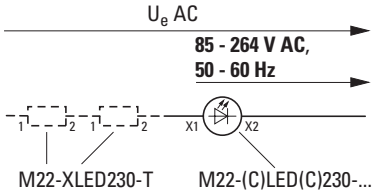


Voltage variants with series elements



M22-XLED60[1]	U_e ≦ AC/DC
1x	60 V
2x	90 V
3x	120 V
...	...
7x	240 V
M22-XLED220	U_e ≦
1 x	220 V DC

1) For increasing the voltage AC/DC.



M22-XLED230-T[1]	U_e ≦
1x	400 V AC
2x	500 V AC

1) AC– for increasing the voltage 50/60 Hz.

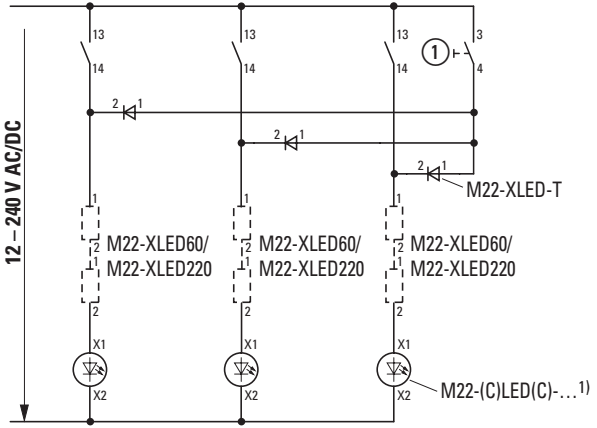
Pilot devices
RMQ-Titan® – Engineering

Connection for light test

The test button is used to check operation of the indicator lights independently of the respective control state. Decoupling elements prevent voltage feedback.

M22-XLED-T

for U_e = 12 to 240 V AC/DC
(also for light test with signal towers SL)



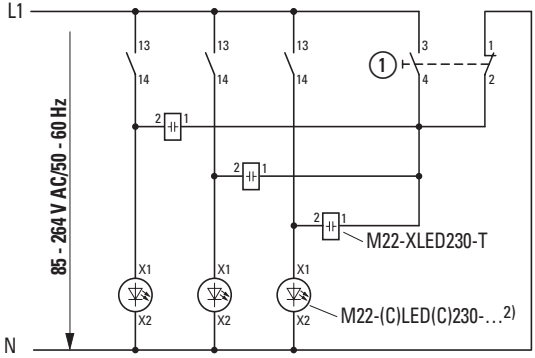
① Test button

1) Only for elements 12 to 30 V

Pilot devices
RMQ-Titan® – Engineering

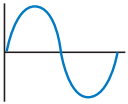
M22-XLED230-T

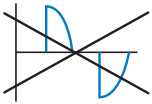
for U_e = 85 to 264 V AC/50 - 60 Hz



① Test button

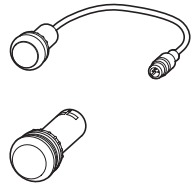
1) For elements 85 to 264 V





Pilot devices
RMQ-Titan® – System C22/C30 compact solution

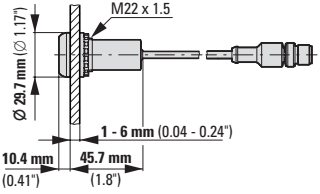
For special applications or requirements, Eaton offers two series of compact control elements from the RMQ C22/C30 range. Thanks to the integrated contacts and LEDs, these products impress with their simple and uncomplicated handling in all important areas. From ordering and warehousing to installation and maintenance.



C22 compact solution

With the practical all-in-one devices of the RMQ compact solution, the cables, connectors and housings are already integrated and pre-installed. The high degrees of protection in the front (up to IP69K) and particularly at the back (IP65) of these devices make them the perfect choice for applications in which protection from dirt or liquids is required. Easy plug-and-play installation is made possible by the compact design of the devices. In addition, each compact device requires only one single article no., considerably simplifying all the processes extending from selection, through ordering and stockkeeping, all the way to installation.

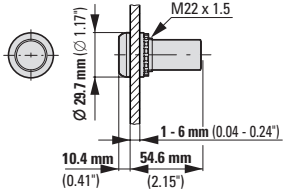
Further informationen →page 1-24



C22 compact

The products from the C22 compact range offer integrated contacts and/or lighting with screw terminals for uncomplicated and trouble-free use. The screw terminals can be tightened with both slotted and cross-head screwdrivers.
The devices in the C22 compact series are only available with black front rings.

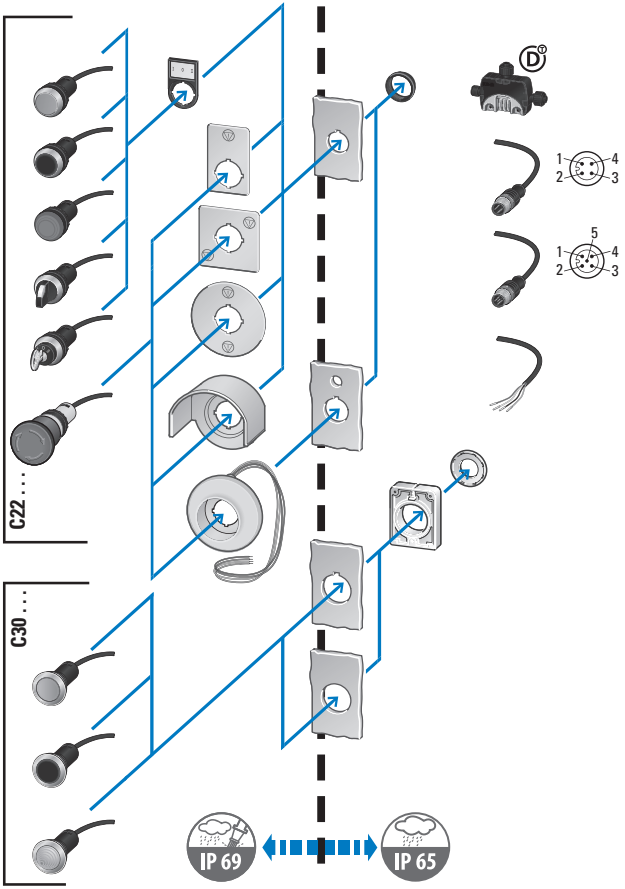
Further informationen →page 1-28



Pilot devices

RMQ-Titan® – System C22/C30 compact solution

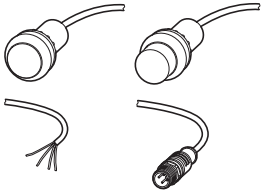
System overview



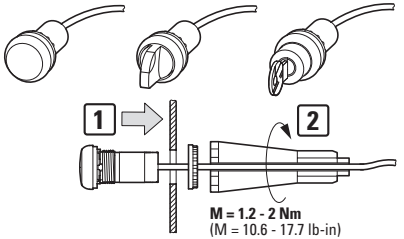
Pilot devices
RMQ-Titan® – System C22 compact solution

Overview C22 compact solution

- Integrated cable
- No enclosures required
- M12 plug or unterminated end
- C22 or C30C (Flat) Front
- Compatible with accessories of RMQ-Titan M22 products
- A broad variety of functions (e.g. Emergency-stop, Indicator lights, Selector switch, Key-operated buttons)



M12 = 0.8 - 1 Nm



M = 1.2 - 2 Nm
(M = 10.6 - 17.7 lb-in)

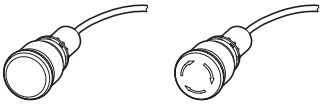
7 mm (0.28")	**"M12A"**		+	
...K11...	1 — 4	1 — 4	2 — 3	
...K20...	1 — 4	1 — 4	2 — 3	
...K02...	–	1 — 4	2 — 3	
...-K10-24-...	1 — 4	1 — 4	2 — LED — 3	
...-K01-24-...	1 — 4	1 — 4	2 — LED — 3	
...L(H)...	2 — LED — 3	2 — LED — 3		
...K10...	1 — 4	1 — 4		
...K01...	1 — 4	1 — 4		

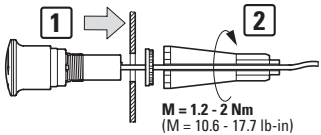
Pin	DIN IEC 304, DIN IEC 757	
1	BN	1
1	WH	9
3	BU	6
4	BK	0

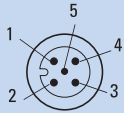
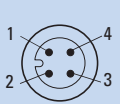
Pilot devices
RMQ-Titan® – System C22 compact solution

C22 compact solution "Emergency-stop"

- 4 pole or 5 pole
- Mushroom shape or palm-tree shape
- Pull-to-release function or turn-to-release function
- Optional with mechanical switch position indication
- ISO13850/EN418 and IEC/EN 60947-5-1





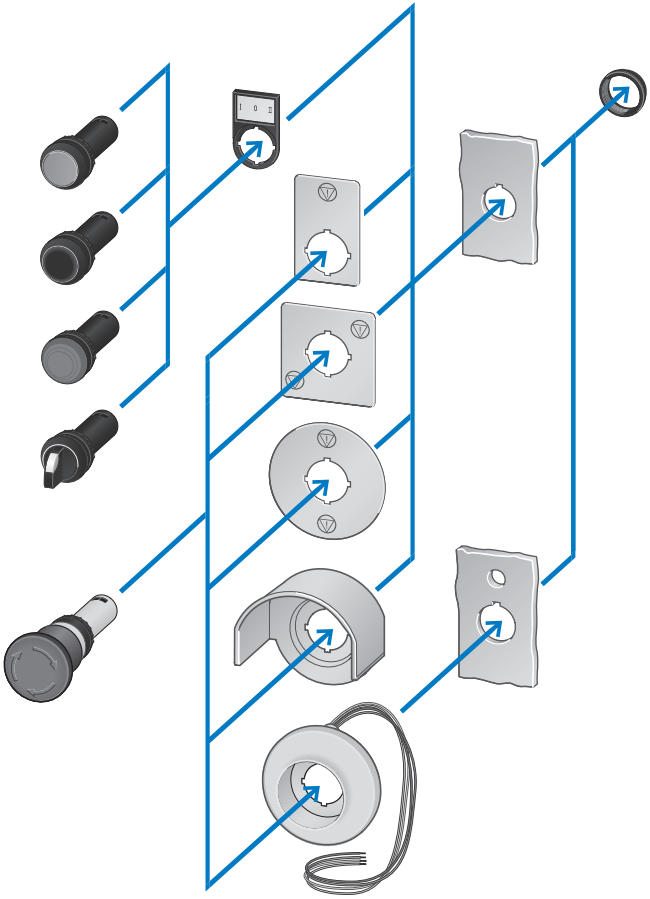
7 mm (0.28")	"M12A" 	"M12A" 	+
...K02...	1 → 2 ⊖ 5 → 4 ⊖	1 → 4 2 → 3	
...K11...		1 → 4 2 → 3	

Pin	DIN IEC 304, DIN IEC 757	
1	BN	1
1	WH	9
3	BU	6
4	BK	0

Notes

Pilot devices
RMQ-Titan® – System C22 compact

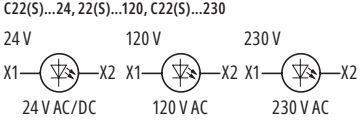
System overview

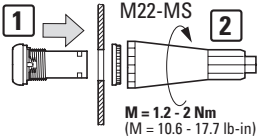


Pilot devices
RMQ-Titan® – System C22 compact

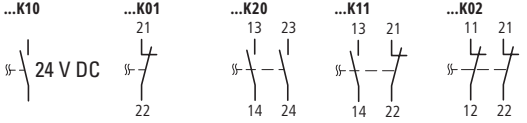
Overview C22 compact

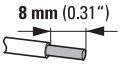
- Integrated contacts
- Screw terminals
- Black brezels
- A broad variety of functions (Pushbutton Emergency-stop, Indicator lights, Selector switch)
- Compatible with accessories of RMQ-Titan M22 products





Contact assignment



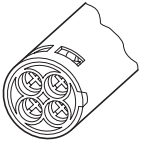


M = 0.8 Nm (M = 7.08 lb-in)

60/75 °C Cu wire only

2 x 0.5 - 1.5 mm²

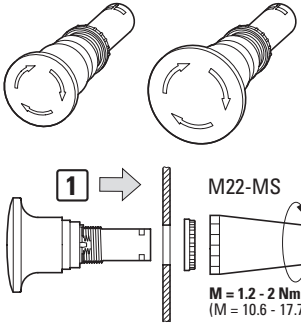
AWG20 - AWG14

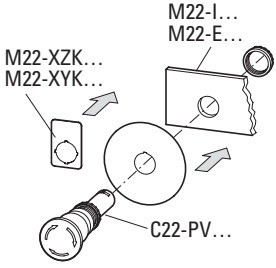


Pilot devices
RMQ-Titan® – System C22 compact

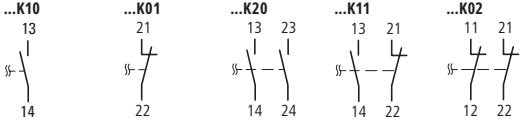
C22 compact "Emergency-stop"

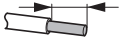
- Palm-tree shape
- Turn-to-release function
- ISO13850/EN418
- IEC/EN 60947-5-1





Contact assignment



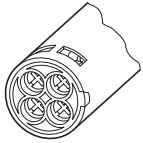


M = 0.8 Nm (M = 7.08 lb-in)

60/75 °C Cu wire only

2 x 0.5 - 1.5 mm²

AWG20 - AWG14



Pilot devices
Signal Towers SL7/SL4

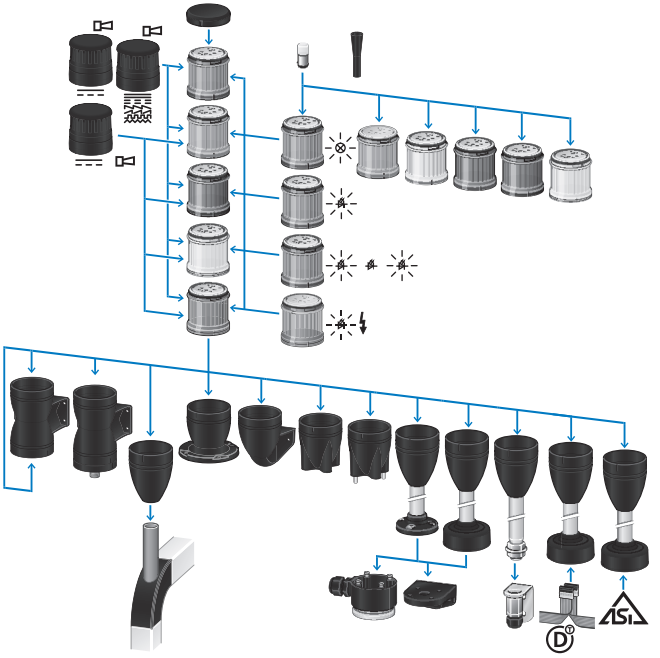
A broad portfolio for all applications

The signal towers are available in two sizes:

- SL7: Diameter 70 mm
- SL4: Diameter 40 mm

Various basic modules enable installation in different applications.

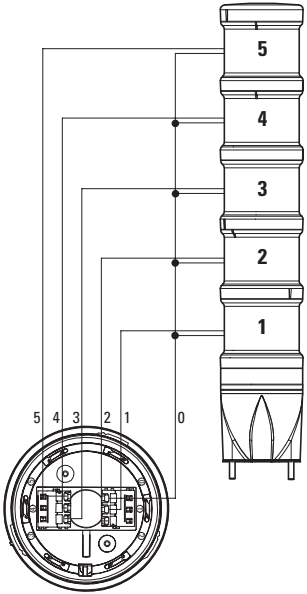
UV-tested plastic and the high protection class of IP66, as well as the permissible ambient temperatures of -30 to +60 C°, also support outdoor operation.



Pilot devices
Signal Towers SL7/SL4

Signal Towers SL7/SL4 – everything under visual control at all times

Signal towers indicate machine states using visible and acoustic signals. Mounted on control panels or on machines, they can be reliably recognized as continuous light, flashing light, strobe light or acoustic device even from a distance, and dealt with as necessary.



Product features

- Continuous light, flashing light, strobe light and acoustic device can be combined as required.
- Optional super-bright light modules (HP)
- Free programmability permits the actuation of five addresses.
- Simple assembly without tools by bayonet fitting.
- Automatic contacting by built-in contact pins.
- Excellent illumination by specially shaped lenses with Fresnel effect.
- Illumination with LEDs.
- A large number of complete devices simplifies selection, ordering and stockkeeping for standard applications.
- Configurable with Eaton's Signal tower configurator →page 1-32
- Also available with AS-Interface or SmartWire-DT.

The various colors of the light elements indicate the operating state in each case to IEC/EN 60204-1 an:

RED:
Dangerous state – Immediate action necessary

YELLOW:
Abnormal status – monitor or -action

GREEN:
Normal status – no action necessary

BLUE:
Discontinuity – action mandatory

WHITE:
Other status – can be used as required.

Pilot devices
Configurators – Pushbutton and Signal Towers

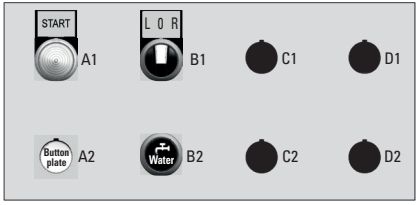
RMQ-Titan® – Pushbutton configurator

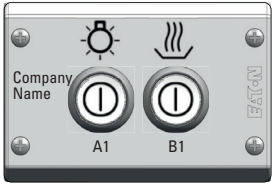
Customized summary and inscription of the pilot devices

- Saves time when selecting components.
- Save and retrieve with a unique configuration ID.
- Documentation with images and bill of material via email.

Example for a customized inscription

- Open the Pushbutton configurator: Eaton.com/config/rmq
- System tab: select series, select parameter
- Layout tab: select and configure items
- Create individual label using the Label Editor function with text/or graphics. Standard graphics can be selected from the library or your own graphics can be uploaded.
- Summary tab: call up an individual configuration ID with one click and optionally have it sent by email for your own documentation.





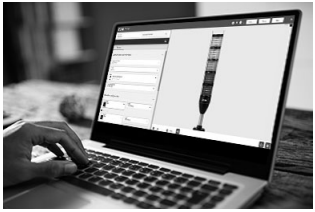
Eaton's Signal tower configurator

The convenient SL7/SL4 signal towers configurator allows you to assemble the signal tower you need with just a few clicks. You can simulate light and sound functions online for a direct review of whether the right modules have been selected. The tool then generates an order list for you to forward directly to Eaton or the wholesaler of your choice.

- Saves time when selecting components.
- Save and retrieve with a unique configuration ID.
- No misconfiguration possible.
- Saving a configuration under a unique configuration ID.
- The configuration can be retrieved at any time and from anywhere.
- Detailed material list of the configured components.
- Functional preview of the configuration.
- Registration or a user account are not necessary.
- Complete configuration including preview image by email if desired.

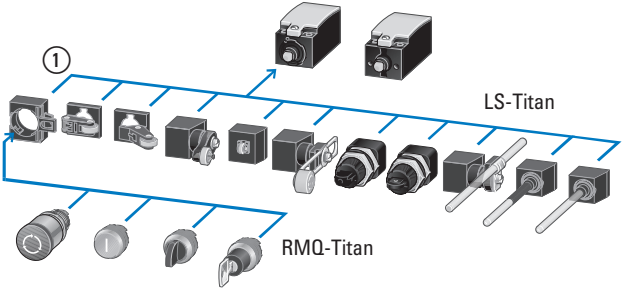
Give our Signal tower configurator a try:

- Eaton.com/config/signaltower



Pilot devices
LS-Titan® Position switches

New combinations for your solutions with LS-Titan®



① Operating heads in four positions, each turned by 90°, can be fitted subsequently.

The LS-Titan® position switches offer maintenance-free and vibration-proof connections with cage clamp terminals or screw terminals. They detect positions safely, accurately and reliably. Two types of enclosures are available: a rugged metal version (LSM) and an insulated plastic version (LS).

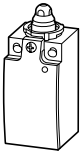
Equipped with two contacts, optionally with NC or NO contact. Using the bayonet fitting, the operating heads can be easily attached in any of the four directions (4 x 90°).

Actuating devices RMQ-Titan® simply snap fitting

Another unique feature is the possibility to combine actuators from the RMQ-Titan® range with the position switches LS-Titan®. Pushbuttons, selector switches or emergency switching off pushbuttons can all be directly snapped on to any position switch as operating head. The complete unit then has at least the high protection type IP66 at front and rear.

Main features

- Modular system
- High degree of protection: IP66, IP67
- Positive opening contacts
- Easy and flexible installation
- Large wiring area



LS, LSM

Pilot devices
LS-Titan® Position switches

Safety position switches LS...ZB

Eaton safety position switches have been specially designed for monitoring the position of protective guards such as doors, hinged flaps, shrouds and protective guards. They meet the requirements of the employers' liability insurance Association for the testing of positive opening position switches for safety functions (GS-ET-15). These requirements include:

"Position switches for safety functions must be designed so that the safety function cannot be bypassed manually or simple tools." Simple tools are: pliers, screwdrivers, pins, nails, wire, scissors, penknives etc.

In addition to these requirements, LS...ZB position switches offer additional manipulation safety by means of an operating head which can rotate but cannot be removed.

Positive opening

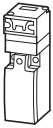
Mechanically operated position switches in safety circuits must have positive opening contacts (see EN 60947-5-1). Here, the term positive opening is defined as follows: "The execution of a contact separation as the direct result of a predetermined motion of the keypad of the switch via non-spring operated parts (e.g. not dependent on a spring)".

Positive opening is an opening movement by which it is ensured that the main contacts of a switch have attained the open position at the same time as the keypad assumes the Off position. Eaton position switches all meet these requirements.

Certification

All Eaton safety position switches are certified by the employers' liability insurance Association or by the Technical Monitoring Service (TÜV), Rheinland.

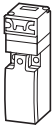
LS...ZB

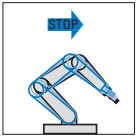


Pilot devices
LS-Titan® Position switches

"Personnel protection" by monitoring the protective device

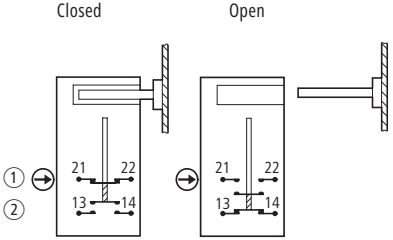
LS...ZB





- Door open
- LS...ZB disconnects power
- No danger

LS...ZB



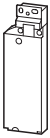
① Safety contact
② Signalling contact

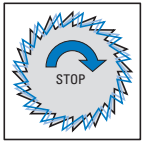
Door closed	→ Safety contact (21 - 22) closed Signalling contact (13 - 14) open
Door open	→ Safety contact (21 - 22) open Signalling contact (13 - 14) closed

Pilot devices
LS-Titan® Position switches

"Enhanced personnel protection" with separate signal for door position

LS...ZB

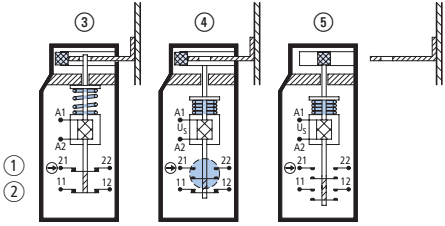




- Stop command
- Waiting time
- Machine is stopped
- Protective mechanism open
- No danger

LS...FT-ZBZ, spring-powered interlock (closed-circuit principle)

LS-S02-...FT-ZBZ

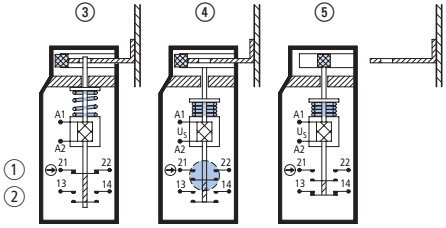


① Safety contact
② Signalling contact
③ Interlocked
④ Released
⑤ Open

Door closed and interlocked	→ Coil at (A1, A2) de-energized also with mains failure or wire breakage: Door interlocked = safe state Safety contact (21 - 22) closed Signalling contact (11 - 12) closed
Releasing of door	→ Apply voltage to coil (A1, A2) e.g. via zero-speed monitor Safety contact (21 - 22) opens Signalling contact (11-12) remains closed
Door open	→ Only possible once it is released Signalling contact (11 - 12) opens.
Door open	→ Both contacts in the open position tamperproof against simple tools
Close door	→ Signalling contact (11 - 12) closes
Lock door	→ Switch off the voltage from coil (A1, A2) 1st actuator interlocked 2nd safety contact (21 - 22) closes

Pilot devices
LS-Titan® Position switches

LS-S11-...FT-ZBZ



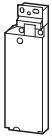
① Safety contact
② Signalling contact
③ Interlocked
④ Released
⑤ Open

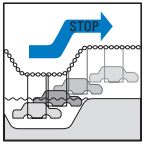
Door closed and interlocked	→ Coil at (A1, A2) de-energized also with mains failure or wire breakage: Door interlocked = safe state Safety contact (21 - 22) closed Signalling contact (13 - 14) open
Releasing of door	→ Apply voltage to coil (A1, A2) e.g. via zero-speed monitor Safety contact (21 - 22) opens Signalling contact (13 - 14) remains open
Door open	→ Only possible once it is released Signalling contact (13 - 14) closes.
Door open	→ Safety contact (21 - 22) open Signalling contact (13 - 14) closed
Close door	→ Signalling contact (13 - 14) opens
Lock door	→ Switch off the voltage from coil (A1, A2) 1st actuator interlocked 2nd safety contact (21 - 22) closes

Pilot devices
LS-Titan® Position switches

"Process protection and enhanced personnel protection" with separate signal for door position

LS...ZBZ

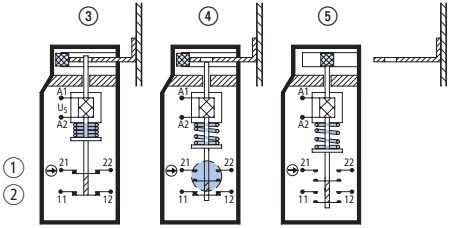




- Stop command
- Waiting time
- Process sequence halted
- Protective mechanism open
- Product OK

LS...MT-ZBZ, magnet-powered interlock (open-circuit principle)

LS-S02-...MT-ZBZ

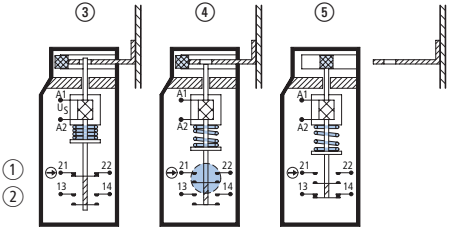


① Safety contact
② Signalling contact
③ Interlocked
④ Released
⑤ Open

Door closed and interlocked	→ Voltage on coil (A1, A2) Safety contact (21 - 22) closed Signalling contact (11 - 12) closed
Releasing of door	→ Coil de-energized (A1, A2) e.g. via zero-speed monitor, Safety contact (21 - 22) opens Signalling contact (11 - 12) remains closed
Door open	→ Only possible once it is released Signalling contact (11 - 12) opens.
Door open	→ both contacts in the open position, even with tampering with simple tools
Close door	→ Signalling contact (11 - 12) closes
Lock door	→ Apply voltage to coil (A1, A2) 1st actuator interlocked 2nd safety contact (21 - 22) closes

Pilot devices
LS-Titan® Position switches

LS-S11-...MT-ZBZ



Door closed and interlocked	→ Voltage on coil (A1, A2) Safety contact (21 - 22) closed Signalling contact (13 - 14) open
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Pilot devices
LS-Titan® Position switches

	LS, LSM	LS...ZB	LS...ZBZ
Standards	• IEC 60947-5-1 • →EN 50047 • Dimensions • Fixing dimensions • Operating points • Minimum IP66, IP67	• IEC 60947-5-1 • IP66	• IEC 60947-5-1 • IP65
Suitable applications	• Also for use in safety circuits, by positive operation and positive opening contacts	• Safety position switches for protection of personnel • with separate operating element for protective covers • Positive operation and positive opening contacts • Approval of employers' liability insurance Association	• Safety position switches for protection of personnel • with separate operating element for protective covers • Positive operation and positive opening contacts • electromagnetic interlock • Approval of employers' liability insurance Association
Drive	• Rounded plunger (centre fixing) • Roller plunger (centre fixing) • Rotary lever • Angled roller lever • Adjustable roller lever • Actuating rod • Spring-rod actuator • Operating heads adjustable in 90° steps	• Coded actuating element • Coding level according to EN ISO 14119: low • Operating head: – Can be rotated by 90° – Can be actuated from four sides and from above	• Coded actuating element • Coding level according to EN ISO 14119: low • Operating head: – Can be rotated by 90° – Can be actuated from four sides

Pilot devices
LSE-Titan® Electronic position switches

Operating point variably adjustable

The operating point on electronic position switches LSE-Titan is adjustable and variable. Two high-speed and bounce-free PNP switching outputs enable high switching frequencies.

The position switch is overload as well as conditionally short-circuit proof and has snap-action switching performance. This ensures a defined and reproducible switching point. The operating point lies in the range from 0.5 to 5.5 mm (as supplied = 3 mm).

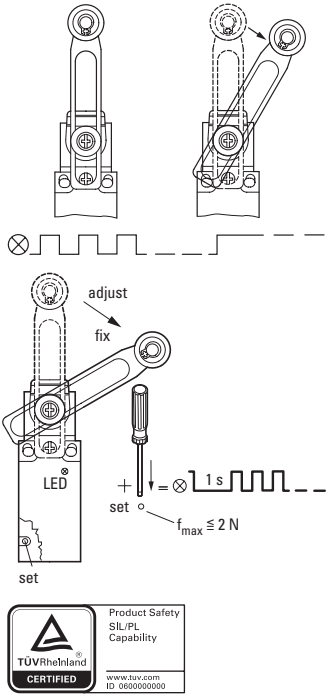
Adjustment to a new operating point is carried out as follows:

Move the plunger from the original to the new switch position. For this purpose, press the setting pushbutton for 1 second. The LED now flashes with a high pulse frequency and the new operating point is retentively set.

The LSE-11 and LSE-02 complete devices can be used in safety-oriented connections. They have the same function as electromechanical position switches.

Note

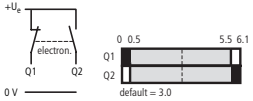
This means that all the devices are also suitable for safety applications designed for personnel or process protection.



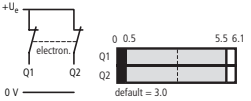
Product Safety
SIL/PL
Capability
TÜVRheinland
CERTIFIED
www.tuv.com
ID 0600000000

Contact travel diagram

LSE-11



LSE-02



Pilot devices
Sensors – Functionality

Inductive Sensors

Inductive sensors are used to detect metal objects. The objects are detected through an electromagnetic field.

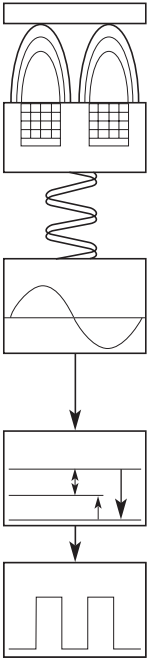
With the ability to detect at close range, inductive proximity sensors are very useful for precision measurement and inspection applications.

How an inductive sensor works

Inductive sensors create an invisible high frequency oscillation field. When metal objects are brought into this field, this oscillating field is affected. Each sensor has a specific sensing range switch point so that metal target detection is very accurate and repeatable.

If a metal object is brought into the field created by the sensor, this is interrupted and causes a reduction in the current flowing through the sensor coil (eddy current damping). The detector circuit senses this change and sends a signal via the sensor output.

Assembly parts



A metal object, or target, enters the sensing field.

The sensor coil is a coil of wire typically wound around a ferrite core. If you could see the electromagnetic field created by it, it would be cone shaped. The target will pass through this field.

The ferrite core shapes the field and the size of the coil determines the sensing range.

The resonance circuit creates a high frequency oscillation of the electromagnetic field (between 100 Hz and 1 MHz). If a metal object is located in the field, this causes a change in the magnetic field oscillation.

This change creates an eddy current which dampens the signal fed back to the sensor coil.

The detector circuit senses the change and switches ON at a particular set point (amplitude). This ON signal generates a signal to the solid-state output.

The output circuit remains active until the target leaves the sensing field. The oscillator responds with an increase in amplitude, and when it reaches the setpoint value, the detector circuit switches OFF. The output returns to its normal state.

Material wire of the target object

The sensing ranges stated by the sensor manufacturer are usually based upon ferrite targets made of carbon-rolled steel (IE FE 235) defined by ISO 630.

Sensing ranges to targets made of other materials have to have a correction factor applied as listed in the table below. To use this table, multiply the sensing distance of the device by the factor given below.

Correction factors

Multiply the sensing distance by the factor given below.

Target object	Sensor size			
	4 - 8 mm	12 mm	18 mm	30 mm
Stainless Steel 400[1)]	0.90	0.90	1.0	1.0
Stainless Steel 300[2)]	0.65	0.70	0.70	0.75
Brass	0.35	0.45	0.45	0.45
Aluminium	0.35	0.40	0.45	0.40
Copper	0.30	0.25	0.35	0.30

1) Stainless steel 400 series to ASTM A240, martensitic or ferritic, magnetizable.

2) Stainless steel 300 series to ASTM A240, austenitic, non-magnetizable.

The index of stainless steels is provided in EN 10088-1.

Pilot devices
Sensors – Functionality

Capacitive sensors

Capacitive sensors are designed to detect both metallic and nonmetallic targets. They are ideally suited for liquid level control and for sensing powdered or granulated material.

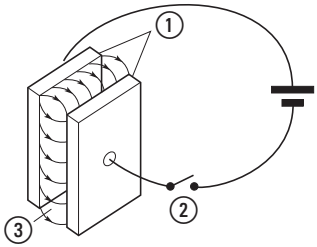
Operation of the capacitive sensors

Capacitive sensors operate using a capacitor. This consists of two metal plates that are separated by an insulating dielectric material. The function of this type of sensor is based on dielectric capacitance, which is the ability of a dielectric to store an electrical charge.

The distance between the plates determines the ability of the capacitor to store an electrical charge.

If an object is put into the electrical field. the capacitance of the capacitor changes. This change is used to implement the on/off switch function.

- Capacitor



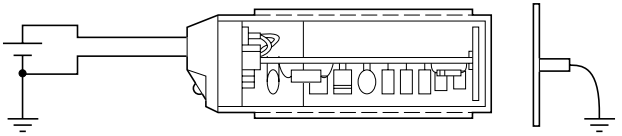
① Plates
② Switch
③ Dielectric

When this principle is applied to the capacitive sensor, one capacitive plate is part of the switch, the enclosure (the sensor face) is the insulator. The target is the other “plate”. Ground is the common path.

Capacitive proximity sensors can detect any target that has a dielectric constant greater than air. Liquids have high dielectric constants. Metal also makes a good target.

Pilot devices
Sensors – Functionality

- Capacitive sensor



Capacitive sensors consist essentially of four basic elements:

- Sensor (Dielectric)
- Resonance circuit
- Detector circuit
- Output circuit.

As an object approaches the sensor, the dielectric constant of the capacitor changes. The oscillator circuit's vibration begins when feedback capacitance is detected. This is just the opposite in the inductive proximity sensor, where the vibration is damped when the target is present.

Effects

Capacitive sensors are activated both by conductive as well as non-conductive objects.

Metals achieve the greatest switching distances due to their high conductivity. Derating factors for various metals, such as with inductive sensors, do not need to be taken into account.

Actuation by objects made of non-conductive materials (insulators):

When an insulator is brought between the electrodes of a capacitor, the capacitance rises relative to the dielectric constant of the insulator. The dielectric constant for all solid and liquid materials is greater than that for air.

Objects made of non-conductive materials affect the active surface of a capacitive proximity switch in the same way. The coupling capacitance is increased. Materials with a high dielectric constant achieve great switching distances.

Notes

When scanning organic materials (wood, grain, etc.) it must be noted that the attainable switching distance is greatly dependent on their moisture content. (ε_{Water} = 80!)

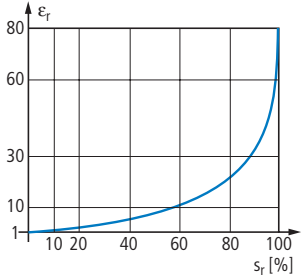
Pilot devices
Sensors – Functionality

Influence of environmental conditions

As can be seen from the following diagram, the switching distance S_r is dependent on the dielectric constant ε_r of the object to be monitored.

Metal objects produce the maximum switching distance (100 %).

With other materials, it is reduced relative to the dielectric constant of the object to be monitored.



The following table lists the dielectric constants ε_r of some important materials. Due to the high dielectric value of water, the fluctuations with wood can be significant. Damp wood therefore is registered much more effectively by capacitive sensors than dry wood.

Material	ε_r
Air, vacuum	1
Teflon	2
Wood	2 - 7
Paraffin	2.2
Kerosene	2.2
Oil of terpentine	2.2
Transformer oil	2.2
Paper	2.3
Polyethylene	2.3
Polypropylene	2.3
Cable insulation	2.5
Soft rubber	2.5
Silicone rubber	2.8
Polyvinyl chloride	2.9
Polystyrene	3
Celluloid	3
Perspex	3.2
Araldite	3.6
Bakelite	3.6
Silica glass	3.7
Hard rubber	4
Oil-impregnated paper	4
Chipboard	4
Porcelain	4.4
Laminated paper	4.5
Quartz sand	4.5
Glass	5
Polyamide	5
Mica	6
Marble	8
Alcohol	25.8
Water	80

Pilot devices
Sensors – Functionality

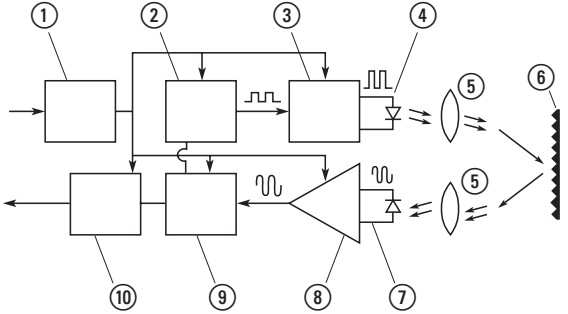
Optical sensors

Optical sensors use light to detect the presence or absence of an object. The main advantages of optical sensors are contactless sensing of objects and greatly extended sensing ranges.

Operating principle of the optical sensor

A LED sends a beam of light, which is picked up by a photodetector. An object is detected when it passes between the LED and photodetector, interrupting the light beam.

Let's look at how an optical sensor works.



① Power supply:
Feeds the sensor circuit with a regulated DC voltage.

② Modulator:
generates pulses to cycle amplifier and LED at desired frequency.

③ Source current amplifier

④ LED

⑤ Lens

⑥ Target object or reflector

⑦ Photodetector:
Either a photodiode or a phototransistor device, selected for a maximum sensitivity at the source LED's emitted light wavelength. Both the source LED and the detector have protective lenses. When the sensor picks up the light, it sends a small amount of current to the detector amplifier.

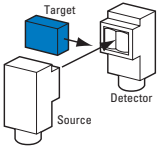
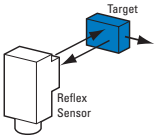
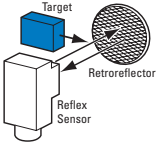
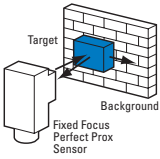
⑧ Detector Amplifier:
Blocks current generated by the background light. It also provides amplification of the signal received to a usable level, and sends it through to the demodulator.

⑨ Demodulator:
Sorts out the light thrown out by the sensor from all other light in the area. If the demodulator decides the signals it receive are okay, it signals the output.

⑩ Output:
Performs switching routine when directed to do so by the demodulator.

Pilot devices
Sensors – Functionality

Detection methods

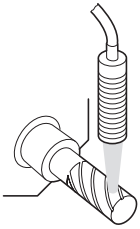
Operating Mode	Description	Operating Mode	Description
Light barriers 	A source unit in one location sends a light beam to a detector unit in another location. An object is detected when it passes between the source unit and the detector unit, interrupting the light beam.	Reflected-light beam 	Light source and receiver are located in the same unit. If a target moves in front of the optical sensor, it reflects the light beam directly back to the receiver.
Polarisation reflex sensor 	Light source and receiver are located in the same unit. If a target moves in front of the optical sensor, a reflector reflects the light beam directly back to the receiver.	Background rejection (Perfect Prox) 	This is a special type of diffuse reflective sensor that includes two detectors. This sensor offers reliable detection of target objects in a defined sensing range and at the same time ignores objects outside of this range. Unlike a standard diffuse reflective optical sensor, color or reflectivity has minimal effect on the sensing range of this sensor.

Pilot devices
Sensors – Functionality

Broken Tool Detection

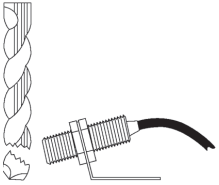
E58 Perfect Prox Sensor

This sensor is used to sense for the presence of the bit on a mill. The high sensing power and background suppression of the Perfect Prox allows reliable detection through high levels of cutting fluids, while ignoring objects just beyond the bit. The rugged harsh duty sensor survives constant exposure to lubricants, cutting fluids and flying metal chips.



Tubular inductive sensor

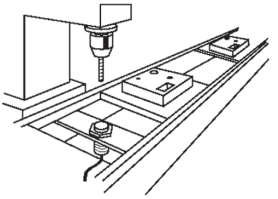
A tubular sensor is used to detect the presence of a drill bit – should the drill bit be broken the sensor would signal a controller.



Machining process

Tubular inductive sensor

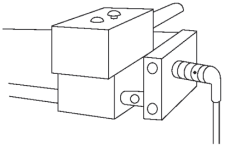
A ferrous only sensor is used in a process where aluminum is being machined. The ferrous only sensor ignores the aluminum (non-ferrous) chips from the machining process and only detects the ferrous target.



Tool Position

Tubular inductive sensor

A tubular sensor is used to detect the position of a tool chuck.

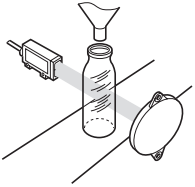


Pilot devices
Sensors – Applications

Bottle Filling Detection

E65 Clear Object Sensor

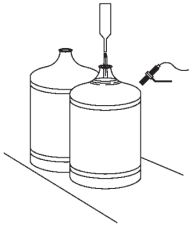
A clear object sensor is used to sense the presence of bottles at a filling operation. The sensor offers high reliability in sensing clear bottles of different colors and thicknesses.



Process control engineering

Tubular capacitive Sensor

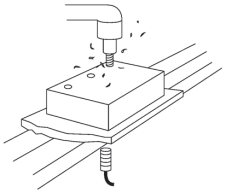
A capacitive sensor used to verify fill level of bottled water on a filling process line.



Conveyor System Control

Tubular inductive sensor

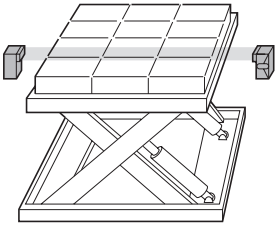
A tubular inductive sensor is used to detect the presence of metal carriers holding parts to be machined.



Stack Height Control

Comet Series Thru-Beam: source, detector

A set of thru-beam sensors determines the height of a scissor lift. For example, when the control is set for “dark-to-light” energize, the lift rises after a layer has been removed and stops when the next layer breaks the beam again.



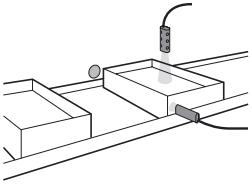
Pilot devices
Sensors – Functionality

Carton Fill-Level Detection

Comet Series reflex sensor

- Visible reflex photoelectric sensor
- Reflected-light beam with background suppression (Perfect Prox)
- Retro-reflector

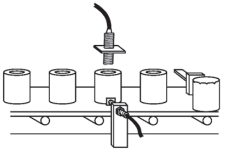
Two sensors work together to inspect the fill level in cartons on a conveyor. A reflex sensor senses the position of the carton and energizes the sensors located over the contents. If the sensor does not “see” the fill level, the carton does not pass inspection.



Lid Detection

Tubular inductive sensor

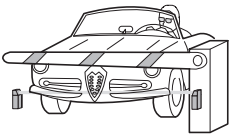
Two sensors are used to detect a can on a conveyor belt and to check whether it has a cover.



Tollbooth Control

E67 Perfect Prox long range sensor

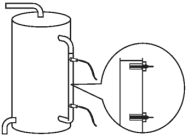
The long range polarized reflex controls are used for the time control of a toll barrier. As soon as the car that has paid passes, the barrier closes in order to ensure that the next car stops. With the initiator E67 Long Range Perfect Prox you can mount the sensor on just one side instead of both. It detects cars with different colors and finishes whilst reliably ignoring all other background objects. The rugged design makes it also suitable for continuous operation in extreme weather conditions.



Liquid Level Detection

Tubular capacitive Sensor

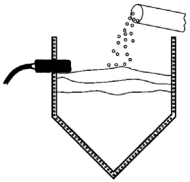
A pair of capacitive sensors are used to sense high and low liquid levels in a tank through a sight glass. This arrangement starts a pump to fill the tank when the lower sensor is energized and shuts the pump off when the top sensor is energized.



Bulk Material Detection

Tubular capacitive Sensor

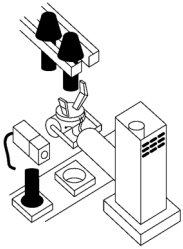
A capacitive sensor is used to control fill level of solids such as plastic pellets in a hopper or bin.



Parts Presence

Limit switch, inductive sensor: Comet Perfect Prox, Inductive sensor iProx

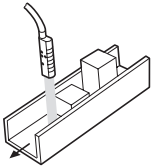
A sensor configured as a limit switch can be used to detect whether a component is present in an automatic assembly machine. The Comet detects all materials, colors and services and masks out the background. The iProx can be programmed to detect a particular material and thus to ignore all other materials.



Parts Presence

Comet reflected-light beam (Perfect Prox), 100 mm

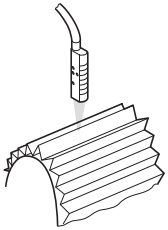
The sensor detects components with different heights from approx. 13 to 76 mm in a channel and can mask out the channel. Installation is simple and does not require any drilling or cutting of the channel.



Filter Paper Length Control

A focused diffuse Comet reflective sensor

A focused diffuse reflective sensor interfaces with a programmable controller to measure a specific length of corrugated automotive filter paper. The controller detects the presence or absence of a corrugation. When a predetermined number of corrugations has been detected, the programmable controller directs a shear to cut the paper.

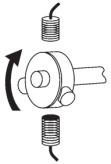


1

Speed monitoring

Tubular inductive sensor

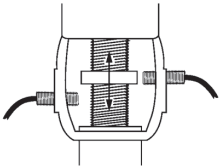
A tubular sensor is used to detect the presence of set screws on a shaft hub providing a control device with signals for speed regulation or detection of rotation.



Motion Control

Tubular inductive sensor

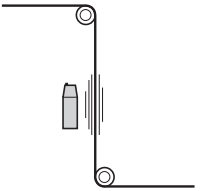
A pair of tubular sensors is used to determine fully open and fully closed valve position.



Clear Plastic Web Break Detection

Comet series 150 mm diffuse focus reflective light sensor

The clear web is detected by an extremely sensitive diffuse reflective sensor. Its short detection range makes it immune to reflective objects in the background. The extremely high excess gain helps it ignore reflection caused by fluttering of the web.

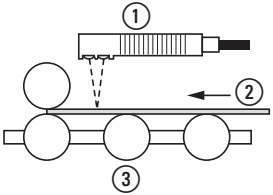


Pilot devices
Sensors – Applications

Paper detection

Comet Perfect Prox, 50 mm series, right angled

Right angle viewing and compact size allow the sensor to be mounted in the tight confines of paper handling systems. High resolution and sharp optical cut-off ensure that background machinery will be ignored while paper will be detected regardless of color and texture.

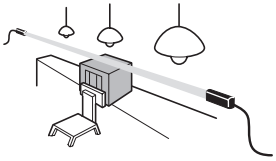


① Comet sensors
② Paper
③ Roller

Damage Warning

Comet E58 series Thru-Beam: source, detector

Source and detector are mounted at opposite ends of a long warehouse storage shelf with the beam situated a safe distance below overhead obstacles (lighting, cable ducts, gas lines, etc.). If a forklift operator interrupts the beam while moving a load, a siren or flashing light will warn them to stop before any damage occurs.



Notes

Switching, control, visualization

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Notes

Switching, control, visualization
SmartWire-DT communication system

Connect, don't wire

The main part of a control system for a machine is these days carried out by a PLC. Typically the PLC is mounted in a control panel at a central position in the system. The control of the switchgear is carried out via special cables from the input and output terminals of the PLC for the control and return signals. With a decentralized configuration the switchgear and the remote input/output system are connected in the same way.

The SmartWire-DT communication system replaces the control wiring previously required between the PLC inputs/outputs and the switching devices. In this way, the inputs/outputs of the PLC are relocated to the switching devices. Pluggable communication modules are used for this task. The communication is implemented via an 8-pole ribbon cable. Special device plugs are used for connecting the communication modules to the cable. The switchgear is supplied on the control circuit side by the connection cable.

The SmartWire-DT system

- reduces the time required for the control wiring and wiring test,
- saves space in the control cabinet because cable ducts are unnecessary and
- reduces the number of inputs/outputs required at the PLC.

The length of a SmartWire-DT network can be extended up to 600 meters. Up to 99 stations can be connected.

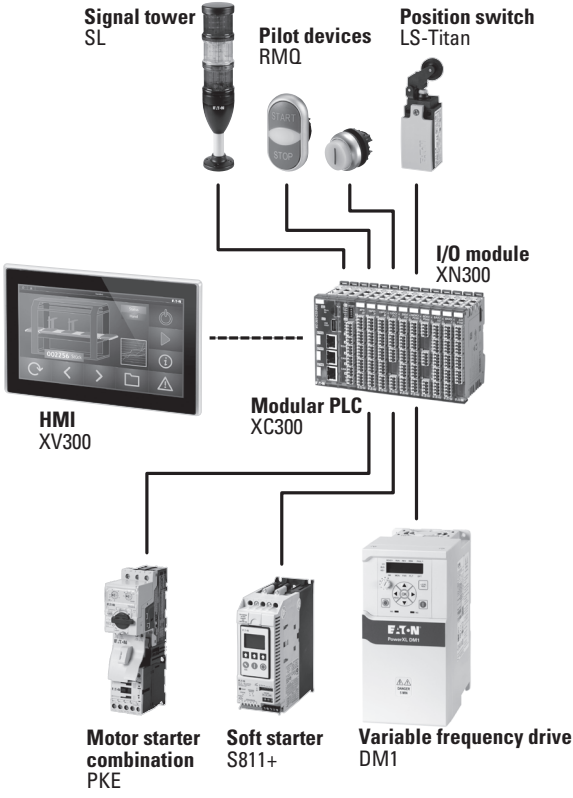
You can use the SmartWire-DT technology flexibly. The connection via standard fieldbus systems (e. g. Profinet, EtherCat, Ethernet/IP) enables SWD gateways to be used on the controller platforms of many manufacturers. Another option is the use of Eaton automation components (e. g. XV100 visualization system) with an integrated SmartWire-DT interface.

The SmartWire-DT communication module enables the communication of the easyE4 base device with other devices, including devices from other manufacturers.

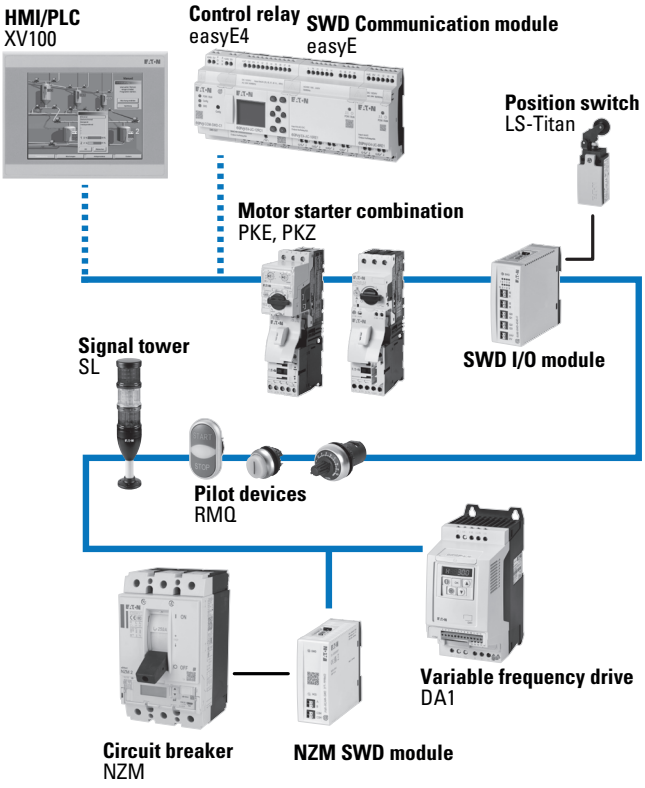
Switching, control, visualization
SmartWire-DT communication system

Evolution in the switchboard

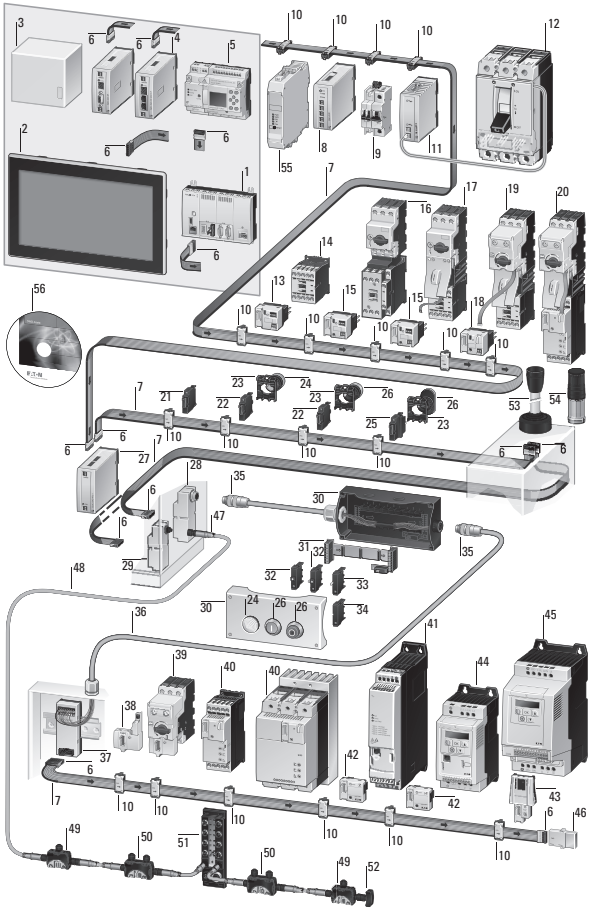
Conventional wiring



SmartWire-DT solution



Switching, control, visualization
SmartWire-DT communication system



Switching, control, visualization
SmartWire-DT communication system

1 Compact PLC
2 Touch display
3 PLC with field bus interface
4 Gateways
5 Control relay easyE4
6 SWD blade terminal, 8 pole
7 SWD ribbon cable, 8 pole
8 SmartWire-DT I/O module
9 SWD module for circuit- breakers and residual current circuit-breakers
10 SWD external device plug, 8 pole
11 SWD interface for NZM
12 NZM circuit-breakers
13 SWD contactor module
14 DILM contactor
15 SWD contactor module with Manual-0-Automatic switch
16 Motor-Protective Circuit-Breakers
17 MSC motor starters
18 SWD PKE module (motor starter)
19 Motor starters with PKE electronic motor protection
20 Soft starter DS7 with electronic motor protection from PKE
21 SWD universal module, front mounting
22 SWD LED element, front mounting
23 RMQ-Titan fixing adapter for flush mounting plates
24 RMQ-Titan indicator lights
25 SWD function elements for front mounting
26 SWD operating elements
27 SWD power feeder module
28 SWD control panel bushing ribbon cable to 8 pole round cable, M20
29 SWD control panel bushing ribbon cable to 5 pole round cable, M12
30 Surface mounting enclosure RMQ-Titan
31 SWD circuit card for function elements, base fixing
32 SWD LED elements for base fixing
33 SWD function elements for base fixing
34 SWD universal modules, base fixing
35 SWD plug-in connector, 8 pole
36 SWD round cable, 8 pole
37 SWD adapter for flat/round cable for top-hat rail mounting
38 SWD PKE module (motor-protective circuit-breaker)
39 Motor-protective circuit-breaker PKE
40 Soft starter DS7
41 Variable speed starter DE1
42 SWD function element for DC1 variable frequency drives, DE1 variable speed starter
43 SWD function element for DA1 variable frequency drive s
44 Variable frequency drives DC1
45 Variable frequency drives DA1
46 SWD bus termination resistor for SWD ribbon cable, 8 pole
47 M12 plug connector, 5 pole
48 SWD round cable, 5 pole
49 SWD I/O module IP67, 2 I/O
50 SWD I/O module IP67, 4 I/O
51 SWD I/O module IP67, max. 16 I/O
52 SWD bus termination resistor IP67 for SWD round cable, 5 pole
53 Base module signal tower SL4/SL7
54 Signal towers SL4/SL7
55 Electronic Motor Starter EMS
56 SmartWire-DT planning and ordering tool (SWD-Assist)

2

PKE communication via SmartWire-DT

Motor-starter combinations fitted with PKE can transfer the following information via SmartWire-DT:

I_max	Maximum motor current (relative): shows the single-phase current (single-phase load) or the maximum current in the appropriate phase (three-phase load).
Thermal image of the motor	Shows the temperature curve of the motor, stated in %, “Overload warning” function possible
Type of trip block display	Shows the type of trip block currently in use.
Display of set Overload value	Shows the currently set value for the overload release.
Display of time-lag class value	Shows the currently set time-lag class (Class 5...20).
PKE switching state display	Shows the currently set ON/OFF switching state.
DILM contactor switching state	Shows the currently set ON/OFF switching state.
Trip indication overload	Shows a differentiated “Overload” fault indication.
Trip indication short-circuit	Shows a differentiated “Short-circuit” fault indication.
Trip indication Phase failure	Shows a differentiated “Phase failure” fault indication.
Trip indication Test	Shows a differentiated “Tripping via test function” fault indication.
ZMR function	Overload relay function: When the ZMR function is set, the contactor disconnects in the event of an overload. The PKE motor-protective circuit-breaker remains switched on (ON setting). The contact is reset with the MANUAL/AUTO function via PKE-SWD-32.

Overload relay function (ZMR)

The ZMR function enables the motor to be switched off by the connected contactor in the event of an overload. To do this the PKE sends the switch off command for the contactor to the PKE-SWD-32 via the data cable of the PKE32-COM.

The trip in response to a motor overload occurs if the thermal motor image of the PKE reaches 110 %.

This value remains set until the thermal motor image has gone below the 100 % level and the operational readiness of the contactor is restored.

The reclosing readiness of the contactor can be selected by the two manual and automatic operating modes of the ZMR function.

The ZMR function can only be used in position "A" of the 1-0-A switch.

In the event of a phase unbalance and activated ZMR function, the value of the thermal motor image is raised from 100 % to 110 % after a trip.

The switched off contactor's readiness to reclose is restored when the value falls below 100 %.

The ZMR function must not be activated with reversing starters since this operation does not ensure the disconnection of the second contactor in the event of an overload.

ZMR Manual mode

In "manual" ZMR operating mode, the retriggering of the contactor must be acknowledged beforehand.

ZMR Automatic mode

In "automatic" ZMR mode, the contactor is ready to reclose immediately after the thermal image drops below 100 %.

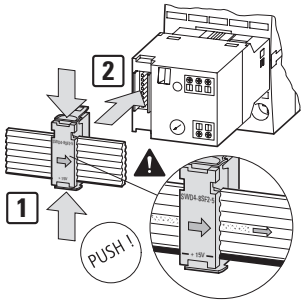
Danger!

If the switch on command for the contactor is sent in "automatic" ZMR mode, the motor starts up automatically after the thermal motor image falls below 100 %. Never disconnect the communication link between the PKE-SWD-32 and the PKE trip block after an overload with the ZMR function activated, as this can cause the contactor to turn on if a switch command is present.

Switching, control, visualization
SmartWire-DT communication system

DOL starter with PKZ

The DOL starters are assembled from a PKZM0 and a DILM7 to DILM32 contactor. The connection to SmartWire-DT is implemented with the DIL-SWD-32-... module. This is fitted directly on the contactor and connected via the SWD device plug with the SWD communication cable.



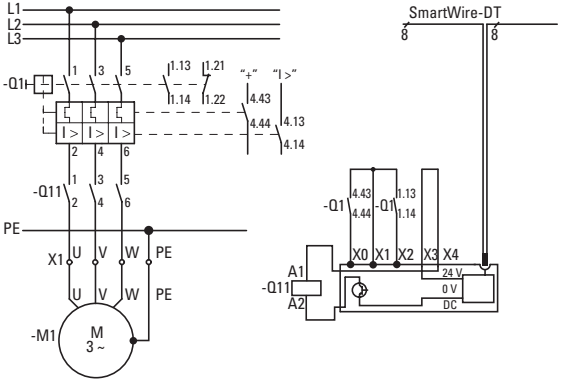
In addition to contactor control, two feedback signals can be sent to the SmartWire-DT system on each SmartWire-DT module for DILM.

The SmartWire-DT module for DILM drives the contactor so that terminals A1-A2 must no longer be wired.

The auxiliary contact X3-X4 is factory fitted with a link. If electrical interlocks are envisaged in the application, the link can be removed and a potential-free contact can be connected.

Two feedback inputs to the programmable logic controller are provided at the three-pole terminal X0-X1-X2. If required, potential-free auxiliary contacts of the PKZ motor protective circuit-breaker can be connected to these two feedback inputs (e. g. NHI-E-...-PKZ0 standard auxiliary contact, AGM2-...-PKZ0 differential trip-indicating auxiliary contact).

→ Figure, page 2-10



Switching, control, visualization
SmartWire-DT communication system

Reversing starter with PKZ

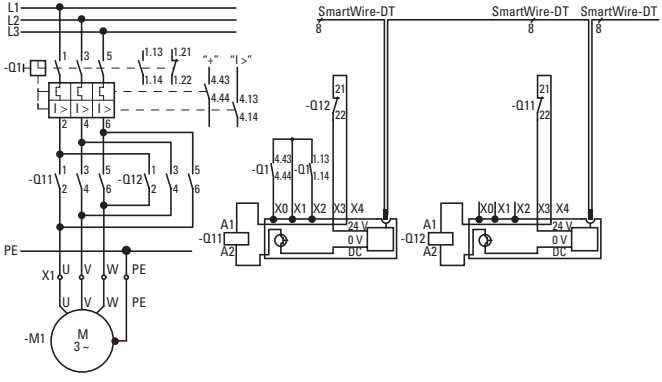
The reversing starters are made up of a PKZM0 motor-protective circuit-breaker and two DILM7 to DILM32 contactors. A DIL-SWD-32-... SmartWire-DT module is fitted to each contactor and connected to the SWD communication cable via the SWD external device plug.

In addition to contactor control, two feedback signals can be sent to the SmartWire-DT system on each SmartWire-DT module for DILM.

The SmartWire-DT modules for DILM drive the contactors so that the connection terminals A1-A2 of the contactors need no further wiring, with the exception of the DILM12-XEV link. The auxiliary contact X3-X4 is factory fitted with a link. For the electrical interlocking of the two contactors this bridge is removed and the auxiliary breaker (contacts 21-22) of the other contactor is linked in as a potential-free contact.

Two feedback inputs to the programmable logic controller are provided at the three-pole terminal X0-X1-X2. If required, potential-free auxiliary contacts of the PKZ motor protective circuit-breaker can be connected to these two feedback inputs (e. g. NHI-E-...-PKZ0 standard auxiliary contact, AGM2-...-PKZ0 differential trip-indicating auxiliary contact).

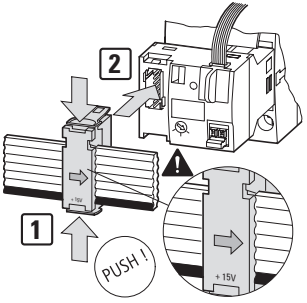
The wiring sets DILM12-XRL and PKZM0-XRM12 can only be used to create a reversing starter when the reversing links are replaced with DILM12-XR. The A2 connections of the contactors must not be bridged.



Switching, control, visualization
SmartWire-DT communication system

DOL starter with PKE

The DOL starters are assembled from a PKE12/PKE32 with the PKE-XTUA-... trip block and a DILM7 to DILM32 contactor. The connection to SmartWire-DT is implemented with the PKE-SWD-32 module. This is fitted to the contactor and connected to the SWD communication cable via the SWD device plug.

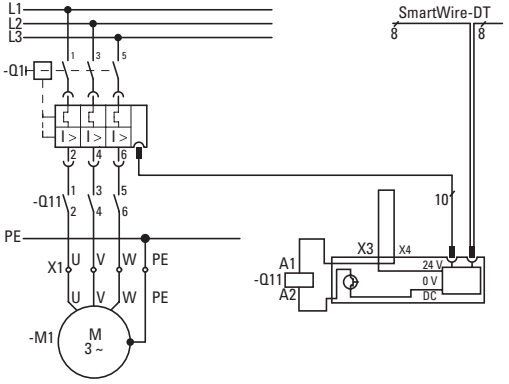


The PKE32-COM is used as a communication link between the PKE-SWD-32 and the PKE trip block. The PKE-SWD-32 receives the data of the PKE trip block via the PKE32-COM and makes this available as input data on the SmartWire-DT network.

The PKE32-COM is fitted on the PKE basic device (PKE12 or PKE32) and is connected with the appropriate interface of the PKE-SWD-32.

The auxiliary contact for the electrical release X3-X4 is connected at the factory with a link. If electrical locks are envisaged in the application, the link can be removed and a potential-free contact can be connected.

The auxiliary contact for the electrical release can be used on the PKE-SWD-32 for safety-related control sections (e. g. safety shutdown of the drive).



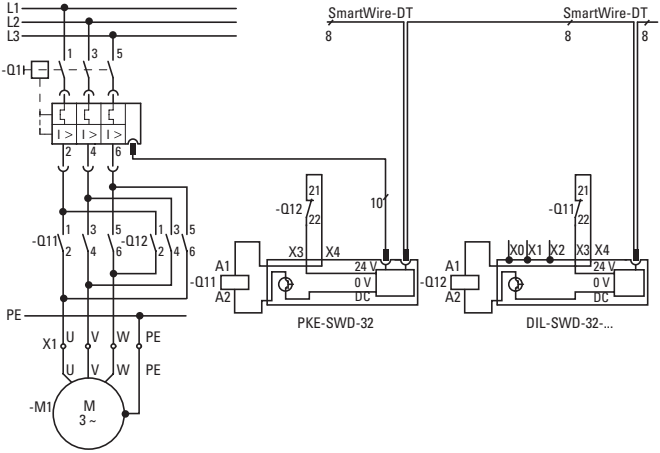
Reversing starter with PKE

The reversing starters are made up from a PKE12/PKE32 with a PKE-XTUA-... trip block and two contactors DILM7 to DILM32. The PKE-SWD-32 is fitted on one of the two contactors of the reversing starter. Unlike DOL starters, the control of the second contactor for reversing starters must be implemented with a SmartWire-DT contactor module (DIL-SWD-32-...). Both SWD modules are then connected to the SWD communication cable via the SWD device plug.

The "Enable" X3-X4 auxiliary contact is factory fitted with a link. For the electrical interlocking of the two contactors this link is removed and the auxiliary breaker (contacts 21-22) of the other contactor is linked in as a potential-free contact.

The auxiliary contact for the electrical release X3-X4 can be used on the PKE-SWD-32 for safety-related control sections. The wiring sets DILM12-XRL and PKZM0-XRM12 must not be used for the assembly of the reversing starters.

The A2 connections of the contactors must not be bridged.



2

Star-delta starter

With SmartWire-DT modules for DILM
They control the contactors so that the terminals A1-A2 of the contactors do not have to be wired. A return signal is also given back to the SmartWire-DT system via the SWD contactor modules for DILM.

The terminals X3-X4 are supplied with a bridging connection. For the electrical interlocking of the two contactors this bridge is removed and the auxiliary breaker (contacts 21-22) of the other contactor is linked in as a potential-free contact.

→Figure, page 2-16

With SmartWire-DT I/O-module EU5E-SWD-4D2R

The SmartWire-DT I/O module actuates the contactor Q11 via the digital relay output Q0. The further procedure is the same as that of a conventional star-delta starter.

The inputs of the SmartWire-DT I/O module are used to implement return signals to the SmartWire-DT system.

→Figure, page 2-17

With SmartWire-DT contactor module and ETR4-51 timing relay

The SWD contactor module for DILM controls the mains contactor Q11 so that the terminals A1-A2 do not have to be wired. A return signal is also given back to the SmartWire-DT system via the SWD protective module for DILM.

The control and the changeover between star contactor and delta contactor have the same wiring and function as the conventional star-delta starter assembly.

→Figure, page 2-18

With PKE and SWD modules for DILM
The star-delta starters are made up from a PKE12/PKE32 with a PKE-XTUA-... trip block and three contactors DILM7 to DILM32. The PKE-SWD-32 is fitted to the mains contactor of the star-delta starter. The star and delta contactor is actuated with SmartWire-DT contactor modules (DIL-SWD-32-...).

All SWD modules are then connected to the SWD communication cable via the SWD device plug.

The “Enable” X3-X4 auxiliary contact is factory fitted with a link. For the electrical interlocking of the star and delta contactor this link is removed and the auxiliary NC contact (contacts 21-22) of the other contactor is linked in as a potential-free contact.

The auxiliary contact for the electrical release X3-X4 can be used on the PKE_SWD-32 for safety-related control sections.

The wiring sets DILM12-XRL and PKZM0-XRM12 must not be used for the assembly of a star-delta starter.

The A2 terminals of star and delta connections must not be bridged.

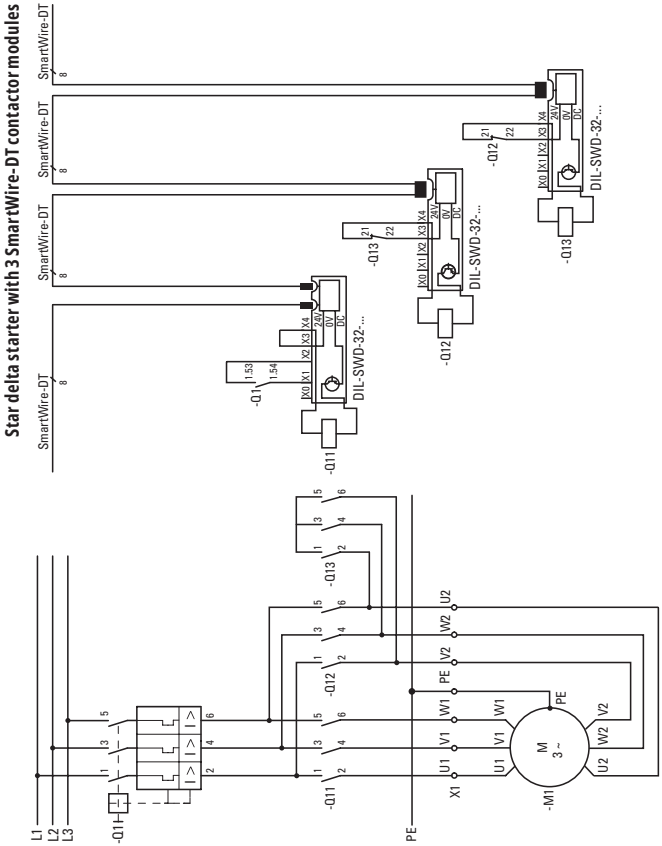
→Figure, page 2-19

With PKE, SWD modules for mains contactor DILM and ETR4-51 timing relay
The star-delta starters are made up from a PKE12/PKE32 with a PKE-XTUA-... trip block and three contactors DILM7 to DILM32. The PKE-SWD-32 is fitted to the mains contactor of the star-delta starter. The star-delta contactor is actuated in a conventional circuit. The PKE-SWD-32 module is connected to the SWD communication cable via the SWD device plug. The wiring sets DILM12-XRL and PKZM0-XRM12 can be used for the assembly of a star-delta starter.

→Figure, page 2-20

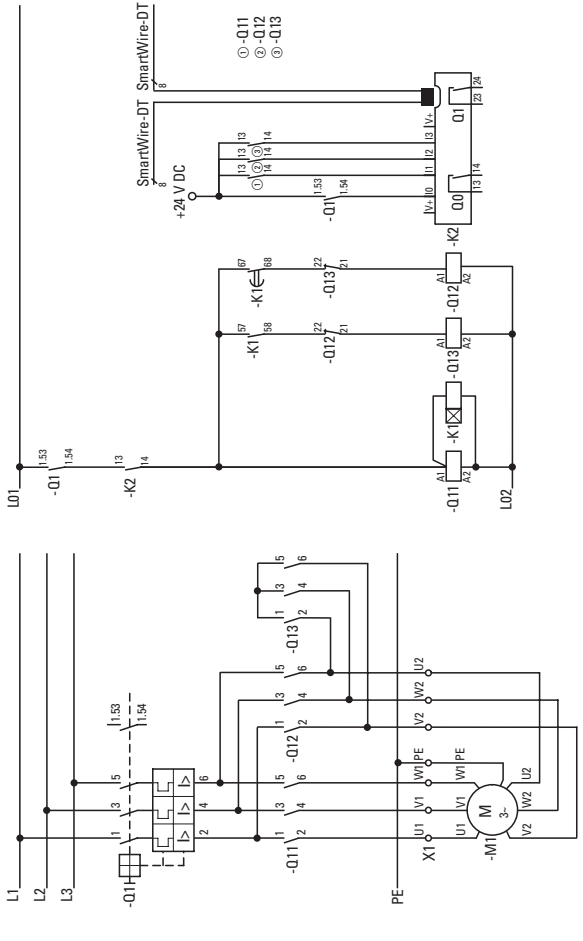
Switching, control, visualization

SmartWire-DT communication system



Switching, control, visualization

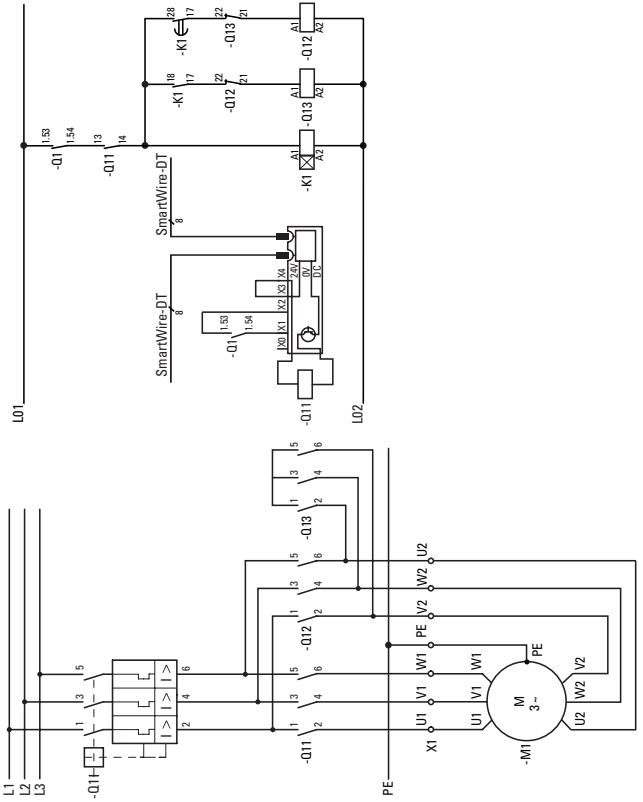
SmartWire-DT communication system



Switching, control, visualization

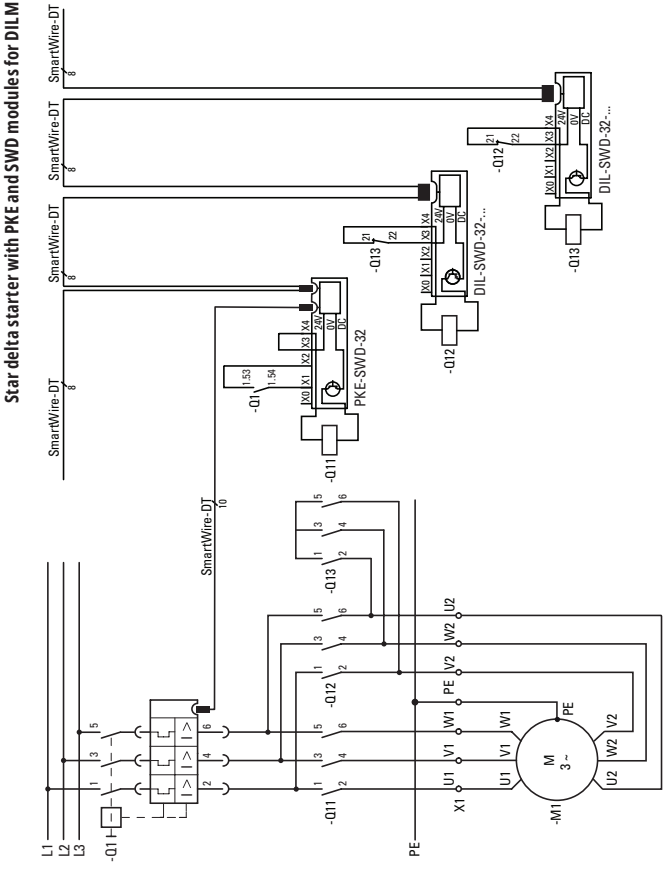
SmartWire-DT communication system

Star delta starter with SmartWire-DT contactor module and ETR4-51 timing relay



Switching, control, visualization

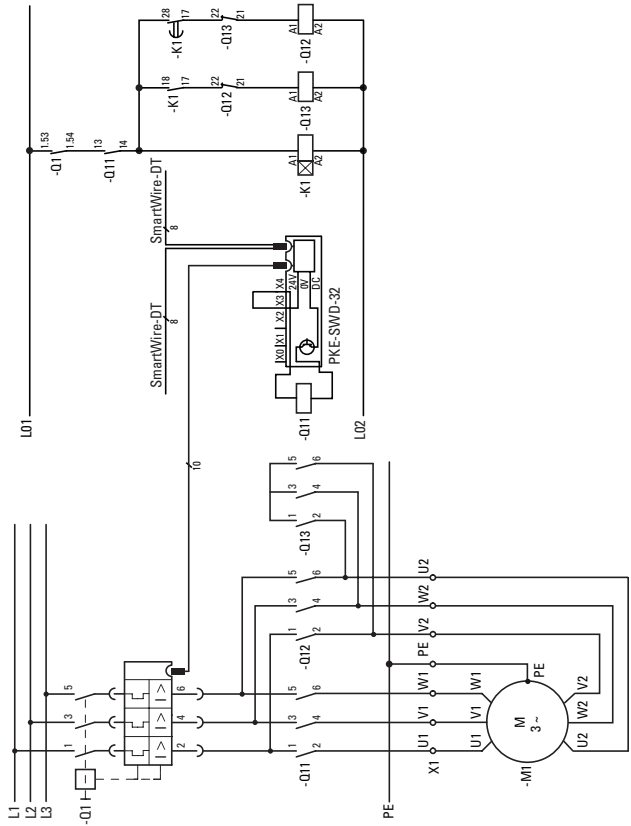
SmartWire-DT communication system



Switching, control, visualization

SmartWire-DT communication system

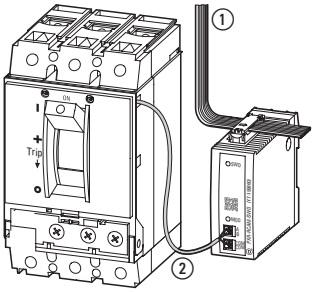
Star delta starter with PKE, SWD module for mains contactor DILM and ETR4-51 timing relay



Switching, control, visualization
SmartWire-DT communication system

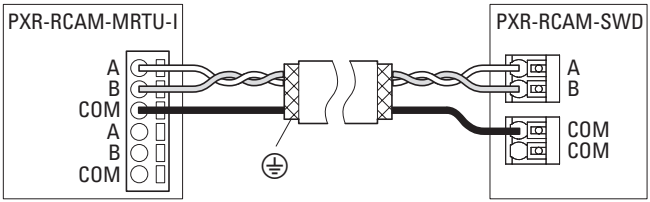
PXR-RCAM-SWD for NZM compact circuit-breakers

The PXR-RCAM-SWD SmartWire-DT module is used for querying a circuit-breaker (NZM2,3,4) with a communication module PXR-RCAM-MRTU-I via an SWD coordinator. On/Off/Trip position of the circuit-breaker and actual currents, voltages, power values and other information can be queried.
The PXR-RCAM-SWD is fitted on a top-hat rail in an installation compartment with protection at least to IP54 (control panel) and could be connected to the NZM via data cable with a maximal length of 2 meters.
An optionally installed remote operator can also be controlled via SmartWire-DT using the NZM relay module.



① SmartWire-DT connection with SWD4-8SF2-5

② Data cable NZM with PXR-RCAM-SWD

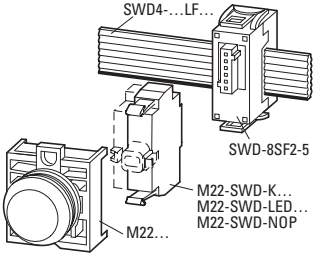


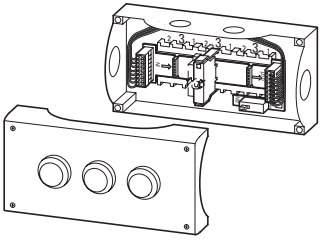
Switching, control, visualization
SmartWire-DT communication system

Pilot devices

Simple pilot devices can be integrated directly in the SmartWire-DT communication system without any time consuming wiring. The function elements are snap fitted in the M22-A fixing adapter and then connected to the SWD communication cable via the SWD device plug.

These function elements are each available in two versions for front or base fixing. Base fixing elements can be combined to form remote operating and display devices using the M22-SWD-I cards and the M22-I... surface mounting enclosures to IP65.





The switch position indications of the control elements and activation of the indicator are implemented with the SmartWire-DT communication system. The function elements stated in the table are available.

M22-SWD-K(C)11	Function element with one changeover contact
M22-SWD-K(C)22	Function element with two changeover contacts
M22-SWD-LED...	LED function elements in white (W), red (R), green (G) or blue (B)
M22-SWD-K11LED...	Function element with one changeover contact and one LED in white (W), red (R), green (G) or blue (B)
M22-SWD-K22LED...	Function element with two changeover contacts and one LED in white (W), red (R), green (G) or blue (B)

Switching, control, visualization
SmartWire-DT communication system

Digital and analog signal processing

The following SWD modules are available for processing digital or analog input/output signals:

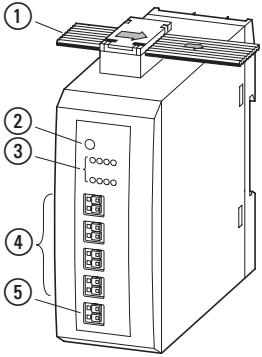
EU5E-SWD-8DX	8 digital inputs
EU5E-SWD-4DX	4 digital inputs with transmitter supply
EU5E-SWD-4D4D	4 digital inputs and 4 digital outputs
EU5E-SWD-4D2R	4 digital inputs and 2 relay outputs 3 A
EU5E-SWD-X8D	8 digital outputs
EU5E-SWD-4AX	4 analog inputs 0 - 10 V, 0 - 20 mA
EU5E-SWD-2A2A	2 analog inputs and 2 analog outputs 0 - 10 V, 0 - 20 mA
EU5E-SWD-4PT	4 temperature inputs PT100, PT1000, Ni1000

The modules are fitted directly on the top-hat rail and then connected with the SWD communication cable via the SWD device plug.

The modules can be fitted directly in the proximity of the sensors/actuators to be connected. This also reduces the remaining wiring required.

The following applications are possible:

- Connection of AC contactors or high rated contactors > DILM32 that do not have a connection option for the DIL-SWD-... module. For this use the EU5E-SWD-4D2R module.
- Connection of auxiliary contacts to modules with digital inputs
- Connection of digital actuators without integrated SWD functionality (signal lights, timing relays ...)
- Connection of any analog inputs/outputs



① SmartWire-DT cable with external device plug

② SmartWire-DT diagnostics LED

③ Status display of inputs and outputs (optional)

④ Input/output terminals

⑤ External supply (optional)

Notes

Safety-related applications

For most applications, disconnection in the event of an emergency or the disconnection by the opening of the protective doors is also required in addition to normal operational switching.

The SmartWire-DT system is not designed for the transfer of safety relevant signals. Using the configuration described below, the SmartWire-DT system can however be used for safety relevant switch offs.

In an emergency the control voltage for the contactor coils can be switched off via the enabling paths of the safety relay. By using additional SmartWire-DT Power modules, contactor groups are made that can be switched off together in an emergency. This type of circuit can be used to create control systems up to PL c in accordance with EN ISO 13849-1 (PL = Performance Level). The safety relay in this example must be PL c or higher (e. g. ESR5-NO-41-24VAC-DC).

→Figure, page 2-26

Feedback circuit

The auxiliary contact integrated in the contactor is a mirror contact according to IEC/EC 60947-4-1. Using this contact the state of the main contacts can be reliably signalled. The mirror contact can be included into the feedback circuit of the safety relay so that the safety relay only gives a new enable signal when the contactor is open.

Measures for higher safety category

In many applications control systems with a performance level of PL d or PL e (PL = Performance Level) to EN ISO 13849-1 are required. Control systems with PL d can be set up using an additional group contactor which is connected in series upstream of the motor feeders. The control voltage for the motor contactors as well as for the group contactor is switched off in an emergency via the safety relay. This redundant disconnection circuit enables the implementation of PL d control systems. The safety relay used must comply with PL d or higher to achieve this safety category (e. g. ESR5-NO-31-24VAC-DC).

Further information on safety engineering for machines and plants is provided in the Eaton Safety Manual: Eaton.com/shb

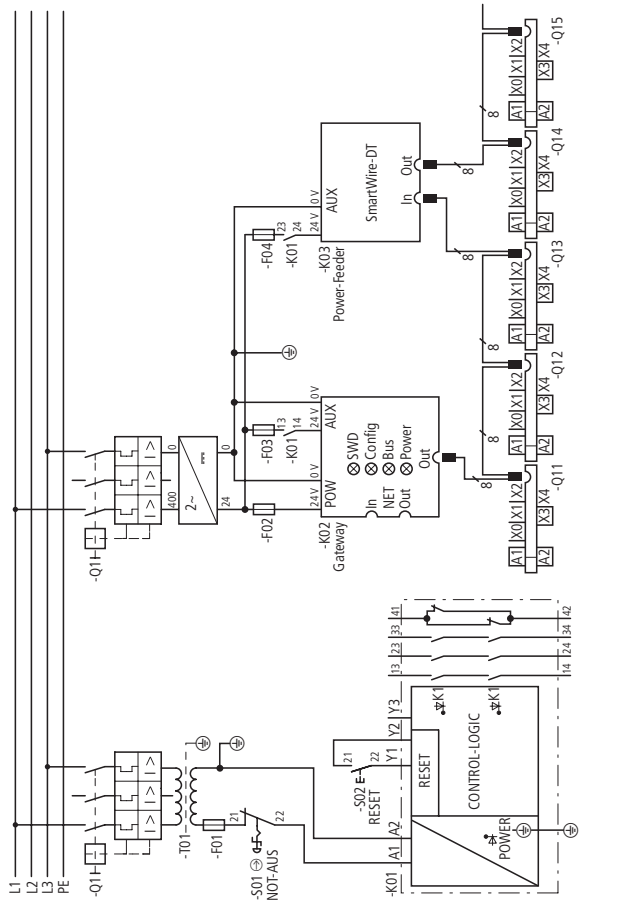
→Section „The way to a safe machine", page 0-12

→Section „Electrical equipment of machines", page 10-21

Switching, control, visualization

SmartWire-DT communication system

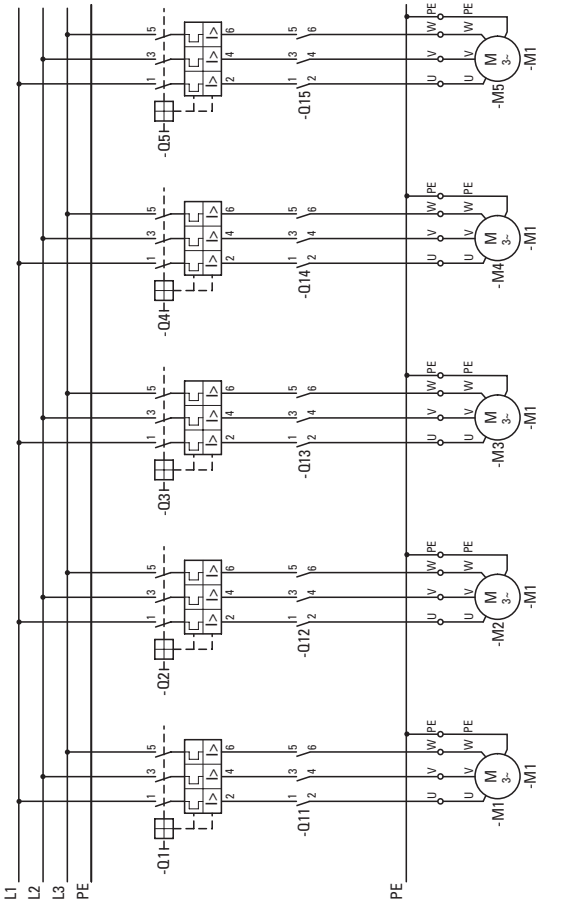
Actuating circuit for safety relevant application



Switching, control, visualization

SmartWire-DT communication system

Mains circuit for safety relevant application



Switching, control, visualization
Timing relays ETR

Electronic timing relays are used in contactor control systems which require short reset times, high repetition accuracy, high operating frequency, and a long component lifespan. Times between 0.05 seconds and 100 hours can be easily selected and set.

The switching capacity of electronic timing relays complies with the utilization categories AC-15 and DC-13.

In terms of the actuating voltages there are with timing relays the following differences:

- **ETR4 Version A**
  Universal devices:
  DC 24 to 240 V
  AC 24 to 240 V, 50/60 Hz
- **ETR4 Version W**
  AC devices:
  AC 346 to 440 V, 50/60 Hz
- **ETR2...** (as modular installation device to DIN 43880)
  Universal devices:
  DC 24 to 48 V
  AC 24 to 240 V, 50/60 Hz
  (ETR2-69-D: 12 to 240 V, 50/60 Hz)

The functions of each of the timing relays are as follows:

- ETR4-11,ETR2-11
  Function 11 (on-delayed)
- ETR2-12
  Function 12 (off-delayed)
- ETR2-21
  Function 21 (fleeting contact on energization)
- ETR2-42
  Function 42 (flashing, pulse initiating)
- ETR2-44
  Function 44 (flashing, two speeds, can be set to either pulse initiating or pause initiating)
- Multifunction relay ETR 4-69/70
  Function 11 (on-delayed)
  Function 12 (off-delayed)
  Function 16 (on- and off-delayed)
  Function 21 (fleeting contact on energization)
  Function 22 (fleeting contact on de-energization)
  Function 42 (flashing, pulse initiating)
- **Function 81** (pulse generating)
  Function 82 (pulse shaping)
  ON, OFF
- Multifunction relay ETR2-69(-D)
  Function 11 (on-delayed)
  Function 12 (off-delayed)
  Function 21 (fleeting contact on energization)
  Function 22 (fleeting contact on de-energization)
  Function 42 (flashing, pulse initiating)
  Function 43 (flashing, pause initiating)
  Function 82 (pulse initiating)
- Star-delta timing relays ETR4-51
  Function 51 (on-delayed)

With ETR4-70 an external potentiometer can be connected. Upon connection, both timing relays automatically recognize that a potentiometer is fitted.

The ETR4-70 has a special feature. Equipped with two changeover contacts which can be converted to two timing contacts 15-18 and 25-28 (A2-X1 linked) or one timing contact 15-18 and a non-delayed contact 21-24 (A2-X1 not linked). If the link A2-X1 is removed, only the timed contact 15-18 carries out the functions described below.

Switching, control, visualization
Timing relays ETR

Function 11

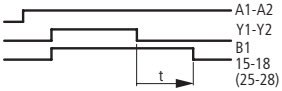
On-delayed

The actuating voltage U_s is applied via an actuating contact to the terminals A1 and A2.

After the set delay time the changeover contact of the output relay goes to the position 15-18 (25-28).

Function 12

Off-delayed

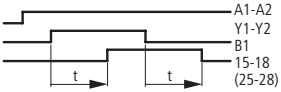


After the supply voltage has been applied to the terminals A1 and A2, the changeover contact of the output relay remains in the original position 15-16 (25-26). If a potential is applied to B1, the changeover contact changes without delay to the position 15-18 (25-28).

If B1 is separated from the potential, once the set time has elapsed, the changeover contact returns to it´s original position 15-16 (25-26).

Function 16

On- and Off-delayed

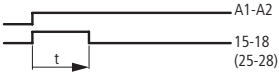


The supply voltage Us is applied directly to the terminals A1 and A2. If a potential is applied to B1, after a set time t the changeover contact goes to the position 15-18 (25-28).

If B1 is separated from the potential, the changeover contact goes back to it´s original position 15-16 (25-26) after the same time t.

Function 21

Fleeting contact on energization

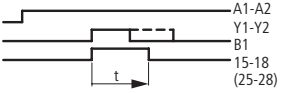


After the voltage U_s has been applied to A1 and A2, the changeover contact of the output relay goes to position 15-18 (25-28) and remains actuated for as long as the set fleeting contact time.

A fleeting pulse (terminals 1-2, 15-18) of defined duration is therefore produced from a two-wire control process (voltage on A25/A28) by this function.

Function 82

Pulse shaping

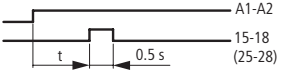


After the supply voltage has been applied to A1 and A2, the changeover contact of the output relay remains in the rest position 15-16 (25-26). If a potential is applied to B1, the changeover contact changes without delay to the position 15-18 (25-28).

If B1 is kept with the potential, the changeover contact remains actuated until the set time has elapsed. If B1 is separated from the potential for longer, the output relay likewise changes back to its rest position after the set time. An output pulse of precisely defined duration is thus produced in the pulse shaping function, irrespective of whether the input pulse via B1 is shorter or longer than the set time.

Function 81

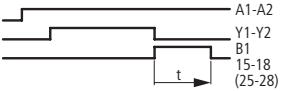
Pulse generating with fixed pulse



The actuating voltage is applied to the terminals A1 and A2 via an actuating contact. After the set delay time has elapsed the changeover contact of the output relay goes to position 15-18 (25-28) and returns to it´s original position 15-16 (25-26) after 0.5 seconds. This function is therefore a fleeting pulse with a time delay.

Function 22

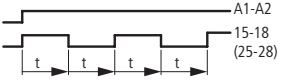
Fleeting contact on de-energization



The supply voltage Us is present directly at A1 and A2. If the contact B1 on ETR4-69/70 or ETR2-69 becomes potential-free again, the contact 15-18 (25-28) closes for the duration of the set time.

Function 42

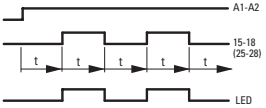
Flashing, pulse initiating



After the voltage Us has been applied to A1 and A2, the changeover contact of the output relay changes to position 15-18 (25-28) and remains actuated for as long as the set flashing time. The subsequent pause duration corresponds to the flashing time.

Function 43

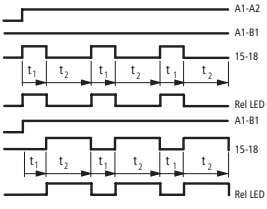
Flashing, pause initiated



After the voltage Us has been applied to A1 and A2 the changeover contact of the output relay stays in position 15-16 for the set flashing time and after the duration of this time goes to position 15-18 (the cycle begins with a pause phase).

Function 44

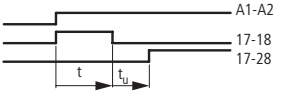
Flashing, two speeds



After the voltage Us has been applied to A1 and A2 the changeover contact of the output relay goes to position 15-18 (pulse initiating). By bridging the contacts A1 and Y1 the relay can be switched to pause initiating. The times t_1 and t_2 can be set to different times.

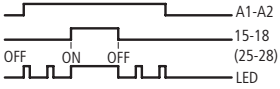
Function 51 Star-delta

On-delayed



If the actuating voltage U_c is applied to A1 and A2, the instantaneous contact switches to position 17-18. After the set time duration the instantaneous contact opens, the timing contact 17-28 closes after a changeover time t_u of 50 ms.

On-Off Function



The On-Off function allows the operation of a control system to be tested and is an aid for example for commissioning. The Off function allows the output relay to be de-energized and it no longer reacts to the function sequence. The On function energizes the output relay. This function is dependent on the supply voltage being applied to the terminals A1/A2. The LED indicates the operating state.

Further information sources

- Instruction Leaflets for download under: Eaton.com/documentation →Keywords: ETR4, ETR2
- Product range catalog "Easy measuring, reliable monitoring and flexible planning: the EMR, ETR and EMT relays"

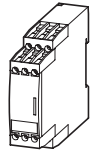
Switching, control, visualization
EMR6 measuring and monitoring relays

EMR6 measuring and monitoring relays protect machines and plants and help to prevent unscheduled downtime in production processes.

With the EMR6 range Eaton covers a large number of requirements:

- Suitable for universal use, thanks to multi-voltage power supplies
- Current monitoring relay EMR6-I... for the monitoring of over-current and under-current
- Voltage monitoring relay EMR6-V... for the monitoring of over-voltage and under-voltage
- Monitoring of phase failure and phase sequences in three-phase networks with EMR6-F...
- Protection against destruction or damage of single system parts, EMR6-W... phase monitoring relay
- Monitoring of phase failure and phase sequences and phase imbalance with EMR6-A...
- Monitoring of fill levels with the liquid level monitoring relay EMR6-N...
- Increase of the operational safety, EMR6-R... insulation monitoring relay
- EMR6-T... for monitoring machine temperatures

EMR6-I... Current monitoring relay



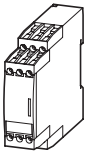
The EMR6-I... current monitoring relay is suitable for the monitoring of AC as well as DC current. E. g. Pumps and drill machines can be monitored for underload or overload. This is possible due to the selectable lower or upper threshold limit.

There are versions with three measuring ranges (30/100/1000 mA, 1.5/5/15 A). The multi-voltage coil allows universal use of the relay. Two output relays with changeover contacts provide flexible signal processing.

Selected bridging of short current peaks
By using the selectable response delay of between 0.1 and 30 seconds short current peaks can be bridged.

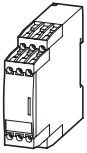
Switching, control, visualization
EMR6 measuring and monitoring relays

EMR6-V... Voltage monitoring relay



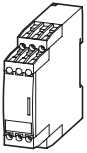
The EMR6-V... voltage monitors are used to monitor overvoltage and undervoltage. With EMR...-VF... a voltage window can also be set. Four measuring ranges for AC/DC between 3 V and 600 V are available. The true r.m.s. value measurement allows any waveform of the measurement signal, e. g., with DC between 15 Hz and 2 kHz. The adjustable release delay and the two output relays with change-over contacts offer a wide range of applications.

EMR6-T... Temperature monitoring relay



EMR6-T... temperature measuring relays are used to monitor the temperature on machines or in facilities. Under- or overtemperature or a temperature window can be set. One or two threshold values and the hysteresis are adjusted on the front. PT100 sensors are used to detect solid, liquid, and gaseous media. For example, it can be used to protect facilities and systems from overheating.

Phase monitoring relay EMR6-W...



The EMR6-W... phase monitoring relay monitors the voltage as well as the rotation field rotation. This provides protection from the destruction or damage of individual system parts. The minimum undervoltage and also the maximum overvoltage can be set here easily, within a defined range to the required voltage.

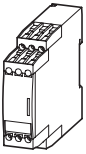
An on-delayed or off-delayed function can also be set. In the on-delayed position short voltage drops can be bridged. The off-delayed position allows for a fault storage for the set time.

The delay time can be set between 0.1 and 30 seconds.

The relay activates with the correct rotation field and voltage. After a drop-out the device does not reactive until the voltage exceeds a 5 % hysteresis.

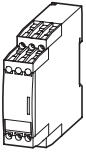
Switching, control, visualization
EMR6 measuring and monitoring relays

EMR6-F... phase sequence relay



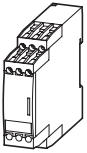
With only the 22.5 mm wide phase sequence relay, portable motors, with which the rotation direction is important (e. g. pumps, saws, drills), can be monitored for correct rotation. This provides space in the switchboard thanks to the narrow width and protection against damage due to the monitoring of the rotating field. With correct rotating field the changeover contact releases the control voltage of the motor switching device. The EMR6-F500-G-1 covers the total voltage range from 200 to 500 V AC.

EMR6-A... phase imbalance relay



The 22.5 mm wide EMR6-A... phase imbalance relay is the correct protection device against phase failure. The motor is then protected against destruction. As the phase failure is monitored on the basis of phase displacement, this can be detected even with a higher motor feedback and an overload of the motor can be prevented.

EMR6-N... liquid level monitoring relay



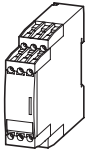
The EMR6-N... liquid level monitoring relay is used mostly as dry running protection for pumps or for the level regulation of liquids. It operates with sensors that measure conductivity of a medium. One sensor is required for the maximum level and one sensor for the minimum level. A third sensor is used for earth potential.

The 22.5 mm wide EMR6-N100 device is suitable for conductive liquids. It can be switched from level regulation to dry running protection. Safety is increased as in both cases the open-circuit principle is used.

The EMR6-N1000... liquid level monitoring relay has an increased sensitivity and is suitable for less conductive media. With the EMR6-N1000-A-1, moving liquids can also be monitored thanks to the selectable pick-up or drop-out delay of between 0.1 and 10 seconds.

Switching, control, visualization
EMR6 measuring and monitoring relays

EMR6-R... Insulation monitoring relay

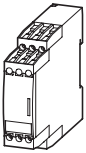


EMR6-R... insulation-monitoring relays are used to monitor insulation resistance and cable breakage in unearthed IT systems. A test or reset can be carried out using a built-in tact switch. The measuring range can be precisely adjusted between 1 - 100 kOhm. If the value falls below the set threshold value, the output relay will drop off.

Applications

- Monitoring of power networks in hospitals
- Monitoring of ship networks
- Monitoring the power supplies of crane systems

EMR6-AW(N)... multifunctional three-phase monitors



The multifunctional three-phase monitors provide the space saving monitoring of the rotation field with different functions. These measure the parameters of phase sequence, phase failure, phase imbalance as well as undervoltage and overvoltage.

The EMR6-AWN... variants also offer monitoring of the neutral conductor.

Depending on device type, the threshold value for phase imbalance can be set between 2 to 25 %. The threshold values for undervoltage and overvoltage are adjustable or permanently set.

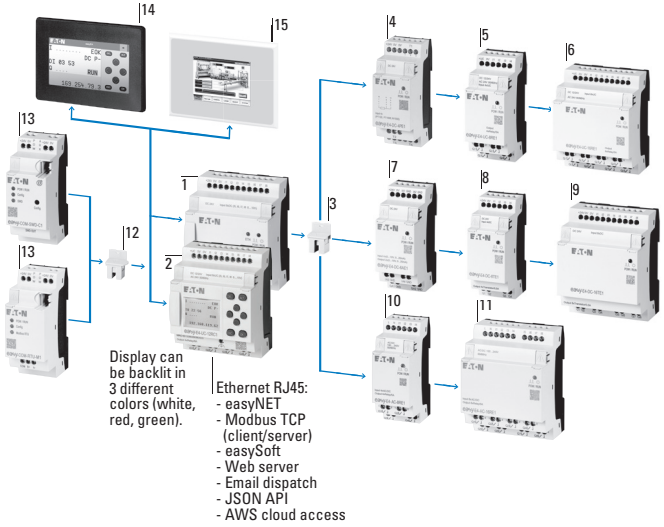
The different options and set values of the EMR6 measuring and monitoring relays are explained in the relevant Instruction Leaflets.

Further information sources

- Instruction Leaflets for download under: Eaton.com/documentation
  → Keyword for a search: EMR6
- Product range catalog “Easy measuring, reliable monitoring and flexible planning: the EMR, ETR and EMT relays”

Switching, control, visualization
Control relay easyE4

System overview easyE4



Max. 1 communication module + 1 base device + 11 expansion modules = max. 13 devices

Switching, control, visualization
Control relay easyE4

1 Control relay easyE4 without display
2 Control relay easyE4 with display
3 Plug connector for expansion modules
4 Expansion module, 4 inputs for temperature sensors
5 Expansion module UC, 8 inputs/outputs
6 Expansion module UC, 16 inputs/outputs
7 Expansion module DC, 6 analog inputs/outputs
8 Expansion module DC, 8 inputs/outputs
9 Expansion module DC, 16 inputs/outputs
10 Expansion module AC, 8 inputs/outputs
11 Expansion module AC, 16 inputs/outputs
12 Plug connector for communication modules
13 Communication module for easyE4 range (SmartWire-DT, Modbus RTU)
14 easy Remote Touch Display, resistive touch, 4.3"
15 XV-102 touch display for easyE4 devices, resistive touch, 3.5" and 5.7"

Switching, control, visualization
Control relay easyE4

More time for the really important things

Whether it's about temperature control in the food industry, simple control tasks in machine- building applications or lighting control in buildings – the easyE4, the next-generation control relay from the Eaton Moeller™ series, makes implementing control tasks even easier, more convenient and faster. Experience the many advantages of this new technology, which allows you to free up valuable time for what's really important.

Various display and visualization options are available

- using either the integrated display with the text display function block to show information,
- the easy Remote Touch Display in two versions: the standard version mirrors the display of the base unit and the advanced version let you create a visualization via easySoft,
- the HMI display of the XV100 series utilizing the powerful Galileo Software for performance visualizations.

The easyE4 comes with various communication options

- Either via the integrated Ethernet interface using Modbus TCP (as client or server) or via communication modules for SmartWire-DT coordinator and Modbus RTU (Master or Slave).
- Via the integrated JSON API interface automation systems can control or exchange data with the easyE4 → Section „JSON API", page 2-64
- The integrated web server can be used for visualization and control of the connected base unit.
- In addition, the web editor can be used to create user defined websites within easySoft which is then deployed to the easyE4 base device's integrated web-server. It can be called up using a web-browser from mobile or standard devices such as smart phones or laptops.
- A cloud connection to Amazon Web Services (AWS) can be set up using MQTT protocol to communicate to support powerful cloud-based applications.

easyE4 is a versatile system which offers extensive functions

- Four programming languages are available: the easy device programming (EDP), ladder diagram (LD), function block diagram (FBD) and structured text (ST).
- One easyE4 device can be expanded by means of one communication module and up to 11 I/O modules with 188 available inputs/outputs for maximum flexibility in line with your requirements.
- All AC, DC and UC expansions can be mixed and combined as required and used optional in the configuration.
- The virtually unlimited combination options of the easyE4 devices and the available expansion modules simplify handling.

The easyE4 supports you every step of the way

Starting with the planning phase, thanks to the optimized device selection process. Enjoy greater flexibility, more transparency and time savings that will allow you to devote yourself to other tasks.

Switching, control, visualization
Control relay easyE4

The multi-functional design simplifies planning. The easyE4 covers different control and regulation tasks in one device:

- Logic functions
- Timing relay and counter functions
- Timer functions
- Arithmetic functions
- PID controller
- Operating and display functions

Programming options that are suited to your needs

- The easyE4 offers flexible programming options, either via the easySoft software or directly on the device for simple applications using easy device programming (EDP).
- Programming the devices is highly user-friendly, thanks to the four available programming languages.
- Display texts, background colors and start graphics can be customized, for example using your company logo.

Everything at a glance during maintenance

Comprehensive maintenance overviews

- Remote visualization and access, for example via a smartphone or tablet.
- Easy data logging of operating states and evaluation of events.
- Simplified diagnostics and troubleshooting, for example with diagnostic status information.

Installation and commissioning made simple

- The number of inputs/outputs can be easily adjusted via expansion modules.
- The expansion modules are connected via an intelligent plug connector. All AC, DC and UC expansions can be mixed and combined as required and used optional in the configuration in different versions of machines.
- The expansion modules can be marked as optional in easySoft configuration.
- A micro SD card can be used to transfer the programming to new devices, which simplifies the commissioning of standardized machinery.
- The easyE4 devices can be wired using standard screw terminals or the time-saving Push-in terminal technology.

Quick and simple implementation during operation

The full advantages of this powerful control relay reveal themselves during operation:

- Rapid response times of less than 2 milliseconds using interrupt function.
- DCF77 synchronization for maximum accuracy in applications where time is critical.
- Rapid detection of the operating states of both the easyE4 and the expansion modules via the integrated display.
- Application-specific parameters can be manually adjusted directly on the device.

Visualization

The easyE4 also offers a variety of visualization options to optimally adapt the solution to your individual needs and requirements.

- The integrated display can be configured in easySoft using the text display function block to show text, values and bar graphs on the display of the easyE4 base unit.
- Thanks to the integrated web server, the data can also be accessed via any mobile device, such as smartphones or tablets.
- The web editor in easySoft can be used to create a JavaScript based website which can be deployed to the web server running on easyE4 base units to create a customer specific visualization which can be called up from any device which runs a standard web browser.

In addition, visualization via industrial displays is also possible:

easyE Remote Touch Display (RTD)

The Remote Touch Display is available in two versions: a standard version and an advanced version – both with a 4.3" screen.

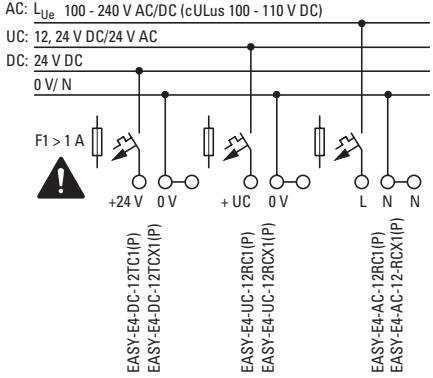
The standard version mirrors the contents of the easyE4 in color and can be used to operate the device – without any programming.

The advanced version can be programmed to deploy a customer specific visualization out of easySoft. It can utilize many different graphic elements to create a visualization according to your needs.

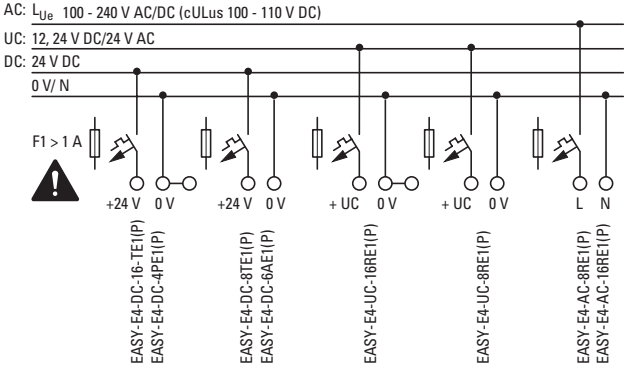
Switching, control, visualization
Control relay easyE4

Connecting the power supply

Base devices



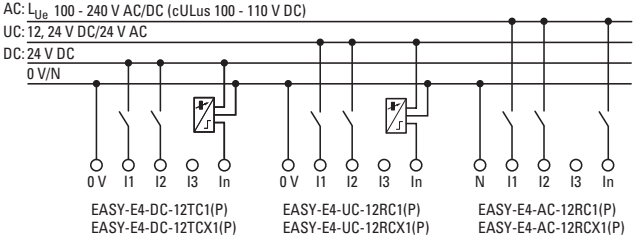
Expansion modules



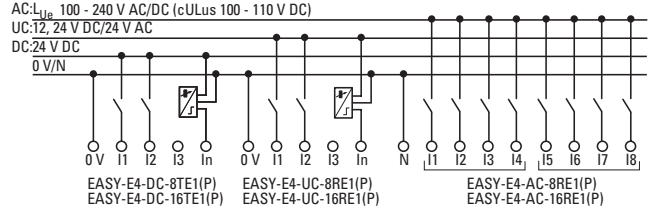
2

Connecting the digital inputs

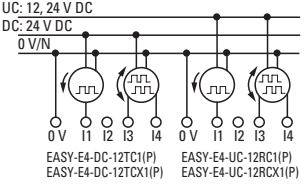
Base devices



Expansion modules



Connecting the digital counter inputs



Only possible with base devices

Base devices with DC and UC voltage come with special counting and measuring functions on inputs I1 to I4.

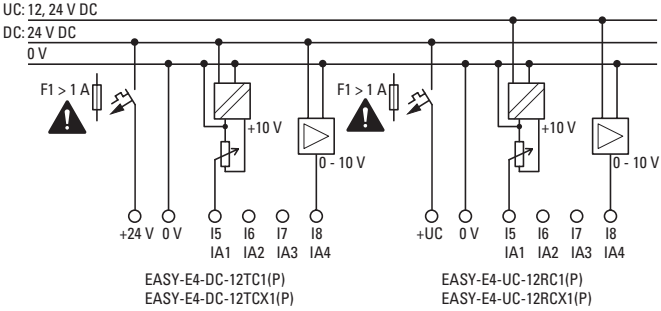
These functions are connected directly to function blocks.

The following applies to EASY-E4-UC-...:
The voltage supplied to the EASY-E4-UC-... must be a DC voltage, since only DC signals will be processed.

You can process the following:

- 4 individual high-speed counter signals (one single counting direction), I1, I2, I3, I4
- 2 incremental counters, I1, I2 and I3, I4
- Frequencies I1, I2, I3, I4

Connecting the analog inputs



Only possible with base devices.

Base devices with DC and UC voltage can read analog voltages within a range of 0 to 10 V via inputs I5, I6, I7, and I8 on the EASY-E4-... base device. The input impedance of the analog inputs is 13.3 kΩ.

The signal has a 12 bit resolution, value range 0 - 4095.

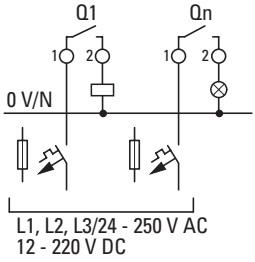
The following applies:

- Input I5 = IA01
- Input I6 = IA02
- Input I7 = IA03
- Input I8 = IA04
- The analog voltage inputs can also be used as digital inputs.

Danger!

Analog signals are more sensitive to interference than digital signals. Consequently, greater care must be taken when laying and connecting the signal lines. The measures described below must be adhered to in order to prevent any deviations in analog values. An incorrect connection can lead to unwanted switching states.

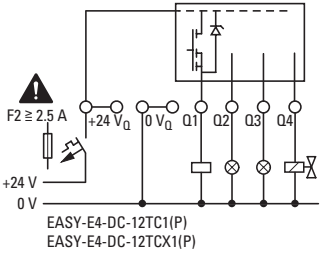
Connecting the relay outputs



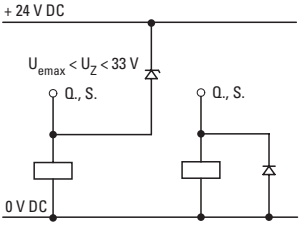
2

Connecting the transistor outputs

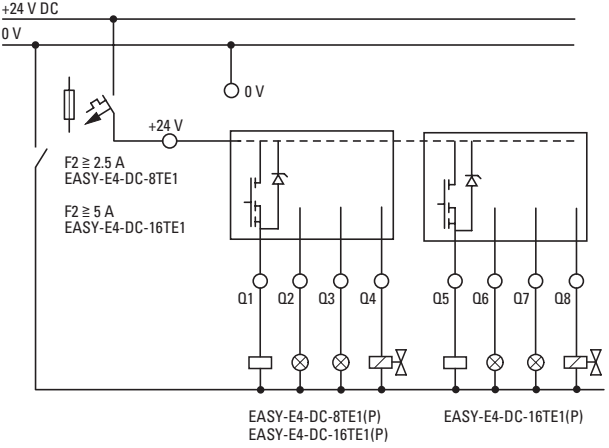
Base devices



Inductive load with suppressor circuit



Expansion modules

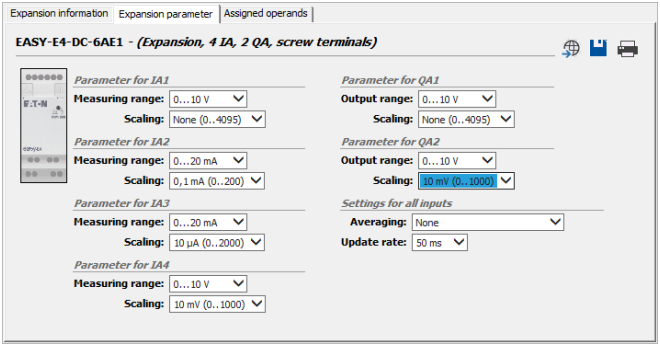


Connecting analog I/O expansion modules

The analog inputs in expansion EASY-E4-DC-6AE1(P) cannot be used as digital inputs. The EASY-E4-DC-6AE1(P) features four analog inputs and two analog outputs. You can use easySoft 8 or higher to set the operating mode for each analog input and analog output.

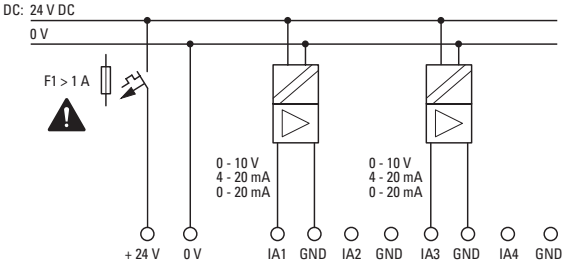
Example with EASY-E4-DC-6AE1

- Device parameters tab

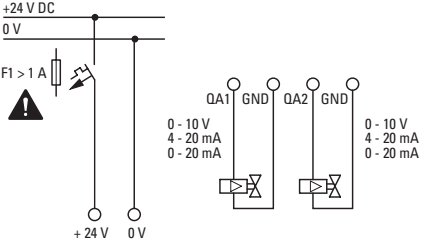


Switching, control, visualization
Control relay easyE4

- Connecting analog inputs EASY-E4-DC-6AE1



- Connecting analog outputs EASY-E4-DC-6AE1



The following options are available:

Resolution analog	Resolution digital	Value
0 - 10 V	12 bit	0 - 4095
4 - 20 mA	12 bit	819 - 4095
0 - 20 mA	12 bit	0 - 4095

For all analog inputs, you can configure noise suppression, averaging, and an update rate in easySoft 8 or higher.

In addition to the specifications in the data sheet, the following applies to EASY-E4-DC-6AE1(P):

	Voltage	12 122 kΩ
	Current	≦ 300 Ω
Voltage output	max. current	10 mA (Load resistance ≧ 1000 Ω)
Current output	Load resistance	≦ 600 Ω

Connecting analog inputs with temperature measuring on expansion modules

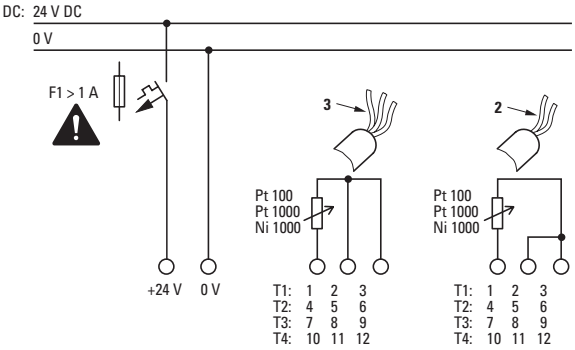
Temperature inputs cannot be used as digital inputs.

The EASY-E4-DC-4PE1(P) analog input expansion features four (4) analog RTD inputs that can be used to integrate Pt100, Pt1000, or Ni1000 temperature sensors.

The Pt100, Pt1000, or Ni1000 inputs are suitable for 2-wire and 3-wire connections. In addition, unshielded or shielded cables with a length of up 30 m can be used for the connection. Finally, averaging for temperature readings can be set up.

When connecting temperature sensors, make sure to use the right configuration depending on whether you are using a 2-wire or 3-wire connection. If the temperature sensors are connected using a 2-wire connection, the corresponding input terminals must be connected to each other, i. e., input terminals 2 and 3 for T1, input terminals 5 and 6 for T2, input terminals 8 and 9 for T3, and input terminals 11 and 12 for T4.

When inputs on an EASY-E4-DC-4PE1(P) are not used, all three input terminals must be connected to each other.



easySoft 8 or higher is required in order to be able to configure the connected RTD sensors. The temperature sensor connections determine which inputs will be used. Up to four different RTD sensors of type Pt100, Pt1000, or Ni1000 with an individual temperature range can be connected to each EASY-E4-DC-4PE1(P) expansion device. Inputs that do not have a sensor connected to them will be "undefined".

Temperature range	Sensor style	Temperature values
1	Pt100/Pt1000	-100 up to +200 °C (-148 up to +392 °F)
2	Pt100/Pt1000	-100 up to +400 °C (-148 up to +752 °F)
3	Pt100/Pt1000	-100 up to +800 °C (-148 up to +1472 °F)
1	Ni1000	-50 up to +100 °C (-58 up to +212 °F)
2	Ni1000	-50 up to +250 °C (-58 up to +482 °F)

By default, all inputs will be undefined and accordingly will be switched off. The temperature ranges for the EASY-E4-DC-4PE1(P) depend on the selected sensor.

Values will be represented as a signed decimal with the following resolution (with the specifics depending on the selected format):

Sensor style	Indicated value at selected representation Degrees Celsius		Nonlinear value
	1/10	1	
Pt100/Pt1000	-1000 up to +2000 °C	-100 up to +200 °C	0 - 4095
Pt100/Pt1000	-1000 up to +4000 °C	-100 up to +400 °C	0 - 4095
Pt100/Pt1000	-1000 up to +8000 °C	-100 up to +800 °C	0 - 4095
Ni1000	-500 up to +1000 °C	-50 up to +100 °C	0 - 4095
Ni1000	-500 up to +2500 °C	-50 up to +250 °C	0 - 4095

Sensor style	Indicated value at selected representation Degrees Fahrenheit		Nonlinear value
	1/10	1	
Pt100/Pt1000	-1480 up to +3920 °F	-148 up to +392 °F	0 - 4095
Pt100/Pt1000	-1480 up to +7520 °F	-148 up to +752 °F	0 - 4095
Pt100/Pt1000	-1480 up to +14720 °F	-148 up to +1472 °F	0 - 4095
Ni1000	-580 up to +2120 °F	-58 up to +212 °F	0 - 4095
Ni1000	-580 up to +4820 °F	-58 up to +482 °F	0 - 4095

The selected scaling and update settings will apply to all the temperature inputs in the corresponding module.

The scaling and the unit (Celsius, Fahrenheit) can be selected for inputs T1 through T4. If no scaling is specified, the corresponding raw value will be given with a 12-bit resolution (dimensionless, 0 - 4095).

Sampling time for all inputs being used:

- 250 ms (no averaging)
- 1 s (averaging over 4 measuring cycles)
- 2.5 s (averaging over 10 measuring cycles)
- 10 s (averaging over 40 measuring cycles)

As soon as the device is switched on, the temperature will be measured and transmitted by all active sensors. However, the reading will not be averaged until after the set sampling time.

The expansion module features a DIAG output for function monitoring and diagnostic purposes. This means that each temperature input can be individually mapped to an operand within a range of ID25 to ID96.

Designation	Event
DIAG	General diagnostic indicating that a diagnostic event is present.
DIAG1	Configured measuring range exceeded at at least one temperature input, or connection cable discontinuity.
DIAG2	Configured measuring range fallen below at at least one temperature input, or a short-circuit has occurred.
T1	<Mapped operand>
T2	<Mapped operand>
T3	<Mapped operand>
T4	<Mapped operand>

The temperature module will write to the easyE4 base device's diagnostic buffer.

Switching, control, visualization
Control relay easyE4

Terminal assignment for individual devices

Base devices

EASY-E4-UC-12RC1(P), EASY-E4-UC-12RCX1(P)

Power supply +UC 0V 0V

Input	I1	I2	I3	I4	I5	I6	I7	I8
Output	Q1/1	Q1/2	Q2/1	Q2/2	Q3/1	Q3/2	Q4/1	Q4/2

EASY-E4-DC-12TC1(P),EASY-E4-DC-12TCX1(P)

Power supply +24V 0V 0V

Input	I1	I2	I3	I4	I5	I6	I7	I8
Power supply +24VQ +24VQ 0V 0V								
Output	Q1	Q2	Q3	Q4				

EASY-E4-AC-12RC1(P), EASY-E4-AC-12RCX1(P)

Power supply L N N

Input	I1	I2	I3	I4	I5	I6	I7	I8
Output	Q1/1	Q1/2	Q2/1	Q2/2	Q3/1	Q3/2	Q4/1	Q4/2

Expansions

UC input expansions with relay outputs

EASY-E4-UC-16RE1(P)

Power supply +UC 0V 0V

Input	I1	I2	I3	I4	I5	I6	I7	I8
Output	Q1/1	Q1/2	Q2/1	Q2/2	Q3/1	Q3/2	Q4/1	Q4/2
Output	Q5/1	Q5/2	Q6/1	Q6/2	Q7/1	Q7/2	Q8/1	Q8/2

EASY-E4-UC-8RE1(P)

Power supply +UC 0V

Input	I1	I2	I3	I4
Output	Q1/1	Q1/2	Q2/1	Q2/2
Output	Q3/1	Q3/2	Q4/1	Q4/2

DC input expansions with transistor outputs

EASY-E4-DC-8TE1(P)
Power supply +24V 0V

Input	I1	I2	I3	I4
Output	Q1	Q2	Q3	Q4

EASY-E4-DC-16TE1(P)
Power supply +24V 0V 0V

Input	I1	I2	I3	I4	I5	I6	I7	I8
Output	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8

AC input expansions with relay outputs

EASY-E4-AC-8RE1(P)
Power supply L N

Input	I1	I2	I3	I4
Output	Q1/1	Q1/2	Q2/1	Q2/2
Output	Q5/1	Q5/2	Q6/1	Q6/2

EASY-E4-AC-16RE1(P)
Power supply L N

Input	I1	I2	I3	I4	I5	I6	I7	I8
Output	Q1/1	Q1/2	Q2/1	Q2/2	Q3/1	Q3/2	Q4/1	Q4/2
Output	Q5/1	Q5/2	Q6/1	Q6/2	Q7/1	Q7/2	Q8/1	Q8/2

Analog input expansion

EASY-E4-DC-6AE1(P)
Power supply +24V 0V

Input	IA1	GND	IA2	GND
Input	IA3	GND	IA4	GND
Output	QA1	GND	QA2	GND

Analog input expansion with temperature measuring

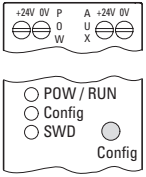
EASY-E4-DC-4PE1(P)
Power supply +24V 0V 0V

Input	IA1-1	IA1-2	IA1-3			
Input	IA2-4	IA2-5	IA2-6			
Output	IA3-7	IA3-8	IA3-9	IA4-10	IA4-11	IA4-12

Switching, control, visualization
Control relay easyE4

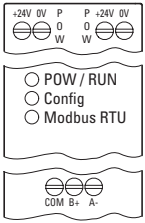
Terminal assignment for easyE4 communication modules

EASY-COM-SWD-...



POW	Supply voltage
+24V	U_{POW} = +24 V DC
0V	U_{POW} = 0 V
AUX	**Supply voltage**
+24V	U_{AUX} = +24 V DC
0V	U_{AUX} = 0 V

EASY-COM-RTU-...



POW	Supply voltage
+24V	U_{POW} = +24 V DC
0V	U_{POW} = 0 V

Assignment	Description
RS485 COM	Modbus RTU Common
B+	Modbus RTU+ (D1*)
A-	Modbus RTU- (D0*)

* D1 and DO are the designators in conformity with modbus.org as defined in the following documents:

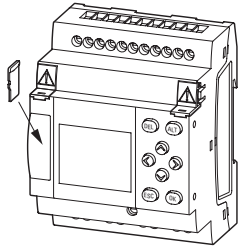
- MODBUS over serial line specification and implementation guide
- MODBUS application protocol specification

MicroSD card

The microSD card can be used for:

- Programming many devices in series
- Log data from datalogger function block
- Update the firmware of base unit and extension modules

It's located at the front of the base unit where the SD card slot can be pulled out and the microSD card can be inserted or removed.



Ethernet Port

Every easyE4 base device features an Ethernet port.
This Ethernet port is a Cat 5 port.

Make sure to use compatible standard RJ45 Ethernet cables only.

The Ethernet port on the base device serves as a communication interface.

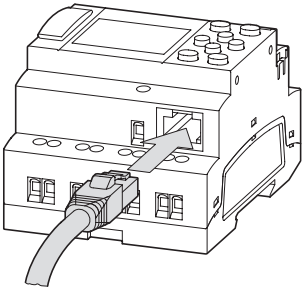
The Ethernet controllers support transfer rates of 10 Mbit/s and 100 Mbit/s.

If you integrate the EASY-E4-... into an Ethernet network, you will need to connect the functional earth to the corresponding terminal.

To commission the communications between the EASY-E4-... control relay and the device to which the Ethernet cable is connected, follow the description for the connected device.

New easyE4 base devices will come with the AUTO IP setting configured by default. In order to configure the settings differently on the EASY-E4-...-12...C1(P)

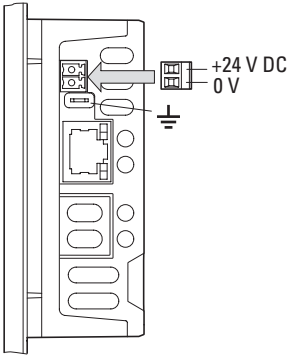
- use the menu structure and go to System Options\Ethernet on the device or
- use the Ethernet settings of easySoft to configure the Ethernet settings with a program download to the device.

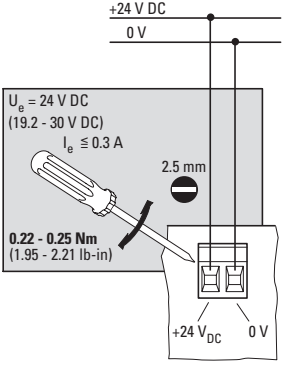


Switching, control, visualization
Control relay easyE4

Remote Touch Display

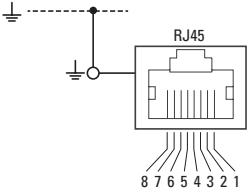
Power supply





7 mm (0.28“)	AWG28 - AWG16 ≧ 60 °C Cu wire only
	0.25 - 0.5 mm²
	0.25 - 1.5 mm²
	0.14 - 1.5 mm²
	0.14 - 1.5 mm²

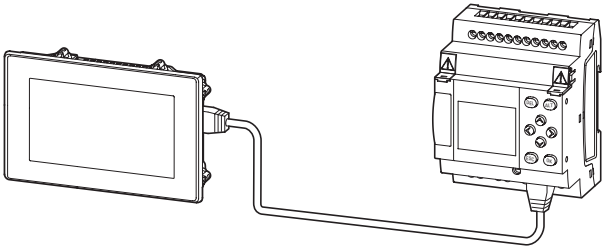
Ethernet



Pin	Ethernet 10/100 MBit
8	–
7	–
6	Rx -
5	–
4	–
3	Rx +
2	Tx -
1	Tx +

Switching, control, visualization
Control relay easyE4

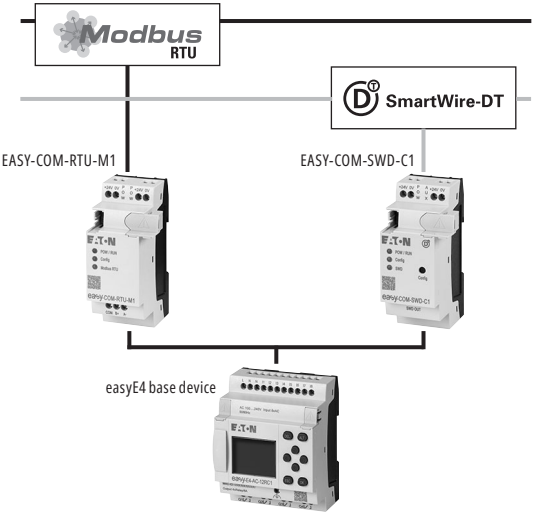
Firmware



	easyE RTD Standard	easyE RTD Advanced
Firmware easyE4	≧ 1.30	≧ 2.10
Auto-IP	✓	✓

Switching, control, visualization
Control relay easyE4

Expansion modules for networking



Modbus RTU

Use the control relay as a Modbus RTU master or slave

- Quick and simple implementation of industrial networks.
- The communication module is easy to connect to the base device using the plug connector.
- Configuration is carried out using easySoft 8 or higher.
- Transmit data even over cable lengths of several hundred meters.

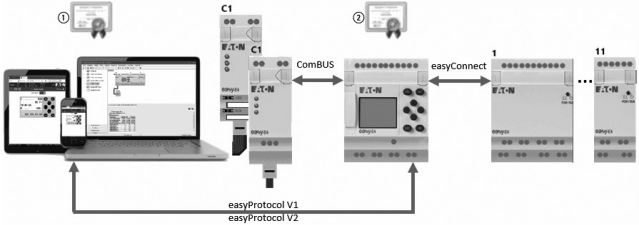
SmartWire-DT

Create an intelligent system with SmartWire-DT

- Monitoring motor frequencies and power measurements allows deviations to be detected early on to help prevent failures.
- Thanks to the availability of diagnostic information for each component, application errors can be quickly located.
- Parameters such as threshold and desired values for the SWD modules can be easily configured and adjusted using the easyE4 or the integrated secure web server.

Switching, control, visualization
Control relay easyE4

Communication connections easyE4 to other devices



① Eaton easyE4 root certificate
② easyE4 device certificate

The easyE4 base device has various interfaces for communication.

- easyConnect is the interface to the digital and analog expansions.
- ComBUS is the interface to the communication modules, such as EASY-COM-SWD-C1, EASY-COM-RTU-M1.

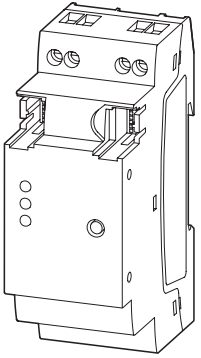
The protocols for both interfaces are proprietary.

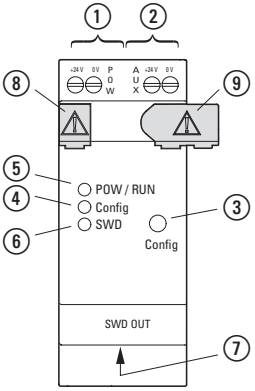
The Ethernet interface on the easyE4 base device can be used for various purposes. The following scenarios are contemplated:

If you want to establish a secure connection to the easyE4 base device through easySoft, a web browser, or the JSON API but are only getting the option of using non-secure connections, make sure that the device time on the easyE4 base device is up to date. If the device time is not up to date, this can result in problems with the certificate check when attempting to establish a connection.

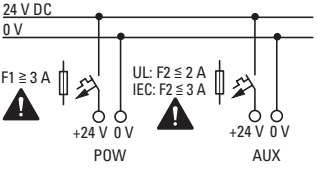
What is communication used for?	Ethernet interface with the following higher protocols	Request certificate
easyE4 programming interface	easyProtocol V1	–
	easyProtocol V2 SSL/TLS	x
	easyProtocol V2 (not encrypted)	–
easyE4 as web server	http	–
	https	x
JSON API	http	–
	https	x

Connection EASY-COM-SWD-...



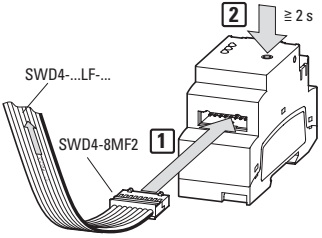


Supply voltage

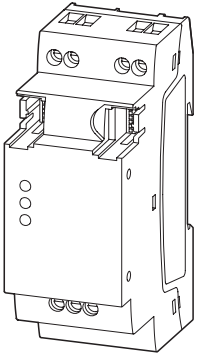


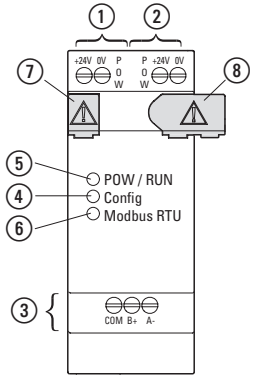
1. Power supply POW
2. Power supply AUX
3. ButtonConfig
4. LED Config
5. LED POW/RUN
6. LED SWD
7. SWD OUT connection socket
8. Covering cab
9. Bus connector plug

Connecting SWD flat cable

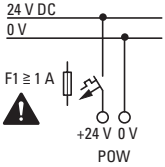


Connection EASY-COM-RTU-...



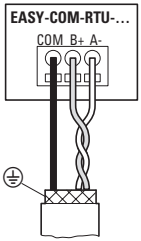


Supply voltage



1. Power supply POW left
2. Power supply POW right
3. Modbus RTU terminals: COM, B+, A
4. LED Config
5. LED POW/RUN
6. LED Modbus RTU
7. Covering cab (for easyE4 connection)
8. Bus connector plug

Connecting outputs



Switching, control, visualization
Control relay easyE4

easySoft 8 or higher

Simple, intuitive and convenient

With the user-friendly easySoft software, programming the easyE4 family is quick and easy. Circuit diagrams can be easily created and adapted via a PC or directly on the device. The easy-to-navigate selection menus, as well as the simulation, online communication and documentation options, make easySoft the ideal programming tool for the easyE4 devices. Four different programming languages are available (EDP, LD, FBD, ST) – easyE4 offers the right programming environment for all needs.

General

- Offers four programming languages: EDP, FBS, KOP, and ST
- Pre-set analytics functions allow for quick commissioning
- The multi-level password protection protects your application and process know-how against unauthorized access.
- Unique IDs for each easyE4 and program ensure that the correct programs are uploaded to your hardware (pairing).
- User functions blocks (UFB) inclusive know-how protection
- Program size only limited by device memory
- Syntax check function incl. help system
- 44 predefined manufacturer function blocks
- No variable declaration necessary, runs on Windows 10 and newer versions.

Communication/Simulation

- Line synchrony value commissioning
- The acquisition of the status data will be carried out at the time of processing and not after program cycle change.
- Time simulation functions
- Stop points/Single step mode and breakpoints
- Operand windows and oscilloscope view
- Free configurable operand list, status display in one window
- Display simulation (inclusive Remote display functionality)
- Auto detection of networked devices

Commissioning functions

- Wiring test
- Numeric value changing in RUN mode
- SD card manager
- Data logger export function to MS-Excel
- Flexible daylight saving time parameters
- Complete program upload from device
- Configure device networking via drag n'drop (*)
- Support for Modbus-TCP/RTU configuration
- Cybersecurity Configuration
- Configuration of email function

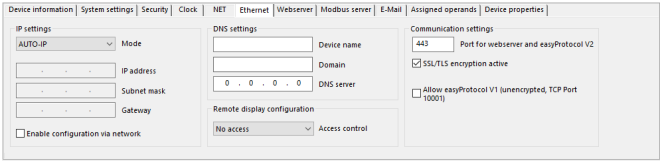
Web server

Using and setting up the web server

The web server offers added value to your easyE4 control relay through multiple use cases. On the one hand, the easyE4 web client offers an easy-to-learn user interface for the several online tasks which do not need a special training and can be used without easySoft. The web client is used from standard web browser and therefore perfectly compatible with mobile devices, laptops or PCs.

On the other hand, the JSON API offers a software interface based on web technologies to integrate the easyE4 into an external software system (e. g. building automation, IoT or a dedicated smartphone app).

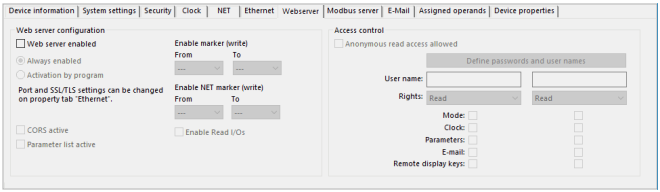
The web server needs to be configured in easySoft by opening the Project view and then going to the "Webserver" tab.



When this option is enabled, the web server passwords and user names dialog box will appear so that you can set up the corresponding users. If the option is disabled, all settings, passwords, and usernames will be reset.

☑ Web server enabled

For easySoft 8 and higher, the web server settings for encryption and the web server port can be found in the Ethernet tab.



We recommend activating encryption and install the easyE4 root certificate on the client systems connected to the easyE4 web server.

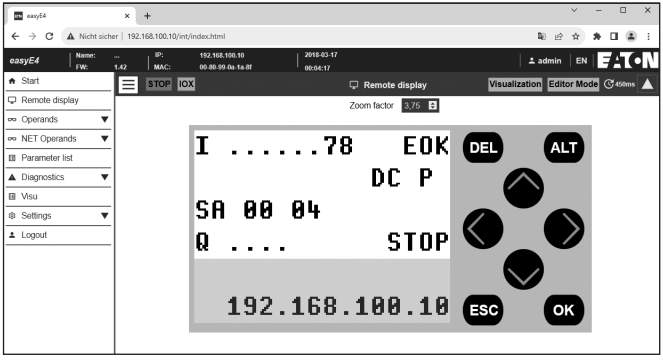
See also the "Product Cybersecurity Guideline easyE4" (MZ049001EN).

2

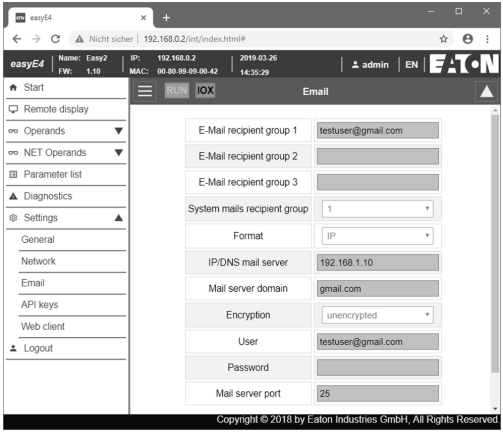
Web client as a simple user interface

The easyE4 web client offers the following main use cases:

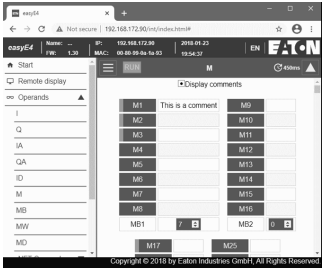
- Use the remote display of the web client to control your easyE4 without the need for direct physical access to the device. The remote display is also useful for devices without display (EASY-E4-...-12...CX1(P)).
- Change system parameters, e. g. email settings, network settings or system time, online. The access to these parameters can be controlled through the web server user management in the easySoft project.

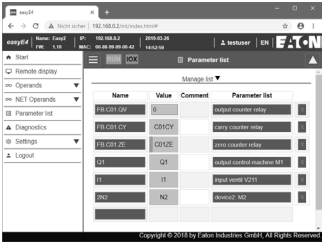


Switching, control, visualization
Control relay easyE4



Supervise the process controlled by easyE4 or change operand values online through the operand pages or the parameter list of the web client. Access rights to the operands can be controlled for the different web users in the user management settings in the easySoft project.





☑ Parameter list active

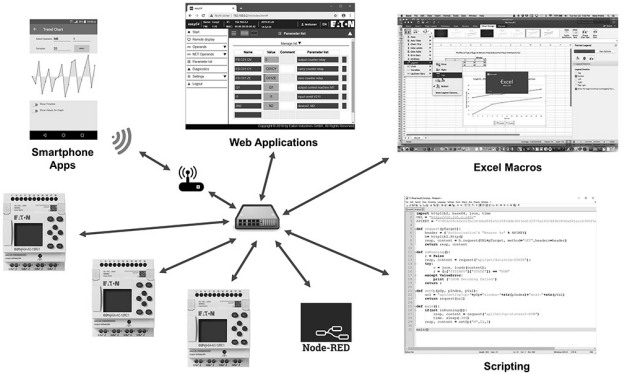
If this option is enabled, the parameter list menu option will be shown in the web client catalog. In this case, it will be able to put together a custom parameter list with operands in the web client. This will make monitoring and controlling the relevant operands significantly easier.

Switching, control, visualization
Control relay easyE4

JSON API

The JSON API is a programming interface which can be used to integrate one or several easyE4 in external software system like building automation systems, Microsoft Excel, IoT or a smartphone apps tailored to the process controlled by easyE4.

The JSON API is based on standard web technology (http, JSON) available in almost every modern programming language or environment.



A special use case of the JSON API is the easyE4 Node-RED plugin which can be used to integrate the easyE4 in a Node-RED based automation or IoT environment.

For details see Node-RED web page:
https://flows.nodered.org/node/node-red-contrib-eaton-easye4

The online documentation of the JSON API describes the proper http URLs to call specific API services and the format of the JSON response.

For details see
Eaton.com/easy-jsonapi

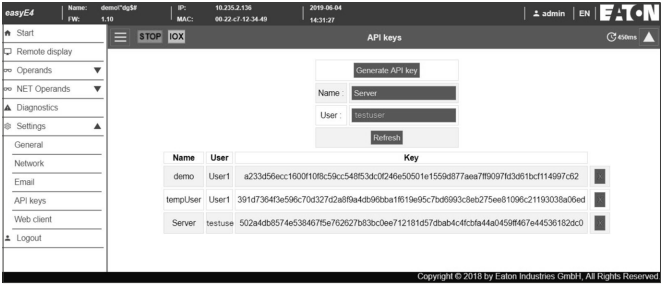
API keys

The JSON API online documentation explains several ways to authorize the client application with the easyE4 web server. It is recommended to utilize the authorization method “API keys”. To generate a new API key the web client offers a special view when logged in as user admin.

Web application and CORS

If one web application needs to connect to more than one web server at once then the cross-origin resource sharing (CORS) needs to be activated in the easySoft project settings in the “Webserver” tab.

☑ CORS active

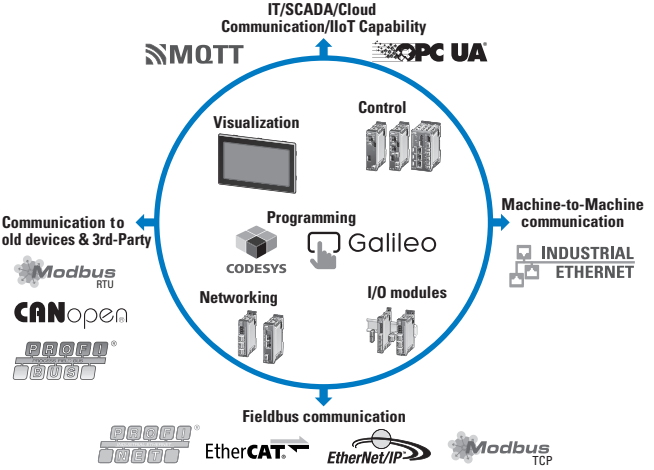


Further information

Video Tutorials easySoft

Switching, control, visualization
Modular PLC

System overview



Eaton's xSystem concept includes visualization devices, controllers, gateways, I/O modules and the CODESYS and GALILEO software tools for programming them. The modular concept and the support of standardized communication interfaces simplify the implementation of modern automation solutions and their integration into the existing infrastructure. Versatile web functionalities at the highest cyber security standard support the networking of value chains and decentralized access to the system.

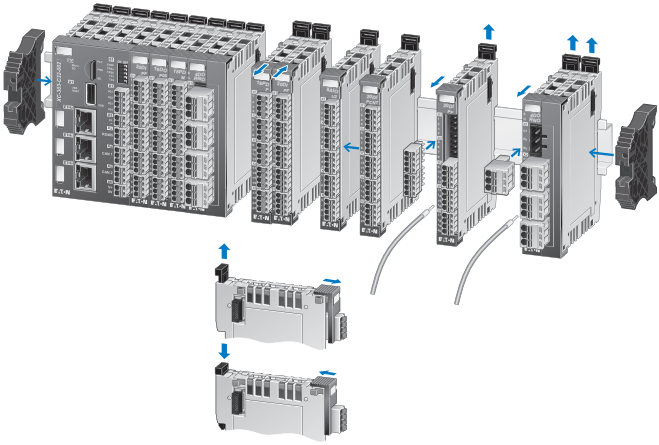
The local I/O level of the controllers and gateways can be set up modularly with the products of the XN300 I/O system and can thus be flexibly adapted and expanded to the requirements of the automation solution.

Switching, control, visualization
Modular PLC

XN I/O system

The I/O level of the controller can be assembled modular by the components of the XN300 I/O system. That way the control block can be adapted to the requirements of the machine to build an optimized solution in smallest space.

The XC devices include the CODESYS runtime and are to program by the engineering tool XSOFT-CODESYS-3. CODESYS programming has almost established itself as the standard due to its spread in open, industrial automation. Existing know-how and created programs are easily and quickly portable.



Switching, control, visualization
Modular PLC

XC100, XC200, XC300

XC100 modular PLCs

The **XC100** is perfect for implementing simple automation tasks with Ethernet-based networking. Expansion with up to six snap-on I/O modules of the XN300 system enables flexible system configurations. Simple control and regulation functions can be ideally implemented with the device and networked with higher levels.

Product features

Designation	XN300 ext.	Retain Data	RTC	USB	SD SLOT	ETH 1GB/100MB
XC-104-C10-100	6 modules	4 kB	√	√	-	-/1 x

Designation	WEB-Visu	OPC-UA	Ethernet/IP	Modbus TCP	EtherCAT
XC-104-C10-100	HTML5	Server	Scanner (MS)	Server/Client	-

Designation	CAN	CANopen	RS485	Modbus RTU
XC-104-C10-100	-	-	-	-

Switching, control, visualization
Modular PLC

XC200 modular PLCs

Standard automation tasks can be flexibly solved with the **XC200** control variants. The local I/O level can be configured with up to 16 I/O modules of the XN300 system. The separate Ethernet interfaces simplify operation in different networks and the integration of external devices with the standard serial interfaces.

Product features

Designation	XN300 ext.	Retain Data	RTC	USB	SD SLOT	ETH 1GB/100MB
XC-204-C20-002	16 modules	32 kB	√	√	-	-/2 x
XC-204-C21-001	16 modules	32 kB	√	√	-	-/2 x
XC-204-C11-003	16 modules	32 kB	√	√	-	-/1 x
XC-204-C10-000	16 modules	32 kB	√	√	-	-/1 x

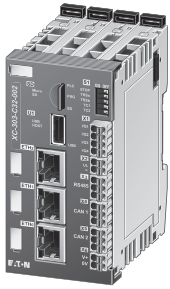
Designation	WEB-Visu	OPC-UA	Ethernet/IP	Modbus TCP	EtherCAT
XC-204-C20-002	HTML5	Server	Scanner (MS)	Server/Client	MS
XC-204-C21-001	HTML5	Server	Scanner (MS)	Server/Client	MS
XC-204-C11-003	HTML5	Server	Scanner (MS)	Server/Client	-
XC-204-C10-000	HTML5	Server	Scanner (MS)	Server/Client	-

Designation	CAN	CANopen	RS485	Modbus RTU
XC-204-C20-002	-	-	√	MS/SL
XC-204-C21-001	1 x	MS/SL	-	-
XC-204-C11-003	1 x	MS/SL	√	MS/SL
XC-204-C10-000	-	-	-	-

Switching, control, visualization
Modular PLC

XC300 modular PLCs

XC300 modular PLCs have comprehensive functions. The local I/O level can be configured with up to 32 snap-on I/O modules of the XN300 system. Ethernet interfaces for connection to different networks, and the standard CAN and RS485 interfaces allow the compact, powerful XC300 controller to be used flexibly in modular automation solutions as a central control and communication point.



Product features

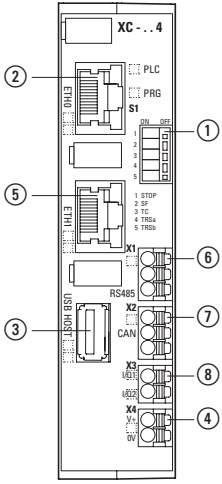
Designation	XN300 ext.	Retain Data	RTC	USB	SD SLOT	ETH 1GB/100MB
XC-303-C32-002	32 modules	128 kB	√	√	√	1 x/2 x
XC-303-C21-001	32 modules	128 kB	√	√	√	-/2 x
XC-303-C11-000	32 modules	128 kB	√	√	√	-/1 x

Designation	WEB-Visu	OPC-UA	Ethernet/IP	Modbus TCP	EtherCAT
XC-303-C32-002	HTML5	Server	Scanner (MS)	Server/Client	MS
XC-303-C21-001	HTML5	Server	Scanner (MS)	Server/Client	MS
XC-303-C11-000	HTML5	Server	Scanner (MS)	Server/Client	MS

Designation	CAN	CANopen	RS485	Modbus RTU
XC-303-C32-002	2 x	MS/SL	√	MS/SL
XC-303-C21-001	1 x	MS/SL	√	MS/SL
XC-303-C11-000	1 x	MS/SL	-	-

Switching, control, visualization
Modular PLC

XC100/XC200



Default setting

Interface	XC-204-...	XC-104-...
② ETH0	192.168.119.204	192.168.119.104
⑤ ETH1	DHCP	–

DIP switch S1 settings ①

	ON	OFF
STOP	PLC stops	PLC runs
SF	Special Function	–
TC	X4 (CAN termination)	–
TRSa, TRSb	X3 (RS485 termination)	–

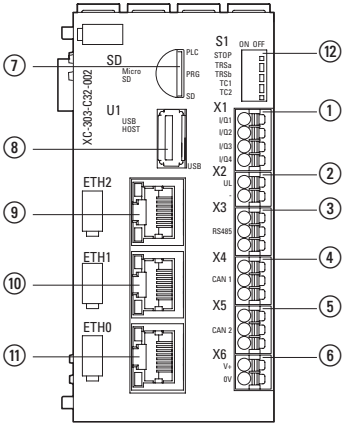
Switching, control, visualization
Modular PLC

Connections XC100/XC200

	XControl		XC-104-C10-...	XC-204-C10-...	XC-204-C11-...	XC-204-C20-...	XC-204-C21-...
①	S1						
	STOP		√	√	√	√	√
	SF		√	√	√	√	√
	TC		–	–	√	√	√
	TRSa		–	–	√	√	√
	TRSb		–	–	√	√	√
②	ETH0		√	√	√	√	√
③	USB	USB 2.0 Host, type A	√	√	√	√	√
④	X4		√	√	√	√	√
	V+	24 V DC	√	√	√	√	√
	0V	GND	√	√	√	√	√
⑤	ETH1		–	–	–	√	√
⑥	X1		–	–	√	√	–
	RS485	RS485 a	–	–	√	√	–
		RS485 b	–	–	√	√	–
		GND RS	–	–	√	√	–
⑦	X2		–	–	√	–	√
	CAN1	CAN_H	–	–	√	–	√
		CAN_L	–	–	√	–	√
		GND CAN	–	–	√	–	√
⑧	X3		–	–	–	√	√
	I/Q1		–	–	–	√	√
	I/Q2		–	–	–	√	√

Switching, control, visualization
Modular PLC

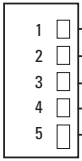
XC300



Default setting

Interface	XC-303-...
⑨ ETH0	192.168.119.248
⑩ ETH1	192.168.137.248
⑪ ETH2	192.168.138.248

DIP switch S1 settings ⑫



	ON	OFF
STOP	PLC stops	PLC runs
TRSa	X3 (RS485)	–
TRSb	X3 (RS485)	–
TC1	X4 (CAN1 termination)	–
TC2	X5 (CAN2 termination)	–

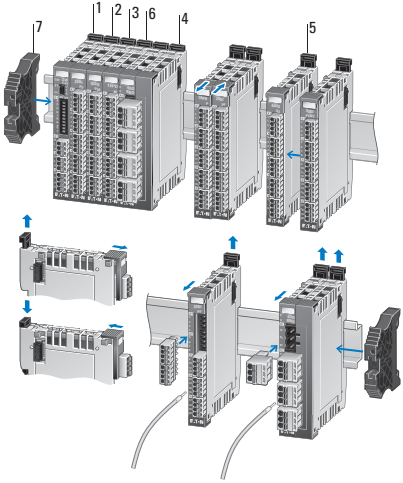
2

Connections XC300

	XControl		XC-303-C11-000	XC-303-C21-001	XC-303-C32-002
①	X1		–	–	√
	I/Q1		–	–	√
	I/Q2		–	–	√
	I/Q3		–	–	√
	I/Q4		–	–	√
②	X2		–	–	√
	UL	24 V DC loc. I/Q	–	–	√
	–	GND loc. I/Q	–	–	√
③	X3		–	√	√
	RS485	RS485 a	–	√	√
		RS485 b	–	√	√
		GND RS	–	√	√
④	X4		–	√	√
	CAN1	CAN_H	–	√	√
		CAN_L	–	√	√
		GND CAN	–	√	√
⑤	X5		√	–	√
	CAN2	CAN_H	√	–	√
		CAN_L	√	–	√
		GND CAN	√	–	√
⑥	X6		√	√	√
	V+	24 V DC	√	√	√
	0V	GND	√	√	√
⑦	SD	MicroSD	√	–	√
⑧	U1	USB 2.0 Host, type A	–	√	√
⑨	ETH2	10/100/1000 MBit/s	–	√	√
⑩	ETH1	10/100 MBit/s	√	√	√
⑪	ETH0	10/100 MBit/s	–	–	√

Switching, control, visualization
Modular I/O system

System overview



1 Gateway
2 Digital input modules
3 Digital output modules
4 Relay modules
5 Analog input/output modules
6 Field potential distributor
7 End bracket

More module types

- Digital input/output modules
- Analog input modules
- Analog output modules
- Technology modules

XN300, the ultra-compact, slice-modular I/O system with a pluggable connection level with high connection density complements the HMI/PLC products to a system solution that focuses on your application.

The high functional and variant diversity reduce the device costs and enable the optimum system solution in the smallest possible space. At the same time, the XN300 I/O system can be used as a local I/O directly on the PLC and as a decentralized I/O in the CAN network or the EtherCAT network.

- High connection density – with up to 20 channels
- Tool-less mounting and Push-in plug-in connection technology
- Extensive range: Gateways (CAN, EtherCAT), digital and analog I/O modules as well as mixing functions for current, voltage and temperature measurement as well as for the operation of DC motor, counters and weighing cells
- Indicator LEDs for communication and signal states
- XN300-Assist with extensive off- and online functions

Switching, control, visualization
Modular I/O system

Engineering

XN300-Assist is a PC software for engineering support when using XN300 I/O's via gateways.

Therefore, a mini USB connection is needed from the computer to the gateway. XN300 provides various offline and online function to simplify I/O block configuration, parameterizaton, ordering and also for system check in start up and firmware update of gateways.

Offline

- order list generation
- configuration and parameterization check
- *.eds and *.ini export for import configuration into CODESYS

Online

- Configuration import
- Status indication of the inputs/outputs
- Wiring test and system diagnostic
- Gateway firmware update

To avoid configuration errors, the XN300-Assist carries out a plausibility check already during the configuration of the system. In addition, you can set the slice module parameters directly in the XN300-Assist and then export them into XSOFT-CODESYS-3 for SDO configuration. Configuration made easy. The online function of the XN300 Assist will support you during commissioning. Various functions – such as the configuration check, the setting of parameters and the reading and setting of signal states – allow you to check the system, including any connected components, even without a connection to the controller.

Further information sources

Configuration with XN300-Assist
Eaton.com/xn300-assist

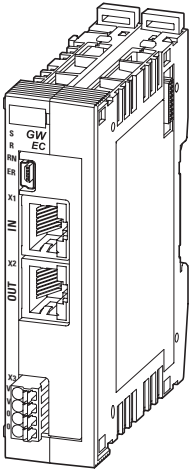
Switching, control, visualization
Modular I/O system

EtherCAT

XN-312-GW-EC gateways can be used to connect a bus system XN300 I/O block to EtherCAT, and make it possible to access the data of up to 32 I/O modules using EtherCAT.

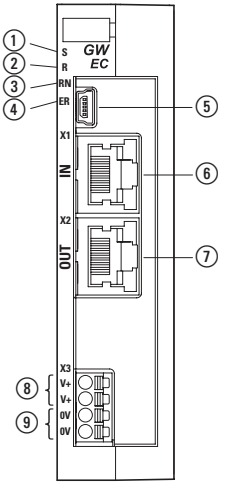
Accordingly, these gateways can be integrated as modular device into control systems that use this type of communication, making it possible to access the data of every single individual system bus module from a PLC.

The gateways will automatically detect the I/O slice modules present on the system bus and send the I/O slice module configuration to the EtherCAT master.



Switching, control, visualization
Modular I/O system

EtherCAT gateway



1. LED S, Sync status
2. LED R, Reset status
3. LED RN, EtherCAT Run status
4. LED EC, EtherCAT Error status
5. Mini USB diagnostic interface
6. EtherCAT IN
7. EtherCAT OUT
8. Power supply, 24 V DC POW (bridged)
9. 0 V (bridged)

The RJ45 X1 (EtherCAT IN) and X2 (EtherCAT OUT) ports are used to establish a connection to the network. EtherCAT IN refers to the connection direction towards the controller, while EtherCAT OUT is used to connect to the next downstream node or set up redundant communications.

The gateway's 24 V DC POW power supply needs to be connected to X3.

A system bus is used for data communication and for supplying power within the system block. The power supply is used to produce the power i.e. for the system bus.

The USB diagnostic interface on XN-312-GW-EC gateways can be used to connect them to a computer in order to use the XN300-Assist planning and commissioning program. In addition to various online and offline functions, XN300-Assist provides the option of updating the XN-312-GW-EC gateway's operating system.

Switching, control, visualization
Modular I/O system

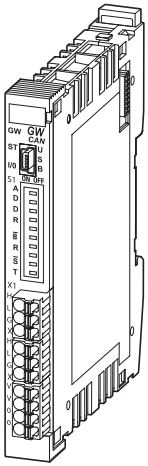
CANopen

XN-312-GW-CAN gateways can be used to connect a system bus XN300 I/O block to CANopen, and make it possible to access the data of up to 32 I/O modules using CANopen.

Accordingly, these gateways can be integrated as modular device into control systems that use this type of communication, making it possible to access the data of every single individual system bus module from a PLC.

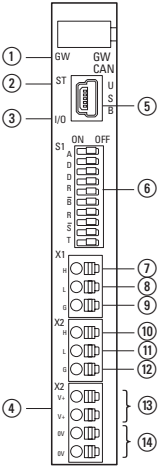
The gateways feature a config check function that can be activated with DIP switches. When this function is used, the gateway will check the I/O slice modules that are present on the system bus and compare the resulting actual configuration with the previously stored target configuration.

If the actual configuration is different from the target configuration, it will not be possible for the gateway to switch to the "Operational" operating state. An actual configuration will be automatically saved as the target configuration when the device starts, provided that DIP switch 9 is in the OFF position.



Switching, control, visualization
Modular I/O system

CAN gateway



1. LED GW, System bus 5 V DC status
2. LED ST, CANopen status
3. LED I/O, Configuration I/O slice modules status
4. LED POW
5. Mini USB diagnostic interface
6. DIP switch for address setting of the node IDs, firmware update, baud rate, config check, bus terminating resistor
7. CAN_H
8. CAN_L
9. GND
10. CAN_H
11. CAN_L
12. GND
13. Power supply, 24 V DC POW
14. 0 V

The connection to the field bus needs to be established by connecting an FMC 1.5/3-ST-3.5 three-pin connector to X1. An internal connection makes it possible to directly connect an additional module to the field bus by connecting it to X2.

The gateway's 24 V DC POW power supply needs to be connected to X3. Two additional terminals are connected in parallel.

A system bus is used for data communication within the system block. The power supply is used to produce the power i.e. for the system bus.

The diagnostic interface on XN-312-GW-CAN gateways can be used to connect them to a computer in order to use the XN300-Assist planning and commissioning program. The interface can also be used to update the operating system.

Expansion modules

Digital input modules

Digital inputs, for a +24 V DC signal level, can be used to read the logic 0 and logic 1 levels. The modules feature input filters designed to suppress glitches on the corresponding signal cables. adapted to the requirements of the machine to build an optimized solution in smallest space.

Features
(according to the module selection)

- 8/16/20 digital inputs
- Counter function makes an internal module register to be incremented every time there is an input pulse.
- Pull-up resistor relays a logic level 0 at 24 V DC and if an input is pulled down to GND, a signal state of 1 will be relayed for that input instead.

Digital output modules

Digital Outputs are short circuit protected, plus switching transistor outputs 24 V DC with different current loads available in purpose to supply drives, signals and valves. The output channels are organized in groups with a separate power supply input each for individual fuse protection. The power supply is monitored for undervoltage.

Features
(according to the module selection)

- 8/12/16 digital outputs
- 0.5 A/1.7 A current loads

Relay output modules

Features
(according to the module selection)

- 4/5 relay outputs
- only NO or NO & NC contacts
- Switching power
  230 V AC/6 A or 115 V AC/6 A or 24 V DC/6 A

Digital input/output modules

Digital inputs, for a +24 V DC signal level, can be used to read the logic 0 and logic 1 levels. Supply voltage of short-circuit proof digital outputs (+24 V DC/0.5 A) is monitored for undervoltage. Lastly, the module features input filters designed to suppress glitches on the corresponding input cables.

Features
(according to the module selection)

- 4/4 digital inputs/outputs or
  8/8 digital inputs/outputs
- Counter function makes an internal module register to be incremented every time there is an input pulse.

Analog input modules

Analog input modules feature from 4 to 10 analog input channels to measure such as:

- temperatures with Pt100, Pt200, Pt500, Pt1000, Ni100, Ni100, or KTY sensors or resistance values within various measuring ranges
- an analog input signal of ±10 V DC. A reference voltage source with 10 V DC/15 mA and 6 outputs makes it possible to directly power potentiometers in order to read their position using the analog voltage inputs
- current input signals within a measuring range of 0 - 20 mA or 4 - 20 mA
- temperatures with thermocouples

For cold-junction compensation, there is KTY sensor on the bottom of the specific analog input module.

In addition, a reference voltage source with 10 V DC/15 mA and 6 outputs makes it possible to directly power potentiometers in order to read their position using the analog voltage inputs.

Analog output modules

Analog Output modules have 4/8 analog output channels to output such as:

- a voltage signal in a range of -10 to 10 V DC (12 bit)
- a configurable signal in a range of -10 to 10 V DC or 0 to 20 mA (16 bit – precise control)

Analog input/output modules

Analog input channels can be used to measure a voltage/current input signal and analog output channels can be used to output a voltage/current signal.

Input channels to measure such as:

- a voltage input signal within a range of -10 to 10 V DC
- current input signals within a measuring range of 0 - 20 mA or 4 - 20 mA

Output channels to output such as:

- a voltage signal within a range of -10 to 10 V DC
- an output range of 0 - 20 mA or 4 - 20 mA

Features (according to the module selection)

- 2/2 or 4/4 analog input/output channels
- reference voltage source with 10 V DC/10 mA and 2 or 4 pins that makes it possible to directly power potentiometers in order to read their position using the aforementioned analog voltage inputs.
- power supply for the current inputs and outputs will be monitored for undervoltage.

Technology modules

Weighing module

Weighing module features two analog input channels that can be used to operate strain gauges and load cells. Accordingly, the module can be used for uncalibrated measurements in weighing applications with the use of Wheatstone bridges with a 4-wire or 6-wire configuration. In addition, the module provides the reference voltage required in order to power the corresponding bridge measurement systems.

DC motor driver module

DC motor driver module features a DC motor driver that can be used to run a brushed motor, as well as two current outputs that can be used to drive two external LEDs. These current outputs have rated operational currents of 20 mA and 350 mA.

The power control module can be used to run a DC motor with supply voltages of 12 - 30 V DC and a maximum motor current of 3.5 A. It can also accommodate higher inrush currents briefly. The output power is controlled with a PWM output, and the operating direction can be defined with the polarity of the switched output driver stage. Accordingly, the output power must be controlled using duty cycles.

In addition, these DC motor driver modules provide up-to-date operating data on the motor so that the information can be used for further analysis or display if necessary.

- Motor driver temperature
- Current motor current
- Motor status
- Let-through energy
- Diagnostics information

In order to integrate the motor into a speed control system, it is recommended to provide a speed feedback signal by using a rotary encoder on the motor together with an XN-322-1CNT-8DIO or XN-322-20-DI-PCNT module. This will make it possible to determine the motor's speed, operating direction, and covered distance (angle of rotation).

The LED drivers can be programmed in such a way that the corresponding LEDs will signal the information obtained by the module. For example, a motor's speed or load can be represented by different LED brightness levels.

Counter module

Counter module features an incremental encoder input (with a TTL or RS-422 level) and a 5 V DC output for powering it. In addition, the device has four digital outputs (24 V DC/2 A) and four digital inputs (24 V DC). These inputs can use the module's configurable latch function in order to have the current counter count be stored in a special register.

SSI interface module

The interface module can be used to read data from up to two absolute encoders and provide it to the PLC. The interface is designed for SSI encoders, e. g., absolute linear encoders, that support natural binary or Gray code.

→ Check to make sure that the encoder is suitable for operation with this XN300 slice module. To do this, compare the technical data for both devices.

Serial interface module

Serial interface module has one, optionally two, RS232 and one RS485 interface. The RS232 interface on connector X1 can be operated with or without handshake signals RTS and CTS. If no handshake signals RTS and CTS are used, these signals can also be configured as a second RS232 interface on X1. In this configuration, two independent RS232 interfaces (D1 and D2) are available without handshake lines.

Both RS232 interfaces support data rates up to 115200 baud. XN-322-2SI-RS also has an RS485 interface on connectors X2 and X3 with switchable 120 Ω terminating and 1 kΩ spreading resistors, which can be switched via software.

The RS485 interfaces are overvoltage-proof up to 15 V DC and can be operated with data rates of up to 921600 baud. An external power supply is not required.

Pulse-Width-Modulation module

Pulse-Width-Modulation (PWM) operation can be configured using two parameters. The period duration is set once and the connected device is controlled by the continuously modified pulse width. Period duration of the PWM can be set in 0.5 µs steps between 50 µs (20 kHz) and 32.8 ms (30.5 Hz). The pulse width indicates the ON-time of the output within a period. It can be adjusted via software in 0.5 µs steps.

Power supply module

Power supply module can be used to distribute the field supply voltage for XN300 slice modules. The targeted use of power supply modules makes it possible to ensure that all slice modules will be properly powered and fused as required for the application in question by segmenting the power supply into sections. Modules are powered via connector X5 using the 24 and 0 V DC pins. The slice modules then distribute this power to nine +24 V DC Out power outputs, each with its own GND output. The power outputs are grouped and short-circuit proof, with each group being able to deliver up to 2 A.

Expansion modules – Power supply

Power distribution 0 V module

Power distribution 0 V module is passive field potential distribution slice module. It provides an output potential of 0 V for a total of 18 pins. This means that this 0 V potential can be tapped without the need for additional terminal strips.

XN-322-18PD-M modules are normally used together with XN-322-18PD-P modules in order to ensure that XN300 slice modules can be segmented into groups that can be fused and switched as such. When used together with digital slice modules, these modules make it possible to use two-wire and three-wire connection configurations.

Power distribution +24 V DC module

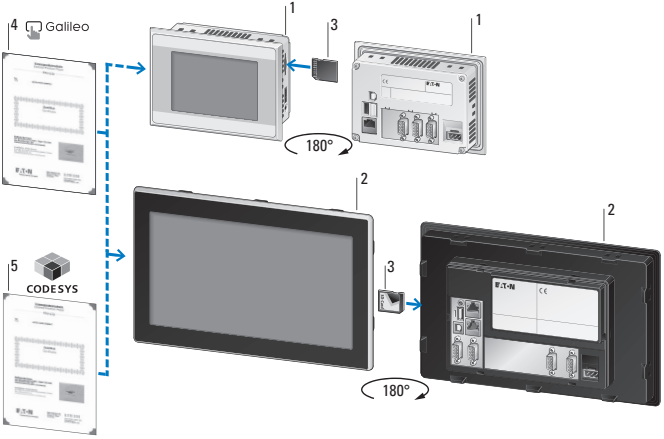
Power distribution +24 V DC module is passive field potential distribution slice module. It provides an output potential of 24 V DC for a total of 18 pins. This means that this voltage can be tapped without the need for additional terminal strips.

XN-322-18PD-P modules are normally used together with XN-322-18PD-M modules in order to ensure that XN300 slice modules can be segmented into groups that can be fused and switched as such. When used together with digital slice modules, these modules make it possible to use two-wire and three-wire connection configurations.

Switching, control, visualization

HMI-PLC – visualization and control with system

System overview



1 XV-102 Touch display with/without PLC,
Resistive touch 3.5", 5.7" in 4:3 format, 7.0" in 16:9 format

2 XV-303/XV-313 Touch display with/without PLC,
Capacitive multi-touch 7.0", 10.1" and 15.6" in 16:9 format

3 SD memory card

4 GALILEO licensing certificate

5 XSOFT-CODESYS-3 licensing certificate

Switching, control, visualization
HMI-PLC – visualization and control with system

General

Galileo

CODESYS

OPC UA

With the XV system of HMI (Human Machine Interface) or HMI-PLC (HMI with PLC functionality) touch panels, Eaton offers machine builders and system integrators a coordinated product range that can be precisely matched to various performance classes.

In combination with powerful processors, the intelligent implementation of the PLC runtime as part of a lean and efficient embedded platform strategy leads to modern, scalable and cost-effective automation concepts.

The use of the CODESYS programming standard and the comprehensive interfaces illustrate the openness of the system. Display sizes from 3.5" to 15", and the option of using capacitive or resistive touch panels allow for an extremely wide range of applications.

Switching, control, visualization
HMI-PLC – visualization and control with system

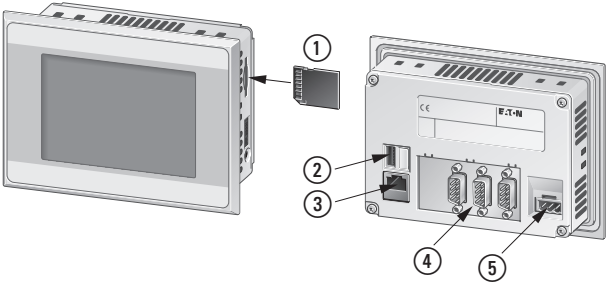
Touch technology	Capacitive	Resistive
Light permeability	100 %	70 - 85 %
Operable with	Fingers	Fingers, gloves, touch pen
Triggering of the function	Without pressure	With slight pressure
Display front	Glass	Plastic film
Device front	Fully flat	Fully flat
Sensitivity to scratches	No	Yes
Resistance to cleaning agent and chemicals	High	Average
Use in humid atmospheres	Yes	Yes

Devices with display sizes from 3.5" to 15" are used in automation applications.

Front degree of protection: IP65

Most touch panels can also be used in portrait format (upright).

Engineering



Rear view of a 7" resistive panel from the XV-102 series with a plastic housing

① SD memory card
(Secure Digital Memory Card)
② USB host, page 2-89
③ Ethernet interface, page 2-90
④ Onboard interface, depending on the device type:
– RS232, page 2-90
– RS485, page 2-91
– CAN, page 2-92
⑤ 24 V DC device supply, page 2-94

② **USB host**
The USB host interface supports USB 2.0.

- Cable
  – Only use standard USB cables with a shield.
  – Maximum cable length: 5 m.

Switching, control, visualization
HMI-PLC – visualization and control with system

③ Ethernet interface

LINK ACT

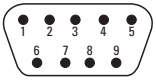
LED	Signal	Meaning
ACT (yellow)	flashes	Ethernet is active (data traffic)
LINK (green)	On	Active network is connected and detected

- Cable
  - Use shielded twisted pair (STP) cable for networking
    For device to device connection: cross over cable
    For connection to hub/switch: 1:1 patch cord
  - Maximal cable length: 100 m

Ethernet interface according to EIA/TIA 568 TSB-36.

④ RS232

The RS232 interface is not galvanically isolated. The device may be damaged by potential differences.
The GND terminals of all bus stations must therefore be connected.



Pin	Signal	Assignment
1	DCD	Data Carrier Detected
2	RxD	Receive Data
3	TxD	Transmit Data
4	DTR	Data Terminal Ready
5	GND	Ground
6	DSR	Data Set Ready
7	RTS	Request to Send
8	CTS	Clear to Send
9	RI	Ring Indicator

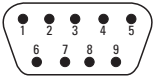
- Wiring
  - Shielded cables must be used.
  - The maximum baud rate depends on the cable length:

Cable length	Max. baud rate
2.5 m	115200 Bit/s
5 m	57600 Bit/s
10 m	38400 Bit/s
15 m	19200 Bit/s
30 m	9600 Bit/s

Switching, control, visualization
HMI-PLC – visualization and control with system

④ RS485

The RS485 interface is not galvanically isolated. The device may be damaged by potential differences. The GND terminals of all bus stations must therefore be connected.



Pin	Signal	Assignment
1	-	nc
2	-	nc
3	B	Line B
4	-	nc
5	GND	Ground
6	-	nc
7	A	Line A
8	-	nc
9	-	nc

nc:
Pin 1, 2, 4, 6, 8 and 9 must not be connected.

- Wiring

When preparing connections, ensure that the cable shield has a low impedance connection with the connector housing.

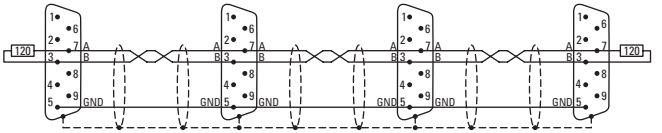
- RS485-topology
  - A bus segment can interconnect up to 32 slaves.
  - Several bus segments can be connected via repeaters (bidirectional amplifiers). Refer to the documentation of the repeater manufacturer for more specific details.
  - The use of repeaters enables the maximum cable length to be increased. Refer to the documentation of the repeater manufacturer for more specific details.
  - A bus segment must be provided with cable termination (120 Ω) at both ends. These terminals must be connected in the connector directly between pin 3 and 7.
  - The bus segment must be terminated at both ends.
  - No more than two terminations must be provided for each bus segment.
  - Operation without correct cable termination can cause transfer errors.

Shielded twisted pair cables must be used.

Cable specification	
Rated cable impedance	120 Ω
Permissible impedance	108-132 Ω
Max. cable length	1200 m
Possible baud rates	9600 bit/s 19200 bit/s 38400 bit/s 57600 bit/s 115200 bit/s

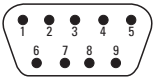
Switching, control, visualization

HMI-PLC – visualization and control with system



④ CAN

The CAN interface is not galvanically isolated. The device may be damaged by potential differences. The GND terminals of all bus stations must therefore be connected.



Pin	Signal	Assignment
1	-	nc
2	CAN-L	Bus line (dominant low)
3	CAN-GND	CAN ground
4	-	nc
5	-	nc
6	GND	Optional CAN ground
7	CAN-H	Bus line (dominant high)
8	-	nc
9	-	nc

Pin 3 (CAN-GND) and 6 (GND) are internally interconnected.
nc: Pin 1, 4, 5, 8 and 9 must not be connected.

The power supply of the CAN bus drivers is implemented internally.

A power supply for third party devices is not provided on the CAN connector.

- Wiring

Shielded twisted pair cables must be used.

Cable specification	
Rated cable impedance	120 Ω
Permissible impedance	108-132 Ω
Capacitance per unit length	< 60 pF/m
Conductor cross-section Max. cable length	≧ 0.25 mm²/100 m ≧ 0.34 mm²/250 m ≧ 0.75 mm²/500 m

Switching, control, visualization
HMI-PLC – visualization and control with system

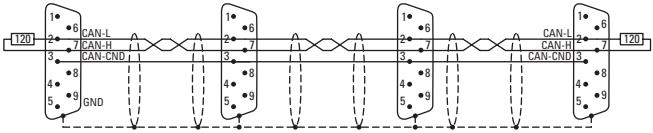
The maximal baud rate depends on the cable length

Cable length	Max. baud rate
25 m	1000 kbit/s
50 m	800 kbit/s
100 m	500 kbit/s
250 m	250 kbit/s
500 m	125 kbit/s
500 m	100 kbit/s
1000 m	50 kbit/s
2500 m	20 kbit/s
5000 m	10 kbit/s

– The use of repeaters is recommended for cable lengths over 1000 m. Repeaters can also be used for galvanic isolation. Refer to the documentation of the repeater manufacturer for more specific details.

– Observe the recommendations of CiA (CAN in Automation).
– When preparing connections, ensure that the cable shield has a low impedance connection with the connector housing. connector housing.

- CAN-Bus-topology
  – A bus segment can interconnect up to 32 slaves.
  – Several bus segments can be connected via repeaters (bidirectional amplifiers). Refer to the documentation of the repeater manufacturer for more specific details.
  – A bus segment must be provided with cable termination (120 Ω) at both ends. These terminals must be connected in the connector directly between pin 2 and 7.
  – The bus segment must be terminated at both ends.
  – No more than two terminations must be provided for each bus segment.
  – Operation without correct cable termination can cause transfer errors.



2

⑤ 24 V DC device supply

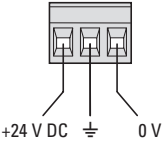
The device has an internal fuse and protection against polarity reversal. The functional earth must only be connected with the connector panel not the 0 V. The housing is plastic and is potential free. The power supply of the device is not galvanically isolated.

The device requires a power supply of 24 V DC from an AC/DC transformer with safe isolation (SELV).

– SELV (safety extra low voltage), circuit in which no dangerous voltage occurs even in the event of a single fault.

- Wiring

Plug connector Phoenix Contact MSTB 2,5/3-ST-5,08, Phoenix Art no. 1757022 is supplied with the device.



Connection	Assignment
+24 V DC	Supply voltage +24 V DC
E	Functional earth with connector panel. Does not have to be connected.
0 V	Supply voltage 0 V

Observe the following when preparing the wiring of the plug connector:

Terminal type	Screw terminal plug-in
Cross-section	min. 0.75 mm^2/ max. 2.5 mm^2 (lead or wire) min. AWG18/ max. AWG12
Stripping length	7 mm
Max. tightening torque	0.6 - 0.8 Nm (5 - 7 lb-in)

Switching, control, visualization
HMI-PLC – visualization and control with system

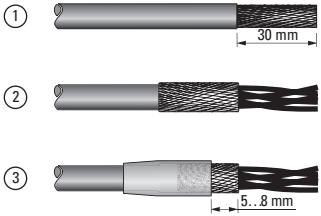
Preparing the cables with the SUB-D connector

The design of the bus cabling is an essential factor for reliable operation and electromagnetic compatibility (EMC).

Wiring requirements

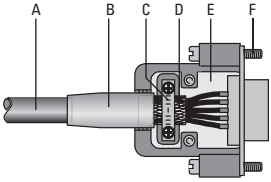
- The cables must be shielded.
- The cable shield must consist of a copper braid.
- The cable shield must have a large area and low-impedance connection to the connector housing. This is achieved by:
  - Using metal or metallized connector housings with a strap for strain relief.
  - The strap must be screw fastened with the connector.

Connecting the cable shield



① Insulate the cable end so that approx. 3 cm of shield braid is exposed.
② Fold back the shield braid over the cable sheath.
③ Attach heat-shrink tubing approx. 3 cm in length over the folded shield braid or use a rubber grommet.
  - 5 - 8 mm shield braid must be exposed at the cable end.
  - The folded shield braid end must be covered by the heat-shrink tubing or rubber grommet.

④ Fit the SUB-D connector to the cable end:
  - The exposed screen braid must be connected to the connector housing with the cable clip.



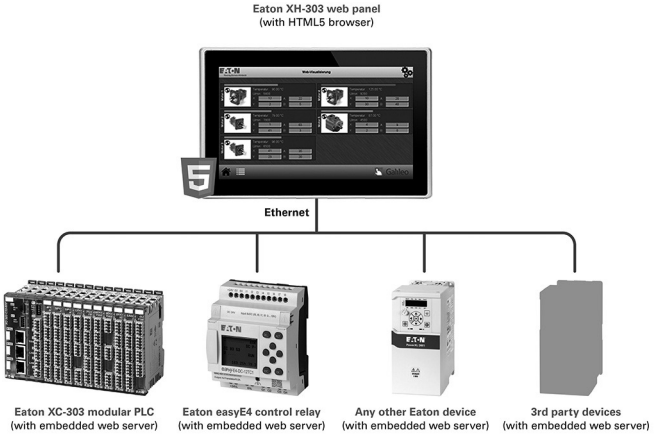
A Cable with cable sheath
B Heat-shrink tubing or rubber grommet
C Gland plate
D Shield braid
E SUB-D plug
F Fixing screw UNC

Switching, control, visualization
Web panel

System overview and functions

XH-303 HMI web panel are HMI devices that communicate with various web servers through an Ethernet port.

The XH-303 web panel devices feature an industrial high-resolution display with capacitive multi-touch technology.



Switching, control, visualization

Features

- Capacitive multitouch, widescreen
- Heavy-duty tempered glass, easy to clean
- Device versions for front mounting, can also be used in portrait mode
- Powerful CPU: ARM Cortex-A53, Quad-Core, 1.8 GHz
- Internal memory: 2 GB DDR4-RAM, 8 GByte eMMC
- Operating system: Linux platform from Eaton for operating system/web browser and configuration

Every XH-303 web panel comes with the following integrated interfaces as standard:

- 1 x Ethernet (1000/100/10 Mbps) as communication interface
- 1 x USB host 2.0 port for device servicing

The following display sizes are available in order to ensure that the unit will best meet the needs of the application at hand:

	XH-303-70-A10-A00-2B	XH-303-10-A10-A00-2B	XH-303-15-A10-A00-2B
Display type	Widescreen color display, TFT, multifinger touch screen		
Screen diagonal	7.0" (17.78 cm)	10.1" (25.65 cm)	15.6" (39.6 cm)
Resolution	1024 x 600 pixels	1280 x 800 pixels	1366 x 768 pixels
Visible screen area	154 x 86 mm	217 x 136 mm	344 x 194 mm

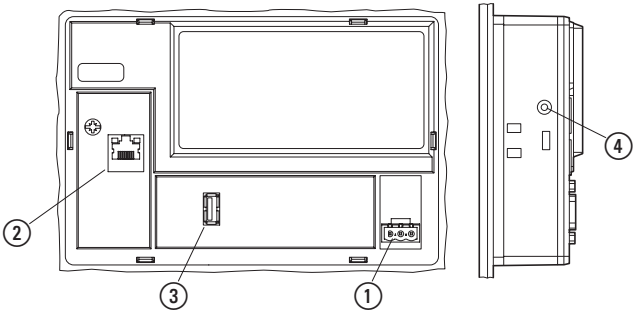
Switching, control, visualization
Web panel

Interfaces to peripheral devices

The interfaces featured by your XH-303 will depend on the XH300 version selected and cannot be modified.

The nameplate will indicate which specific interfaces are included with the unit.

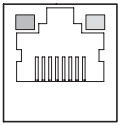
All XH-303 models have this basic interface equipment:



① 24 V DC: Supply voltage, plug connector MSTB 2,5/3-ST-5,08
② Ethernet 1: RJ45 socket, 8 pole, 2 LEDs (CAT5e/6), LAN1, 1000/100/10 Mbps
③ USB host: USB 2.0, not galvanically isolated, plug type A, full power (500 mA)
④ CTRL: Button to activate the software "Config Tool"

For the network, use shielded twisted-pair (STP) cables only.
Max. cable length: 100 m.

② RJ45 socket



Ethernet

The Ethernet port on the XH-303 web panel is used as a communication interface. The Ethernet controllers support transfer rates of 1000 Mbit/s, 100 Mbit/s and 10 Mbit/s. When the green LED lights up (② left), this means that there is a LINK, i. e., that an active network is connected and has been detected. When the yellow LED flashes (② right), this means that data is being transferred.

Switching, control, visualization
XP500 Industrial PC

The high-performance industrial PC series XP500 provides an HMI solution in the high-end area. In addition to panel PCs, the range also includes box PCs and terminals which, in combination with an extender module, enable visualization even in wide-ranging facilities.

Features

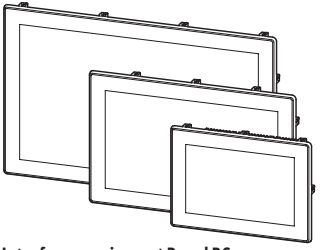
- Projected capacitive touch technology for intuitive operation like smartphones or tablets
- 4-finger touchscreen enables precise operation with several fingers or two hands simultaneously
- Operating System: Windows 10 Enterprise LTSC
- High-performance CPU: Intel Atom E3950, Quad-Core
- Pre-installed Galileo or Visual Designer runtime license
- Anti-glare, single-paned safety glass for use in rough industrial environments
- Modern, hygienic design for simple cleaning

	XP-504-10-...	XP-504-15-...	XP-504-21-...
Display type	Widescreen color display, TFT, multifinger touch screen		
Screen diagonal	10.1" (25.65 cm)	15.6" (39.6 cm)	21.5" (54.6 cm)
Resolution	1280 x 800 pixels	1366 x 768 pixels	1920 x 1080 pixels
Visible screen area	217 x 136 mm	344 x 194 mm	476 mm x 277 mm

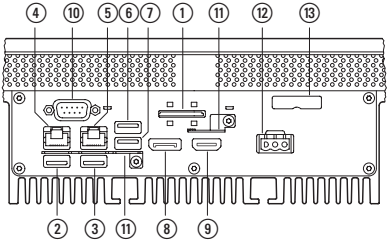
Switching, control, visualization
XP500 Industrial PC

Using peripheral devices – External connections

XP-504 Panel PC



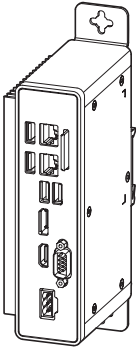
Interfaces equipment Panel PC



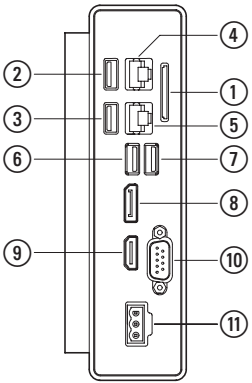
① SD card slot (optional)*: SD or SDHC according to SDA specification 2.0, min. 8 GB
② USB host 3.0: USB3.0/2.0, plug type A
③ USB host 3.0: USB3.0/2.0, plug type A
④ Ethernet 1 LAN: RJ45 socket, 8 pole, 2 LEDs (CAT5e/6), LAN, 1000 MBit/s
⑤ Ethernet 2 LAN: RJ45 socket, 8 pole, 2 LEDs (CAT5e/6), LAN, 1000 MBit/s
⑥ Dual USB host 3.0: Dual-USB3.0/2.0 T, plug type A and
⑦ Dual USB host 3.0: Dual-USB3.0/2.0 T, plug type A
⑧ DP: Standard display interface
⑨ HDMI: Standard display interface 1.4b
⑩ RS232/422/485: 9 pole SUB-D plug, not galvanically isolated, configurable via BIOS, default setting: RS232 full duplex
⑪ Strain relief: metal plate for fixing the USB port and HDMI port
⑫ 24 V DC: Power supply MSTBT 2,5/3-ST-5,08
⑬ Battery: BR2032 (190 mAh, 3 V) from Panasonic

Switching, control, visualization
XP500 Industrial PC

XP-504 Box PC



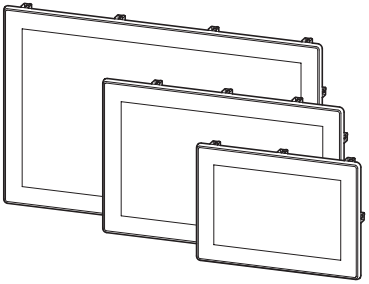
Interfaces equipment Box PC



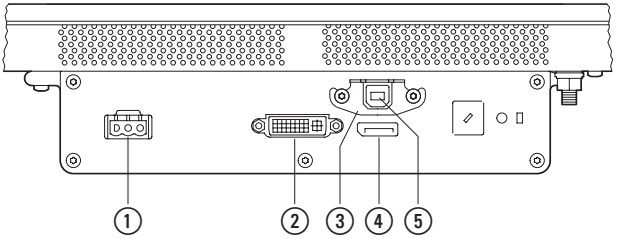
① SD card slot: SD or SDHC according to SDA specification 2.0, min. 8 GB
② USB host 3.0: USB3.0/2.0, plug type A
③ USB host 3.0: USB3.0/2.0, plug type A
④ Ethernet 1 LAN: RJ45 socket, 8 pole, 2 LEDs (CAT5e/6), LAN, 1000 MBit/s
⑤ Ethernet 2 LAN: RJ45 socket, 8 pole, 2 LEDs (CAT5e/6), LAN, 1000 MBit/s
⑥ Dual USB host 3.0: Dual-USB3.0/2.0 T, plug type A
⑦ Dual USB host 3.0: Dual-USB3.0/2.0 T, plug type A
⑧ DP: Standard display interface
⑨ HDMI: Standard display interface 1.4b
⑩ RS232/422/485: 9 pole SUB-D plug, not galvanically isolated, configurable via BIOS, default setting: RS232 full duplex
⑪ 24 V DC: Power supply MSTBT 2,5/3-ST-5,08

Switching, control, visualization
XP500 Industrial PC

XP-504 Terminal

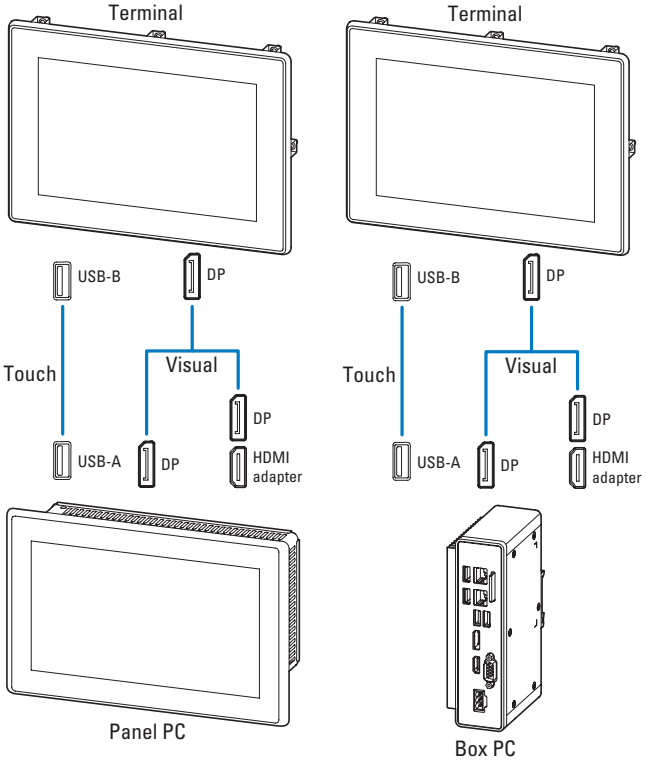


Interfaces equipment Terminal



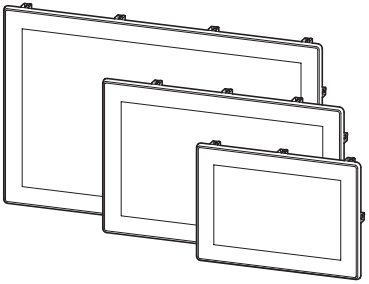
① 24 V DC: Power supply
MSTBT 2,5/3-ST-5,08
② DVI-I: Standard display interface
③ Strain relief: metal plate for fixing the USB port
④ DP: Standard display interface
⑤ USB-B: USB 2.0, not galvanically isolated, plug type B
(used by the touch functionality)

Connection of a Terminal with Box PC/Panel PC

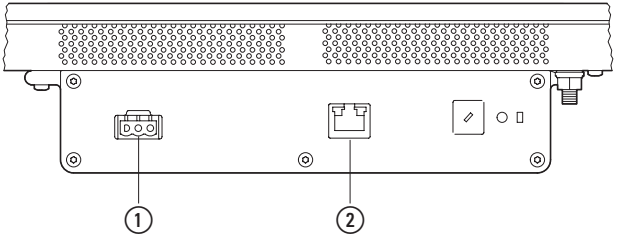


Switching, control, visualization
XP500 Industrial PC

XP-504 Terminal with Extender RX



Interfaces equipment Terminal with Extender RX

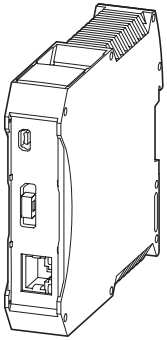


① 24 V DC: Power supply
MSTBT 2,5/3-ST-5,08

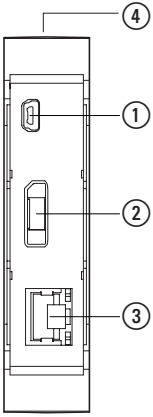
② RJ45 (Extender RX) EXT IN:
RJ45 socket, 8 pole, 2 LEDs (CAT5e/6)

Switching, control, visualization
XP500 Industrial PC

XP-504 Extender TX

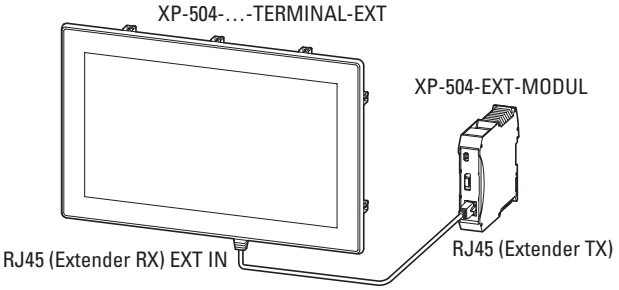


Interfaces equipment Extender TX



① Mini USB-B
② DP: Standard display interface
③ RJ45 (Extender TX): RJ45 socket, 8 pole, 2 LEDs (CAT5e/6)
④ 24 V DC: Power supply MSTBT 2,5/4-ST-5,08

Terminal and terminal extender module connection



Motors

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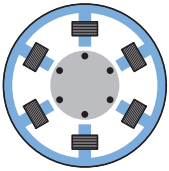
Motors
Motor technology – Basic information

Drives engineering selection criteria

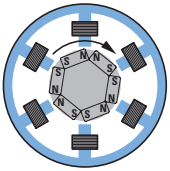
Each drive task requires a drive motor. The speed, torque and controllability of each motor must fulfill the requirements of the task. As a general rule, the application determines the drive.

Three-phase asynchronous motor



The most frequently used drive motor in industrial plants and large buildings is the three-phase asynchronous motor. Its robust and simple design, as well as a high degree of protection and standardized designs are features of this low-cost electric motor. Comparable to a rotating transformer, a three-phase current generates a magnetic field in the windings of the stator. This magnetic field also flows through the rotor via an air gap. So that a magnetic field induces a voltage in the conductor bars of the rotor, there must be a speed difference between the rotor speed and the stator speed, the so-called slip. Due to the fact that the conductor bars at the lower and upper ends are short-circuited to each other, the induced voltage generates a current flow in the bars. This in turn generates a magnetic field in the rotor, which follows the magnetic field of the stator. This is where the name asynchronous motor comes from, since torque can only be built up when the above conditions are given. If there is no speed difference, the motor cannot build up torque.

Permanent magnet motors (PM motors)



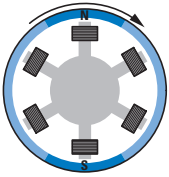
PM motors are three-phase motors that are excited by permanent magnets and have a speed that is directly proportional to the supply frequency.

Together with a high-pole-count, three-phase stator winding, the permanent magnets on the rotor make it possible to produce large torques at low speeds, which in turn makes it possible to forgo the use of a gearbox in many applications.

By combining high efficiency and good power factor characteristics with a lightweight and compact construction, PM motors make for a compelling choice when compared to asynchronous motors. Accordingly, these high efficiency motors are primarily found in roller and press drives, agitator and mill drives, drives for extruder screws, and drives used by the crane industry for a variety of applications.

Motors
Motor technology – Basic information

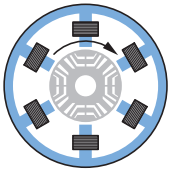
Brushless DC motors (BLDC motors)



Contrary to what their name might seem to imply, brushless DC motors (BLDC, also referred to as "EC motors") do not have the same configuration as a DC motor, but are instead put together the same way as three-phase synchronous motors. The three-phase AC field coil in brushless DC motors generates a rotating magnetic field that pulls the permanently excited rotor along. When using vector control, the rotor position is determined based on the back-EMF generated in the stator's coils. This means that the variable frequency drive's output voltage must always be live in all three phases (block voltage control), even when the rotor is stationary. If this condition is met, short current pulses will be generated when the system is stationary – these pulses will not move the motor, but they will have an effect on the rotor's magnetic field.

The control response for BLDC motors is to a large extent the same as that for a shunt DC motor. BLDC motors are primarily used in drive systems for machine tools, servo drives in conveyor systems, and compressors and metering pumps.

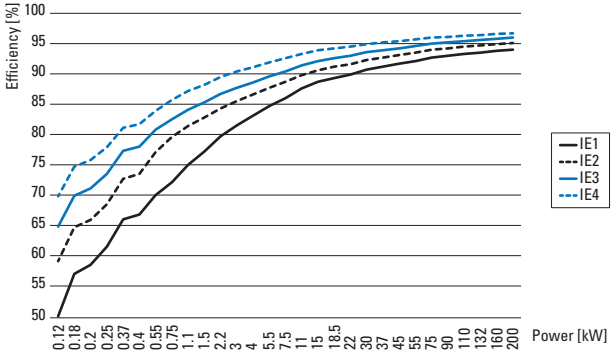
Synchronous reluctance motors (SyncRM)



Synchronous reluctance motors have the same configuration as a three-phase asynchronous motor. In order to prevent eddy currents, their rotor is made of a soft magnetic material such as electrical steel, and in general terms can have one of two different sheet cross-sections. In the case of reluctance motors intended to be run as grid-connected systems, the rotor additionally features a rotor cage (similar to that used in asynchronous motors). This cage makes it possible for the motor to start asynchronously on the grid until it synchronizes ("falls into step") to it and is able to follow the rotating field. In the case of reluctance motors with a rotor that features salient poles with flux directing sections and flux barrier sections, a variable frequency drive with sensorless vector control is required (DC1-...E1). This combination makes it possible to have a rotor speed that is synchronous with the rotating field and achieve optimum operation even when there are load changes. The losses in the rotor will be practically negligible within this context. Synchronous reluctance motors have better efficiency than conventional asynchronous motors and, in contrast to them, can meet the requirements for the IE4 international efficiency class. Synchronous reluctance motors are primarily used in turbomachinery (rotating equipment) in process engineering, where they are used to drive pumps, fans, compressors, and turbines, as well as mixers, centrifuges, and conveyor systems.

Motors
Motor technology – Basic information

Efficiency for asynchronous motors



Efficiency curves for asynchronous motors according to IE classification (source: IEC 60034-30-1)

To make it easier to select energy-efficient drive components, classifications for their efficiency were introduced in 2008. For motors for operation on the public grid, they are defined in the international standard IEC 60034-30-1, together with the legal requirements for energy efficiency. The efficiencies or efficiency classes at 50 Hz and 60 Hz are defined for single-phase and three-phase motors (with exceptions).
A distinction is made between four efficiency classes (IE = International Efficiency):

- IE1: Standard Efficiency
- IE2: High Efficiency
- IE3: Premium Efficiency
- IE4: Super Premium Efficiency

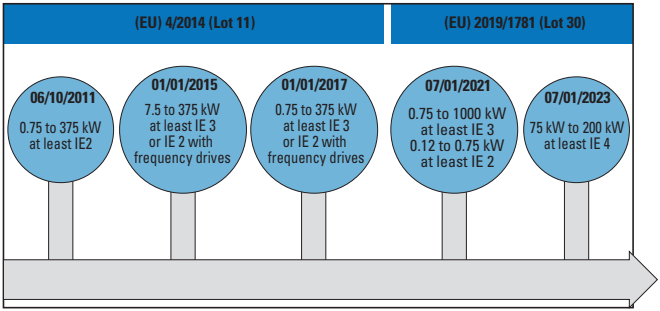
A fifth efficiency class, IE5, has not yet been defined in detail, but is to be included in the next edition of the standard.

Motors
Motor technology – Basic information

With its study on electric motors (Lot 11), Regulation (EC) No. 640/2009 provided for a step-by-step plan in which it was specified from when which efficiency requirements apply to newly marketed electric motors. In its current version, this plan extends until January 2017. To drive efficiency further, the EU institutions agreed on a new, more far-reaching regulation at the beginning of 2019 with the follow-up study Lot 30.

Since July 1, 2023: The energy efficiency of 2-, 4-, or 6-pole three-phase motors that are not brake motors, Ex eb motors with increased safety, or other explosion-proof motors with a rated power between 75 kW and 200 kW must be at least IE4 efficiency.

At the same time, three-phase motors in the application range with a rated power between 0.12 kW and less than 0.75 kW must at least correspond to the efficiency IE2. The energy efficiency of Ex eb motors for increased safety with a rated output of 0.12 kW to 1,000 kW, with 2, 4, 6, or 8 poles, and single-phase motors with a rated output equal to or above 0.12 kW must be at least IE2 efficiency.



Legal framework for the environmentally sound design of electric motors

Motors
Drives Engineering – Basic information

Motor starting variants

- **Direct-on-line start** ①
  In the simplest case the motor is connected directly with a contactor. The combination of motor protection and cable protection (fuse) is called a motor starter (MSC = Motor Starter Combination).
  By applying the full mains voltage to the motor windings, DOL starting may produce large starting currents which may result in troublesome voltage changes.
  Direct-on-line starting three-phase motors must not cause interference voltage changes in the public utility grid. This requirement is generally fulfilled if the apparent power of a three-phase asynchronous motor does not exceed 5.2 kVA or its startup current does not exceed 60 A. With a mains voltage of 400 V and 8 times the starting current, this corresponds to a rated motor current of 7.5 A and thus a motor rating of 4 kW. The motor rating denotes the mechanical output of the motor at the shaft.
  On motors with occasionally higher starting currents than 60 A and motors with starting currents of more than 30 A, which cause feedback disturbances on the public supply, e. g. by a heavy-duty start, frequent switching or varying current consumption (elevators, reciprocating saws), further measures for avoidance of the disruptive voltage variations must be undertaken.
  Motors with powers exceeding 4 kW and voltages rated at 400/690 V can be stated in this case using a star-delta configuration.
  Direct-on-line start imposes the motor windings to thermal stresses and, when only briefly, to momentary electro-dynamic forces. Very frequent, direct-on-line starting reduces the life of the windings on a standard motor (e. g. periodic intermittent operation).

- **Star-delta starter** ②
  With a star-delta motor start, the start-up of the three-phase asynchronous motor is implemented by a changeover of the windings. The jumpers in the motor terminal box are omitted, and all 6 winding connections are connected to the mains supply using a so-called star-delta switch (manually actuated switch or automatic contactor circuit). During the operating connection, the windings of the motor are connected in delta. The winding voltage (U_W) must therefore be equal to the phase voltage (U_{LN}) of the three-phase system. For example, at a mains supply voltage of 3 AC 400 V the voltage ratings on the rating plate of the motor must be specified as 400/690 V. In a star connection, the mains voltage (U_{LN}) on the individual motor windings is reduced by a factor of 1/“Root“3 (~ 0.58).
  For example: 400 V x 1/ “Root” 3 = 230 V.
  Starting torque and inrush current are (in the star connection) reduced to about a third of the values for the delta connection. Typical starting current: 2 - 2.5 I_e. Due to the reduced starting torque, the star-delta configuration is only suitable for drives with smaller load torques or load torques (M_L) that increase with speed, such as is the case with pumps and fans (ventilators/blowers). They are also used where the drive is only subject to a load after it has accelerated up to speed, for example, with presses and

centrifuges. With the changeover of the circuit configuration from star to delta, the current drops to zero, and the speed of the motor reduces depending on the load. The changeover to delta then causes a dramatic rise in the current, as the full mains voltage is now applied to the motor windings. Voltage dips will result on unreliable or weak supply systems. The motor torque also jumps to a higher value during changeover, which causes additional loading on the entire drive system. If, for example, pumps are operated with star-delta starters, a mechanical damper is often used to provide system damping and to prevent a critical "water hammer" to the system. Automatic changeover from star to delta is usually controlled by a timing relay on the contactor circuit. The time required for starting in the star connection is dependent on the load on the motor and should continue until the motor has reached about 75 to 80 % of its operating speed (n_N) to ensure that the least possible post-acceleration is necessary after changeover to delta. This post-acceleration is associated in delta configuration with high currents just as is the case with direct-on-line starting. Switching over too quickly between star and delta can result in disconnection arcing (on the switching contacts) and can cause a short-circuit. The changeover time interval should be selected so that it is long enough to quench the arcs. At the same time, the speed of the drive should be reduced as little as possible. Special timing relays for star-delta changeover fulfil these demands. The correct phase sequence for the changeover from star to delta must be observed when connecting the conductors to the motor and starter. The operating direction of the motor must be considered and observed. Incorrect connection of the phases can cause very high peak currents at restart, because of the slight drop in speed during the de-energized changeover interval.
The current peaks endanger the motor windings and stress the switchgear contacts unnecessarily. When starting in the star connection, the star contactor first of all connects the winding ends U2, V2, W2. Then the main contactor applies the mains voltage (U_{LN}) to the winding ends U1, V1, W1. After the set starting time has timed out, the timing relay switches off the star contactor, and the delta contactor connects terminals U2, V2 and W2 to the mains voltage.

- **Soft starter** ③
  In many cases, the direct-on-line start and the staged star-delta start of the three-phase asynchronous motor is not the best solution, as high peak currents influence the electrical supply, and torque surges subject the mechanical components of the machine or system to high levels of stress. The soft starter provides a remedy. It enables a continuous and surge-free increase in torque and also offers the opportunity for a selective reduction in starting current. The motor voltage is also increased within the adjustable starting time from a selected starting voltage to the rated motor voltage. The soft starter can also control the run down of the drive by reduction of the voltage. The characteristic curve of the three-phase asynchronous motor

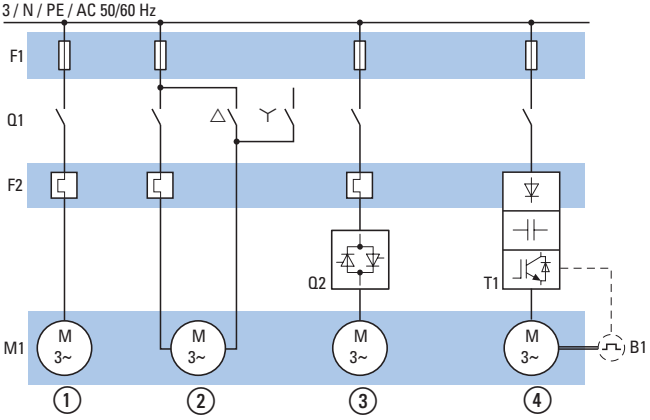
only applies when the full mains voltage (U_{LN}) is available.
If a lower voltage is applied, there is a quadratic reduction in torque ($M \sim U_2$). When compared, for example, to the star-delta start-up, the motor voltage is reduced to 58 % (~ 1/"Root"3) and the torque is reduced to about 33 % (one third). The difference between the load characteristic (M_L) and torque characteristic of the motor (M_M), and accordingly the acceleration force, can be influenced by adjusting the motor voltage. The soft starter should be preferred for all applications with start-up under load (load cannot be connected after start-up) to the star-delta configuration. It is a good replacement for the star-delta configuration for economic reasons and also for energy-conservation reasons, particularly for high-power drives.

Variable frequency drives (4)
The frequency inverter is ultimately the best solution for continuous and stepless starting of the three-phase asynchronous motor. The adjustable current limitation prevents high current peaks in the electrical mains supply and abrupt loads in the mechanical parts of the machine and systems. In addition to the smooth start-up, the frequency inverter also enables stepless speed (frequency) control of the three-phase asynchronous motor. Whereas motors connected directly to the mains supply can only achieve the ideal operating conditions at the steady state operation point (= rating plate specifications), they can be utilized over the entire speed range with frequency control, for example, from 4 V at 0.5 Hz to 400 V at 50 Hz. The constant ratio of voltage to frequency (U/f) guarantee independent operating points with rated-load torque (M_M). When compared to the previously described solutions, the frequency inverters appear to be the most expensive solution at first glance. Higher acquisition costs and the necessary additional installation measures (shielded motor cables and RFI filter for electromagnetic compatibility, EMC) are the main reasons. But during operation at the very latest, the soft motor start in addition to the energy efficiency and process optimisation shows the economic benefits. This is especially true for pumps and fans. By the matching of rotation speed to the production process and the compensation for external interference, the frequency controlled drive unit guarantees a longer service life and functional security.

– with the voltage/frequency control (U/f) or vector control for frequency-controlled motor operation,
– with vector control or servo control for high speed accuracy and additional torque adjustment.

Associated circuit diagrams → page 3-9

Motors
Drives Engineering – Basic information

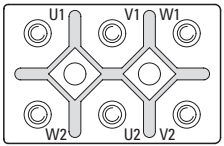


B1: Speed measuring (pulse generator)
F1: Fuse protection (short-circuit and cable protection)
F2: Motor protection (protection from thermal overload, overload relay)
M1: Three-phase asynchronous motor
Q1: Switching (contactor, motor contactor)
Q2: Soft starter, electronic motorstarter
T1: Variable frequency drives

Motor connection

When connecting a three-phase motor to the mains supply, the data on the rating plate of the motor must correspond to the mains voltage and frequency.

The standard connection is implemented via six screw terminals in the terminal box of the motor and with two types of circuit, the star connection and the delta connection, depending on the mains voltage.



Motors
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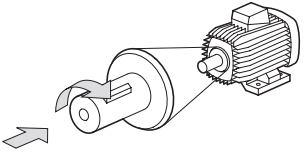
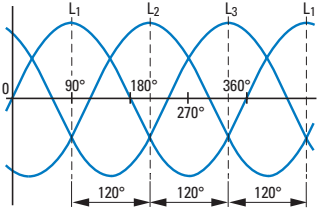
The rotation direction of a motor is always determined by directly looking at the drive shaft of the motor (from the drive end). On motors with two shaft ends, the driving end is denoted with D (= Drive), the non-driving end with N (= No drive).



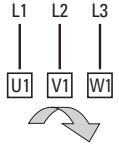
Regardless of the circuit type and the type of three-phase asynchronous motor, the connections must be labeled, so that their alphabetical sequence (e. g. U1, V1, W1) corresponds with the order of the mains voltage sequence (L1, L2, L3) and causes the motor to rotate clockwise.



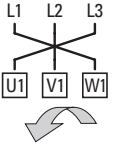
On the three-phase asynchronous motor, three windings are arranged offset from each other by 120°/p (p = number of pole pairs). When a three-phase AC voltage with a 120° phase sequence is applied, this produces a rotation field in the motor.

The effect of inductance causes the rotation field and torque to be formed in the rotor winding. The speed of the motor thus depends on the number of pole pairs and the frequency of the supply voltage. The rotation direction can be reversed by swapping over two of the supply phases.

Clockwise (FWD)



Anticlockwise operation (REV)



FWD = forward run (clockwise rotation field)
REV = reverse run (anticlockwise rotation field active)

Information on the rating plate

The electrical and mechanical rating data of the motor must be stated on its rating plate (IEC 34-1, VDE 0530). The data on the rating plate describes the stationary operation of the motor in the area of its operating point (M_N, e. g. at 400 V and 50 Hz). The operating data is unstable in the motor start phase.

The following examples show the rating plates for two motors with a motor shaft output of 4 kW and the respective connection circuits on a three-phase AC network with 400 V and 50 Hz.

Motors
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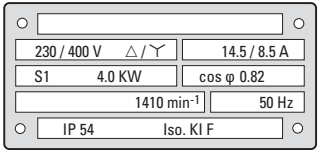
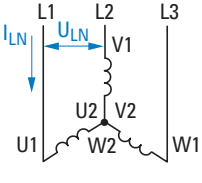
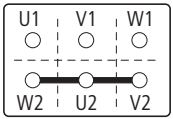
Star circuit



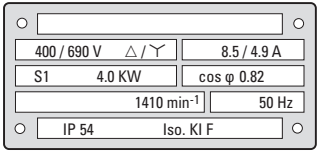


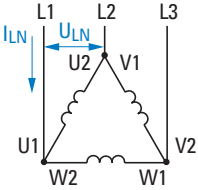
$U_{LN} = \sqrt{3} \times U_W$, $I_{LN} = I_W$



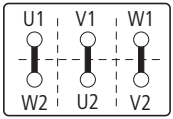
- With the specified 230/400 V voltage, this motor must be connected to the three-phase supply (U_{LN} = 400 V) in a star configuration.
- The voltage of each motor winding is designed for 230 V. The windings must therefore be connected in sequence to the phase voltage (400 V).
- The three winding phases (W2-U2-V2) are configured in the terminal box to the so-called star point. The voltage of the individual phases to the star point is 230 V (= U_W).

Delta circuit





$J_{LN} = U_W$, $I_{LN} = \sqrt{3} \times I_W$



- With the specified 400/690 V voltage, this motor must be connected to the three-phase supply (U_{LN} = 400 V) in a delta configuration.
- Each motor winding is designed here for the maximum phase voltage of 400 V and can be connected directly.
- The three winding phases (U1 – W2, V1 – U2, W1 – V2) are combined in the terminal box and connected directly to the individual phases.

Motors
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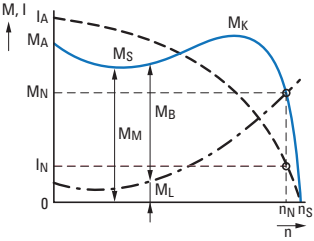
Startup characteristics

The following figure shows the characteristic startup curves of a three-phase asynchronous motor.



I_A: Starting current
I_N: Rated operational current at the operating point
M_A: Starting torque
M_B: Accelerating torque ($M_M > M_L$)
M_K: Breakdown torque
M_L: Load torque
M_M: Motor torque
M_N: Rated load torque, (stable operating point, intersection point of the threephase speed torque characteristic with the load characteristic)
M_S: Pull-up torque
n: Speed (actual value)
n_N: Rated speed at the operating point
n_S: Synchronous speed ($n_S - n_N$ = slip speed s)

Synchronous speed:

$$n_S = \frac{f}{p}$$

Slip speed in %:

$$s = \frac{n_s - n}{n_s} \cdot 100\%$$

Three-phase asynchronous motor speed:

$$n = \frac{f}{p} \cdot (1 - s)$$

f: Frequency of voltage in Hz (= s^{-1})
n: Speed in r.p.m.
p: Number of pole pairs
s: Slip speed in r.p.m.

Electric power:

$$P_1 = U \times I \times \sqrt{3} \times \cos \varphi$$

P_1: Electrical power in W
U: Rated operating voltage in V
I: Rated operational current in A
cos φ: Power factor

Motor output (power equation):

$$P_2 = \frac{M_n \times n}{9550}$$

P_2: Mechanical shaft output power in kW
M_N: Rated torque in Nm
n: Speed in r.p.m.

Efficiency:

$$\eta = \frac{P_2}{P_1}$$

Comparison of startup variants

The features of the startup variants ① to ④ (→page 3-6) are shown on page 3-15 and page 3-16.

The graphs show the typical characteristics.

Motors
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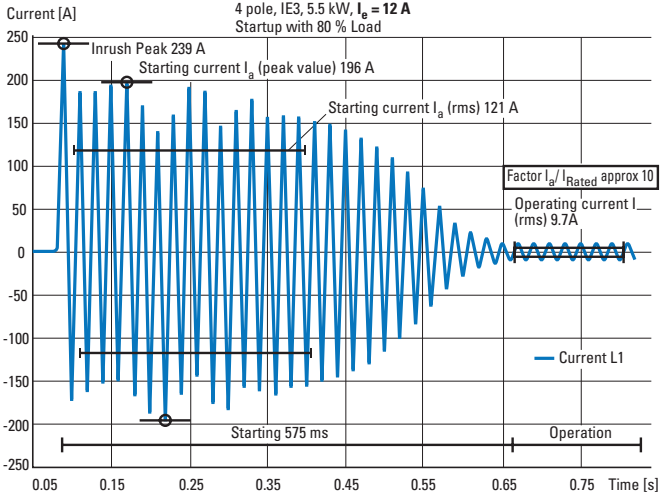
Starting currents with efficient motors



To meet the energy efficiency requirements of IEC 60034-30-1, motor manufacturers have adapted their motor concepts and designs. Among other things, stators with a higher copper mass are used, iron cores with thinner silicon sheets and a higher silicon content are used, the air gaps are optimized, more conductor material on the rotor is used, and the cooling systems are improved. As a result of these changes, IE3 and IE4 motors have a higher inductance and lower copper losses, so the starting currents are higher than those of standard IE1 and IE2 motors.

When considering the starting phase of IE3 and IE4 motors, two types of current must be distinguished: The inrush current only occurs in the first and second half-wave after the motor is switched on. In comparison to an IE1 motor, this peak inrush current – depending on the rated power – can be between 20 % and 50 % higher for IE3 motors and even higher for IE4 motors. The subsequent starting current is also significantly higher for IE3 motors – the starting current ratio (starting current/nominal current) increases by up to 35 % for motors with an output of less than < 3 kW, by up to 15 % for medium-sized motors, and by less than 7 % for motors with more than 75 kW.

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Here again, IE4 motors have a significantly higher starting-current ratio. The lower rated current is only reached after the inrush and starting current has decayed. The currents depend on the construction of the motor, the mains conditions (e. g., the voltage stability of the power supply), the length of the motor supply cables and the switch-on phase position.

Switchgear that is used together with IE3 and IE4 motors must be able to safely handle both the higher starting and inrush currents. This also means that the motor protection must be able to distinguish between the inrush current of the motor and a fault (e. g., a short circuit). The relationship between the inrush current and the effective value of the full load current of the motor plays an important role, because it is related to the response value of the short-circuit release of the motor protection circuit breakers. Only if the short-circuit tripping current is above the ratio between the peak value of the inrush current and the effective value of the full load current of the IE3 or IE4 motor, no unwanted tripping occurs when the motor is switched on.

Contemporary programs for dimensioning low-voltage networks help with the correct selection of protective components. The xSpider program from Eaton, for example, also takes the influence of the motors into account when calculating the short-circuit current.

Care should also be taken to ensure that motor starters and soft starters are approved for operation with energy-efficient motors. This is because if the contactors are not suitable for IE3 or IE4 motors, the increased starting currents cause faster wear of the contact device and thus faster welding of the contacts. Process downtimes are a definite possibility in applications with frequent switching operations.

The same applies to motor protection switches or motor starter combinations. These must also be designed for operation with increased starting currents so that these do not lead to false tripping and faster wear. An increased maintenance effort need not be feared.

Eaton motor starters meet the current IEC/EN standards of the 60947-x series and will also meet future standards.

Eaton motor starters have been tested up to 15 times the inrush current. As soon as the starting currents for operating IE4 motors are within these limits, they are mastered by Eaton motor starters.

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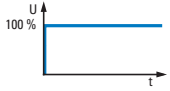
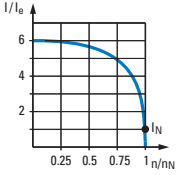
Direct motor start ①

Voltage curve



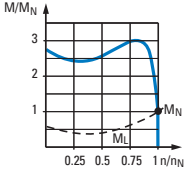
- Mains load high

Current curve



- Relative startup current
  4 to 8 x I_e (depending on motor)

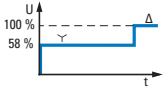
Torque behaviour



- Relative startup torque
  1.5 to 3 x M_N (depending on the motor)
- Features:
- – Strong acceleration with large starting current
  – High mechanical load
- Scope of application:
  Drives on powerful supply networks that allow high starting currents (torques)

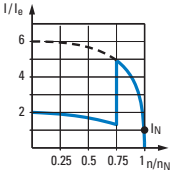
Star-delta starter ②

Voltage curve



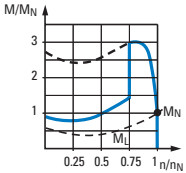
- Medium mains load

Current curve



- Relative starting current
  1.3 to 3 x I_e (~ ⅓ compared to DOL start)

Torque behaviour



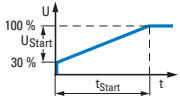
- Relative starting torque
  0.5 to 1 x M_N (~ ⅓ compared to DOL start)
- Features:
  – Startup with reduced current and torque
  – Current, torque peak on switching
- Application range:
  Drives that are only subject to loads after the startup

Motors

Drives Engineering – Basic information

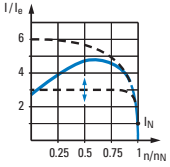
Soft starters ③

Voltage curve



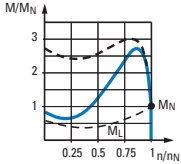
- Low to medium mains load

Current curve



- Relative starting current
  2 to 6 x I_e (reduced by voltage control)

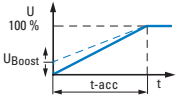
Torque behaviour



- Relative starting torque
  0.1 to 1 x M_N ($M \sim U^2$, quadratically adjustable by voltage control)
- Features:
  – adjustable starting characteristics
  – controlled deceleration possible
- Application range
  Drives with starting behavior adjusted to working machine.

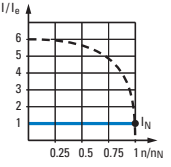
Variable frequency drives ④

Voltage curve



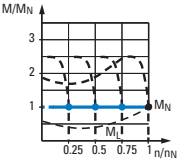
- Low mains load

Current curve



- Relative starting current
  ≦ 1 to 2 x I_e (adjustable)

Torque behaviour



- Relative starting torque
  ~ 0.1 to 2 x M_N ($M \sim U/f$, adjustable torque)
- Features:
  – high torque at low current
  – adjustable starting characteristics
- Application range:
  Drives requiring a controlled and infinitely variable speed adjustment.

Motors
Motor protection

Selection aids

The Eaton motor starter configurator enables you to determine quickly and reliably which motor starter is the most suitable for the application concerned. For this only the operating voltage, the motor rating, the tripping class, coordination types and motor start type are required. With the help of the further selection criteria, the user can also decide whether a solution with motor-protection circuit-breaker, overload relays or even electronic motor starter is required.

As a result of the configuration you will receive a list with the necessary components including article designations and order numbers.

Directly from the configurator, you also have the option of downloading the documentation for the selected components.

The motor starter configurator can be found under:
Eaton.com/moem-tools

Motors
Motor protection

Overload relay with reclosing lockout

They should always be used where continuous contact devices (two-wire control) are concerned (e. g. pressure and position switches), to prevent automatic restarting. The reset button can be fitted as an external feature in order to make it accessible to all personnel. Overload relays for example are always supplied with manual reset. but can be converted to automatic reset by the user.

Overload relay with reclosing lockout

They can be used only with pulsed contact devices (three-wire control) such as pushbuttons etc., because on these, the cooling of the bimetal strips cannot lead to automatic reconnection.

Special circuitry

Special circuitry such as is found in star-delta switches, individually compensated motors, current transformer-operated overload relays etc. may require that the relay settings deviates from the motor rated operational current.

Frequently recurring operating cycles

It makes motor protection difficult. The relay should be set to higher than rated motor current in view of its shorter time constant. Motors which are rated for a high operating frequency will stand this setting to a certain degree. Although this will not ensure complete protection against overload, it will nevertheless provide adequate protection against non-starting.

Back-up fuses and instantaneous releases

They are needed to protect not only the motor, but also the relay, against the effects of short-circuits. Their maximum rating is shown clearly on every relay and must be adhered to without fail. Higher ratings – chosen for instance according to the cable cross-section – would lead to the destruction of the motor and relay.

The following important questions and answers give a further guide to the behaviour of an installation with motor protection.

To what current must the overload relay properly be set?

To the rated motor current – no higher, no lower. A relay set to too low a figure will prevent the full utilization of the motor; set too high, it will not guarantee full overload protection. If a correctly set relay trips too frequently, then either the load on the motor should be reduced or the motor should be exchanged for a larger one.

When is it right for the overload relay to trip?

Only when the current consumption of the motor increases due to mechanical overloading of the motor, undervoltage or phase failure when the motor is under full load or thereabout, or when the motor fails to start due to a stalled rotor.

When does the overload relay fail to trip in good time although the motor is endangered?

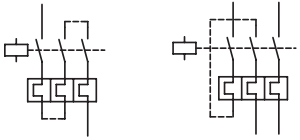
With changes in the motor which do not cause an increase in current consumption: Effects of humidity, reduced cooling due to a reduction in speed or motor dirt, temporary additional external heating of the motor or bearing wear.

What causes destruction of the overload relay?

Destruction will take place only in the event of a short-circuit on the load side of the relay when the back-up fuse is rated too high. In most cases, this will also endanger the contactor and motor. Therefore, always adhere to the maximum fuse rating specified on every relay.

3-pole overload relays should be so connected in the case of single-phase and DC motors so that all three poles of the overload relay carry the current, whether in 1-pole or 2-pole circuits.

1-pole **2-pole**



An important characteristic feature of overload relays conforming to IEC/EN 60947-4-1 are the tripping classes (CLASS 10 A, 10, 20, 30). They determine different tripping characteristics for the various starting conditions of motors (normal starting to heavy starting duty).

Pick-up times

Response limits of time-delayed overload relays at all-pole load.

Type of overload relay	Multiple of current setting						Reference ambient temperature
	A t > 2 h starting from cold state of relay	B t ≦ 2 h	C Tripping classes 10 A 10 20 30	C Tripping time in minutes ≦ 2 ≦ 4 ≦ 8 ≦ 12	D Tripping class 10 A 10 20 30	D Tripping time in seconds 2 < T ≦ 10 4 < T ≦ 10 6 < T ≦ 20 9 < T ≦ 30	
Non-ambient temperature compensated thermal relays and magnetic relays	1.0	1.2	1.5		7.2		+40 °C
Ambient temperature compensated thermal relays	1.05	1.2	1.5		7.2		+20 °C

In the case of thermal overload relays with a current setting range, the response limits must apply equally to the highest and the lowest setting of the associated current.

Motors
Motor protection

Response limits of 3-pole thermal overload relays at 2-pole load

Type of thermal overload relay	Multiple of current setting				Reference ambient temperature
	A t > 2 h, starting from cold state of relay		B t ≦ 2 h		
Ambient temperature compensated, without phase failure sensitivity	3 poles	1.0	2 poles 1 pole	1.32 0	+20 °C
Non-ambient temperature compensated, without phase failure sensitivity	3 poles	1.0	2 poles 1 pole	1.25 0	+40 °C
Ambient temperature compensated, with phase failure sensitivity	2 poles 1 pole	1.0 0.9	2 poles 1 pole	1.15 0	+20 °C

In the case of thermal overload relays with a current setting range, the response limits must apply equally to the highest and the lowest setting of the associated current.

Overload capacity

Overload relays and releases have heating coils which can be thermally destroyed by overheating. The making and breaking currents of the motor flow in thermal overload relays which are used for motor protection. These currents are between 6 and 12 x I_e (rated operational current), depending on the utilization category and the size of the motor.

The point of destruction depends on the frame size and design. It is usually approximately 12 to 20 x I_e.

The point of destruction is the point of intersection between the projected tripping characteristic curves and the multiple of the current.

Short-circuit strength of the main circuit

With currents that exceed the breaking capacity of the motor starter in relation to the utilization category (EN 60947-1, VDE0660, Section 102, Table 7), it is permissible for the current flowing during the break time of the protective device to damage the motor starter.

The permissible behaviour of starters under short-circuit conditions is defined in the so-called types of coordination (1 and 2). It is common practice to state in the details of protective devices which type of coordination is ensured by them.

Type 1 coordination

In the event of a short circuit the starter must not endanger persons and installations.
It does not have to be fit for renewed operation without repair.

Type 2 coordination

In the event of a short-circuit the starter must not endanger persons and installations. It must be fit for renewed operation. There is a risk of contact weld. for which the manufacturer must give maintenance instructions.

The tripping type of the overload relay must not differ from the given tripping characteristic after a short-circuit.

Short-circuit strength of the auxiliary contact

The manufacturer details the required overcurrent protective device. The combination is subjected to three test disconnection's at 1000 A prospective current with a power factor between 0.5 and 0.7 at rated operational voltage. Welding of the contacts may not occur (EN 60947-5-1, VDE 0660 Part 200).

Motor protection in special applications

Heavy starting duty

An adequate tripping time is essential in order to allow a motor to start up smoothly. In the majority of cases, overload relays such as motor-protective circuit-breakers PKZ(M) or circuit-breakers NZM can be used. The tripping time can be taken from the tripping characteristics in the Product range catalog "Switching and protecting motors".

In the case of especially high-inertia motors, whose run-up time exceeds the tripping delay of the above devices, it would be completely wrong to adjust an overload relay which tripped out before the run-up time expired, to a current level higher than the rated motor current. This would, it is true, solve the starting problem, but the motor would no longer be adequately protected during run. However, there are other solutions to the problem:

Current transformer-operated overload relays ZW7

The ZW7 consists of three special saturable core current transformers, supplying an overload relay Z... It is used principally for medium and large motors. Up to two times rated operational current I_e, the transformation ratio I_1/I_2 of the saturable core current transformers is practically linear. Within this range it does not differ from the normal overload relay, i. e. it provides normal overload protection during normal operation. However, within the transformer characteristic range ($I > 2 \times I_e$), the secondary current no longer increases proportionally to the primary current.

This non-linear increase in the secondary current produces an extended tripping delay if overcurrents greater than twice rated operational current occur, and hence permits longer start-up times.

Adjusting the current transformer-operated overload relay ZW7 for lower rated motor current

The setting ranges quoted in the Product range catalog "Switching and protecting motors", apply when the incoming cable is looped once through the transformer relay.

If the current transformer-operated overload relay ZW7 is required to provide protection to a motor of below 42 A rating (minimum value in the setting range of 42 A to 63 A), the necessary range adjustment is achieved by looping the incomer several times through the aperture in the relay. The change in the rated motor current quoted on the rating plate is inversely proportional to the number of loops.

Example:

With the ZW7-63 relay, which has a setting range from 42 A to 63 A, a rated motor current of 21 A to 31.5 A can be accommodated by looping the leads twice through the relay.

Bridging of motor protection during starting

For small motors the bridging of the motor protection during starting is more economical. Because of the additional parallel contactor, the overload relay does not carry the full current during starting. Only when the motor has reached full speed is the bridging contactor switched off and the full motor current is then carried by the overload relay. Provided it has been set correctly to the rated motor current, this will ensure full motor protection during operation. Starting must be monitored.

The motor is a limiting factor with regard to the tripping delay of the current transformer-operated relay and the bridging period. One must ensure that the motor is able to tolerate the high temperature generated by direct starting, for the prescribed starting time. Motor and starting procedure have to be selected carefully when dealing with machines having a very large rotating mass, which are practically the only ones subject to this problem when direct starting is used. Depending on the operating conditions adequate protection of the motor winding may no longer be given by an overload relay. In that case it must be weighed up whether an electronic overload relay ZEV, ZEB or a thermistor overload relay EMT6 in conjunction with an overload relay Z meets the requirements.

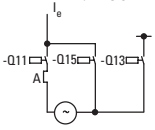
Example circuits →page 3-24

Motors
Motor protection

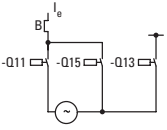
Star-delta switch (Y Δ)

1 operating direction
Changeover time with overload relay in position

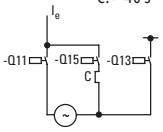
A: < 15 s



B: > 15 < 40 s



C: > 40 s



Setting of the overload relay

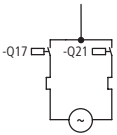
0.58 x I_e
Full motor protection in Y (star) position

1 x I_e
Only partial motor protection in Y position

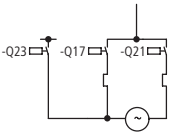
0.58 x I_e
Motor not protected in Y position

Multi-speed switches

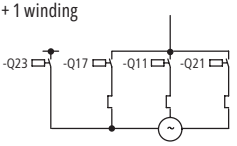
2 speeds
2 separate windings



One tapped winding



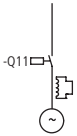
3 speeds
1 x tapped winding
+ 1 winding



Attention must be paid to short-circuit protective device of the overload relays.
Separate supply input wirings should be provided if required.

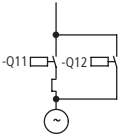
Heavy starting duty

ZW7 current transformer-operated overload relays



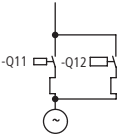
For medium and large motors

Bridging of motor protection during starting



For small motors; no protection during starting

Bridging during starting using bridging relay



Automatic cut out of the bridging contactor

Motors
Motor protection

Individually compensated motor

$I_w = I_e \times \cos\varphi$ [A]

$I_b = \sqrt{I_e^2 - I_w^2}$ [A]

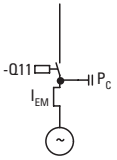
$I_c = U_e \times \sqrt{3} \times 2\pi f \times C \times 10^{-6}$ [A]

$$I_c = \frac{P_c \times 10^3}{\sqrt{3} \times U_e}$$

I_e = Rated motor operational current [A]
I_w = Active current
I_b = Reactive current } Proportion of motor rated operational current [A]
I_c = Capacitor-Rated operational current [A]
I_{EM} = Setting current of overload relay [A]
cos φ = Motor power factor
U_e = Rated operational voltage [V]
P_c = Rated capacitor output [kvar]
C = Capacitance of capacitor [µF]

Capacitor connected

to protective conductor terminals

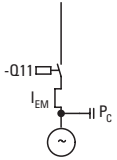


Setting I_{EM} of overload relay

$I_{EM} = 1 \times I_e$

Capacitor does not relieve loading of cable between contactor and motor.

to motor terminals



$I_{EM} = \sqrt{I_w^2 + (I_b - I_c)^2}$

Capacitor relieves loading of cable between contactor and motor; normal arrangement.

Thermistor overload relay for machine protection

Thermistor overload relays for machine protection are used in conjunction with temperature-dependent semi-conductor resistors (thermistors) for monitoring the temperature of motors, transformers, heaters, gases, oils, bearings etc.

Depending on the application, thermistors have positive (PTC thermistors) or negative (NTC thermistors) temperature coefficients. With PTC thermistors the resistance at low temperature is small. From a certain temperature it rises steeply. On the other hand, NTC thermistors have a falling resistance-temperature characteristic, which does not exhibit the pronounced change behaviour of the PTC thermistor characteristic.

Temperature monitoring of electric motors

Thermistor overload relays for machine protection EMT6 comply with the characteristics for the combination of protective devices and PTC sensors to EN 60947-8. They are therefore suitable for monitoring the temperature of series motors

When designing motor protection, it is necessary to differentiate between stator-critical and rotor-critical motors:

- **Stator-critical**
  Motors whose stator winding reaches the permissible temperature limit quicker than the rotor. The PTC sensor fitted in the stator winding ensures that the stator winding and rotor are adequately protected even with a stalled rotor.
- **Rotor-critical**
  Squirrel-cage motors whose rotor in the event of stalling reaches the permissible temperature limit earlier than the stator winding. The delayed temperature rise in the stator can lead to a delayed tripping of the thermistor overload relay for machine protection. It is therefore advisable to supplement the protection of rotor-critical motors by a conventional overload relay. Three-phase motors above 15 kW are usually rotor-critical.

Overload protection for motors in accordance with IEC 204 and IEC/EN 60204. These standards specify that motors above 2 kW used for frequent starting and stopping should be adequately protected for this type of duty. This can be achieved by fitting temperature sensors. If the temperature sensor is not able to ensure adequate protection with stalled rotors, an overcurrent relay must also be provided.

Generally, where there is frequent starting and stopping of motors, intermittent operation and excessive frequency of operation, the use of overload relays in conjunction with thermistor overload relays is to be recommended. In order to avoid premature tripping out of the overload relay in these operating conditions, it is set higher than the predefined operating current. The overload relay then assumes stalling protection; the thermistor protection monitors the motor winding.

Motors
Motor protection

Thermistor overload relays for machine protection can be used in conjunction with up to six PTC sensors to DIN 44081 for direct monitoring of temperatures in Ex e motors compliant with the ATEX directive (94/9 EC). An EC type testing certificate can be provided.

Protection of current and temperature-dependent motor-protective devices

Protection of the motor under the following conditions	Using bimetal	Using thermistor	Using bimetal and thermistor
Overload in continuous operation	+	+	+
Extended starting and stopping	(+)	+	+
Switching to stalled rotor (stator-critical motor)	+	+	+
Switching on stalled rotor (rotor-critical motor)	(+)	(+)	(+)
Single-phasing	+	+	+
Intermittent operation	–	+	+
Excessive operating frequency	–	+	+
Voltage and frequency fluctuations	+	+	+
Increased coolant temperature	–	+	+
Impaired cooling	–	+	+

\+ Full protection
(+) Partial protection
– No protection

Motors
Circuit documents

General

Circuit documents serve to explain the function of circuits or electrical connections. They provide information for the construction, installation and maintenance of electrical installations.

The supplier and the operator must agree on the form in which the circuit documents are to be produced: paper or digital. They must also agree on the language or languages in which the documentation is to be produced. In the case of machines, user information must be written in the official language of the country of use to comply with according to the European Machinery Safety Directive/Regulation and ISO 12100.

The circuit documents are divided into two groups:

Classification according to the purpose

Explanation of the mode of operation, the connections or the physical position of the apparatus. This consists of:

- Explanatory circuit diagrams,
- Block diagrams,
- Equivalent circuit diagrams,
- Explanatory tables or diagrams,
- Flow diagrams, tables
- Time flow diagrams, tables
- Wiring diagrams,
- Device wiring diagrams,
- Interconnection diagrams,
- Terminal diagrams,
- Assignment diagrams.

Classification according to the type of representation

Simplified or detailed:

- 1-pole or multi-pole representation,
- Connected, semi-connected or separate representation,
- Topographical representation.

In addition to this, there is the processorientated representation with the function block diagram (see previous pages).

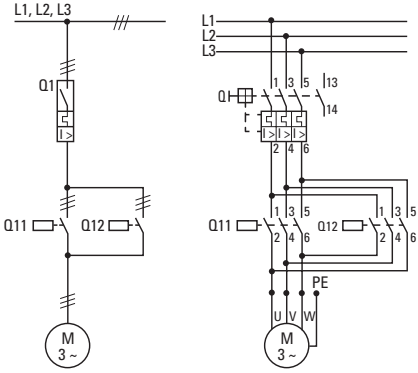
Examples for drawing up circuit documents are given in DIN EN IEC 61082-1.

Circuit diagrams

Diagrams indicate the voltage-free or current-free status of the electrical installation. A distinction is drawn between:

- Block diagram. Simplified representation of a circuit with its main parts. It shows how the electrical installation works and how it is subdivided.
- Circuit diagram. Detailed representation of a circuit with its individual components,which shows how the electrical installation works.
- Equivalent circuit diagram. Special version of an explanatory circuit diagram for the analysis and calculation of circuit characteristics.

Motors
Circuit documents



Circuit diagram: 1-pole and 3-pole representation

Wiring diagrams

Wiring diagrams show the conductive connections between electrical apparatus. They show the internal and/or external connections but, in general, do not give any information on the mode of operation. Instead of wiring diagrams, wiring tables can also be used.

- Unit wiring diagram. Representation of all the connections within the device or combination of devices.
- Interconnection diagram. Representation of the connections between the device or combination of devices within an installation.
- Terminal diagram. Representation of the connection points of an electrical installation and the internal and external conductive connections connected to them.
- Location diagram (location diagram). Representation of the physical position of the electrical apparatus, which does not have to be to scale.

You will find notes on the marking of electrical apparatus in the diagram as well as further diagram details in the chapter “Specifications, Formulae, Tables”.

Motors
Contactor markings

The contactors in contactor combinations have, in accordance with EN 81346-2 for apparatus and function, the code letter Q, as well as numerical identification, which shows the function of the device (e. g. Q22 = mains contactor with anticlockwise operation for high speed).

With contactor combinations which are made up of several basic types, the basic type is always maintained. Thus, the circuit diagram for a reversing star-delta starter, for example, is formed by combining the basic circuit of the reversing contactor and that of the standard star-delta starter.

Other marking of electrical apparatus:

- for the IEC world →page 10-2
- for North America →page 9-14

Motors
Direct-on-line start of three-phase motors

Typical circuits with DIL contactors

Fuseless without overload relay

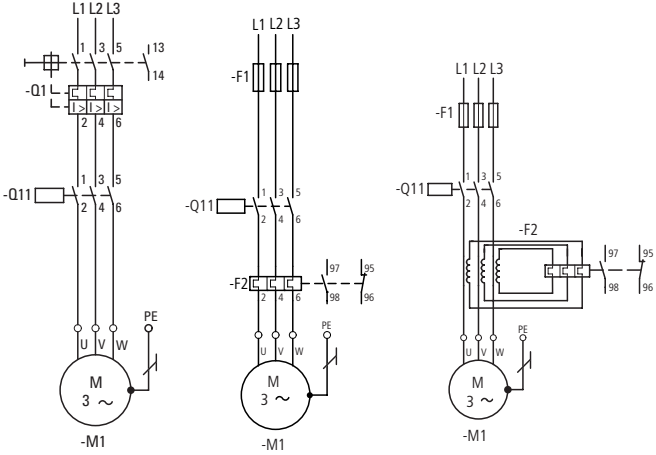
Short-circuit protection[1] and overload protection by means of PKZM motor-protective circuit-breaker or NZM circuit-breaker.

Fuses with overload relay

Short-circuit protection[2] for contactor and overload relay by means of fuses F1.

Short-circuit protection[3] for contactor by means of fuses F1.

Overload protection by motor-protective relay F2.



[1] Protective device in the input wiring in accordance with the Product range catalog "Switching and protecting motors" or Instruction Leaflets.

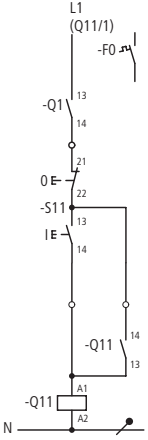
[2] Fuse size in accordance with data on the rating plate of the overload relay.

[3] Fuse size in accordance with the Product range catalog "Switching and protecting motors" (Technical data for contactors)

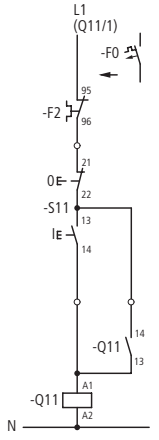
Motors
Direct-on-line start of three-phase motors

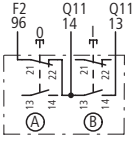
Typical circuit with bridging of overload relay during starting

Without overload relay



With overload relay





The short-circuit strength capacity of the contacts in the circuit has to be considered when selecting F0.
Double pushbutton

Control circuit device

I: ON
0: OFF

For connection of further actuators

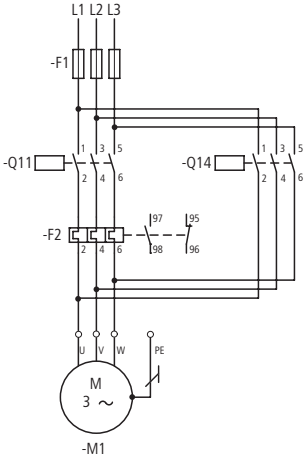
→ Section "Three-wire control", page 3-39

Method of operation: Actuation of pushbutton I energizes the coil of contactor Q11. The contactor switches on the motor and maintains itself after the button is enabled via its own auxiliary contact Q11/14-13 and pushbutton 0 (three-wire control contact). Contactor Q11 is de-energized, in the normal course of events, by actuation of pushbutton 0. In the event of an overload, it is de-energized via the normally closed contact 95-96 on the overload relay F2. The coil current is interrupted, and contactor Q11 switches the motor off.

Motors

Direct-on-line start of three-phase motors

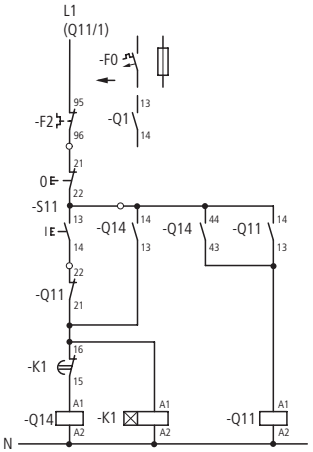
Application on drive motors with heavy starting duty



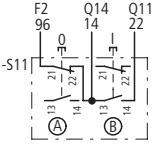
For connection when used with motor-protective circuit-breakers PKZM..., PKE and circuit-breakers NZM(H)... → Section "Fuseless without overload relay", page 3-35

Motors

Direct-on-line start of three-phase motors



Q14:Bridging contactor
K1: Timing relays
Q11:Mains contactor



Control circuit device
I: ON
0: OFF

For connection of further actuators
→ Section "Three-wire control", page 3-39

Function

Actuation of pushbutton I energizes bridging contactor Q14 which then maintains itself via Q14/13-14. At the same time, voltage is applied to the timing relay K1. The mains contactor Q11 is closed by Q14/44-43 and maintains itself via Q11/14-13. When the set time – which corresponds to the start-up time of the motor – has elapsed, the bridging contactor Q14 is disconnected by K1/16-15.

K1 is likewise disconnected and, exactly as Q14, can only be energized again after the motor has been switched off by pressing pushbutton 0. The N/C Q11/22-21 prevents Q14 and K1 closing whilst the motor is running. In the event of an overload, normally closed contact 95-96 on the overload relay F2 effects de-energization.

Motors

Direct-on-line start of three-phase motors

2 operating directions, DIUL reversing contactor

Fuseless without overload relay

Short-circuit protective device and overload protection by means of motor-protective circuit-breaker PKZM, PKE or circuit-breaker NZM.

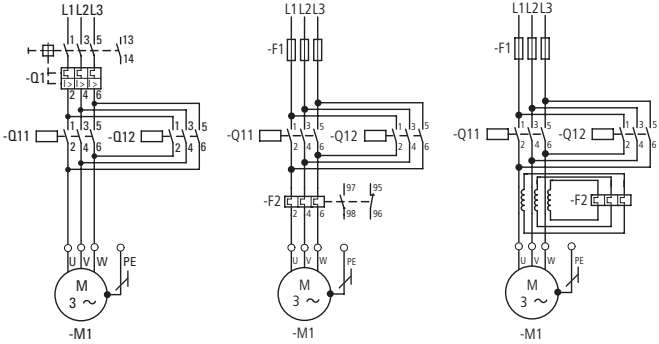
Fuse size in the input wiring in accordance with the Product range catalog "Switching and protecting motors" or Instruction Leaflets.

Fuseless without overload relay

Short-circuit protection[1)] for contactor and overload relay by means of fuses F1.

Short-circuit protection[1)] for contactor by means of fuses F1.

Overload protection by motor-protective relay F2.

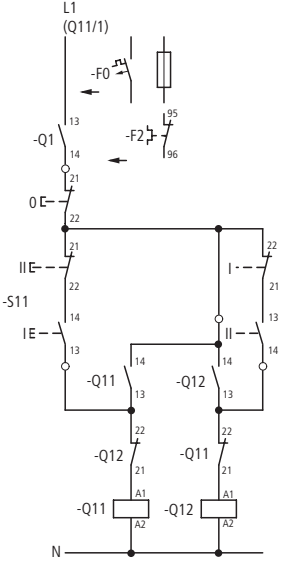


[1)] Fuse size in accordance with data on the rating plate of the overload relay F2

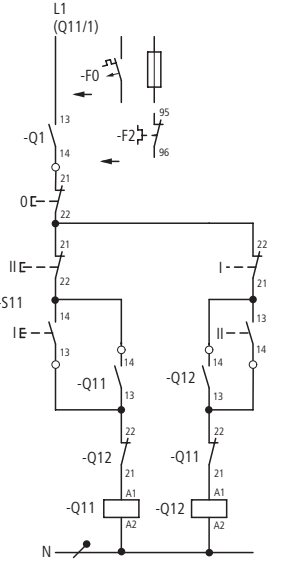
Motors

Direct-on-line start of three-phase motors

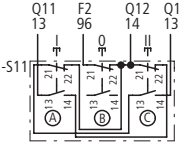
Changing direction of rotation **after** actuation of the 0 pushbutton



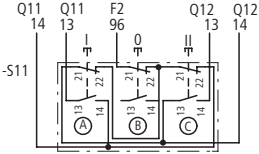
Changing direction of rotation **without** actuation of the 0 pushbutton



Q11: Mains contactor, clockwise
Q12: Mains contactor, anticlockwise operation



Control circuit device
(three-way pushbutton)
I = Clockwise
0 = Stop
II = anticlockwise operation



Motors

Direct-on-line start of three-phase motors

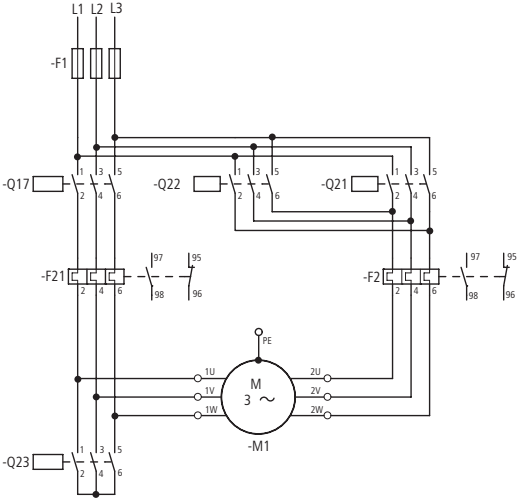
Method of operation: Actuation of pushbutton I energizes the coil of contactor Q11. It switches on the motor running clockwise and maintains itself after button I is enables via its own auxiliary contact Q11/14-13 and pushbutton 0 (three-wire control). The normally closed contact Q11/22-21 electrically inhibits the closing of contactor Q12. When pushbutton II is pressed, contactor Q12 closes (motor running anticlockwise).

Depending on the circuit, direction can be changed from clockwise to anticlockwise either after pressing pushbutton 0, or by directly pressing the pushbutton for the reverse direction. In the event of an overload, normally closed contact 95-96 of the overload relay F2 or the normally open contact 13-14 of the motor-protective circuit-breaker or the circuit-breaker will switch.

Operating direction and two speeds (reversing contactor)

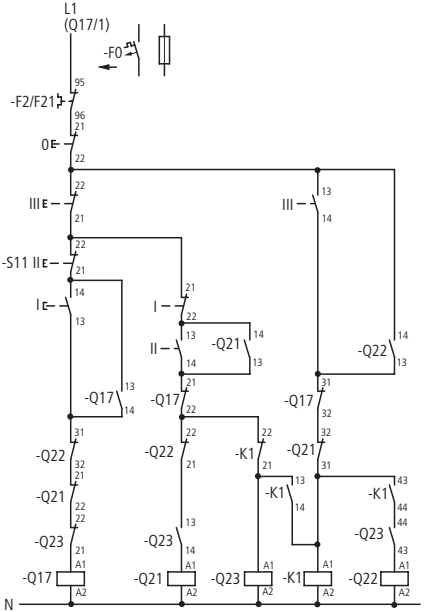
Special circuit (tapped winding) for feed drives, etc.

FORWARD: feed or high-speed
RETRACT: high-speed only
STOP: tapped winding



Motors

Direct-on-line start of three-phase motors



0: Stop
I: Low speed – FORWARD (Q17)
II: High speed – FORWARD (Q21 + Q23)
III: High speed – BACK (Q22 + Q23)

Q17: Feed forward
Q21: High-speed forward
Q23: Star contactor
K1: Contactor relay
Q22: Retract high-speed

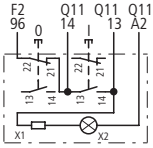
Method of operation: Forward travel is initiated by pressing pushbutton I or II according to the speed required. Pushbutton I switches on the feed motion via Q17. Q17 maintains itself via its N/O 13-14. If the feed movement is to occur at high-speed star contactor Q23 is energized via pushbutton II which energizes the high speed contactor Q21 via its N/O Q23/13-14. Both of the contactors are maintained via Q21/13-14. A direct switch over from feed to high-speed during the process is possible.

High-speed reverse is initiated by pushbutton III. Contactor relay K1 picks up and energizes star contactor Q23 via K1/14-13. High-speed contactor Q22 is energized via normally open contacts K1/43-44 and Q23/44-43, and is maintained via Q22/14-13. The reverse motion can only be stopped via pushbutton 0. Direct changeover/reversal is not possible.

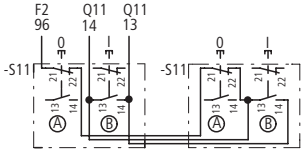
Motors
Control circuit devices for direct-on-line start

Typical example of circuits with contactors DILM...

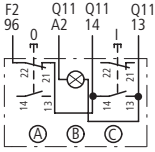
Three-wire control



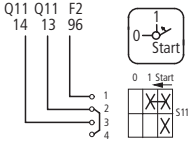
Illuminated pushbutton actuators



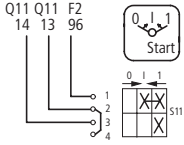
Two double actuator pushbuttons



Double actuator pushbutton with indicator light

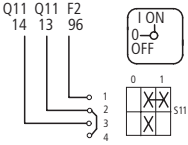


T0-1-15511 spring-return switch with automatic return to position 1

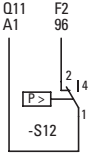


T0-1-15366 spring-return switch with automatic return to position of rest

Two-wire control



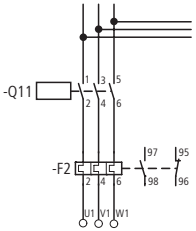
Changeover switch T0-1-15521 with fleeting contact in the intermediate position



MCS pressure switches

Motors
Star-delta switching of three-phase motors

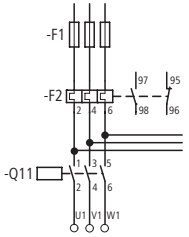
Star-delta switch with overload relay



Arrangement in the motor line

In a standard circuit configuration, the star-delta switch with overload relay, i. e. a thermally delayed overcurrent relay, is installed in the cables leading to the motor terminals U1, V1, W1 or V2, W2, U2. The overload relay can also be operated in a star circuit as it is usually connected in series with the motor winding and the relay current flowing through it = rated motor current x 0.58.

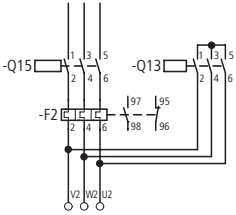
The complete circuit diagram
→ Section "Automatic star-delta switches SDAINL", page 3-42.



Arrangement in the mains supply line

Instead of the arrangement in the motor line, the overload relay can be placed in the **mains supply line**. The section shown here indicates how the circuit diagram differs from that on
→ Section "Automatic star-delta switches SDAINL", page 3-42.
For drives where the F2 relay trips out when the motor is starting in the star connection, the F2 relay rated for the **rated motor current can be switched in the mains line**. The tripping delay is thus increased by approximately four to six times. In the star connection, the current also flows through the relay but here the relay does not offer full protection since its limit current is increased to 1.73 times the phase current. It does, however, offer protection against non-starting.

Motors
Star-delta switching of three-phase motors

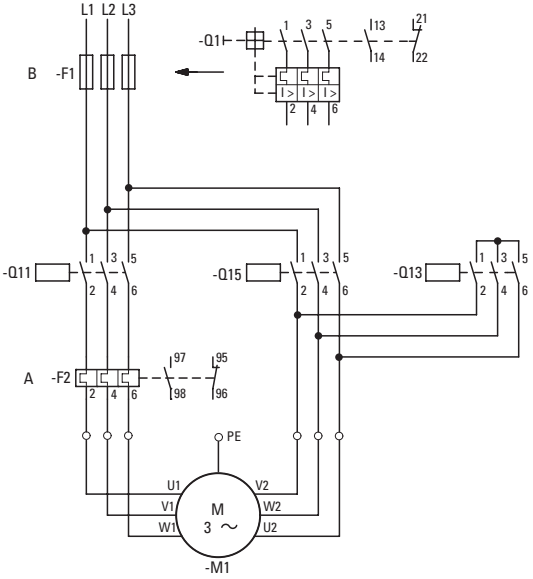


Configuration in the delta connection

Instead of the arrangement in the motor line or mains supply line, the overload relay can be placed in the delta connection. The cutout shown here indicates the modified circuit diagram from → Section "Automatic star-delta switches SDAINL", page 3-42. When heavy, long-starting procedures are involved (e. g. for centrifuges) the F0.58 relay, rated for relay current = rated motor current x 2, can also be connected in the connecting cables between the delta contactor Q15 and the star contactor Q13. In the star connection no current then flows through the F2 relay. The motor is therefore not protected when starting. This connection is always used when exceptionally heavy and long starting procedures are involved and when saturable core current transformeroperated relays react too quickly.

Motors
Star-delta switching of three-phase motors

Automatic star-delta switches SDAINL



Arrangement and rating of protective devices

Position A	Position B
F2 = 0.58 x I_e with F1 in position B $t_a \leqq 15$ s	Q1 = I_e t_a > 15 - 40 s
Motor protection in Y- and △-configuration	Only partial motor protection in Y-configuration

Rating of switchgear

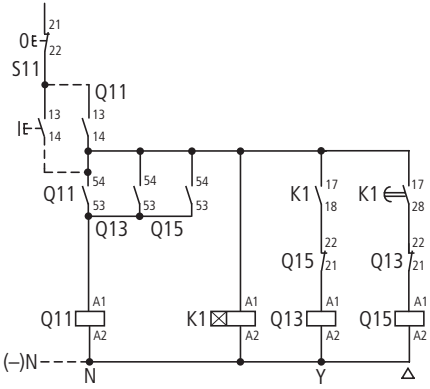
Q11, Q15 = 0.58 x I_e

Q13 = 0.33 x I_e

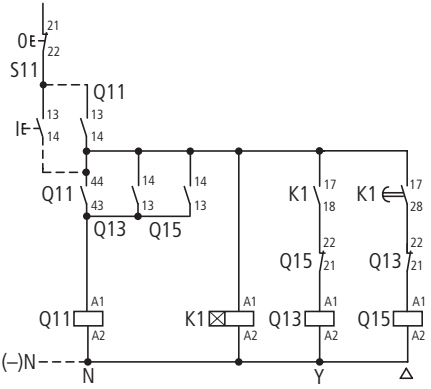
Motors
Star-delta switching of three-phase motors

Further notes on the configuration of the overload relay → Section "Automatic star-delta switches SDAINL", page 3-42

SDAINLM12 to SDAINLM55



SDAINLM70 to SDAINLM260



Pushbutton

K1: Timing relay approx. 10 s
Q11: Mains contactor
Q13: Star contactor
Q15: Delta contactor
Double pushbutton

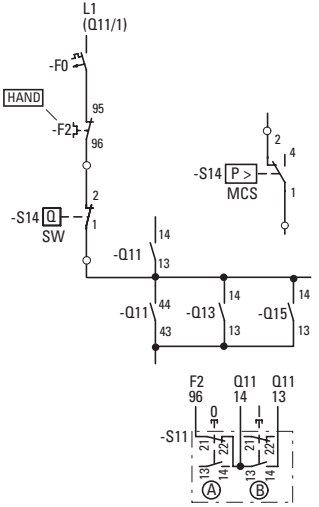
Function

Pushbutton I energizes timing relay K1. The normally open contact K1/17-18 (instantaneous contact) which applies voltage to star contactor Q13, which closes and applies voltage to mains contactor Q11 via normally open contact Q13/14-13. Q11 and Q13 maintain themselves via the N/O Q11/14-13 and Q11/44-43. Q11 applies mains voltage to motor M1 in star connection.

Motors
Star-delta switching of three-phase motors

For connection of further control circuit devices → Section "Control circuit devices for star-delta starting", page 3-48

SDAINLM12 to SDAINLM260 Two-wire control



Double pushbutton
Control circuit device
I = ON
0 = OFF

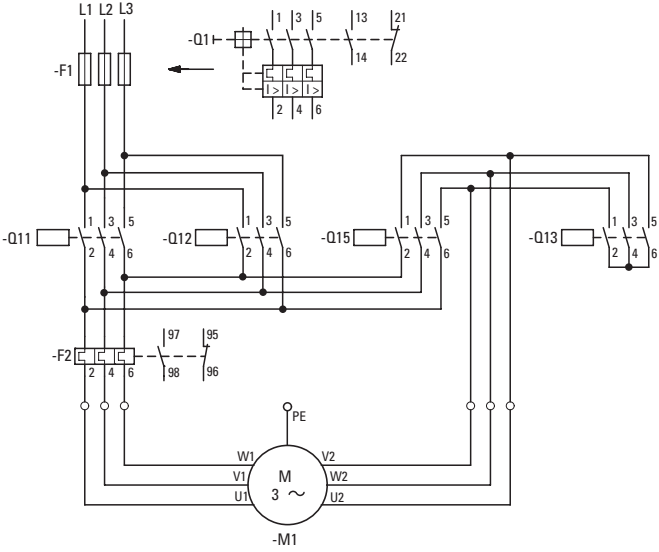
When the set changeover time has elapsed, K1/17-18 opens the circuit of Q13 and after 50 ms closes the circuit of Q15 via K1/17-28. Star contactor Q13 drops out. Delta contactor Q15 closes and switches motor M1 to full mains voltage. At the same time, normally closed contact Q15/22-21 interrupts the circuit of Q13 thus interlocking against renewed switching on while the motor is running.

The motor cannot start up again unless it has previously been disconnected by pushbutton 0, or in the event of an overload by the normally closed contact 95-96 of overload relay F2, or via normally open contact 13-14 of the motor-protective circuit-breaker or standard circuit-breaker.

Motors
Star-delta switching of three-phase motors

Automatic reversing star-delta switches

2 operating directions



Rating of switchgear

Q11, Q12: I_e

F2, Q15: $0.58 \times I_e$

Q13: $0.33 \times I_e$

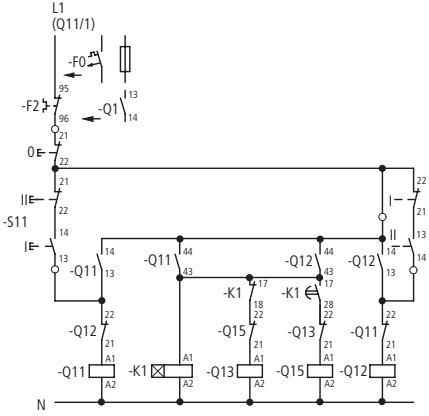
The maximum motor output is limited by the upstream reversing contactor, and is lower than with automatic star-delta switches for only one direction of operating direction.

Standard version: Relay current = motor rated operational current x 0.58

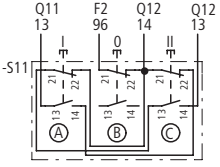
For other arrangements of overload relay
→ Section "Star-delta switch with overload relay", page 3-40

Motors
Star-delta switching of three-phase motors

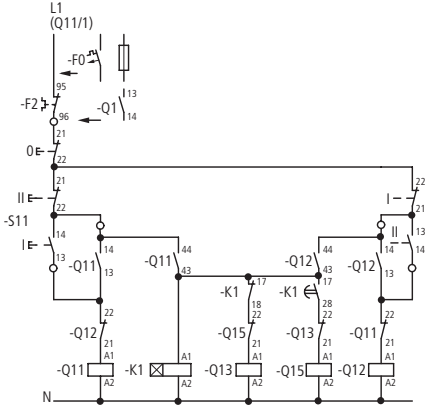
Changing direction of rotation **after** actuation of the 0 pushbutton



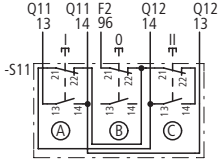
Three-way pushbutton
Control circuit devices
I = clockwise
0 = Stop
II = anticlockwise operation



Changing direction of rotation **without** actuation of the 0



Three-way pushbutton
Control circuit devices
I = clockwise
0 = Stop
II = anticlockwise operation



Motors
Star-delta switching of three-phase motors

For connection of further actuators
→ Section "Control circuit devices for star-delta starting", page 3-48

Function

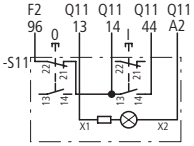
Pushbutton I energizes contactor Q11 (e. g. clockwise). Pushbutton II energizes contactor Q12 (e. g. anticlockwise operation). The contactor first energized applies voltage to the motor winding and maintains itself via its own auxiliary contact 14-13 and pushbutton 0. The normally open contact 44-43 fitted to each mains contactor energizes the star contactor Q13. Q13 energizes and switches on motor M1 in the star connection. At the same time, timing relay K1 is triggered. When the set changeover time has elapsed, K1/17-18 opens the circuit of Q13. Q13 drops out. K1/17-28 closes the circuit of Q15.

Delta contactor Q15 energizes and switches motor M1 to the delta configuration, i. e. full mains voltage. At the same time, normally closed contact Q15/22-21 interrupts the circuit of Q13, thus interlocking against renewed switching on while the motor is running. Motor direction can be changed, either after pressing pushbutton 0, or by direct actuation of the reverse button, depending upon the circuit. In the event of an overload, disconnection is effected by the normally closed contact 95-96 of the overload relay F2.

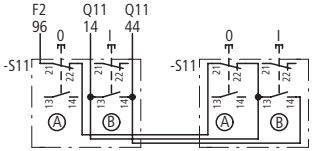
Motors
Control circuit devices for star-delta starting

Automatic star-delta switches

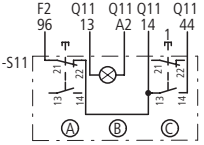
Pulse encoder



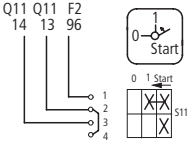
Illuminated pushbutton actuators



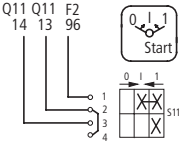
Two double actuator pushbuttons



Double actuator pushbutton with indicator light

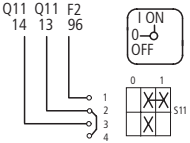


Spring-return switch T0-1-15511 with automatic return to position 1.

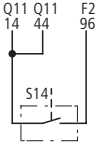


Spring-return switch T0-1-15366 with automatic return to position of rest.

Two-wire control



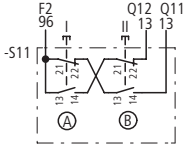
Changeover switch T0-1-15521 with fleeting contact in the intermediate position



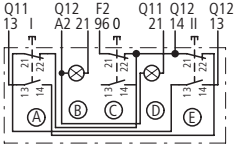
e. g. selector switch
Cam switch T
LS position switches
MCS pressure switches

Motors
Control circuit devices for star-delta starting

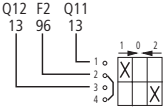
Three-phase current-reversing contactor-reversing star-delta switch



Two-way pushbutton[1] without self-maintaining circuit (inching) for use only with reversing contactors



Three-way pushbutton with indicator light. Reversing after actuation of pushbutton 0

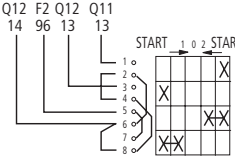


FS 4011

Spring-return switch[1]
T0-1-8214, without self-maintaining circuit (inching)
automatic return to off position
only for reversing contactors

FS 684

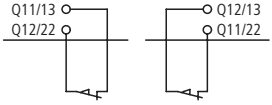
Changeover switch[1]
Switch T0-1-8210 remains in position 1 or 2



FS 140660

Spring-return switch
T0-2-8177 with automatic return to position 1 or 2

Limit switch
Connected by removing the links between the contactor terminals Q11/13 and Q12/22 and between Q12/13 and Q11/22 and interposing the position switches.



[1] Overload relays always with reclosing lockout

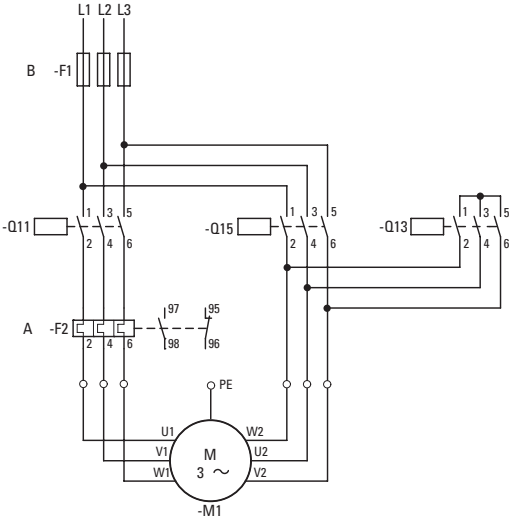
Motors
Control circuit devices for star-delta starting

Adverse star-delta wiring

If adverse interconnection of motor winding is used high compensating currents can occur when switching from star to delta contactor.

These compensating currents can reach into the area of short-circuit currents and highly stress switchgear and motor. Faulty trippings of the protection organs are possible. Following wiring diagram shows for instance the adverse wiring of motor windings in the motor connection box for clockwise rotation.

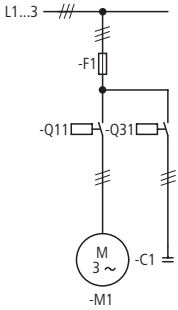
Compare also with best variant →Section "Automatic star-delta switches SDAINL", page 3-42



Motors
Switching of capacitors

DIL contactors for capacitors – individual switching

Individual compensation

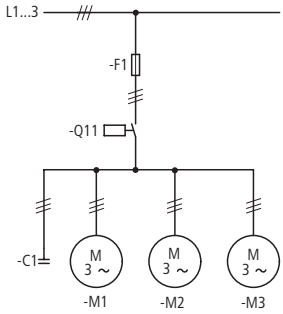


When capacitors are switched on, contactors are heavily stressed by transient current peaks. When a single capacitor is switched on, currents up to 30 times the rated operational current can occur; these can, however, be reliably switched by Eaton DIL contactors.

When installing capacitors, the VDE specification 0560 part 4 (Germany) and the standards which apply to each country should be observed. According to these, capacitors not directly connected to an electrical device which forms a discharge circuit, should be equipped with a rigidly connected discharge device. Capacitors connected in parallel to the motor do not require a discharge device, since discharging is performed via the motor winding.

No switch-disconnectors or fuses must be installed between the discharge circuit and the capacitor.

Group compensation

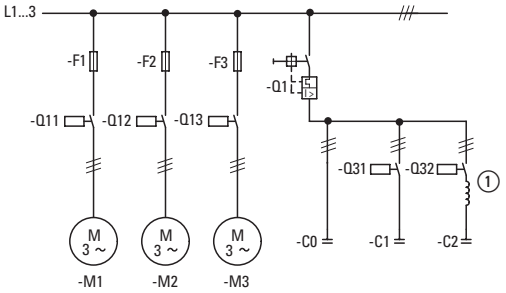


A discharge circuit or discharge device must reduce the residual voltage of the capacitor to less than 50 V within a minute of the capacitor being switched off.

Motors
Switching of capacitors

Contactor for capacitor DILK... – Individual and group compensation

Group compensation



1 Additional inductance with standard contactor

In the case of group compensation where capacitors are connected in parallel, it must be noted that the charging current is taken not only from the mains but also from the capacitors connected in parallel. This produces inrush current peaks which can exceed 150 times the rated operational current. A further reason for these peak currents is the use of low-loss capacitors as well as the compact construction, with short connecting elements between contactor and capacitor.

Where standard contactors are used, there is danger of welding. Special contactors for capacitors such as those available from Eaton in the DILK... range which can control inrush current peaks of up to 180 times the rated current, should be used here.

If no special contactors are available, the inrush currents can be damped by additional inductance's. This is achieved either by longer input wirings to the capacitors or by inserting an air-cored coil with a minimum induction of approximately 6 µH (5 windings, diameter of the coil approximately 14 cm) between contactor and capacitor. The use of series resistors is another way of reducing high inrush currents.

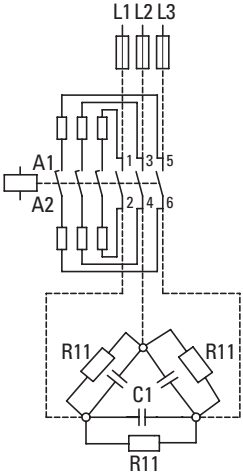
Use of reactors

Frequently the capacitors in group compensation are provided with reactors to avoid harmonics. The reactors also act to limit the inrush current and normal contactor can be used.

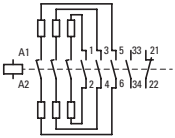
Motors
Switching of capacitors

Contactors DILK for capacitors

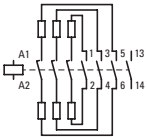
Individual circuit with series resistors



DILK12 to DILK25 (12.5 to 25 kvar/400 V)

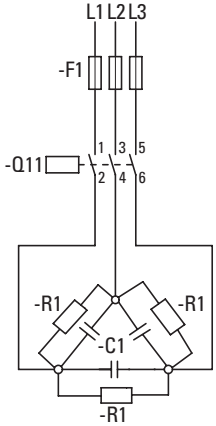


DILK33 to DILK50 (33.3 to 50 kvar/400 V)



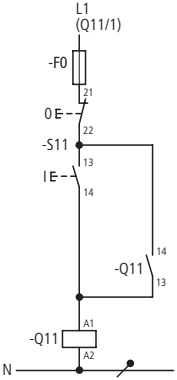
Contactors DIL for capacitors

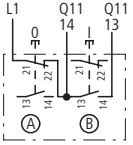
Individual circuit without quick-discharge resistors



R1 discharge resistors fitted in capacitor

Motors
Switching of capacitors





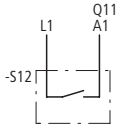
Double pushbutton

For connection of further actuators:

→Section "Control circuit devices for star-delta starting", page 3-48

Maintained contact sensors

In the case of actuation by means of power factor correction relay, check that this has sufficient power to actuate the contactor coil. Interpose a contactor relay if necessary.



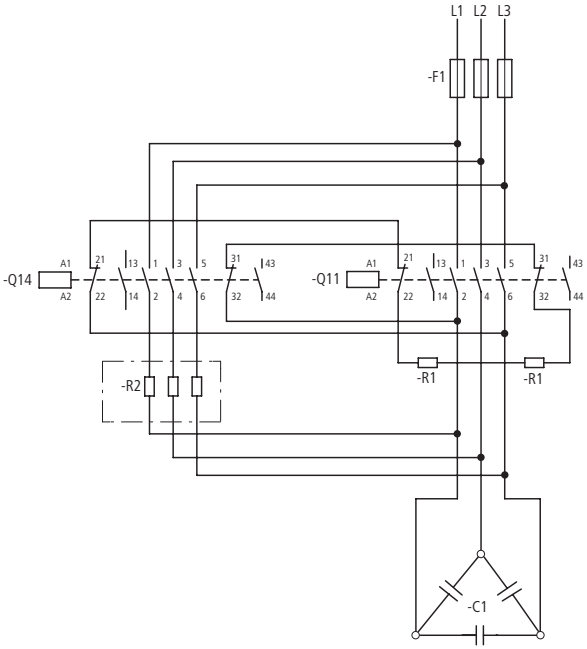
Function

Pushbutton I actuates contactor Q11, which picks up and maintains itself via its own auxiliary contact 14-13 and pushbutton 0 on voltage. Capacitor C1 is thus energized. Discharge resistors R1 are not active when contactor Q11 is energized. Actuation of pushbutton 0 effects de-energization. Normally closed contacts Q11/21-22 then switch discharge resistors R1 to capacitor C1.

Motors
Switching of capacitors

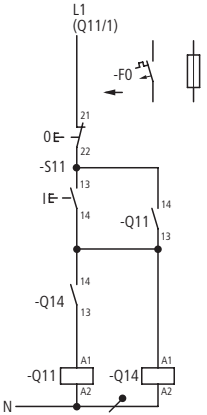
Capacitor contactor combination

Capacitors contactor with pilot contactor and series resistors. Individual and parallel circuit with and without discharge resistors and with series resistors.

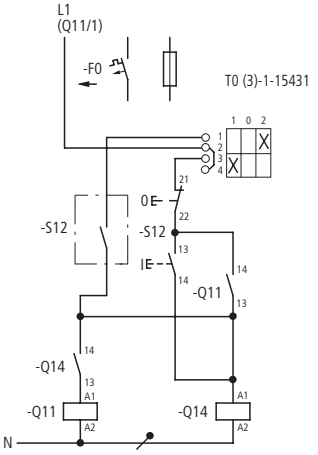


On the version without discharge resistors, resistors R1 and the connections to the auxiliary contacts 21-22 and 31-32 are omitted.

Motors
Switching of capacitors



Q11: Mains contactor
Q14: Pilot contactor
Actuation by double pushbutton S11



Actuation by selector switch S13, two-wire control S12 (power factor correction relay) and double pushbutton S11

Function

Actuation by double pushbutton S11: Pushbutton I energizes pilot contactor Q14. Q14 switches capacitor C1 in with bridged series resistors R2. N/O Q14/14-13 energizes mains contactor Q11. Capacitor C1 is then switched in with bridged series resistors R2. Q14 is maintained via Q11/14-13 when Q11 has closed.

Discharge resistors R1 are not operative when Q11 and Q14 are energized. Pushbutton 0 effects de-energization. N/C Q11/21-22 and 31-32 then switch discharge.

Motors
Switching and protection of transformers and chokes

Contactors DILM for primary switching of transformers and chokes

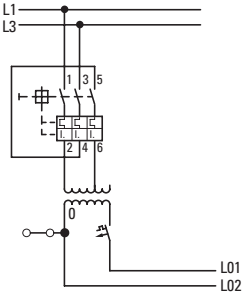
According EN60947-4-1, table 7 the rating for the switching of transformers by means of AC-3 values and appropriate utilization category AC-6a can be deduced according table 9 as following:

I_e (AC-6a):
Rated primary current of transformer

Defined by inrush current of utilization category AC-3:
0.45 x I_e (AC-3)

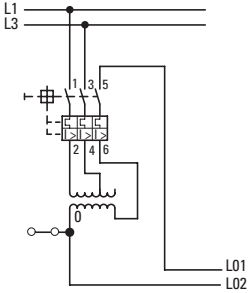
The contactor can thereby rated with
I_e (AC-3) = I_e (AC-6a, transformer)/0.45

With this rating transformers with a 30-fold inrush peak current of the rated current are considered.



Separate primary and secondary protection

Grounded circuit. In non-grounded circuit, remove link and provide insulation monitoring.

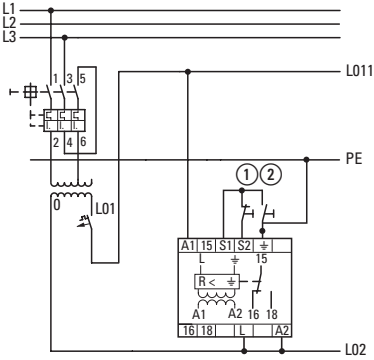


Combined primary and secondary protection

Grounded circuit. In non-grounded circuit, remove link and provide insulation monitoring.
Maximum ratio of U1/U2 = 1/1.73
Circuit not to be used with STI/STZ (safety or isolating transformers).

Motors

Switching and protection of transformers and chokes



Separate primary and secondary protection, with insulation monitoring on the secondary side

① Clear button

② Test button

Contactors and motor-protective circuit-breakers/relays

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Contactor relays

Contactor relays are often used in control and regulating functions. They are used in large quantities for the indirect control of motors, valves, clutches and heating equipment.

In addition to the simplicity which they offer in project engineering, panel building, commissioning and maintenance, the high level of safety which they afford is a major factor in their favor.

Security

The contactor relay contacts themselves constitute a considerable safety feature. By design and construction they ensure potential isolation between the actuating circuit and the operating circuit, in the de-energized state, between the contact input and output. All DIL contactor relays have double-break contacts.

The Employers' liability insurance association demands that, for control systems of power-driven metalwork presses, the contacts of contactors must be interlocked and opposing. Interlocking means that the contacts are mechanically connected to one another such that N/C contacts and N/O contacts can never be closed simultaneously. At the same time, it is necessary to ensure that the contact gaps are at least 0.5 mm over the lifespan, even when defective (e. g. when a contact is welded). The contactor relays DILER and DILA fulfil this requirement.

Contactor relays DIL

Two contactor relay series are available as a modular system:

- Contactor relays DILER,
- Contactor relays DILA.

Modular system

The modular system has many advantages for the user. The system is formed around basic units, which are equipped with additional functions by means of modules. Basic units are intrinsically functional units, consisting of an AC or DC drive and four auxiliary contacts.

Modules having auxiliary functions

Auxiliary contact modules having 2 or 4 contacts. The combination of N/O and N/C contacts is according to EN 50011. The auxiliary contact modules of the contactors DILEM and DILM cannot be snapped onto the basic device to prevent duplication of terminal markings e. g. contact 21/22 on the basic device and 21/22 on the add-on auxiliary contact module.

The DILA and DILM7 to DILM38 contactors of the DILA-XHIR22 auxiliary contact are available specially for switching the smallest signals for electronic applications.

The system and the Standard

European Standard EN 50011 "Terminal markings, distinctive numbers and reference letters for certain contactor relays" has a direct bearing on the use and application of the modular system. There are various types, which the Standard differentiates between by means of reference numbers and reference letters, depending on the number and position of the N/O and N/C contacts in the device, and their terminal markings.

Ideally devices with the reference letter E should be used. The basic devices DILA-40, DILA-31, DILA-22 as well as DILER-40, DILER-31 and DILER-22 comply with the E version.

For 6 and 8 pole contactor relays, the "E" version means that four N/O contacts must be arranged in the lower/rear contact level. If, for example, the available auxiliary contact modules are used in the DILA-22 and DILA-31, they result in contact configurations with reference letters X and Y.

Below are 3 examples of contactors with 4 N/O and 4 N/C contacts with different reference letters. Version E is to be preferred.

Example 1

DILA-XHI04

+

DILA-40

≙ 44 E

DILA40/04

Example 2

DILA-XHI13

+

DILA-31

≙ 44

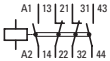
XDILA31/13

Example 3

DILA-XHI22

+

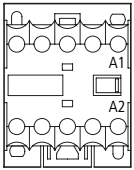
DILA-22



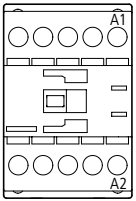
≙ 44 Y

DILA22/22

Coil connections



DILER



DILA

On the top positioned terminals A1–A2 of the contactor DILER the following accessories are connected to limit the relay coil switch off breaking voltage peaks:

- RC suppressors
- Free-wheel diode suppressors
- Varistor suppressors

On the contactor relay DILA the coil connection A1 is at the top and A2 at the bottom.
As suppressor circuits the following are connected on the front:

- RC suppressors
- Varistor suppressors

The DC operated contactors DILER and DILA have an integrated suppressor circuit. For sensitive electronic applications an additional diode suppressor for DILA can be used.

Suppressor circuit

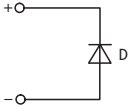
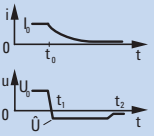
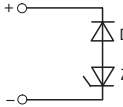
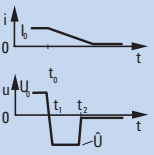
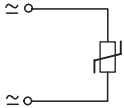
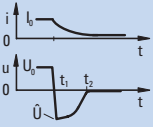
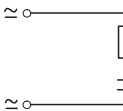
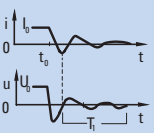
Electronic equipment is nowadays being increasingly used in combination with conventional switching devices such as contactors. This equipment includes programmable logic controllers (PLCs) timing relays and coupling modules, whose operation can be adversely affected by disturbances from interactions between all the components.

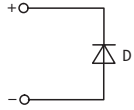
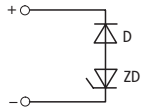
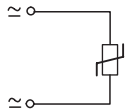
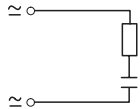
One of the disturbance factors occurs when inductive loads, such as coils of electromagnetic switching devices, are switched off. High cut-off induction voltages can be produced when such devices are switched off and, under some circumstances, can destroy adjacent electronic devices or, via capacitive coupling mechanisms, can generate interference voltage pulses and thus cause function disturbances.

Since interference-free disconnection is impossible without an accessory, the coils may be connected to a suppressor module, depending on the application. The advantages and disadvantages of the various suppressor circuits are explained in the following table.

Notes

4

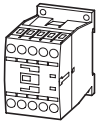
Circuit diagram	Load current and voltage responses	Protected against polarity reversal also for AC	Additional drop-out delay	Induction voltage limiting defined
		–	Very long (approx. 50 ms)	1 V
		–	average	U_{ZD}
		Yes	Short (approx. 2 - 3 ms)	U_{VDR}
		Yes	Short (approx. 5 - 10 ms)	–

Circuit diagram	Damping also below U_{LIMIT}	Additional heat dissipation through circuitry	Notes	
	–	–	Advantages:	Dimensioning uncritical, minimum possible induction voltage, very simple and reliable
			Disadvantage:	Long drop-out delay
	–	–	Advantages:	Very short drop-out delay. Dimensioning uncritical. Simple construction
			Disadvantage:	No damping below U_{ZD}
	–	–	Advantages:	Dimensioning uncritical. High energy absorption. Very simple construction
			Disadvantage:	No damping below U_{VDR}
	Yes	Yes	Advantages:	HF damping due to stored energy, immediate de-energization, highly suitable for AC.
			Disadvantage:	Precise dimensioning required

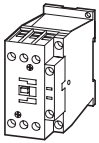
Contactors and motor-protective circuit-breakers/relays

Contactors DIL, overload relays Z

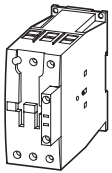
Overview of DIL contactors, 3-pole



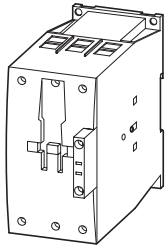
DILM7 up to DILM15



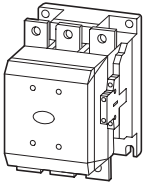
DILM17 up to DILM38



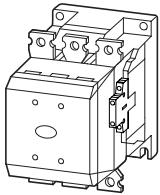
DILM40 up to DILM72



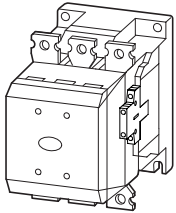
DILM80 up to DILM170



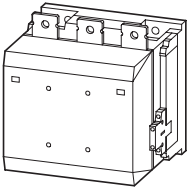
DILM185A,
DILM225A



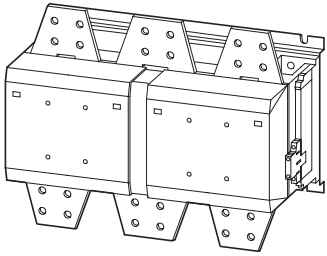
DILM250,
DILM300A



DILM400 up to DILM500
DILH600, DILH800



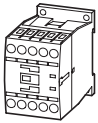
DILM580 up to DILM1000
DILH1200, DILH1400



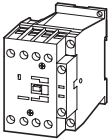
DILM1600
DILH2000, DILH2200, DILH2600

Overview DILP contactors, 4-pole

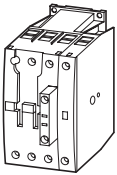
DILEM4



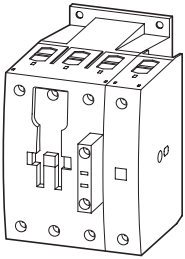
DILMP20



DILMP32 up to DILMP45



DILMP63 up to DILMP80



DILMP125 up to DILMP200

Part no.	Rated operational current 50 – 60 Hz open Conventional thermal current $I_{th} = I_e$, AC-1 open		
	40 °C A	50 °C A	60 °C A
DILEM4	22	20	19[1)]
DILMP20	22	21	20
DILMP32-10	32	30	28
DILMP45-10	45	41	39
DILMP63	63	60	54
DILMP80	80	76	69
DILMP125	125	116	108
DILMP160	160	150	138
DILMP200	200	188	172

[1)] At 55 °C

Contactors and motor-protective circuit-breakers/relays

Contactors DIL, overload relays Z

Rated operating current I_e [A] AC-3 at 400 V	max. rating [kW] AC-3				Conventional thermal current $I_{th} = I_e$ [A] AC-1 at 40 °C	Type
	220 V, 230 V	380 V, 400 V	660 V, 690 V	1000 V		
6.6	1.5	3	3	–	22	DILEEM
9	2.2	4	4	–	22	DILEM
12	3.5	5.5	4	–	22	DILEM12
7	2.2	3	3.5	–	22	DILM7
9	2.5	4	4.5	–	22	DILM9
12	3.5	5.5	6.5	–	22	DILM12
15.5	4	7.5	7	–	22	DILM15
17	5	7.5	11	–	40	DILM17
25	7.5	11	14	–	45	DILM25
32	10	15	17	–	45	DILM32
38	11	18.5	17	–	45	DILM38
40	12.5	18.5	23	–	60	DILM40
50	15.5	22	30	–	80	DILM50
65	20	30	35	–	98	DILM65
72	25	37	35	–	98	DILM72
80	25	37	63	–	110	DILM80
95	30	45	75	–	130	DILM95
115	37	55	90	–	160	DILM115
150	48	75	96	–	190	DILM150
170	52	90	140	–	225	DILM170

Contactors and motor-protective circuit-breakers/relays

Contactors DIL, overload relays Z

Part no.	Auxiliary contact blocks		Overload relays
	For surface mounting	For side mounting	
DILEEM	02DILEM 11DILEM 22DILEM	–	ZE-0.16 up to ZE-12
DILEM			
DILEM12			
DILM7	DILA-XHI(V)... DILM32-XHI...	DILA-XHI...-S	ZB12-0,16 up to ZB12-16 ZEB12-1.65 up to ZEB12-20
DILM9			
DILM12			
DILM15			
DILM17		DILM32-XHI11-S	ZB32-0,16 up to ZB32-38 ZEB32-1.65 up to ZEB32-45
DILM25			
DILM32			
DILM38			
DILM40	DILM150-XHI(V)...	DILM1000-XHI(V)...	ZB65-10 up to ZB65-75 ZEB65-45 up to ZEB65-100
DILM50			
DILM65			
DILM72			
DILM80			ZB150-35 up to ZB150-175 ZEB150-100
DILM95			
DILM115			
DILM150			
DILM170			

Contactors and motor-protective circuit-breakers/relays

Contactors DIL, overload relays Z

Rated operating current I_e [A] AC-3 at 400 V	max. rating [kW] AC-3				Conventional thermal current $I_{th} = I_e$ [A] AC-1 at 40 °C	Type
	220 V, 230 V	380 V, 400 V,	660 V, 690 V	1000 V		
185	55	90	140	108	337	**DILM185A**
225	70	110	150	108	356	**DILM225A**
250	75	132	195	108	400	**DILM250**
300	90	160	195	132	430	**DILM300A**
400	125	200	344	132	612	**DILM400**
500	155	250	344	132	857	**DILM500**
580	185	315	560	600	980	**DILM580**
650	205	355	630	600	1041	**DILM650**
750	240	400	720	800	1102	**DILM750**
820	260	450	750	800	1225	**DILM820**
–	315	560	1000	1100	1225	**DILM1000**
–	500	900	1600	1770	2200	**DILM1600**
–	–	–	–	–	850	**DILH600**
–	–	–	–	–	1050	**DILH800**
–	–	–	–	–	1450	**DILH1200**
–	–	–	–	–	1714	**DILH1400**
–	–	–	–	–	2450	**DILH2000**
–	–	–	–	–	2700	**DILH2200**
–	–	–	–	–	3185	**DILH2600**

Contactors and motor-protective circuit-breakers/relays

Contactors DIL, overload relays Z

Part no.	Auxiliary contact blocks		Overload relays
	For surface mounting	For side mounting	
DILM185A	–	DILM1000-XHI...	Z5-70/FF225A up to Z5-250/FF225A
DILM225A			
DILM250		DILM820-XHI...	Z5-70/FF250 up to Z5-300/FF250
DILM300A			ZW7-63 up to ZW7-630
DILM400			
DILM500			
DILM580			
DILM650			
DILM750			–
DILM820			
DILM1000			–
DILM1600			

Accessories

Device	DILE(E)M	DILM7 to DILM170		DILM185A to DILM500	DILM580 to DILH2600
		AC	DC		
Suppressor circuit	DC	– or from DILM115	✓	✓	✓
RC suppressors	✓	✓	–	–	–
Varistor suppressors	✓	✓	–	–	–
Motor suppressor module	–	to DILM15	to DILM15	–	–
Star-point bridge	✓	✓	✓	✓	–
Paralleling link	✓	✓	✓	to DILM185A	–
Mechanical interlock	✓	✓	✓	✓	to DILM1000
Sealable shroud	✓	–	–	–	–
Cable terminals	–	–	–	✓	to DILM820
Individual coils	–	from DILM17	from DILM17	✓	✓
Electronic modules	–	–	–	–	–
Electronic modules including coils	–	–	–	✓	✓
Terminal shroud	–	from DILM17	from DILM17	✓	✓ [1)]
Timer module	–	to DILM38	to DILM38	–	–

[1)] Terminal cover to DILM1000

Contactors DILM

These are designed and tested to IEC/EN 60 947, VDE 0660. For every motor rating between 3 kW and 900 kW (at 400 V) there is a suitable contactor available.

Equipment features

- Magnet system
  Due to the new electronic operation the DC contactors from 17 to 72 A have a sealing power of only 0.9 to 1 W.
  Even for 170 A is only 1.9 W necessary.
- Accessible control voltage connections
  The coil connections are on the front of the contactor. They are not covered by the main current wiring.
- Can be controlled directly from the PLC
  The contactors DILA and DILM to 38 A can be controlled directly from the PLC.
- Integrated suppressor DC
  With all DC contactors DILM a suppressor is integrated in the electronics.
- Plug-in suppressor circuits AC
  With all AC contactors DILM up to 95 A a suppressor can be simply plugged in on the front when required.
- Conventional control of contactors DILM185A to DILH2600 via coil terminals A1-A2.
- Additional actuation of contactors DILM250 to DILH2600:
  – Directly from a PLC via terminals A3-A4
  – By a low-power contact via terminals A10-A11.
- Conventional control of contactors DILM250-S to DILM500-S via coil connections A1-A2. There are two coil terminals (110 to 120 V 50/60 Hz and 220 to 240 V 50/60 Hz).
- All contactors up to DILM170 are finger and back-of-hand proof to VDE 0160 Part 100. Additional terminal covers are available from DILM185A onwards.
- Double-frame terminal for contactors DILM7 to DILM170
  With the new double frame-clamp the cable connection area is not limited by the screw. They give total security with varying cross sections and have protection against incorrect insertion to ensure safe connection.
- Integrated auxiliary contact
  The contactors up to DILM32 have an integrated auxiliary contact as N/O or N/C contact. The motor contactors DILM8(11,14)...-PI and DILM17...38-PI have two integrated auxiliary contacts, 1 NO and 1 NC.
- Screw or spring-cage terminal
  The contactors DILE(E)M and DILM40 to DILM150, including the corresponding auxiliary contacts, are available with screw or spring terminals (except main conductors of DILM).
- The shake proof and maintenance free spring-cage terminals can terminate two conductors each of 0.75 to 2.5 mm^2 with or without ferrules.

- Connection terminals
  For DILM7 up to DILM72 the connection terminals for all auxiliary contacts and coils as well as for main conductors can be tightened with a Pozidriv screwdriver size 2.
  For contactors DILM80 to DILM170 Allen screws are used for the main conductors.
- Push-in terminals
  DILM7-PI up to DILM38-PI are equipped with the Push-in terminals for easy, safe and fast wiring.
  Push-in terminals are available for auxiliary contacts, coil connections and main contacts.
- Mounting
  All contactors can be fitted on to a mounting plate with fixing screws. DILE(E)M and DILM up to 72 A can also be snapped on to a 35 mm top-hat rail to IEC/EN 60715.
- Mechanical interlock
  With two connectors and a mechanical interlock an interlocked contactor combination up to 170 A can be achieved without extra space requirement. The mechanical interlock ensures that both connected contactors cannot be simultaneously be operated. Even with a mechanical shock the contacts of both contactors cannot close simultaneously.

In addition to individual contactors, complete contactor combinations are also available:

- DIUL reversing contactors from 3 to 75 kW/400 V
- SDAINL star-delta starters from 5.5 to 132 kW/400 V

DC operated contactors

The xStart contactor series DILM7 to DILM225A has been particularly optimized in the development of DC actuated contactors. The DILM17 to DILM225A DC operated contactors are no longer switched on or off in the conventional way using a coil but by means of an electronic unit.

The integration of electronics in the contactor drives makes different technical features possible which enable the contactors to offer outstanding performance in their daily use.

Universal voltage coils

The DILM17 to DILM225A DC operated contactors cover the entire DC control voltage range with only 4 control voltage variants.

	Rated actuation voltage
RDC24	24 - 27 V DC
RDC60	48 - 60 V DC
RDC130	110 - 130 V DC
RDC240	200 - 240 V DC

Voltage tolerance

Contactors are built in compliance with the IEC/EN 60947-4-1 standard. The requirement for operational safety even with small mains supply fluctuations is implemented with the reliable switching of contactors at between 80 to 110 % of the rated control circuit voltage. The DC operated DILM17 to DILM225A contactors now cover an even wider range in which they switch reliably. They allow reliable operation between 0.7 x U_{cmin} and 1.2 x U_{cmax} of the rated actuation voltage. The greater voltage tolerance than stipulated by the standard increases operating safety even with less stable mains conditions.

Suppressor circuit

Conventionally operated contactors generate voltage peaks at the coil to current change dI/dt which can have a negative effect on other components in the same actuating circuit. To prevent damage, contactor coils are often connected in parallel with additional suppressor circuits (RC suppressors, varistors or diodes).

Thanks to their electronics, the DC actuated contactors DILM17 to DILM225A switch without any effect on the network. An additional suppressor is therefore unnecessary since the coils do not generate any external overvoltages. The other DILM7 to DILM15 DC operated contactors have a built-in suppressor circuit.

When using DC operated contactors from Eaton in the project design, the issue of transient voltage surge suppression in control circuits is therefore unnecessary since all DC operated contactors are free of system disturbance or are provided with a suppressor circuit.

Contactor dimensions

The electronic circuit offers the coil a higher inrush consumption and reduces this after the closing operation to the required sealing power. This enables the AC and DC operated contactors to be implemented with the same dimensions. When designing AC and DC operated contactors for a project, the additional problem of different mounting depths is eliminated so that the same accessories can be used.

Pick-up and hold-in power

The electronic circuit on the DILM17 to DILM225A DC operated contactors controls their operation. A suitably high power is provided for the pickup to ensure the reliable switching of the contactor. A very low sealing power is required for holding the contactor. The electronics only provides this power.

Rated power [1]	Contactor	Power consumption	
		Pick-up	Sealing
7.5 - 15 kW	DILM17 DILM25 DILM32 DILM38	12 W	0.9 W
18.5 - 37 kW	DILM40 DILM50 DILM65 DILM72	24 W	1 W
37 - 45 kW	DILM80 DILM95	90 W	1.5 W
55 - 90 kW	DILM115 DILM150 DILM170	149 W	1.9 W
90 - 110 kW	DILM185A DILM225A	180 W	2.1 W

[1] AC-3 at 400 V

For project design, the reduced sealing power also means a considerable reduction in the heat dissipation in the switch cabinet. This allows side by side mounting of the contactors in the switch cabinet.

Applications

The three-phase motor dominates the electric motor sector. Apart from individual low-power drives, which are often switched directly by hand, most motors are controlled using contactors and contactor combinations. The power rating in kilowatts (kW) or the current rating in amperes (A) is therefore the critical feature for correct contactor selection.

Physical motor design results in that rated currents for the same rating sometimes differ widely. Furthermore it determines the ratio of the transient peak current and the starting current to the rated operational current (I_e).

Switching electrical heating installations, lighting fittings, transformers and power factor correction installations, with their typical individual characteristics, increases the wide range of different uses for contactors.

The operating frequency can vary greatly in every application. The difference can be, for example, from less than one operation per day up to a thousand operations or more per hour. Quite often, in the case of motors, a high operating frequency coincides with inching and plugging duty.

Contactors are actuated by hand or automatically, using various types of command devices, depending on the travel, time, pressure or temperature. Any interrelationships required between a number of contactors can easily be produced by means of interlocks via their auxiliary contacts.

The auxiliary contact of the contactor DILM can be used as mirror contact to IEC/EN 60947-4-1 Appendix F to show the condition of the main contacts. A mirror contact is an N/C contact that cannot be simultaneously closed with the N/O main contacts.

Other applications

- Contactors for capacitors for power factor correction DILK for 12.5 to 50 kvar/400 V.
- Lighting contactors for DILL lighting systems for 12 to 20 A/400 V (AC-5a) or 14 to 27 A/400 V (AC-5b).

Contactors and motor-protective circuit-breakers/relays
Solid state relays HLR

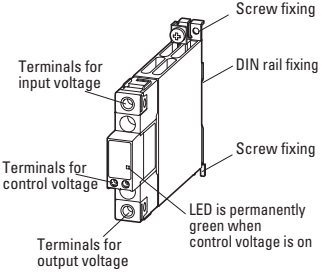
Product features HLR

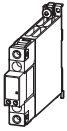
The HLR range solid state relays are for 1-phase or 3-phase switching of resistive or motor loads.

- Zero-voltage switching
- Overvoltage protection by integrated varistor
- Control monitoring by LED indicator
- Integrated heat sink or thermally conductive foil
- Connection with screw terminals
- High electrical lifespan
- Compact size
- Low noise emission
- Resistant against shock, vibration and pollution
- Low feed-in control power and low reaction time

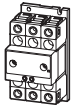
Applications:

- Medical devices and building technology
- Furnaces, HVAC, compressors, pumps, Packaging machinery
- Transportation

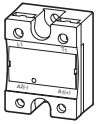




HLR.../1...
- 1-phase, integrated heat sink
- Rated operational current AC-51, 15 up to 40 A
- Control voltage 3 up to 32 V DC, 20 up to 275 V AC
- Rated operational voltage max. 600 V AC



HLR.../3...
- 3-phase, integrated heat sink
- Rated operational current AC-51, 20 up to 30 A
- Control voltage 4 up to 190 V DC, 20 up to 275 V AC
- Rated operational voltage max. 600 V AC



HLR.../1H...
- 1-phase, pre-assembled thermally conductive foil
- Rated operational current AC-51, 25 up to 125 A
- Control voltage 3 up to 32 V DC
- Rated operational voltage max. 600 V AC

Motor protection using Z thermal overload relays

Overload relays are included in the group of current-dependent protective devices. They monitor the temperature of the motor winding indirectly via the current flowing in the supply cables, and offer proven and cost-efficient protection from destruction as a result of:

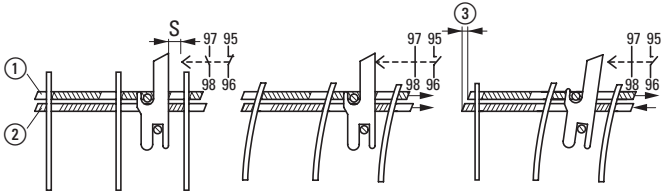
- Non starting,
- Overload,
- Phase failure.

Overload relays operate by using the characteristic changes of shape and state of the bimetal when subjected to heating. When a specific temperature is reached, they operate an auxiliary switch. The heating is caused by resistances through which the motor current flows. The equilibrium between the reference and actual value occurs at various temperatures depending on the magnitude of the current.

Tripping occurs when the response temperature is reached. The tripping time depends on the magnitude of the current and preloading of the relay. Whatever the current, the relay must trip out before the motor insulation is endangered, which is why EN 60947-4-1 states maximum response times. To prevent nuisance tripping, minimum times are also given for the limit current and locked-rotor current.

Phase failure sensitivity

Overload relays Z offer, due to their design, an effective protection against phase failure. They have phase failure sensitivity to IEC 60947-4-1 and VDE 0660 part 102 and therefore can also provide protection for Ex e motors (→ following diagrams).



normal operation (no fault) three-phase overload one phase drops out

① Trip bridge
② Differential bar
③ Differential travel

When the bimetallic strips in the main current section of the relay deflect as a result of three-phase motor overloading, all three act on a trip bar and a differential bar. A shared trip lever switches over the auxiliary contact when the limits are reached. The trip and differential bars lie against the bimetallic strips with uniform pressure. If, in the event of phase failure for instance, one bimetallic strip does not deflect (or recover) as strongly as the other two, then the trip and differential bars will cover different distances. This differential movement is converted in the device by a step-up mechanism into a supplementary tripping movement, and thus accelerates the tripping action.

Design note → Section "Motor protection in special applications", page 3-22

Further information to motor protection → Section "Motors", page 3-1

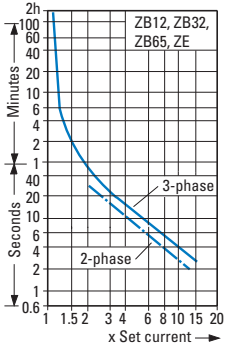
For multi motor applications after soft starter or frequency converter the influence of harmonics or from 50/60 Hz deviating frequencies have to be considered and compensated accordingly by readjustment if required.

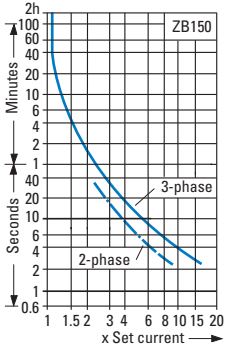
Further information → Section "Electronic motor starter and variable frequency drives", page 5-1

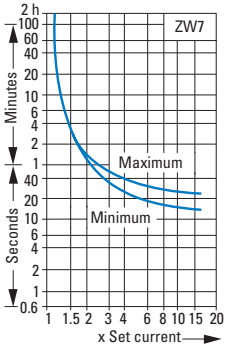
Tripping characteristics

The overload relays ZE, ZB12, ZB32, ZB65 and the ZB150 up to 175 A are, due to the German Physical/Technical Bureau (PTB), suitable for protection of Ex e-motors to the ATEX-Guidelines 94/9 EG or 2014/34/EU. In the relevant manual all tripping characteristics are printed for all currents.

These characteristic curves are mean values of the spreads at an ambient air temperature of 20 °C from cold. The tripping time is dependant upon the current. When units are warm, the tripping delay of the overload relay drops to about a quarter of the value shown.







Operating principle and control

Like the thermal overload relays operating on the bimetallic operating principle, electronic motor-protective relays are current-dependent protective devices. ZEB electronic motor-protective relays are an alternative to a bimetal overload relay.

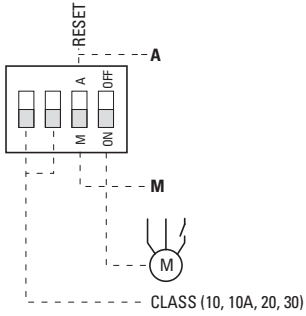
The measuring of the actual motor current present in the three-phase conductors of a motor feeder is implemented on the ZEB overload relay with integrated current transformers for the range from 0.3 to 175 A.

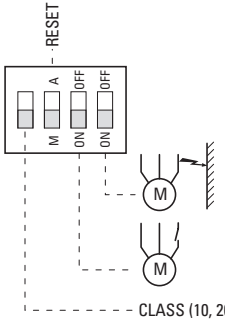
Like the ZEB, overload relays with electronic wide-range overload protection operate with a larger current transfer ratio. Compared to conventional bimetal relays, this provides the device with a wide current setting range ratio of 1 : 5.

The ZEB...-GF overload relay provides optional protection of the motor from earth faults. It adds the currents of the phases and evaluates any imbalance. If the imbalance is greater than 50 % of the set rated motor current, the relay trips.

By selecting one of the 4 tripping classes (CLASS 10A, 10, 20, 30) via DIP switches, the protected motor can be adapted to normal or heavy starting conditions. This allows the thermal reserves of the motor to be utilized safely. The overload relay does not require any auxiliary voltage and is fed internally via the current transformer.

Setting the DIP switches





The ZEBs come with the usual NC contacts (95-96) and NO contacts (97-98) for overload relays.

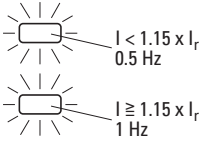
Contactors and motor-protective circuit-breakers/relays
Electronic overload relay ZEB

The current of the motor is set via a setting dial. It is also possible to switch off phase failure sensitivity via the DIP switches when protecting single phase motors.

The manual or automatic reset can also be set on the DIP switch.

No external power supply is required thanks to the independently fed electronic circuit.

A diagnostics LED gives a visual warning of an overload.

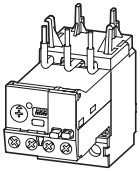


ZEB electronic overload relays can be fitted directly to DILM contactors up to 170 A.

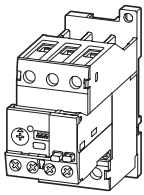
Separate mounting (rail mounting) is only possible with ZEB.../KK.

Device overview

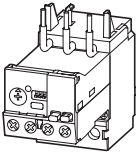
ZEB12, ZEB32
Direct mounting



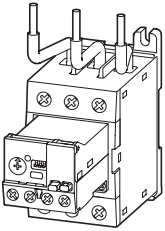
ZEB32.../KK
Separate mounting



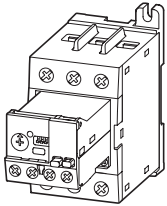
ZEB65
Direct mounting



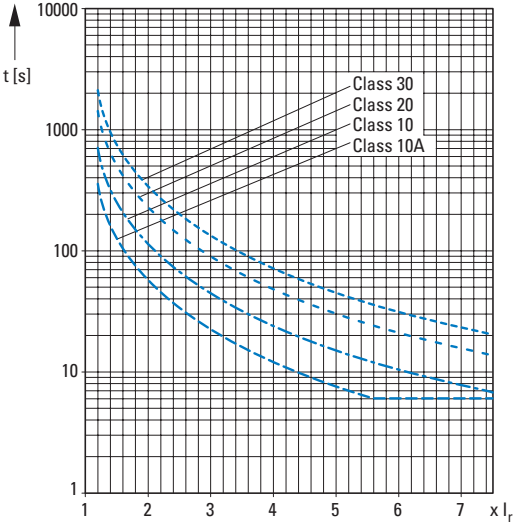
ZEB150
Direct mounting



ZEB150.../KK
Separate mounting



Tripping characteristics

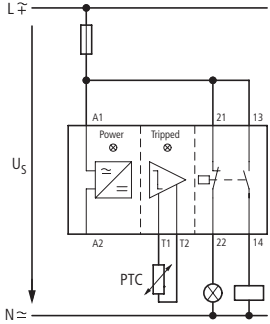


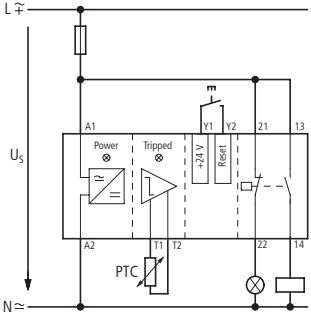
Class	t_A [s]						
I_r	x 3	x 4	x 5	x 6	x 7.2	x 8	x 10
30	133.5	72.5	45.7	31.4	21.7	17.5	11.2
20	89.0	48.3	30.4	21.0	14.5	11.7	7.5
10	44.5	24.2	15.2	10.5	7.2	6.0	6.0
10A	22.3	12.1	7.6	6.0	6.0	6.0	6.0

Contactors and motor-protective circuit-breakers/relays

Thermistor overload relay for machine protection EMT6

EMT6 for PTC thermistors





Method of operation

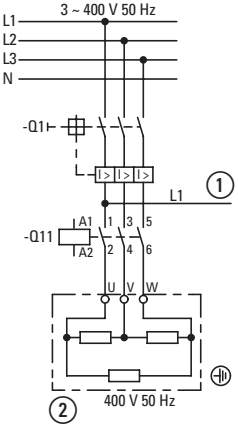
The output relay is actuated when the control voltage is switched on and the resistance of the PTC thermistor temperature sensor is low. The auxiliary contacts operate. On reaching the nominal response temperature (NAT), the sensor resistance becomes high and causes the output relay to drop-out. The defect is indicated by an LED. As soon as the sensors have cooled enough so that the respective smaller resistance is reached the EMT6-(K) switches automatically on again. With the EMT6-(K)DB(K) the automatic re-switch on can be defeated by switching the device to “Hand”. The unit is reset using the reset button.

The EMT6-K(DB) and EMT6-DBK are fitted with a short-circuit recognition in sensor circuit monitor. Should the resistance in the sensor circuit fall below 20 Ω it trips. The EMT6-DBK also has a zero voltage safe reclosing lockout and stores the fault by a voltage drop. Switching on again is possible only after the fault has been rectified and the control voltage is present again.

Since all the units use the closed-circuit principle, they also respond to a wire breakage in the sensor circuit.

The thermistor machine protection relays with short-circuit recognition EMT6-...K... are accredited for protection of Ex e motors to ATEX-Guideline 2014/34/EU by the DEKRA EXAM. For protection of Ex e motors the ATEX-Guidelines require short-circuit recognition in the sensor circuit. Because of their integrated short-circuit recognition the EMT6-K(DB) and EMT6-DBK are suitable for this application.

EMT6 as contact protection relay



Application example

Control of a storage tank heater

① Actuating circuit

② Heater

Q11: Heater protection

Functional description

For this see circuit page 4-29.

Switching on the heater

The heater can be switched on provided the main switch Q1 is switched on, the safety thermostat F4 has not tripped and the condition $T \leqq T_{min}$ is satisfied. When S1 is actuated, the control voltage is applied to the contactor relay K1, which maintains itself via a N/O contact. The changeover contact of the contact thermometer has the position I-II. The low resistance sensor circuit of the EMT6 guarantees that Q11 is actuated via K2 N/O contact 13-14; Q11 goes to self-maintain.

Switching off the heater

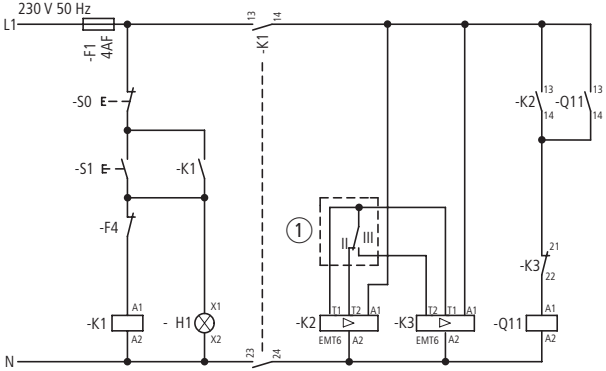
The heater protection Q11 stays in self maintain until the main switch Q1 is switched off, the pushbutton S0 is pressed, the thermostat trips or $T = T_{max}$.

When $T = T_{max}$ the changeover contact of the contact thermometer has the position I-III. The sensor circuit of the EMT6 (K3) is low resistance, the N/C contact K3/21-22 open. The main protection Q11 drops out.

Contactors and motor-protective circuit-breakers/relays
Thermistor overload relay for machine protection EMT6

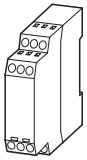
Safety against wire breakage

Security against wire breakage in the sensor circuit of K3 (e. g. non-recognition of the limit value T_{max}) is guaranteed by the use of a safety thermostat that when T_{max} is exceeded it's normally closed contact F4 switches off so that "switch off by de-energization" is carried out.



① Contact thermometer changeover contacts
I-II position at $T \leqq T_{min}$
I-III position at $T \leqq T_{max}$

S0: Off
S1: Start
F4: Safety thermostat
K1: Control voltage "On"
K2: Switch on at $T \leqq T_{min}$
K3: Switch off at T_{max}



Operating principle

The CMD (Contactor Monitoring Device) monitors the main contacts of a contactor for welding. It compares the contactor control voltage with the state of the main contactors and indicates this reliably with a mirror contact (IEC EN 60947-4-1 Ann. F). If the contactor coil is de-energized and the contactor does not drop out, the CMD trips the backup circuit-breaker or switch-disconnector via an undervoltage release.

The CMD also monitors the functioning of the internal relay using an additional auxiliary make contact of the monitored contactor. For this the auxiliary make and break contact is positively driven. The break contact is designed as a mirror contact.

Approved switchgear combinations

To ensure the functional reliability of the entire unit, consisting of contactor, circuit-breaker and CMD, the CMD is only approved for use with specific contactors as well as circuit-breakers or switch-disconnectors. CMD can be used for monitoring the welding of all DILEM and DILM7 to DILH2000 contactors.

All auxiliary break contacts of these contactors are designed as mirror contacts and can be used for monitoring tasks. The NZM1 to NZM4 or N1 to N4 can be used as backup circuit-breakers or switch-disconnectors when fitted with a NZM...-XUVL undervoltage releases.

Applications

These combinations are used in safety-oriented applications. Previously, the series connection of two contactors was recommended with circuits of safety category 3 and 4. Now one contactor and the contactor monitoring device is sufficient for safety category 3. The CMD contactor monitoring relay is used for emergency-stop applications in compliance with EN 60204-1. It can also be used in the American automotive industry. In this sector there is a demand for solutions that reliably detect the welding of the motor starters and disconnect the motor feeder safely.

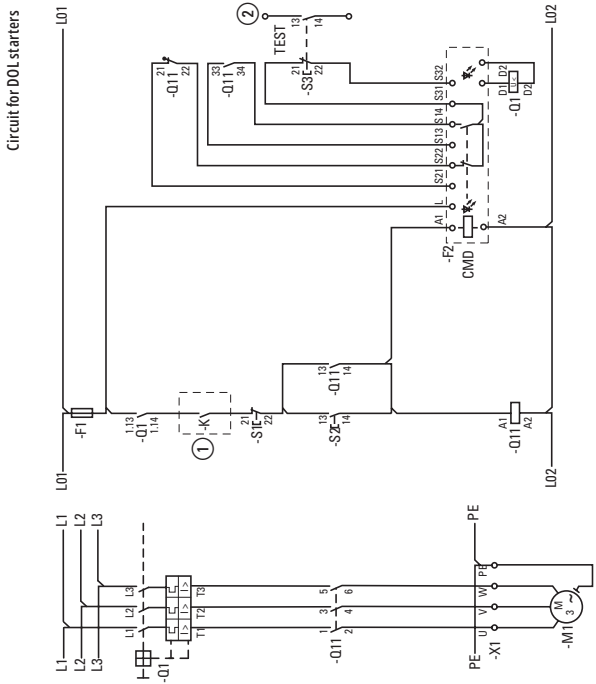
The CMD is approved as a safety module by the German employers' liability insurance association. It also has UL and CSA approval for the North American market.

Further information can be found in the manuals

- CMD(24VDC): MN121001ZU-DE/EN
- CMD(220-240VAC): MN121002ZU-DE/EN

Contactors and motor-protective circuit-breakers/relays

Contactor monitoring device CMD

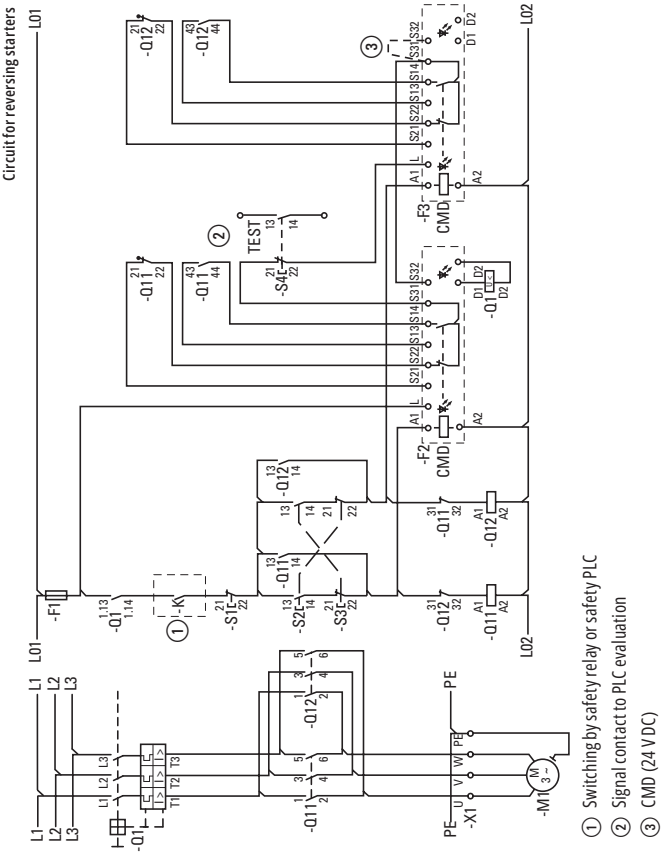


① Switching by safety relay or safety PLC

② Signal contact to PLC evaluation

Contactors and motor-protective circuit-breakers/relays

Contactor monitoring device CMD



① Switching by safety relay or safety PLC
② Signal contact to PLC evaluation
③ CMD (24 V DC)

Notes

4

Definition

Motor-protective circuit-breakers are circuit-breakers used for the switching, protection and isolation of circuits primarily associated with motor loads. At the same time, they protect these motors against destruction from locked-motor starting, overload, short-circuit and phase-failure in three-phase power supplies. They have a thermal trip block (PKZ) or an electronic release (PKE) for protecting of the motor winding (overload protection) and an electromagnetic release (short-circuit protective device).

The following accessories can be fitted to motor-protective circuit-breakers:

- Undervoltage releases,
- Shunt release,
- Auxiliary contact,
- Trip-indicating auxiliary contact.

Motor-protective circuit-breakers at Eaton

PKZM01

The PKZM01 motor-protective circuit-breaker up to 25 A is supplied with the pushbutton actuator. The fitted mushroom button is available for emergency-off actuation on simple machines. The PKZM01 is primarily installed in surface-mounted or flush-mounted enclosures. Many accessories of the PKZM0 can be used.

PKZM4

The PKZM4 motor-protective circuit-breakers are a modular and efficient system for switching and protecting motor loads up to 65 A. It is the “big brother” of the PKZM0 and can be used with almost all PKZM0 accessory parts.

PKZM0

The PKZM0 motor-protective circuit-breaker is a modular and efficient system for switching and protecting motor loads up to 32 A and transformers up to 25 A.

Versions:

- Motor-protective circuit-breakers
- Transformer-protective circuit-breaker

Description → Section ”The motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4”, page 4-36

PKE

PKE for motor and distribution circuit protection

The PKE is a modular and efficient system for protecting, switching and signalling of motors and systems in low-voltage switchgear systems up to 65 A, consisting of:

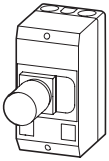
- Motor-protective circuit-breaker basic units
- Trip blocks

Description → Section ”Motor and system protection with PKE”, page 4-37

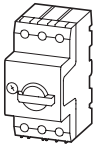
Contactors and motor-protective circuit-breakers/relays

Motor-protective circuit-breaker

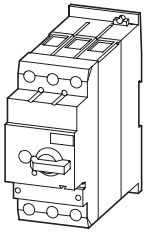
PKZM01
Circuit-breakers in surface mounting enclosure



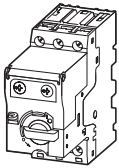
PKZM0
Circuit-breakers up to 32 A



PKZM4
Circuit-breakers up to 65 A

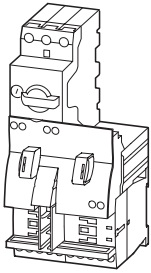


PKE
Circuit-breakers with electronic wide-range overload protection

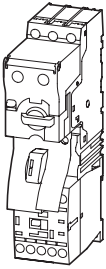


MSC-D
DOL starters

MSC-R
Reversing starters



MSC-DEA
DOL starters (for SmartWire-DT)



Contactors and motor-protective circuit-breakers/relays
PKZM01, PKZM0 and PKZM4 – description

The motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4

The PKZM01, PKZM0 and PKZM4 with their bimetal releases with a current-dependent delay offer a proven technical solution for motor protection. The releases offer phase failure sensitivity and are temperature compensated. The rated currents of the PKZM0 up to 32 A are divided up into 15 ranges, 14 ranges on the PKZM01 up to 25 A and 7 ranges on the PKZM4 up to 65 A. The installation (motor) and the supply cable are reliably protected and motor startup is ensured by the short-circuit releases, permanently set to 15.5 x I_u. The phase failure sensitivity of the PKZM0 and PKZM4 enables them to be used for the protection of Ex e motors. An ATEX certificate has been awarded. The motor-protective circuit-breakers are set to the rated motor current in order to protect the motors.

The following accessories complement the motor-protective circuit-breaker for the various secondary functions:

- Undervoltage release U,
- Shunt release A,
- Standard auxiliary contact NHI,
- Trip-indicating auxiliary contact AGM.

Motor and system protection with PKE

The PKE achieves its modularity by combining the motor or system-protective circuit-breaker with various accessories. The exchangeable motor-protective trip blocks with electronic wide range overload protection (current range 1:4) are available as a standard or enhanced version for connection to SmartWire-DT. This results in numerous application options and adaptation to widely differing requirements.

The circuit-breaker

The PKE circuit-breaker consists of:

- Basic device, 3 types for 12 A, 32 A and 65 A and
- Pluggable trip block.

There is a choice of trip blocks:

- Motor protective trip blocks (5 variants for the range 0.3 to 65 A)
- System protective trip block (2 variants for the range 15 to 65 A)

All trip blocks are provided with adjustable overload releases.

Overload from ... to...:

- Motor protective trip blocks: also with adjustable tripping classes (CLASS 5, 10, 15 and 20) for protecting heavy starting motors.
- System protective trip block: also with adjustable short-circuit release 5 to 8 x I_e.

The phase failure sensitivity of PKE allows for the use in the protection of Ex e motors. An ATEX certificate has been awarded. The motor-protective circuit-breakers are set to the rated motor current in order to protect the motors.

The following accessories of PKZM0 complement the motor-protective circuit-breaker PKE for the various secondary functions:

- Undervoltage release U,
- Shunt release A,
- Standard auxiliary contact NHI,
- Trip-indicating auxiliary contact AGM.

Standards

The PKE motor-protective circuit-breaker is compliant with IEC/EN 60947 and VDE 0660. The PKE also meets the requirements for isolation and main switch functions stipulated in EN 60204.

Contactors and motor-protective circuit-breakers/relays
PKM0, PKZM0-...-T – description

Motor-protective circuit-breakers without overload release

PKM0

The PKM0 motor-protective circuit-breaker is a protective switch for starter combinations or for use as a basic unit in a short-circuit protective switch in the range 0.16 A to 32 A. The basic device is without overload release, but equipped with short-circuit release. This circuit-breaker is used for protection of resistive loads where no overloading is to be expected.

These protective switches are also used in motor-starter combinations with and without reclosing lockout, where an overload relay or a thermistor overload relay is used as well.

Transformer-protective circuit-breakers

PKZM0-...-T

The transformer-protective circuit-breaker is designed for protecting transformer primaries. The short-circuit releases in the types from 0.16 A to 25 A are permanently set to 20 x I_u. The response ranges of the short-circuit releases are higher here than with motor-protective circuit-breakers in order to cope with the even higher inrush currents of idling transformers without tripping. The overload release in the PKZM0-T is set to the rated current of the transformer primary. All the PKZM0 system accessories can be combined with the PKZM0-T.

Motor-protective circuit-breakers with Push-in terminals

PKZM0-...-...PI...

The PKZM0 is also available in a version with Push-in terminals. Here also conductors without ferrules can be connected. The connections are maintenance free. Two variants are available, i. e. one with Push-in terminals on both sides and one mixed with Push-in terminals only at the output. Here on the input the three-phase commoning links B3...-PKZ0 can be used.

Motor starter combinations

The MSC motor-starter combinations are available up to 32 A. Motor starters up to 16 A consist of a PKZM0 or PKE motor-protective circuit-breaker and a DILM contactor. Both are connected by a tool-less mechanical connection element. Furthermore, a plug-in electrical connector is used to establish the connection with the main circuit wiring. The PKZM0 or PKE motor-protective circuit-breaker and the DILM contactors up to 15.5 A are provided with the relevant interfaces for this purpose.

The MSC motor-starter combinations from 16 A consist of a motor-protective circuit-breaker PKZM0 or PKE and a contactor DILM. Both are fitted to a top-hat rail and mechanically and electrically interconnected by a connector element.

The MSC is available as a MSC-D DOL starter and as a MSC-R reversing starter.

The combinations of PKZM4 or PKE65 with the proven DILM contactors are available for motor ratings over 15 kW/400 V.

Combination with soft starter or variable frequency drives

For multi motor applications after soft starter or variable frequency drives the influence of harmonics or from 50/60 Hz deviating frequencies have to be considered.

In combination with variable frequency drives and upstream sinus filter at frequencies above 60 Hz the overload release of the motor-protective circuit-breakers PKZM0/PKZM4 trips earlier, i. e. the release has to be readjusted at a higher current. Up to 500 Hz this effect is indeed low. The tripping current of short-circuit releases increase at higher frequencies, i. e. tripping occurs at higher short-circuit currents. The effect is more distinct, approximately 30 - 40 %.

Due to higher thermal load of the devices caused by higher frequencies a derating is recommended.

The operation of motor-protective circuit-breakers PKZM0/PKZM4 without upstream sinus filter is not permissible because overheating of devices are possible.

Further information → Section "Electronic motor starter and variable frequency drives", page 5-1

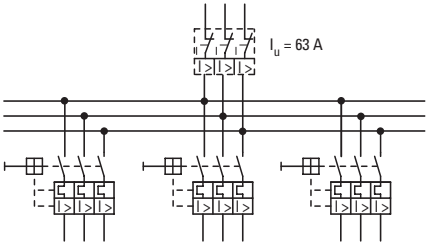
Contactors and motor-protective circuit-breakers/relays
PKZM0 and PKZM4 – current limiters

CL-PKZ0

The current limiter module CL-PKZ0 is a short-circuit protective device specially developed for the PKZM0 and PKZM4 for non-intrinsically-safe areas. The CL module has the same base area and uses the same terminations as the PKZM0. When they are mounted on a top-hat rail alongside one another, it is possible to connect them using B3...-PKZ0 three-phase commoning links. The switching capacity of the series connected PKZM0 or PKZM4 + CL is 100 kA at 400 V. In the event of a short-circuit, the contacts of the motor-protective circuit-breaker and CL will open.

While the current limiter returns for the closed rest position, the motor protective-circuit breaker trips via the instantaneous release and produces a permanent isolating gap. The system is ready to operate again, once any defect has been rectified. The current limiter can conduct an uninterrupted current of 63 A. The module may be used for individual or group protection. Any direction of incoming supply may be used.

Individual and group protection using CL-PKZ0



Use the BK25/3-PKZ0 for terminals > 6/4 mm²

For grouped connection with three-phase commoning link B3...PKZ0. Observe load factors in accordance with VDE 0660-600-2.

Examples:

PKZM0-16, PKZM4-16 or	PKZM0-16/20, PKZM4-16/20 or	PKZM0-20, PKZM4-20 or	PKZM0-25, PKZM4-25
4 x 16 A x 0.8 = 51.2 A	2 x (16 A + 20 A) x 0.8 = 57.6 A	3 x 20 A x 0.9 = 54 A	2 x 25 A x 0.9 = 45 A

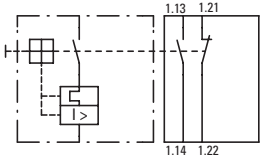
Contactors and motor-protective circuit-breakers/relays

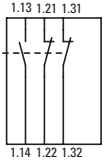
PKZM01, PKZM0, PKZM4 and PKE – auxiliary contacts

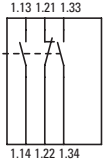
Auxiliary contacts and standard auxiliary contacts NHI for PKZM01, PKZM0, PKZM4 and PKE

They switch at the same time as the main contacts. They are used for remote indication of the operating state, and interlocking of switches between one another. They are available with screw connections or Push-in technology.

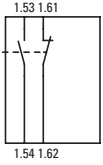
Side mounted:

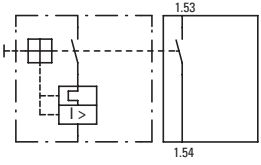






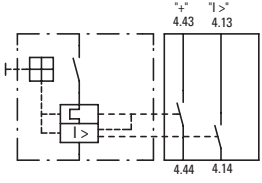
Front mountable:

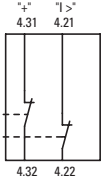




AGM trip-indicating auxiliary contacts for PKZM01, PKZM0, PKZM4 and PKE

These provide information about the reason for the circuit-breaker having tripped. In the event of a voltage/overload release (contact 4.43-4.44 or 4.31-4.32) or short-circuit release (contact 4.13-4.14 or 4.21-4.22) two potential-free contacts are actuated independently of one another. It is thus possible to indicate the difference between short-circuit and overload. AGM are available with screw connections or Push-in technology.





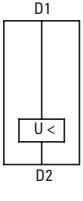
Voltage releases

These operate according to the electromagnetic principle and act on the switch mechanism of the circuit-breaker. They are available with screw connections or Push-in technology.

Undervoltage release

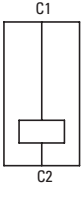
These switch the circuit-breaker off when no voltage is present. They are used for safety tasks. The U-PKZ20 undervoltage release, which is connected to voltage via the VHI20-PKZ0 or VHI20-PKZ01 early-make auxiliary contacts, allows the circuit-breaker to be switched on. In the event of power failure the undervoltage release switches the circuit-breaker off via the switch mechanism. Uncontrolled restarting of machines is thus reliably prevented. The safety circuits are proof against wire breaks.

The VHI20-PKZ0 cannot be used together with the PKZM4!



Shunt releases

These switch the circuit-breaker off when they are connected to voltage. Shunt releases can be provided in interlock circuits or for remote releases where voltage dips or interruptions are not to lead to unintentional switch off.

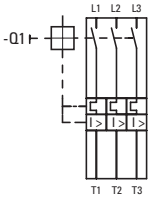


Contactors and motor-protective circuit-breakers/relays

PKZM01, PKZM0, PKZM4 and PKE – block diagram

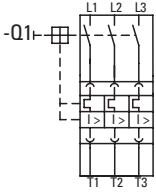
Motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4

Manually operated motor starter



Motor-protective circuit-breakers PKE

Manually operated motor starter

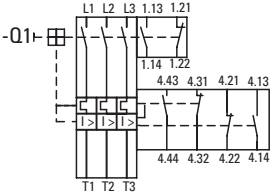


Contactors and motor-protective circuit-breakers/relays

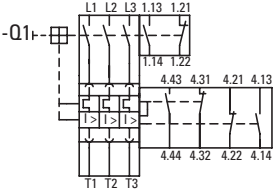
PKZM01, PKZM0, PKZM4 and PKE – block diagram

Motor-protective circuit-breakers with auxiliary contact and trip-indicating auxiliary contact

PKZM01(PKZM0-...)(PKZM4...) + NHI11-PKZ0 + AGM2-10-PKZ0

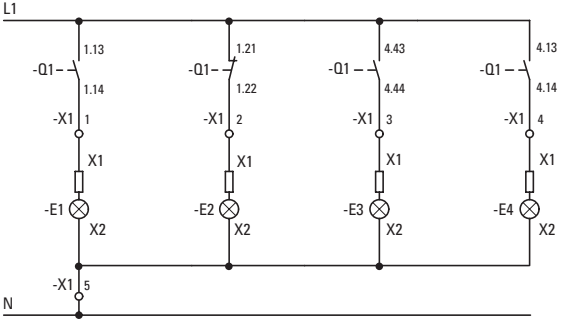


PKE... + NHI11-PKZ0 + AGM2-10-PKZ0



For differential fault indication

(Overload or short-circuit)



E1: circuit-breaker ON
E2: circuit-breaker OFF
E3: general fault, overload release
E4: short-circuit release

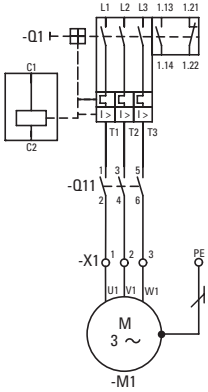
Contactors and motor-protective circuit-breakers/relays

PKZM01, PKZM0, PKZM4 and PKE – block diagram

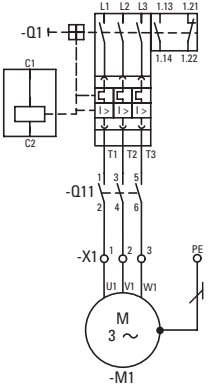
Remote switch off via shunt release

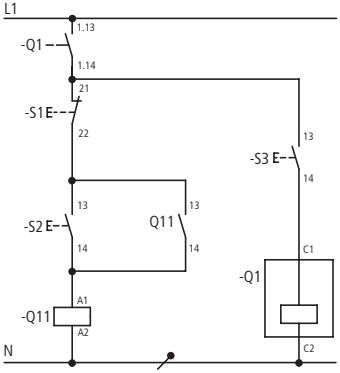
Motor starters with auxiliary contact and shunt release

PKZM0-... + DILM... + A-PKZ0



PKE... + A-PKZ0





S1: OFF
S2: ON
S3: OFF circuit-breaker

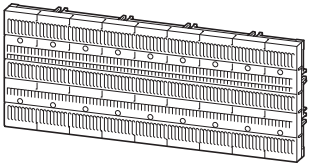
Contactors and motor-protective circuit-breakers/relays
Feeder System MSFS

Feeder System MSFS

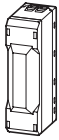
The MSFS is a feeder system for motor starter combinations and applicable for safe enregy distribution up to 125 A within a cabinet. The modular solution can be easily and intuitively integrated in machines and switchboards due to mounting by pluggable contacts.
The installation of the feeder system is quick, easy and safe.

Features

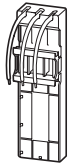
- Rated current I_n = 125 A
- For motor starters up to I_n = 32 A (DOL, reversing starter, soft starter DS7)
- Protection against accidental contact IP20
- Two boards for (225 mm) max. 4 and (405 mm) max. 8 motor starter
- Feed via Push-Lock technology
- Certified IEC and UL



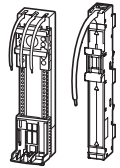
Board



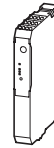
Incomer module (Feeder module)



Adapter



Electronic motor starter



Power supply unit 24 V DC

Electronic motor starter and variable frequency drives

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Application of the electronic motor starter (EMS2)	5-3
Soft starter basic information	5-19
Application of a two-phase soft starter (DS7)	5-34
Application of a three-phase soft starter (S811+)	5-51
Variable frequency drives basic information	5-57
Measures to improve network quality	5-74
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Application of the decentralised drive system (Rapid Link 5)	5-104

Notes

Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Product features EMS2

EMS2 series electronic motor starters serve to switch and protect three-phase asynchronous motors.

Depending on the version, the following functions are available:

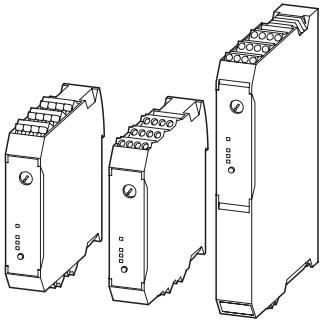
- DOL starter (DO = Direct Online)
- Reversing starter (RO = Reverse Online)
- Motor protection
- Overload protection
- Phase failure
- Phase imbalance
- Category 3 controlled stop
  PL e DIN EN ISO 13849, SIL 3 IEC 61508

The compact devices contain the required interlocks which are necessary for the specified functions in order to reduce the wiring.

Do not operate single-phase motors in conjunction with an EMS2 electronic motor starter!

In circuits in potentially dust-explosive areas of zones 21 and 22, it must be guaranteed that the equipment connected to this circuit complies with category 2D or 3D or is certified as such.

This is a product for environment A (industry). The device can cause unwanted radio interference if used in Class B environments (household). In this case, the user may be obligated to take the necessary precautionary measures.



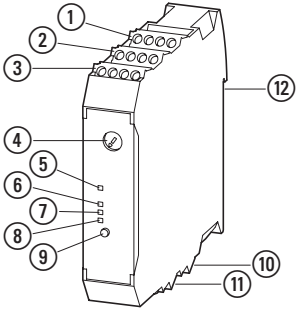
Further features

- Wide-range overload protection
- 22.5 mm width
- Additional monitoring functions of the EMS2...-SWD
- Hybrid switching technology for long electrical durability
- ATEX approval for the EMS2-D(R)OS(F)...
- Integrated short-circuit protection with EMS2-ROSF...

Applications

- Slide control
- Horizontal/vertical conveyors
- Small drives
- Fan

EMS2 – when installed on a top-hat rail



1. Terminals for control voltage U_S and ON/R/L
2. Reset (and reference point of the control inputs for motor starters with safety function)
3. Relay output
4. Setting dial for motor protection
5. LED **PWR** (green)
6. LED **ERR** (red)
7. LED **L** (yellow) – for reversing starters
8. LED **R** (yellow) – for reversing starters or LED **ON** (yellow) – for direct starters
9. Set/reset button
10. Terminals for input voltage
11. Terminals for output voltage
12. Top-hat rail fitting

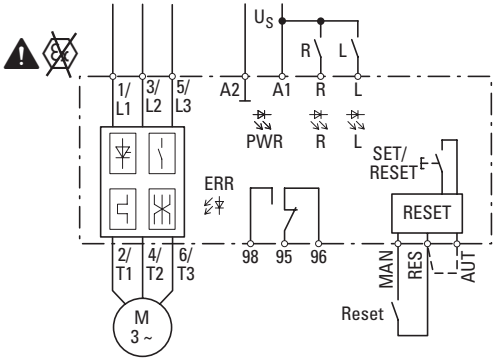
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Variants DO (DOL starter) and RO (Reversing starter)

Type	Minimum current	Rated operational current I_e		Control voltage U_S		Terminals	
		AC51 EN 60947-4-3	AC53a EN 60947-4-2	24 V DC	115 V AC - 230 V AC	Push-in	Screws
DOL starter							
EMS2-DO-T-2,4-24VDC	0.18 A	2.4 A	2.4 A	✓	–	✓	–
EMS2-DO-T-9-24VDC	1.5 A	9 A	6.5 A	✓	–	✓	–
EMS2-DO-Z-2,4-24VDC	0.18 A	2.4 A	2.4 A	✓	–	–	✓
EMS2-DO-Z-9-24VDC	1.5 A	9 A	6.5 A	✓	–	–	✓
EMS2-DO-Z-2,4-230VAC	0.18 A	2.4 A	2.4 A	–	✓	–	✓
EMS2-DO-Z-9-230VAC	1.5 A	9 A	6.5 A	–	✓	–	✓
Reversing starter							
EMS2-RO-T-2,4-24VDC	0.18 A	2.4 A	2.4 A	✓	–	✓	–
EMS2-RO-T-9-24VDC	1.5 A	9 A	6.5 A	✓	–	✓	–
EMS2-RO-Z-2,4-24VDC	0.18 A	2.4 A	2.4 A	✓	–	–	✓
EMS2-RO-Z-9-24VDC	1.5 A	9 A	6.5 A	✓	–	–	✓
EMS2-RO-Z-2,4-230VAC	0.18 A	2.4 A	2.4 A	–	✓	–	✓
EMS2-RO-Z-9-230VAC	1.5 A	9 A	6.5 A	–	✓	–	✓

Block diagram reversing starter



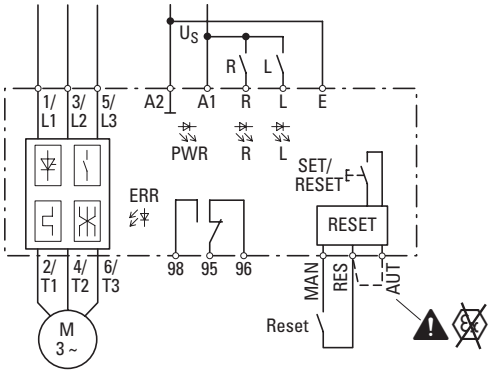
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

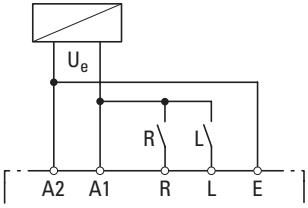
Variants DOS (DOL starter) and ROS (Reversing starter)

Type	Minimum current	Rated operational current I_e		Control voltage U_S		Terminals	
		AC51 EN 60947-4-3	AC53a EN 60947-4-2	24 V DC	115 V AC - 230 V AC	Push-in	Screws
DOL starter							
EMS2-DOS-T-3-24VDC	0.18 A	3 A	3 A	✓	–	✓	–
EMS2-DOS-T-9-24VDC	1.5 A	9 A	7 A	✓	–	✓	–
EMS2-DOS-Z-3-24VDC	0.18 A	3 A	3 A	✓	–	–	✓
EMS2-DOS-Z-9-24VDC	1.5 A	9 A	7 A	✓	–	–	✓
Reversing starter							
EMS2-ROS-T-3-24VDC	0.18 A	3 A	3 A	✓	–	✓	–
EMS2-ROS-T-9-24VDC	1.5 A	9 A	7 A	✓	–	✓	–
EMS2-ROS-Z-3-24VDC	0.18 A	3 A	3 A	✓	–	–	✓
EMS2-ROS-Z-9-24VDC	1.5 A	9 A	7 A	✓	–	–	✓

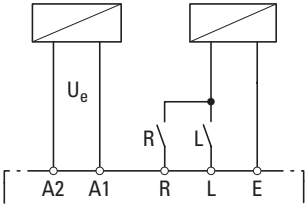
Block diagram DOL starter with safety function



Mutual voltage sources for supply and control inputs



Separate voltage sources for supply and control inputs



Manual reset

After remedying the error, the error message can be reset manually. In the case of a message from the motor protection, note that the error message can be reset only after the cooling-down time has passed. The L, R or ON LED lights up permanently during the cooling-down time.

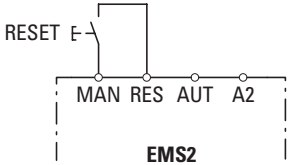
After the cooling-down time, the permanent light changes to flashing, meaning a reset is now possible.

For a reset, the EMS2 motor starter requires a signal with a rising edge on the MAN terminal with a duration of less than 2 seconds.

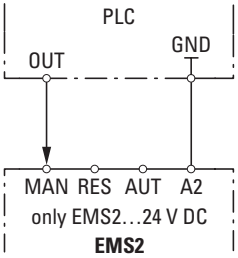
If the signal is longer or the reset button on the front of the device is pressed for longer, the device remains in error mode and the set motor current is displayed.

If the signal lasts for longer than 6 seconds, the device switches to programming mode (→Section "Setting of the motor protection", page 5-8).

Circuit for a manual reset via external button



Circuit for a manual reset via PLC



If the message is to be reset by an external button, this must be connected between the RES and MAN terminals.

Only for devices with a control voltage U_S of 24 V DC

A reset can also be carried out with a 24 V signal from an external PLC. To do so, the output of the PLC needs to be connected to the MAN terminal. The reference point for the PLC output voltage must be connected with terminal A2.

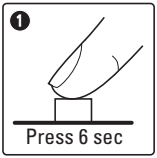
Setting of the motor protection

5

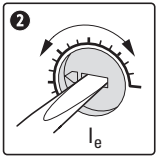
Ensure that the following conditions are met when setting the motor protection or when displaying the set value:

– The device is supplied with voltage.
– There are no errors.
– There is no start signal on the terminals ON, L or R.

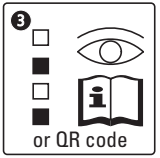
- Activating parameterization mode
  Press the RESET button for at least 6 seconds.
  → The green **PWR** LED flashes once.



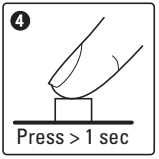
- Setting the motor rated current
  Turn the potentiometer to the desired value.



- Checking the value on the LEDs
  Compare the set value with that which is displayed on the LEDs (→Table, page 5-9).



- Leaving parameterization mode
  Press the RESET button.



Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Settings of the motor protection

Code				Setting I_n		
PWR PWR	PWR PWR	L –	R ON	I_e = 2.4 A (EMS2-...-2,4...)	I_e = 3 A (EMS2-...-3...)	I_e = 9 A (EMS2-...-9...)
0	0	0	0	0.18 A	0.18 A	1.5 A
0	0	0	1	0.25 A	0.3 A	1.0 A
0	0	1	0	0.41 A	0.44 A	2.5 A
0	0	1	1	0.56 A	0.6 A	3.0 A
0	1	0	0	0.71 A	0.68 A	3.5 A
0	1	1	0	0.87 A	0.88 A	4.0 A
0	1	1	0	1.02 A	1.0 A	4.5 A
0	1	1	1	1.117 A	1.1 A	5.0 A
1	0	0	0	1.33 A	1.2 A	5.5 A
1	0	0	1	1.48 A	1.5 A	6.0 A
1	0	1	0	1.63 A	1.6 A	6.5 A
1	0	1	1	1.79 A	1.9 A	7.0 A
1	1	0	0	1.94 A	2.1 A	7.5 A
1	1	0	1	2.09 A	2.4 A	8.0 A
1	1	1	0	2.25 A	2.7 A	8.5 A
1	1	1	1	2.4 A	3.0 A	9.0 A

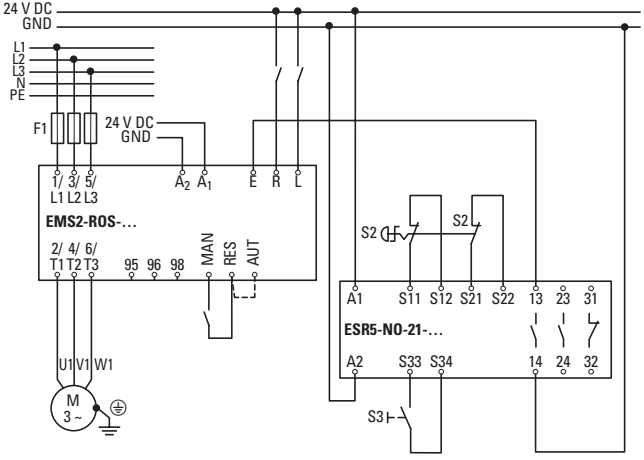
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Single-channel controlled stop application (cat. 3, SIL 3, PL e) with error prevention

Motor starter EMS2-ROS... is used in conjunction with an ESR5 series safety relay. The mutual reference point of the control inputs (terminal **E**) is switched via the safety relay.

The preset for the control commands for the operating direction takes place directly at 24 V DC on the **L** or **R** terminal.



Example: With a higher-level safety relay combination within a closed control cabinet

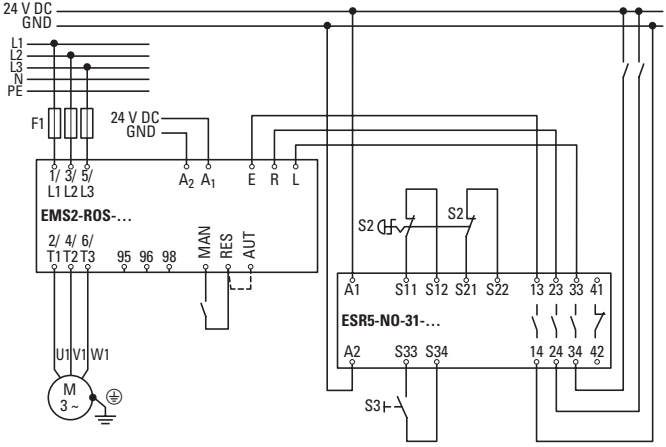
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Reversing starter 24 V DC with safety function (dual-channel) (cat. 3, SIL 3, PL e)

The EMS2-ROS... motor starter is used in combination with an ESR5 series safety relay. The mutual reference point of the control inputs (terminal **E**) and the control commands **L** and **R** are switched via the safety relay.

The preset for the control commands for the operating direction takes place directly at 24 V DC on the **L** or **R** terminal.



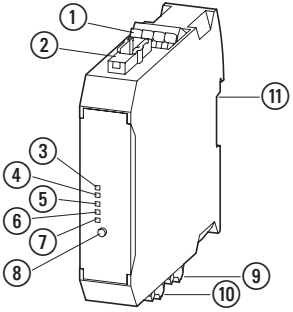
Example: Reversing starter with safety function (dual-channel)

5

EMS2-...-SWD – when installed on a top-hat rail

The supply of the device as well as the actuation of the operating direction takes place via the internal SmartWire-DT (SWD) interface. In addition, the motor starter uses this interface in order to provide additional information for a superordinate controller.

EMS2...-SWD are only available with Push-in terminals.



1. EMS2-DO/RO: Terminals without function
   EMS2-DOS/ROS: safety-oriented enable
2. Connection for SWD external device plug
3. LED **PWR** (green)
4. LED **SWD** (green)
5. LED **ERR** (red)
6. LED **L** (yellow) – for reversing starters
7. LED **R** (yellow) – for reversing starters;
   LED **ON** (yellow) – for direct starters
8. Set/reset button
9. Terminals for input voltage
10. Terminals for output voltage
11. Top-hat rail fitting

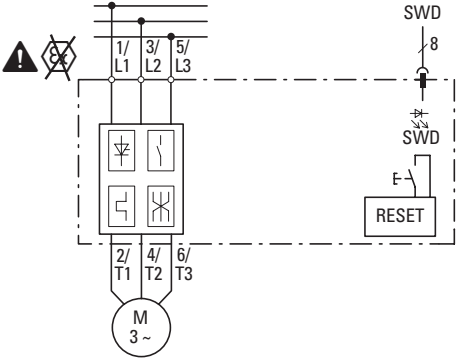
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

Variants DO (DOL starter) and RO (Reversing starter)

Type	Minimum current	Rated operational current I_e	
		AC51 EN 60947-4-3	AC53a EN 60947-4-2
DOL starter			
EMS2-DO-T-3-SWD	0.18 A	3 A	3 A
EMS2-DO-T-9-SWD	1.5 A	9 A	7 A
Reversing starter			
EMS2-RO-T-3-SWD	0.18 A	3 A	3 A
EMS2-RO-T-9-SWD	1.5 A	9 A	7 A

Block diagram reversing starter with SWD



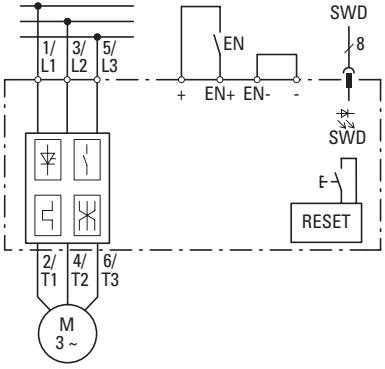
Electronic motor starter and variable frequency drives

Application of the electronic motor starter (EMS2)

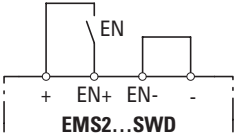
Variants DOS (DOL starter) and ROS (Reversing starter)

Type	Minimum current	Rated operational current I_e	
		AC51 EN 60947-4-3	AC53a EN 60947-4-2
DOL starter			
EMS2-DOS-T-3-SWD	0.18 A	3 A	3 A
EMS2-DOS-T-9-SWD	1.5 A	9 A	7 A
Reversing starter			
EMS2-ROS-T-3-SWD	0.18 A	3 A	3 A
EMS2-ROS-T-9-SWD	1.5 A	9 A	7 A

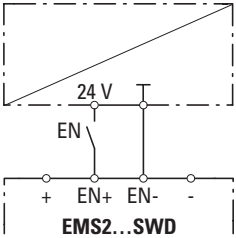
Block diagram reversing starter with safety function and SWD



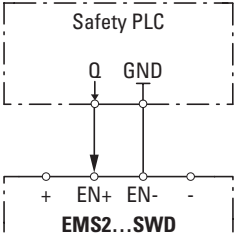
Safety-oriented enable with internal voltage from the EMS2-...-SWD motor starter



Safety-oriented enable with external voltage



Safety-oriented enable via a safe PLC output



Electronic motor starter and variable frequency drives

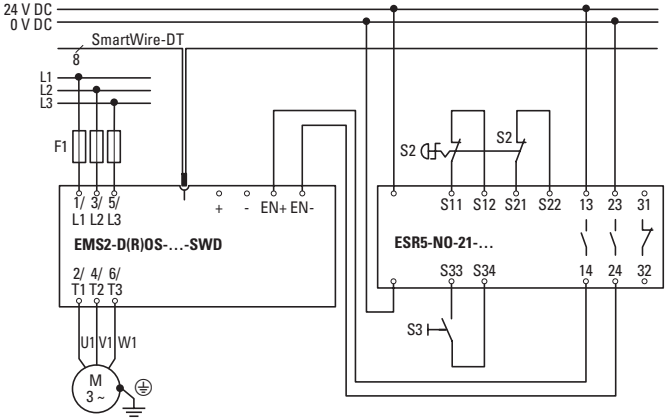
Application of the electronic motor starter (EMS2)

Single-channel controlled stop application (cat. 3, SIL 3, PL e)

The EMS2-D(R)OS-...-SWD motor starter is used in combination with an ESR5 series safety relay.

A cable for the safety-oriented enable (EN+) is connected via the safety relay. For the enable, the internal voltage on the terminals + and - is used. This type of wiring is then only accepted if the EMS2-...-SWD motor starter and the safety relay are located in the same control panel.

The background to this is a possible cross short-circuit which can lead to a bridging within the controlled stop circuit. This is more probable for cables which are located outside of the control panel than for a wiring within the same control panel.



Example: Single-channel controlled stop application with error prevention

Electronic motor starter and variable frequency drives

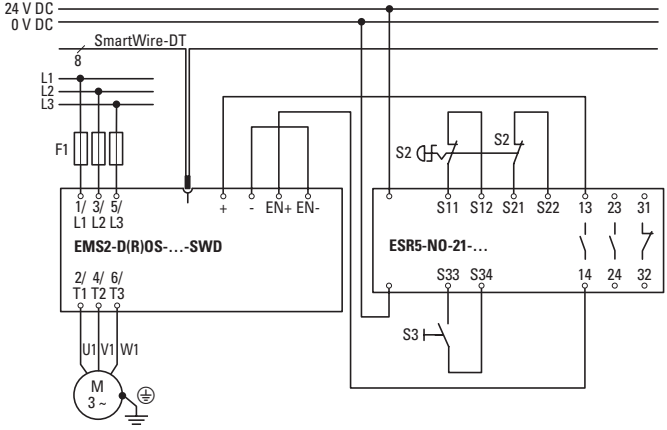
Application of the electronic motor starter (EMS2)

Dual-channel controlled stop application (cat. 3, SIL 3, PL e)

The EMS2-D(R)OS-...-SWD motor starter is used in combination with an ESR5 series safety relay.

A cable for the safety-oriented enable (EN+/EN-) is connected via the safety relay.

For the enable, an external voltage of 24 V is used. This type of wiring is then only accepted if the motor starter EMS2-...-SWD and the safety relay are located in the same control panel.

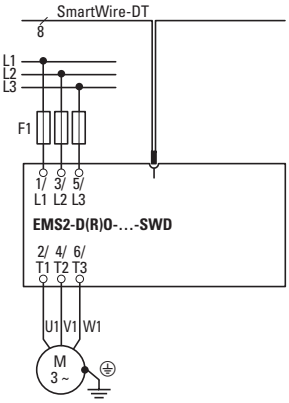


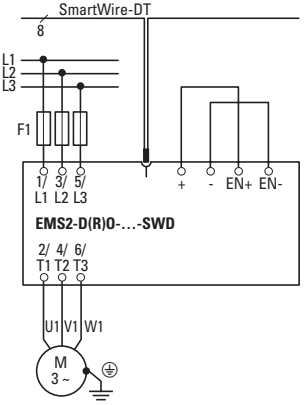
Example: Dual-channel controlled stop application

Application without controlled stop

In this application, the EMS2-...-SWD series devices are not included in a controlled stop chain.

When using EMS2-DOS-...-SWD or EMS2-ROS-...-SWD, the terminals + must be bridged with EN+ and – with EN-, so that a start signal is accepted via SWD.





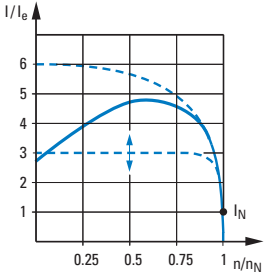
2 examples: Application without controlled stop with error prevention

Electronic motor starter and variable frequency drives
Soft starter basic information

Soft starters

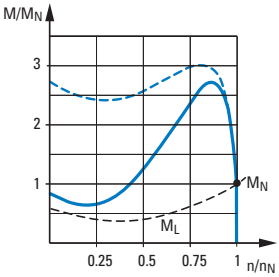
Soft starters are electronic devices for the soft starting of three-phase motors. Soft starters must comply with the product standard IEC/EN 60947-4-2.

During the startup phase of a motor, a soft starter controls the power supply smoothly and continuously up to the rated value (U_{LN}) by controlling the phase angle. This voltage control limits the starting current since the motor current behaves proportionally to the motor voltage. The resulting smooth torque increase enables the motor to be adapted to the load behavior of the motor.



The mechanical components of this type of drive unit are therefore accelerated very smoothly. This has a positive effect on the lifespan, operating behavior and operating processes, and prevents any adverse effects such as:

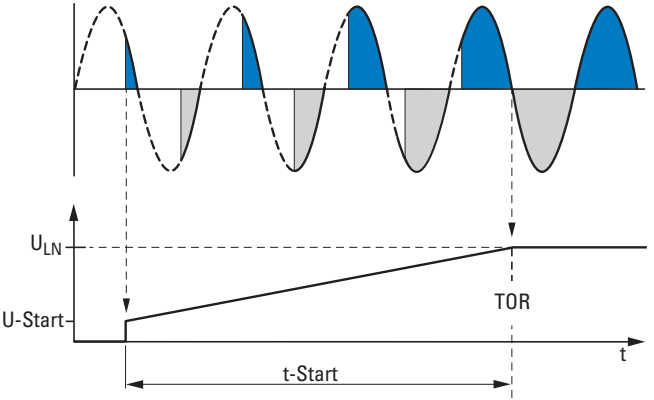
- Impacting of cog edges in the gearbox
- Reduction of the water hammers in pipe systems
- Slipping of V belts
- Jitter with conveyor systems



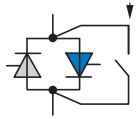
After a time controlled voltage change has elapsed (TOR = Top-of-Ramp), so-called bypass contacts can be used to bridge the phase angle control for the static continuous operation. The considerably lower transition resistance of the mechanical switch contacts compared to power semiconductors enables heat dissipation in the soft starter to be reduced and the lifespan of the power semiconductors to be extended.

Electronic motor starter and variable frequency drives

Soft starter basic information



U_{LN} = Mains voltage
U-Start = Start voltage
t-Start = Ramp time of the voltage change
TOR = Top-of-Ramp (end point of the voltage control: $U = U_{LN}$)



Note

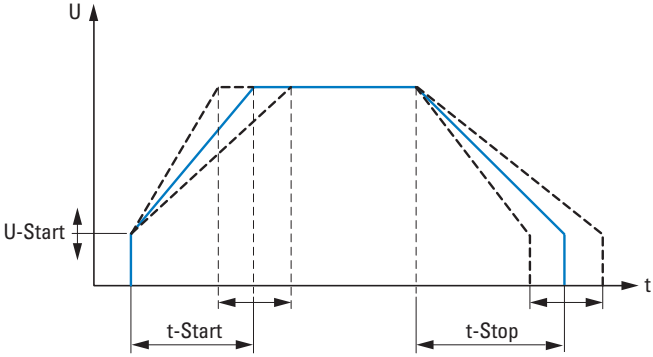
The acceleration time of a drive with a soft starter always depends on the load and the breakaway torques. When commissioning this type of drive system, the required breakaway torque should be set first of all by means of the start voltage (U-Start) and then the shortest possible ramp time (t-Start) should be determined for the linear voltage change.

As well as the time-controlled startup of a motor, the soft starter also enables a time-controlled reduction of the motor voltage and thus a controlled stopping of the motor. This type of stop function is primarily used for pumps in order to prevent pressure waves (water hammer). Jerky movements and therefore the wear on drive chains and drive belts as well as bearings and gears can be reduced.

Note

The set ramp time for the deceleration (t-Stop) must be greater than the load-dependent uncontrolled deceleration time of the machine.

Control of the motor voltage



The ratio of the overload current to the rated operational current, the total of the times for the controlled overload current, as well as the duty factor and start cycle form the overload current profile of a soft starter; this data is stated on the rating plate in accordance with IEC/EN 60947-4-2.

Example
55A: AC-53a: 3-5 : 75-10

55A = Rated operational current of the soft starter

AC-53a = Load cycle in accordance with IEC/EN 60947-4-2

3 = 3-fold overcurrent at start (3 x 55 A = 165 A)

5 = Overcurrent duration in seconds

75 = Duty factor within the load cycle in %

10 = Number of permissible starts per hour

Other overload cycles and operating frequencies can be calculated. Further information on this is provided in the relevant soft starter manual.

Note

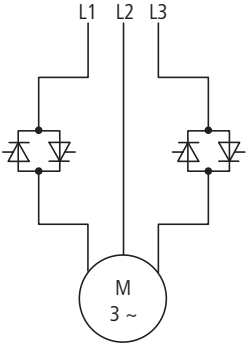
The controlled deceleration presents a similar load on the power semiconductors in the soft starter as the start phase. If therefore the deceleration ramp is activated on a soft starter with a maximum of 10 permissible starts per hour, the number of permissible starts is reduced to 5 per hour (plus 5 stops within the same hour).

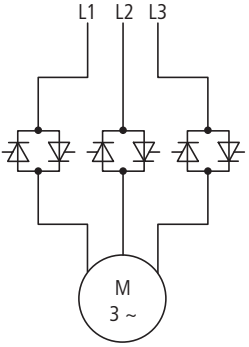
Electronic motor starter and variable frequency drives
Soft starter basic information

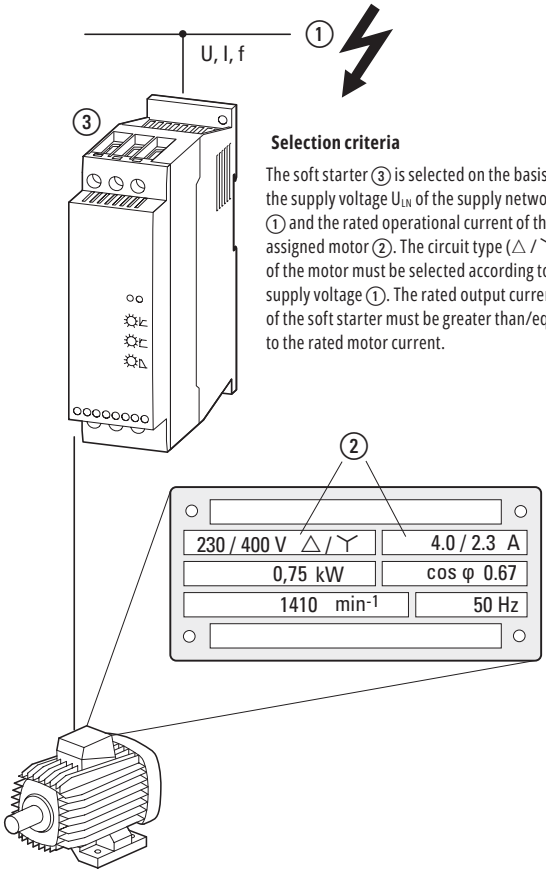
Types

Soft starters are usually divided into two types:

- Two-phase controlled, electronic soft starters for simple tasks:
  - Use is limited to small and medium rated motor (< 250 kW).
  - Simple handling with limited setting options and time controlled voltage ramps.
  - For simple applications where importance is placed on jerk-free operation in the starting phase.
  - They are an inexpensive alternative to the star-delta starter.
  - They can only be used in so-called In-Line configurations.
- Three-phase controlled, electronic soft starters for complex tasks:
  - For medium to high motor ratings up to 800 kW as compact devices
  - The devices are provided with an adjustable current limitation and integrated motor protection functions.
  - They have preset application characteristics and can be parameterized for optimizing the machine start functions.
  - Control inputs, signal contacts and optional fieldbus interfaces enable a wide range of communication options to be implemented.
  - They can be used in both In-Line and In-Delta configurations.
    Example: see S811+ →page 5-56







Selection criteria

The soft starter ③ is selected on the basis of the supply voltage U_{LN} of the supply network ① and the rated operational current of the assigned motor ②. The circuit type (△ / Y) of the motor must be selected according to the supply voltage ①. The rated output current I_e of the soft starter must be greater than/equal to the rated motor current.

Electronic motor starter and variable frequency drives
Soft starter basic information

Selection criteria

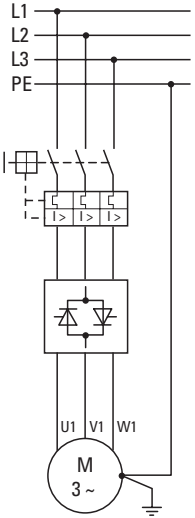
When selecting the drive, the following criteria must be known:

- Type of motor (three-phase asynchronous motor)
- Mains voltage = rated operating voltage of the motor (e. g. 3 AC ~ 400 V)
- Rated motor current (recommended value, dependent on the circuit type and the power supply)
- Load torque (quadratic, linear)
- Starting torque
- Ambient temperature (rated value +40 °C).

The switching and protective devices (electromechanical components) in the main circuit of the motor feeder are designed on the basis of the rated operational current (I_e) of the motor and the utilization category AC-3 (standard IEC 60947-4-1).

The utilization category here is AC-53a (IEC/EN 60947-4-2 standard).

- AC-3 = squirrel-cage motors: startup, switch off during operation.
- AC-53a = control of a squirrel-cage motor: eight-hour duty with starting currents for start processes, settings, operation



Motor feeder with DS7 soft starter combined with PKZM0 in In-Line circuit

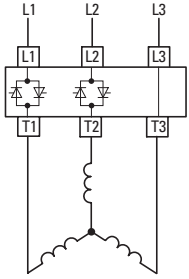
Permissible connection circuits of the motor

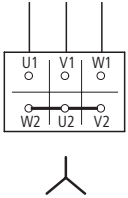
Three-phase asynchronous motors can be connected to a soft starter, depending on the mains voltage in a star or delta connection.

Example

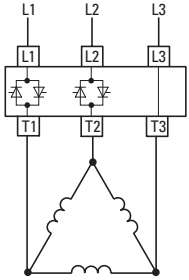
2-phase controlled soft starter (DS7)

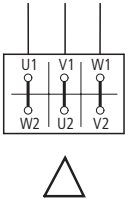
Star circuit





Delta circuit

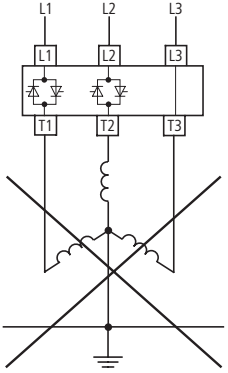




5

Note

Three-phase motors with a neutral point (star circuit) must not be connected to a two-phase controlled soft starter as one phase is connected here directly to the mains voltage and causes impermissible overheating in the motor.



Caution!
Not permissible

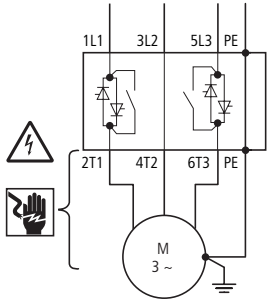
Danger!
Dangerous voltage.
Risk of death or serious injury.

The power section of soft starters is formed with semi-conductors (thyristors). When a supply voltage (U_{LN}) is present, there is also a dangerous voltage present at the output to the motor in the OFF/STOP state.

This warning applies to all soft starter types.

Example

2-phase controlled soft starter



Electronic motor starter and variable frequency drives

Soft starter basic information

Soft starters and coordination types to IEC/EN 60947-4-3

The following coordination types are defined in IEC/EN 60947-4-3, 8.2.5.1:

Type 1 coordination

In type 1 coordination, the device must not endanger persons or the installation in the event of a short-circuit and does not have to be capable of continued operation without repairs or parts replacements.

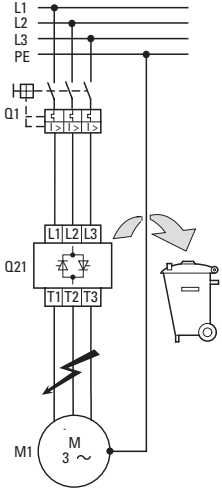
Type 2 coordination

In type 2 coordination, the device must not endanger persons or the installation in the event of a short-circuit and must be capable of continued use without repairs or parts replacements. For hybrid control devices and contactors, there is a risk of contact welding, for which the manufacturer must give maintenance instructions.

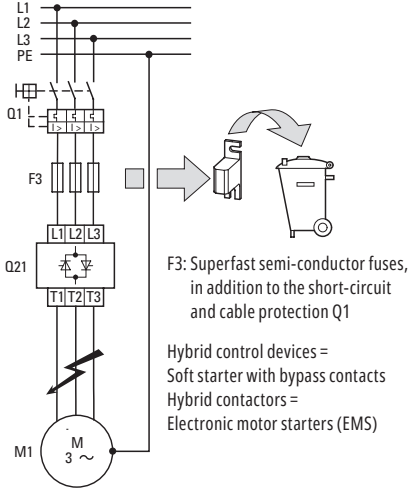
The assigned short-circuit protective device (SCPD) must trip in the event of a short-circuit. If a fuse is used, this has to be replaced. This is part of the normal operation of the fuse, also for type 2 coordination.

Note

Superfast semiconductor fuses must always be arranged directly in front of the power semiconductors (short cable lengths).



Type 1 coordination



Type 2 coordination

F3: Superfast semi-conductor fuses, in addition to the short-circuit and cable protection Q1

Hybrid control devices =
Soft starter with bypass contacts
Hybrid contactors =
Electronic motor starters (EMS)

Parallel connection of several motors to a single soft starter

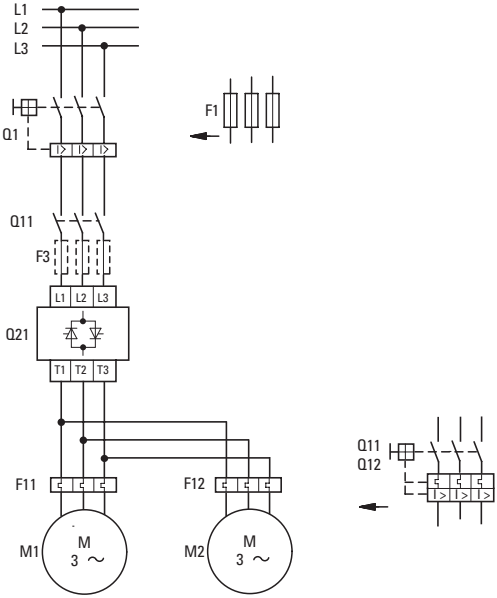
You can also use soft starters to start several motors connected in parallel. This does not, however, allow the startup behavior of the individual motors to be controlled.

Notes

- The current consumption of all connected motors must not exceed the rated operational current I_e of the soft starter.
- Each motor must be protected from thermal overload individually, e. g. with thermistors and/or overload relays (F11, F12). Alternatively, motor-protective circuit-breakers (Q11, Q12) can also be used.
- It is advisable to use this circuit type only with motors of a similar rating (maximum deviation: one rating size). Problems may arise during starting if motors with significant rating differences (for example 1.5 kW and 11 kW) are connected to the output of a soft starter. The lower-rated motors may not be able to reach the required torque due to the relatively high ohmic resistance of their stators. During the startup these require a higher voltage.
- The last motor must not be switched off in operation since the resulting voltage peaks may cause damage to the electronic components in the soft starter and thus to its failure.

Electronic motor starter and variable frequency drives

Soft starter basic information



F11, F12:
Motor protection (overload relay) or motor-protective circuit-breaker (Q11, Q12)

F3:
Superfast semi-conductor fuses (optional, additionally to Q1 and F1)

Q1 or F1:
Short-circuit and cable protection

Using soft starters with three-phase slip ring motors

When upgrading or modernizing older installations, contactors and rotor resistors of multistage three-phase stator automatic starters can be replaced with soft starters. This is done by removing the rotor resistors and assigned contactors and short-circuiting the slip rings of the motor's rotor. The soft starter is then connected into the feeder. The smooth starting of the motor can then be implemented.
→ Figure, page 5-31

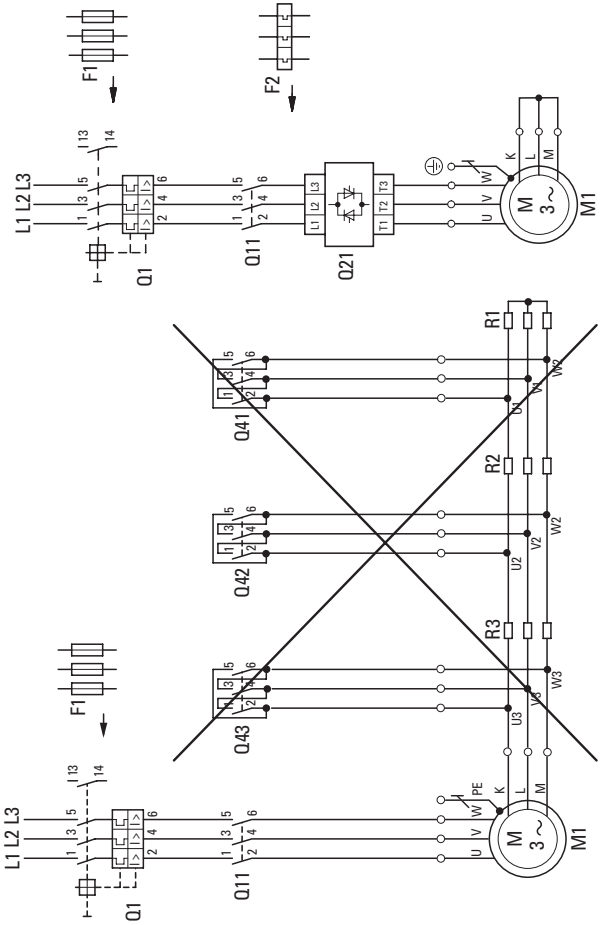
Notes

- Slip ring motors develop a high starting torque with low starting current. They can thus be started at the rated load and this must be taken into account when selecting a soft starter. The soft starter cannot replace the rotor resistors in every application.
- Depending on the type of motor, it may be necessary to keep the last resistor group permanently connected to the slip ring rotor terminal (K-L-M).

Q1: Cable and motor overload protection
or
F1: Cable protection and
F2: Overload protection required (thermistor, bimetal relay) if the soft starter (Q21) does not include this function. Example: overload relay F2 in combination with contactor Q11.
M1: Slip-ring motor

Electronic motor starter and variable frequency drives

Soft starter basic information



Motors with compensation capacitors

As resistive-inductive loads, three-phase motors draw reactive power from the network. This reactive power can be compensated by means of capacitors (C_x) ① (improved power factor cos φ).

WARNING

The output of a soft starter must not be connected to any capacitive loads (capacitors) ②. This would damage the soft starter.

If capacitors are to be used for reactive power compensation and thus to improve the power factor, they must be connected to the mains side of the soft starter ③. If the soft starter is used together with an isolating or main contactor (Q11), the capacitors must be disconnected from the soft starter (Q12) when the contactor contacts are open.

The following figure ③ shows a safe arrangement. The compensation capacitors are switched via a capacitor contactor (Q12). The capacitor contactor is controlled via the TOR (Top-of-Ramp) signal of the soft starter. The capacitors are disconnected from the mains during the critical start and stop times.

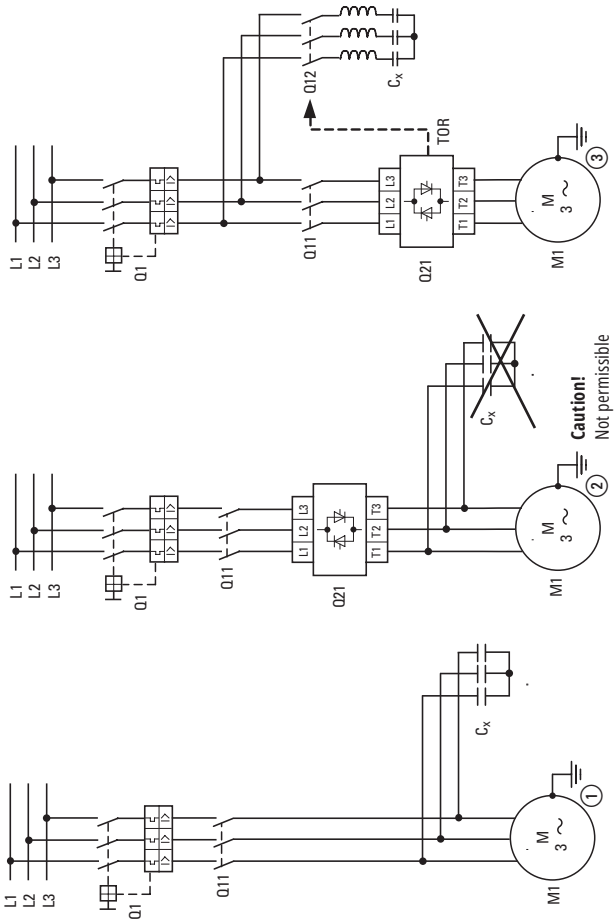
Note

In networks with electronically controlled loads (e. g. soft starters), the compensation devices must always be connected with a series inductance.

C_x: Capacitors for reactive power compensation
Q1: Motor-protective circuit-breaker
Q11: Mains contactor
Q12: Contactor for capacitors
Q21: Soft starter
M1: Three-phase asynchronous motor

Electronic motor starter and variable frequency drives

Soft starter basic information



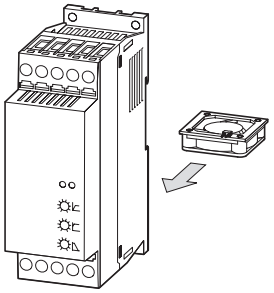
Electronic motor starter and variable frequency drives
Application of a two-phase soft starter (DS7)

DS7 product features

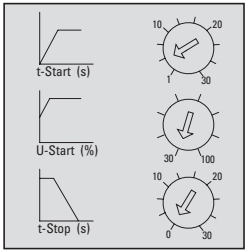
The DS7 is a two-phase controlled soft starter with integrated bypass relay. The advantage of this device is a more compact design and a more favorable price than a 3-phase controlled soft starter.

- 4 sizes: 1 (4 - 12 A); 2 (16 - 32 A); 3 (41 - 100 A); 4 (135 - 200 A)
- Power section and control section are galvanically isolated
- Power section:
  – Rated operational voltage: 200 – 480 V, -15 % /+10 %
  – Mains frequency: 50/60 Hz ±10 %
  – Overload cycle: AC53a: 3 – 5: 75 – 10 (three times the starting current, 5 seconds start time, 75 % load cycle and 10 starts per hour)
- Control voltage/regulator supply voltage:
  – DS7-340...: 24 V AC/DC, -15 %/+10 %
  – DS7-342...: 120 - 230 V AC, -15 %/+10 %
  – AC: 50/60 Hz ±10 %
- Relay contacts (potential-free)
  – TOR (Top-of-Ramp): 230 V AC, 1 A, AC-11 (in size 1 with potential connection to the control section)
  – RUN (operational signal): 230 V AC, 1 A, AC-11 (not in size 1)
- Ambient temperature during operation: -5 to +40 °C, max. +60 °C with derating and device fan
- Load cycle: 10 starts per hour, max. 40 starts per hour, with derating and integrated device fan (optional)
- Status display (LEDs)
  – RUN = Operating signal (green)
  – Error = Error message (red)

DS7 with device fan DS7-FAN-032



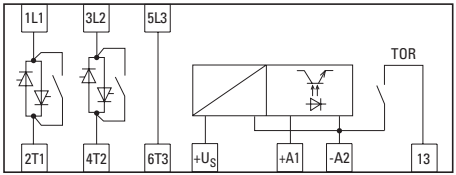
- Parameterization/setting via three parameters accessible on the front:
  – t-Start = Start time (1 - 30 s) for the voltage increase from the value U-Start up to mains voltage (U_{LN})
  – U-Start = The start voltage (30 - 100 %), determines the starting torque of the motor
  – t-Stop= Soft stop time (0/1 - 30 s) for the voltage reduction from the mains voltage (U_{LN}) to the value U-Start



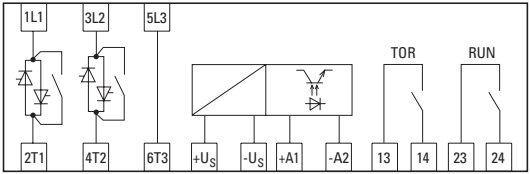
Electronic motor starter and variable frequency drives
Application of a two-phase soft starter (DS7)

The number and arrangement of the control terminals, as well as the structure in the power section of the individual sizes vary according to the power section.

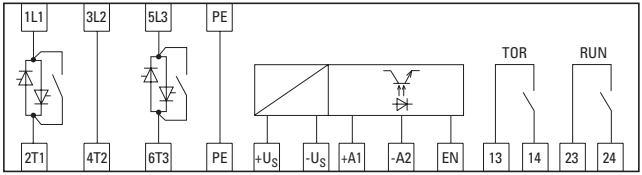
Size 1 (4 to 12 A)



Size 2 (16 to 32 A)



Size 3 and 4 (41 to 200 A)

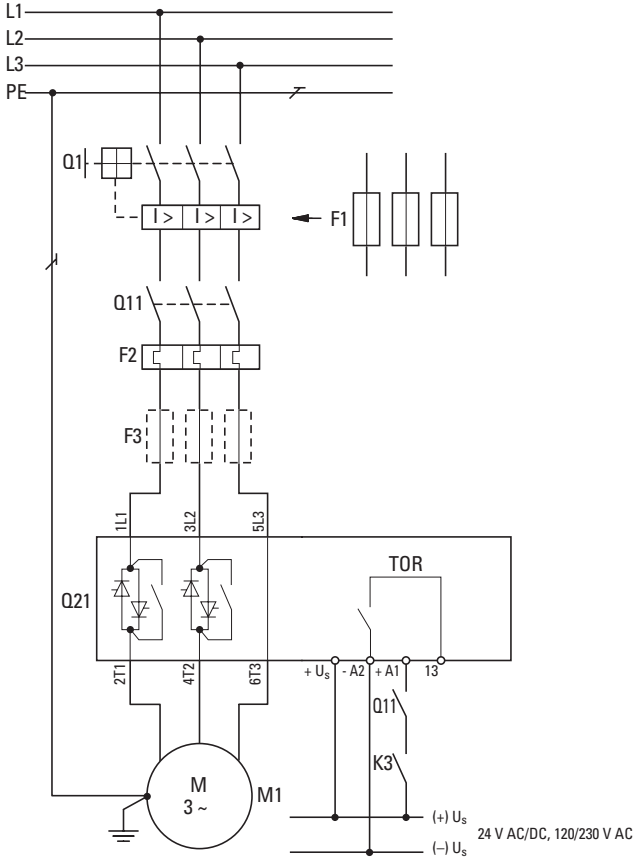


Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Standard connection with upstream mains contactor and soft stop ramp

Standard connection with mains contactor, size 1 (4 to 12 A)



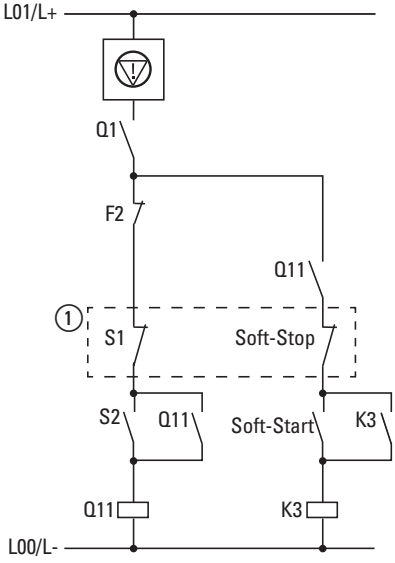
Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Control section with mains contactor

Q1, F1: Short-circuit- and cable protection
Q11: Mains contactor
F2: Motor protection
F3: Optional semiconductor fuse for type 2 coordination
K3: Auxiliary contactor for Start/Stop
S1: Switch for Start
S2: Switch for Stop

① if a coast stop without soft stop is required
setting: t-Stop = 0

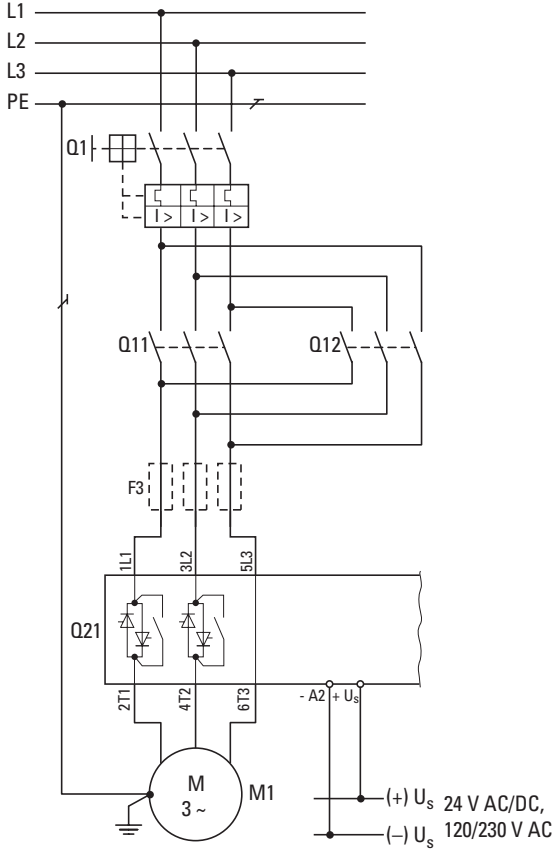


Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Rotation direction reversal with soft stop ramp

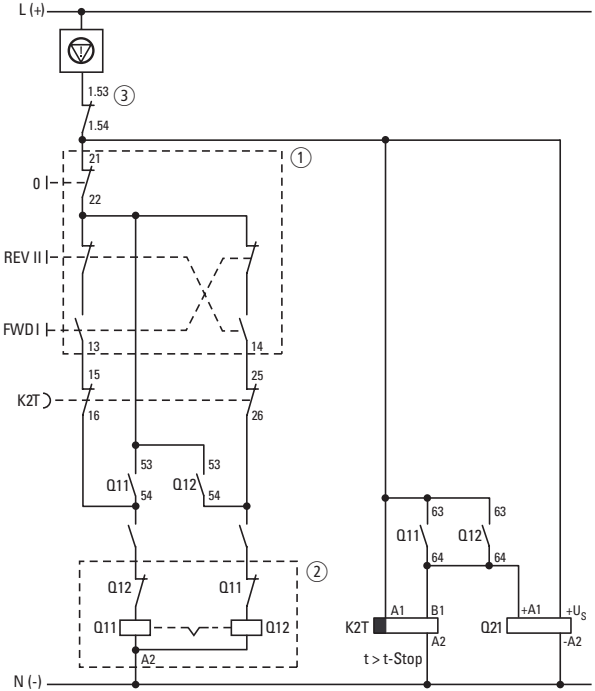
Size 1 (4 to 12 A)



Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Control section for bidirectional operation



FWD = Clockwise rotation field (Forward Run)

REV = Counterclockwise rotation field (Reverse Run)

Q11 = Mains contactor FWD

Q12 = Mains contactor REV

① Assembled control station

② Reversing starter

③ Standard auxiliary contact

Electronic motor starter and variable frequency drives
Application of a two-phase soft starter (DS7)

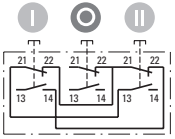
Control section for bidirectional operation

Note

The control voltages ($+U_S$) of the DS7 soft starter and the contactor control must have the same potential:
24 V DC/AC or 120/230 V AC

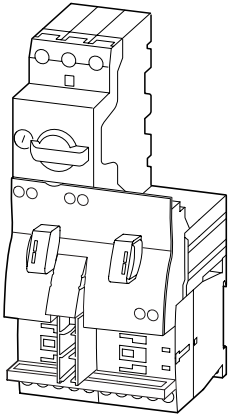
Q1, Q11, Q12 = MSC-R motor-starter combination ② is a compact device with electrical and mechanical interlocking.

The NHI-E-10-PKZ0 auxiliary contact ③ is added to Q1 for cable and motor protection.



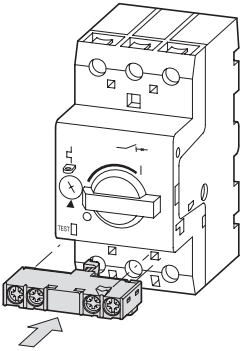
M22-I3-M1

① Contact sequence of assembled control station



MSC-R-...

② Reversing starter

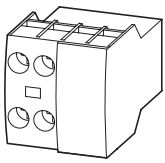


NHI-E-10-PKZ0

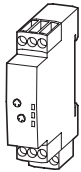
③ Standard auxiliary contact (grey)

Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)



DILA-XHI20



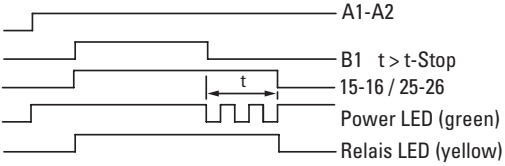
ETR2-11

Two DILA-XHI20 auxiliary contact modules are added to the two reversing contactors Q11 and Q12.

The NO contact 53/54 is used for the self-maintaining of reversing contactors Q11 and Q12; NO contact 63/64 activates the timing relay K2T and the soft starter Q21.

The pushbutton actuators 0, I, II as a complete device (M22-I3-M1) for surface mounting ① enable the rotation direction change via the stop button.

K2T is an off-delayed timing relay (type ETR2) and simulates here the RUN signal.
The drop-out time must be greater than the stop time (t-Stop) set on the DS7 soft starter. Switching to the other direction is only possible after the value set here has elapsed.

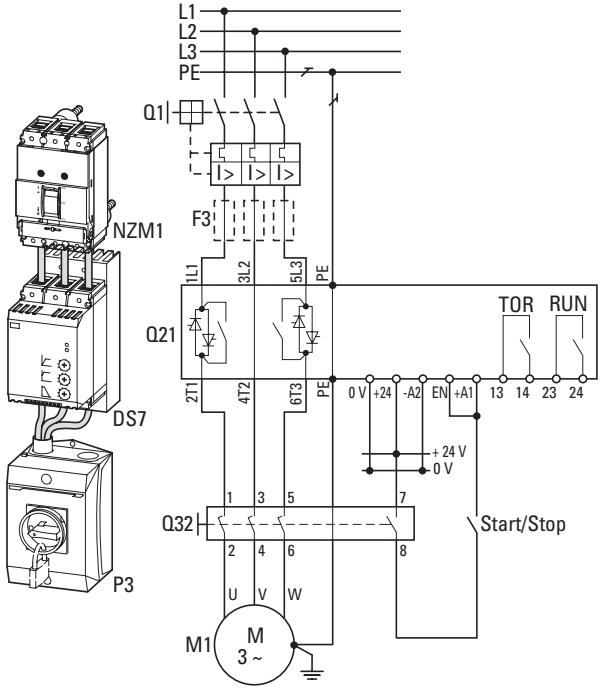


Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Compact motor starter with maintenance switch

Soft starter DS7, circuit-breaker NZM1 and
maintenance switch P3, size 3 + 4 (41 to 200 A)



F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)

Q1: Cable and motor protection

Q21: DS7 soft starters

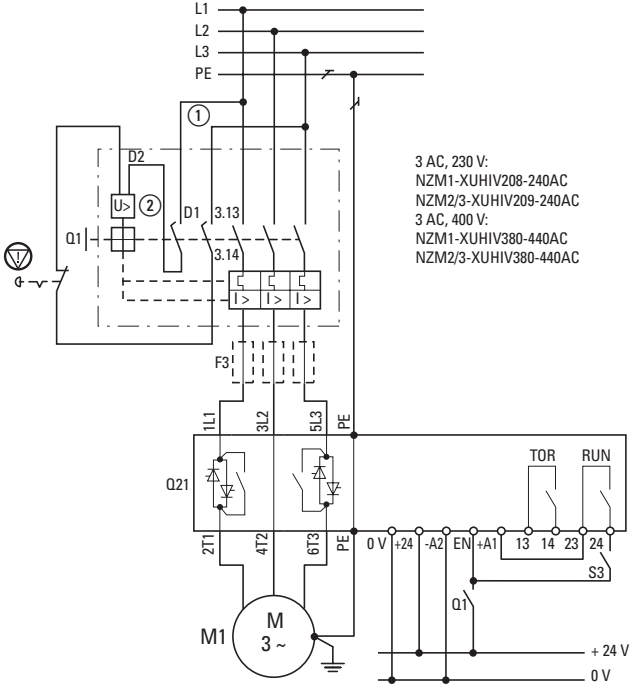
Q32: Maintenance switch (local)

M1: Three-phase motor

Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

NZM circuit-breaker with emergency-off function to IEC/EN 60204 and VDE 0113 Part 1, size 3 + 4 (41 to 200 A)



3 AC, 230 V:
NZM1-XUHIV208-240AC
NZM2/3-XUHIV209-240AC
3 AC, 400 V:
NZM1-XUHIV380-440AC
NZM2/3-XUHIV380-440AC

Ⓥ Emergency switching off
F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)
Q1: Cable and motor protection (NZM1, NZM2)
Q21: DS7 soft starters
M1: Motor

① Control circuit terminal
② Undervoltage release with early-make auxiliary contact

Bypass circuit

Note

The devices of the DS7-34... series are already provided with integrated bypass contacts. An external bypass for continuous operation with a DS7 soft starter is therefore not required.

Bypass circuit for emergency operation

In pump applications the bypass contactor is often required to provide emergency operation capability. A service switch is used to select between soft starter operation and DOL starter operation via a bypass contactor (Q22). This is used to fully isolate the soft starter. In this case, it is important that the output circuit is not opened during operation. The interlocks ensure that a switchover is only possible after a stop. An electrical and/or mechanical interlocking of contactors Q22 and Q31 ensures a safe operating state.

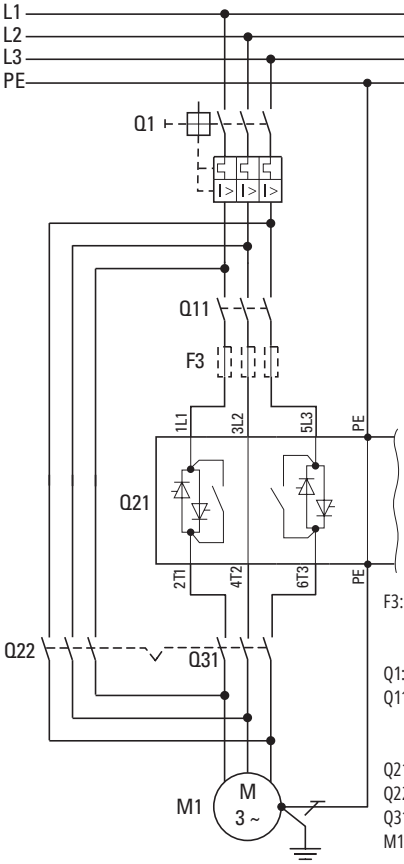
Note

Unlike simple bypass operation, the bypass contactor must be designed here in accordance with utilization category AC-3.

Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

DS7 power section ≧ 41 A with bypass emergency operation (example: pump)

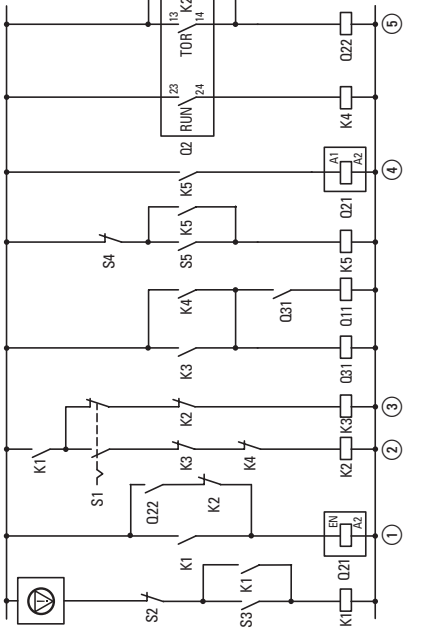


F3: Superfast semiconductor fuse (optional) for type 2 coordination (additional to Q1)
Q1: Cable and motor protection
Q11: Mains contactor (optional) for disconnection in emergency operation
Q21: Soft starters
Q22: Bypass contactor
Q31: Motor contactor
M1: Motor

Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Actuation with bypass emergency operation – (pump operation)



Note

The control system shown here can also be used for the DS7 soft starter in size 2 (16 to 32 A).

Electronic motor starter and variable frequency drives
Application of a two-phase soft starter (DS7)

Starting several motors sequentially with a soft starter (cascaded control)

When starting several motors one after the other using a soft starter, keep to the following changeover sequence:

1. Start using soft starter
2. Switch on bypass contactor Qn2 via TOR (Top-of-Ramp)
3. Block soft starter
4. Switch soft starter output with Qn1 to the next motor
5. Restart

Notes

- When starting several motors with one soft starter the thermal load of the soft starter (starting frequency, current load) must be taken into account. If the starts are to occur in close succession, the soft starter must be dimensioned larger (i. e. the soft starter must be designed with an accordingly higher load cycle).
- Due to the thermal design of the DS7 soft starters, we recommend the use of an (optional) fan when using a DS7 series device for starting several motors.

F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)
Q1: Cable protection
Q2: Soft starter DS7
Qn1: Contactor (1, 2, n)
Qn2: Mains bypass contactor for motor (1, 2, n)
Qn3: Motor protection (motor-protective circuit-breaker or bimetal relay
Mn: Motor (1, 2, n)

Notes

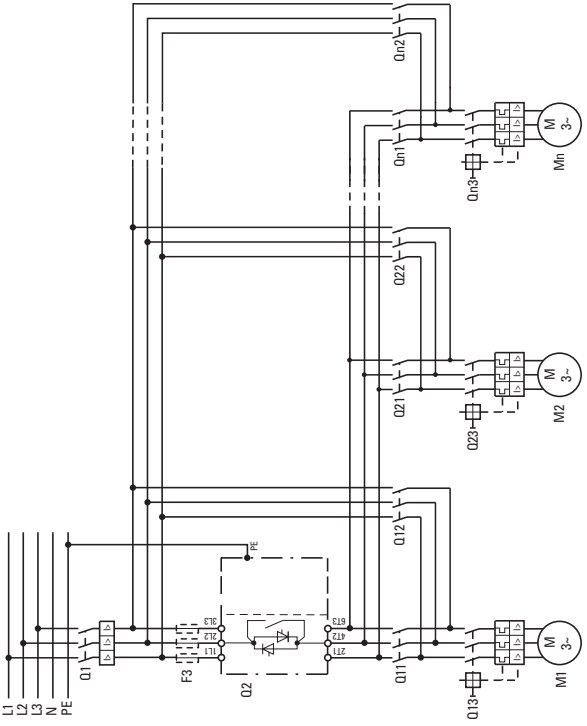
- The control system shown here can also be used for the DS7 soft starter in size 2 (16 to 32 A), however without an enable signal ①.
- Bimetal relays can also be used as an alternative to the overload relays Q13, Q23, ... , Qn3 (see page 5-29).

Electronic motor starter and variable frequency drives

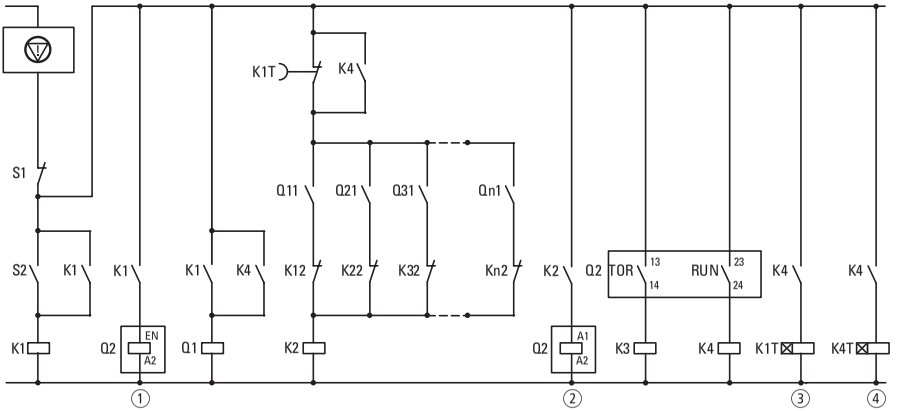
Application of a two-phase soft starter (DS7)

Cascade control

Power section for motor cascade (example for size 3 and 4)



Actuation, motor cascade, part 1



① Enable

② Soft start/Soft stop

③ Starting frequency monitoring. The timing relay must be set so that the soft starter does not have a temperature overload. The correct time is based on the permissible operating frequency of the selected soft starter. If necessary, use soft starters with a higher rating.

④ Set the timing relays to approx. 2 s off-delay. This ensures that the next motor branch can not be connected as long as the soft starter is running.

N/C contact S1 switches all motors off at the same time.

Electronic motor starter and variable frequency drives

Application of a two-phase soft starter (DS7)

Actuation, motor cascade, part 2

① Motor 1
② Motor 2
③ Motor n

The N/C contact S3 is required if motors also have to be switched off individually.

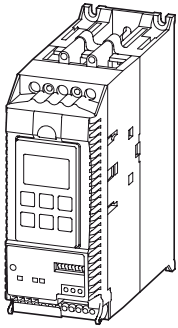
Electronic motor starter and variable frequency drives
Application of a three-phase soft starter (S811+)

Product features S811+

The S811+ is a three-phase controlled soft starter with integrated bypass relay. The advantage of this device is an integrated overload protection.

- 5 sizes:
  N (37 - 66 A); R (105 - 135 A); T (180 - 304 A); U (360 - 500 A); V (360 - 850 A)
- Parameterizable and communication-capable with pluggable control terminals.
  - Operating unit with LCD display
  - Fieldbus connection via Modbus RTU
  - Optional fieldbus modules: Modbus TCP, Profibus-DP, DeviceNet
- Power section and control section are galvanically isolated
- Power section:
  - Rated operational voltage 200 - 600 V ±10 %
  - Mains frequency: 50/60 Hz ±10 %
  - Overload cycle: AC-53b: 2 - 30: 30 870 (two times the starting current, 30 seconds starting time, 30 s pause time between 2 starts) AC-53a: 4.0 - 32: 99 - 3 (four times the starting current, 32 seconds starting time, 99 % load cycle and 3 starts per hour
- Control section:
  - Control voltage: 24 V DC, ±15 %
- 4 configurable digital inputs
  - 2 configurable relay outputs 230 V AC 1.5A
- Ambient temperature during operation: -40 up to +50 °C

S811+ Size N



- Parameterization/setting via operating unit with LCD display:
  - Rated motor current for the use of the overload protection function
  - Phase sequence and phase monitoring for monitoring the correct direction of rotation.
  - Starting method: voltage ramp, currentlimitation or pump start
  - Kick-start torque and kick-start time
  - Start time (0.5 - 360 s) for the voltage increase from the value of the start voltage up to mains voltage (U_{LN})
  - Starting torque (0 - 100 %), start voltage of the soft starter
  - Soft stop time (0 - 60 s)/Pump stop time (5 - 120 s) for the voltage reduction from the mains voltage (U_{LN}) to the value if the start voltage
  - Motor wiring: Inline or In-Delta

Electronic motor starter and variable frequency drives

Application of a three-phase soft starter (S811+)

Enable/immediate stop without ramp function (e. g. for Emergency-stop)

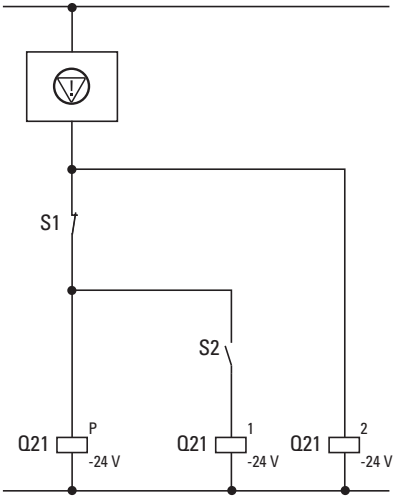
The digital input P (= Permissive) is the enable function and is not configurable. This must be live (+24 V DC), to enable a start command of the device from from any source. If the supply to the P circuit is interrupted, the device interprets this as a stop command. If a soft stop or pump stop is selected, this starts and finishes to the end of the ramp.

In the connection example, 2 digital inputs are used for the start and stop but it is also possible to control the device via only one switch at digital input P for start and stop.

When the operating conditions require an immediate de-energization, one of the configurable digital inputs must be set to the E-Stop function.

Warning!

You must in all operating conditions always first stop the soft starter ("Run" relay scanning), before you mechanically interrupt the power conductors. Otherwise a flowing current is interrupted – thus resulting in voltage peaks, which in rare cases may destroy the thyristors of the soft starter.



Ⓥ	Emergency switching off
P1, P2:	Digital inputs
Q21:	Soft starter (E2 = 6 → E-Stop)
S1:	Off
S2:	On

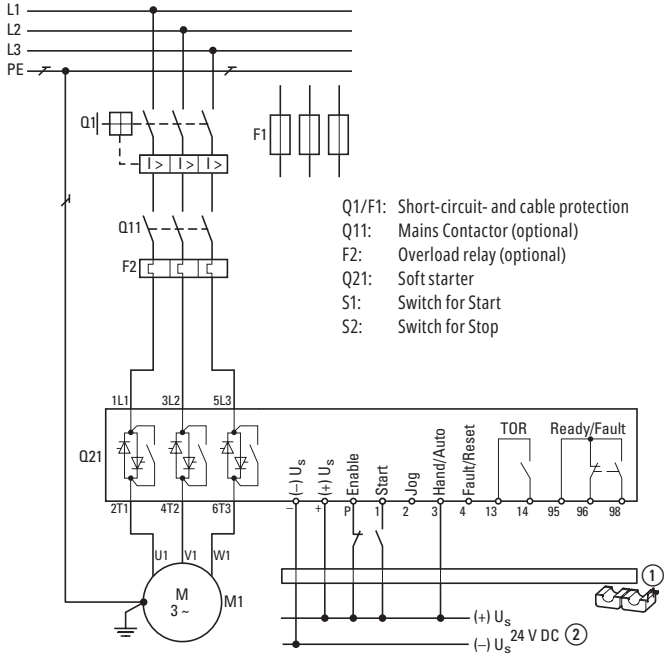
Electronic motor starter and variable frequency drives

Application of a three-phase soft starter (S811+)

Inline connection with separate contactor and overload relay

Standard connection

To disconnect from the mains, either a mains contactor in front of the soft starter or a central switching device (contactor or main switch) is required.



Q1/F1: Short-circuit- and cable protection
Q11: Mains Contactor (optional)
F2: Overload relay (optional)
Q21: Soft starter
S1: Switch for Start
S2: Switch for Stop

① Ferrite folding core (included)

② External control voltage (24 V DC) required.
I_S = 1 A, I_{PEAK} = 10 A for 150 ms at Switching the bypass contacts
Short-circuit- and cable protection: Protective switch Q1 or fuses F1

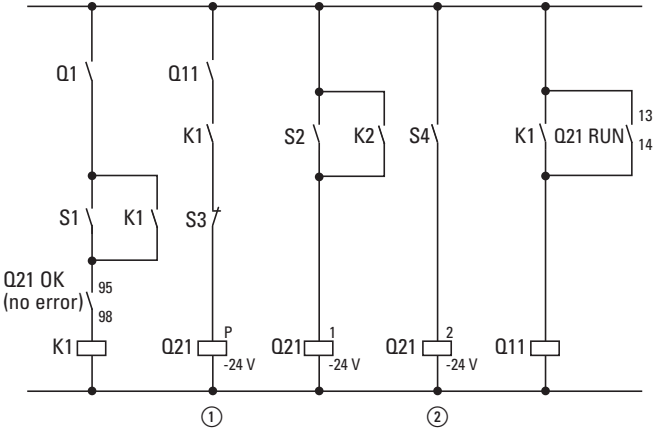
Electronic motor starter and variable frequency drives

Application of a three-phase soft starter (S811+)

Soft starter with separate mains contactor

If the soft starter is to be disconnected from the mains via a mains contactor, the run input control must be set to level sensing (DIP S1 = Off) and the fault reset mode must be set to autoreset.

Actuation



M1: Motor with temperature sensor (thermistor)
Q1: Cable and motor protection
Q11: Mains contactor
Q21: Soft starter
S1: Mains contactor On
S2: Soft start
S3: Soft stop (deceleration ramp)
S4: Coast stop
K1: Auxiliary contactor mains on

① Enable
② Soft start/Soft stop

Q21: Soft starter
Input configuration
(E2 = 6 → E-Stop)
Relay configuration
(0 = 5 → Motor energized)

In-delta connection

Soft starters are normally connected directly in series with the motor (so-called "in-line connection"). The S811+ soft starter also allows operation in an in-delta connection.

The antiparallel thyristors are connected directly in series to the individual motor windings.

Advantages (compared with in-line connection):

- Inexpensive since the soft starter only has to be designed for approx. 58 % (1/√3) of the rated current – particularly with motor ratings > 30 kW and when replacing star-delta starters.
- For the same motor rating the required soft starter rating is reduced.

Disadvantages
(compared with in-line connection):

- As in a star-delta circuit, the motor must be connected with six conductors.
- The S811+ soft starter overload protection is active only in one line so that additional motor protection must be fitted in the parallel phase or in the supply cable. The motor can be protected for example via thermistors.

Notes

- The voltage of the motor winding must match the rated voltage. For a 400 V mains voltage the motor must therefore be marked with 400 V/690 V.

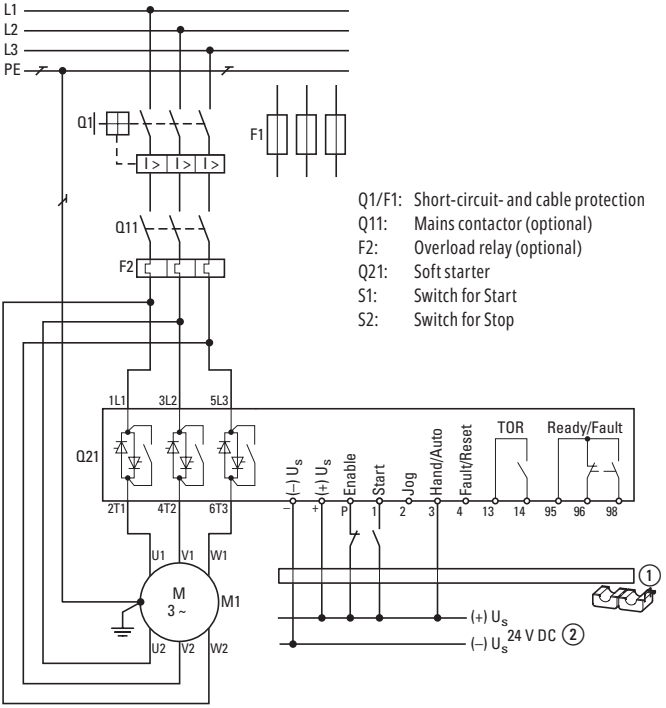
Electronic motor starter and variable frequency drives

Application of a three-phase soft starter (S811+)

In-Delta connection with separate contactor and overload relay

Standard connection

To disconnect from the mains, either a mains contactor in front of the soft starter or a central switching device (contactor or main switch) is required.



Q1/F1: Short-circuit- and cable protection
Q11: Mains contactor (optional)
F2: Overload relay (optional)
Q21: Soft starter
S1: Switch for Start
S2: Switch for Stop

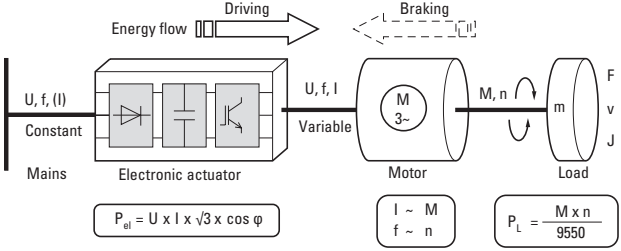
① Ferrite folding core (included)
② External control voltage (24 V DC) required.
I_S = 1 A, I_{PEAK} = 10 A for 150 ms at Switching the bypass contacts
Short-circuit- and cable protection: Protective switch Q1 or fuses F1

Electronic motor starter and variable frequency drives

Variable frequency drives basic information

Design and mode of operation of variable frequency drives

Variable frequency drives provide variable and stepless speed control of three-phase motors.



Variable frequency drives convert the constant mains voltage and frequency into a DC voltage, from which they generate a new three-phase supply with variable voltage and frequency for the three-phase motor. The variable frequency drives draws almost only active power (p.f. ~ 1) (cos φ ~ 1) from the mains supply.

The reactive power needed for motor operation is supplied by the DC link. This eliminates the need for p.f. (cos φ) correction on the mains side.

Variable frequency drives must comply with the product standard IEC/EN 60947-4-2.

U = Rated operating voltage [V]
f = Frequency [Hz]
I = Rated operational current [A]
M = Torque [Nm]
n = Speed [r.p.m.]
F = Force [N]
v = Speed [m/s]
J = Moment of inertia [kg • m^2]
P_{el} = Electric power [kW]
P_L = Mechanical shaft output power [kW]

cos φ = power factor (P/S)
with
P = Active power = $P_{el} = P_1$ [kW] and
S = Apparent power [kVA]

η = $P_L/P_{el} = P_2/P_1$ = Efficiency

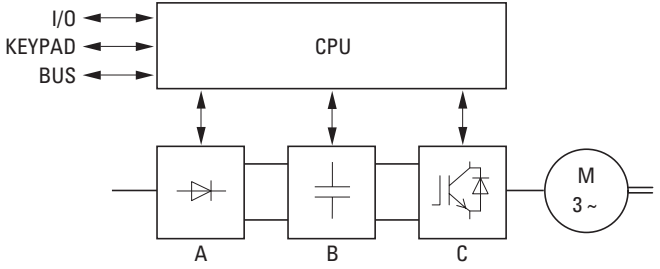
5

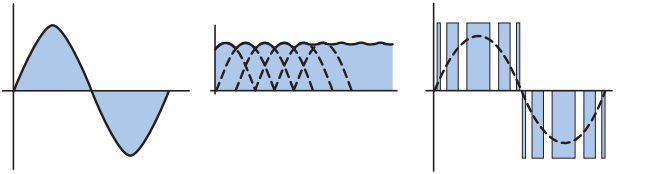
Block diagram with main components of a variable frequency drives

Internal open and closed-loop control circuits (central processing unit) monitor all variable values in the variable frequency drives and automatically switch the process off if a value reaches a dangerous level.

The power section of a static compact variable frequency drives consists of three subgroups:

- Rectifier (A)
- Internal DC link (B)
- Inverter module (C)





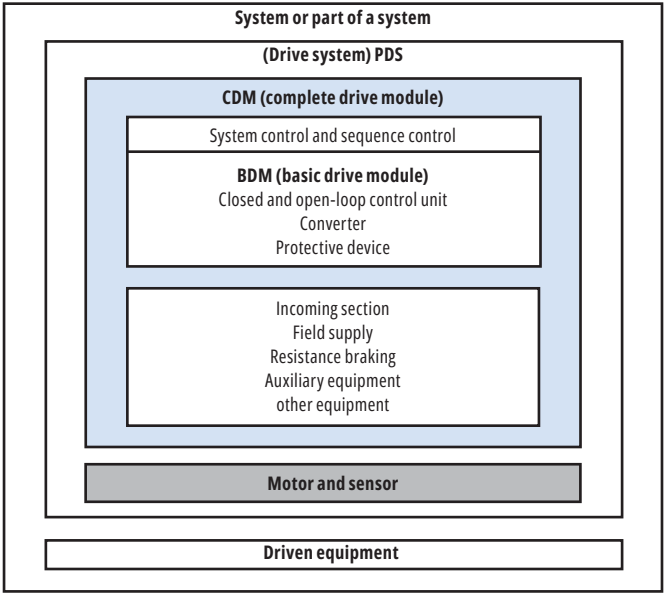
U_{LN}: Line supply from mains AC power supply

U_{DC}: DC link circuit voltage

The pulsating DC link voltage is between 1.31 times and 1.41 times the conductor voltage.

Output voltage = switched DC link voltage with sinusoidal pulse width modulation (PWM)

Drive system (PDS) to EN 61800-3



BDM (basic drive module)

Electronic power converter with associated control which is connected between the electrical power supply and a motor. The module controls speed, torque, force, position, current, frequency and voltage individually or jointly or all parameters together. The BDM can transfer the power from the electrical supply to the motor and also the power from the motor to the electrical supply.

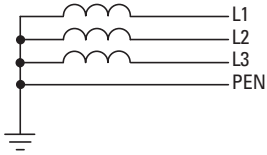
CDM (complete drive module)

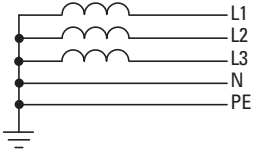
Drive module which consists of but is not restricted to the BDM and additional devices such as protective equipment, transformers, and auxiliary devices. This, however, does not include the motor and the sensors that are mechanically connected to the motor shaft.

5

Electrical mains connection

Variable frequency drives can be connected and operated without restriction on star-point-grounded AC mains (according to IEC 60364).





Connection and operation on asymmetrically grounded networks such as phase grounded delta networks (USA) or non-grounded or resistively grounded (> 30 Ω) IT networks are only permissible with restrictions and require additional engineering measures.

The standardized rated operating voltages of the utility companies fulfil the following conditions at the point of transfer to the consumer:

- Maximum deviation from the rated voltage (U_{LN}): ±10 %
- Maximum deviation in the voltage symmetry: ±3 %
- Maximum deviation from the rated frequency: ±4 %

A further voltage drop of 4 % in the consumer networks is permissible in relation to the lower voltage value (U_{LN} -10 %) of the supplying mains voltage. The power supply voltage at the consumer can therefore have a value of U_{LN} -14 %.

In ring meshed networks (as used in the EU) the consumer voltages (230 V/400 V/690 V) are identical to the power supply voltages of the utility companies. In star networks (for example in North America/USA), the stated consumer voltages take the voltage drop

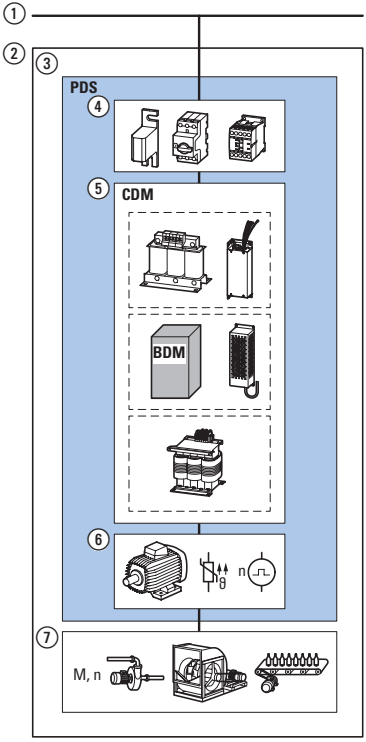
Mains voltages in North America

Supply voltage U_{LN} of the utility company	Motor voltage according to UL 508 C	Consumer voltage (rated value for the motors)
120 V	110 - 120 V	115 V
240 V	220 - 240 V	230 V
480 V	440 - 480 V	460 V
600 V	550 - 600 V	575 V

Electronic motor starter and variable frequency drives

Variable frequency drives basic information

Examples of drive control



1. Electrical supply system (mains connection, grounding system configuration, mains voltage, frequency, voltage balance, THD, compensation systems)
2. Overall system – consisting of motor and load system
3. PDS = Power Drive System
4. Safety and switching (disconnecting devices, fuses, cable cross-sectional areas, residual current circuit-breakers, mains contactors)
5. CMD = Complete Drive Module: Variable frequency drives with auxiliary equipment (mains and motor chokes, radio interference suppression filter, brake resistor, sine filter)
   BDM = basic drive module: variable frequency drives)
6. Motor and sensor (temperature, motor speed)
7. Load system: Driven system equipment (process, speed, torque)

5

Notes about correct installation of variable frequency drives

For an EMC-compliant installation, observe the following instructions. These enable electrical and magnetic interference fields to be limited to the required levels. The necessary measures work only in combination and should be taken into consideration at the engineering stage. To subsequently modify an installation to meet EMC requirements is possible only at considerable additional cost.

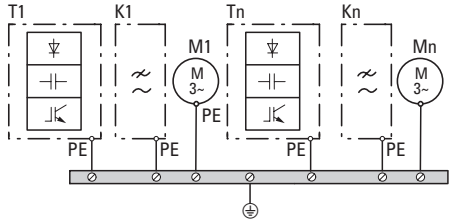
Measures for EMC-compliant installation are:

- Earthing measures,
- Shielding measures,
- Filtering measures,
- Chokes.

They are described in more detail below.

Earthing measures

These must be implemented to comply with the legal standards and are a prerequisite for the effective use of further measures such as filters and shielding.
All conducting metallic enclosure sections must be electrically connected to the earth potential. For EMC compliance, the important factor is not the cable's cross-section, but its surface, since this is where high frequency current flows to earth. All earth points must have a low impedance, be highly conductive and routed directly to the central earth point (potential equalization bar or star earth). The contact points must be free from paint and rust. Use galvanized mounting plates and materials.

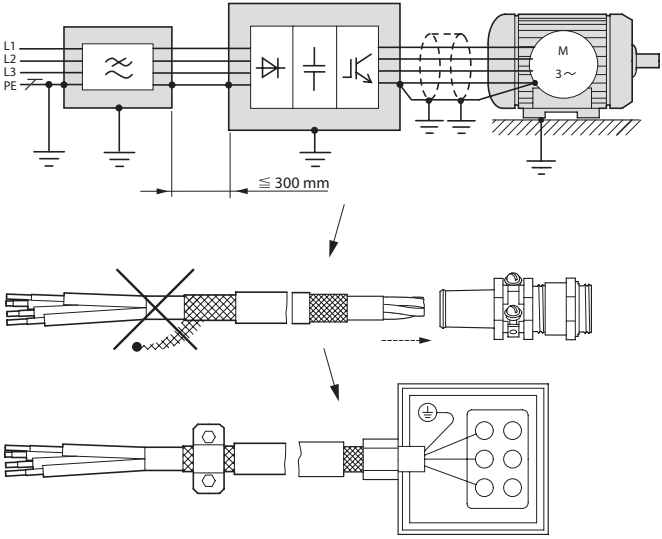


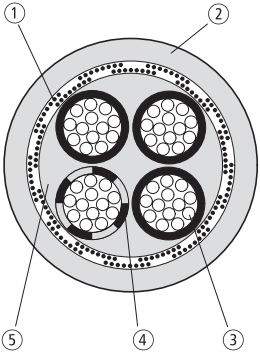
K1 = Radio interference suppression filter
T1 = Variable frequency drives

Electronic motor starter and variable frequency drives

Variable frequency drives basic information

Shielding measures





Four-core shielded motor supply cable:

1. Copper shield braid, earth at both ends with large-area connections
2. PVC outer casing
3. Drain wire (copper, U, V, W, PE)
4. PVC core insulation, 3 x black, 1 x green-yellow
5. Textile and PVC fillers

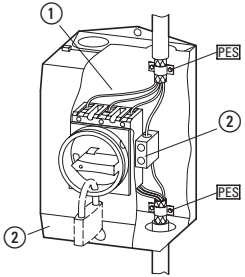
Electronic motor starter and variable frequency drives

Variable frequency drives basic information

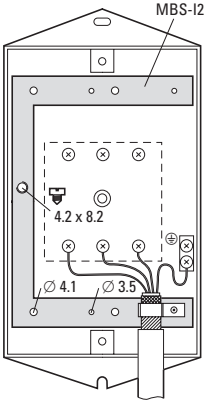
Shielding reduces emitted interference (noise immunity of neighboring systems and devices against external influences). Cables between variable frequency drives and motor must be shielded. However, the shield must not be considered a replacement for the PE cable. Four-wire motor cables are recommended (three phases plus PE). The shield must be connected to earth (PES) at both ends with a large-area connection. Do not connect the shield with pigtails. Interruptions in the shield, such as terminals, contactors, chokes, etc., must have a low impedance and be bridged with a large contact area.

To do this, sever the shield near the module and establish a large-area contact with earth potential (PES, shield terminal). Free, unshielded cables should not be longer than about 100 mm.

Example: Shield attachment for maintenance switch



1 Metal plate (e. g. MBS-I2)
2 Earthing terminal
3 Maintenance switch



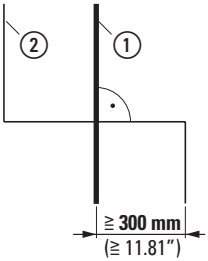
Note

Maintenance switches at of variable frequency drives outputs must be operated only at zero current.

Control and signal lines must be twisted and may be double-shielded, the inner shield being connected to the voltage source at one end and the outer shield at both ends.

Electronic motor starter and variable frequency drives

Variable frequency drives basic information



The motor cable must be laid separately from the control and signal lines (> 30 cm) and must not run parallel to any power cables.

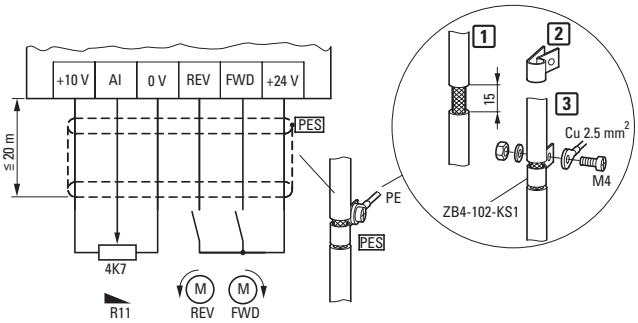
Note

Inside control panels also cables should be shielded if they are more than 30 cm long.

① Power cables: network, motor, DC link circuit, braking resistor
② Signal cables: analog and digital control signals

Example of shielding control and signal cables:

Standard connection of a variable frequency drives with setpoint potentiometer R11 (M22-4K7), control signals for clockwise and anticlockwise rotation (FWD, REV) and ZB4-102-KS1 mounting accessory



5

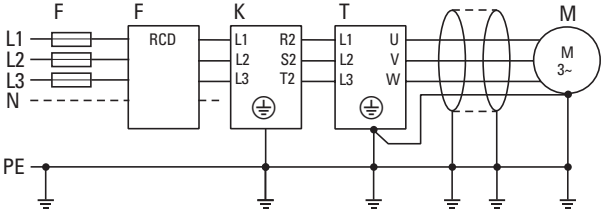
Residual-current device (RCD)

Radio interference filters produce leakage currents which, in the event of a fault (phase failure, load unbalance), can be considerably larger than the rated values. To prevent dangerous voltages, all components (variable frequency drives, RFI filter, motor, shielded motor cables) in the PDS must be earthed. As the leakage currents are high-frequency interference sources, the earthing connections and cables must have a low impedance and large contact surfaces.

The residual current device on the variable frequency drives with 3 phases must be of type B and with 1 phase of type F as sinusoidal AC and pulsed DC residual currents may occur.

With leakage currents ≧ 3.5 mA, EN 60335 (VDE 0160) states that one of the following conditions must be fulfilled:

- The protective conductor must have a cross-section ≧ 10 mm^2,
- The protective conductor must be open-circuit monitored, or
- An additional protective conductor must be fitted.



Control methods

The IGBTs in the inverter of the variable frequency drives are controlled with sinusoidal **p**ulse-**w**idth **m**odulation (PWM). In real-life applications, the industry draws a distinction between the following control methods:

- Voltage frequency control (V/f control),
- V/Hz control with slip compensation,
- Sensorless vector control (speed control),
- Vector control (closed-loop), speed control.

Volts-per-Hertz control

Volts-per-Hertz control is the best known and most commonly used method. In it, the rotating field frequency for the motor is defined with a simple characteristic (linear or quadratic), and the corresponding three-phase line-to-line motor voltage is selected in such a way that the motor will not be undermagnetized or overmagnetized.

The main applications for V/Hz control are:

- pump and fan drives,
- horizontal conveying and transportation systems,
- multiple motor drives (parallel operation of several motors at the variable frequency drives's output).

V/f control section with slip compensation

With the V/f control section with slip compensation the load-dependent speed change of individual drives can be compensated for (without sensors).

Sensorless vector control

With sensorless vector control the magnetic fields of rotor and stator are opposed to one another. With asynchronous motors the magnetic flux in the rotor must be mapped in an electronic model of the motor. This requires the input of the physical parameters of the rating plate on the motor.

In vector operation, the variable frequency drives can only control one motor at the output end. A parallel operation of several motors is not possible here. The exact calculation of the phase voltages at the variable frequency drives's output, however, improves the motor's operational behavior. The motor also heats up less in the lower speed range. The field-oriented vector control results in a significant improvement in the drive dynamics as well as optimizing performance; it also increases the range of possible applications.

The main applications of sensorless vector control are:

- Material machining and processing equipment,
- Condensors (compressor),
- Heavy starting duty (extruder, agitators, mixer),
- Lifting mechanisms and lifting gear (vertical movement, crane, lift).

Vector feedback control (closed loop)

With the vector feedback control, the output current of the variable frequency drives serves as the controlled variable. This makes it possible to perfectly adjust the three-phase motor in line with the corresponding torque boost. The motor speed can be controlled in connection with an rpm sensor (tachometer, pulse generator).

Safe Torque Off (STO)

The STO function is a safety function of the variable frequency drives, in which the power supply to the motor is interrupted immediately. This function is realized via a hardware circuit.

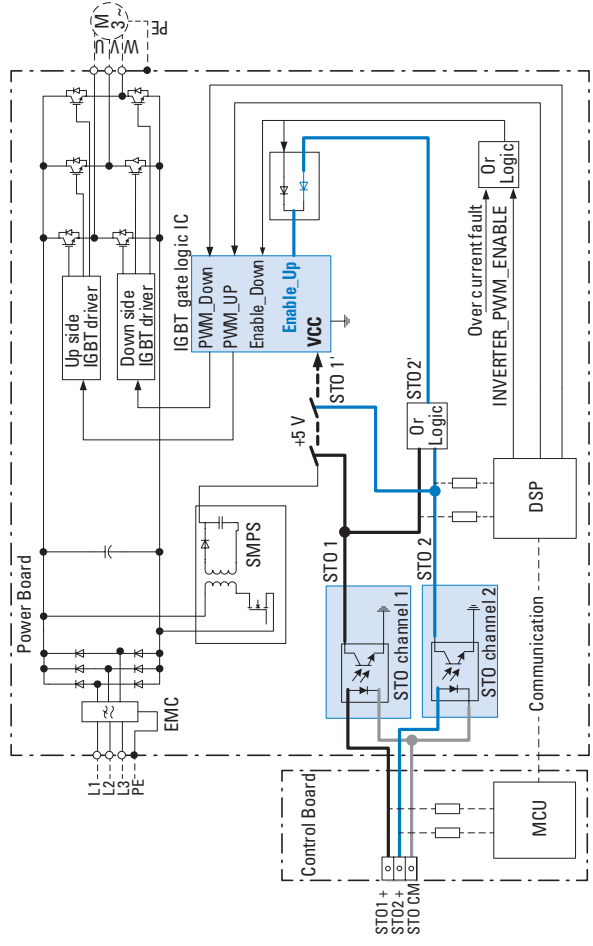
The enable and the control voltage input of the IGBT control are deactivated.

The response time until the motor voltage is switched-off is ≦ 1 ms.

The switch-off should be consistent within 200 ms via both STO inputs, otherwise an STO fault will be generated.

The STO function can be used wherever a drive comes to a standstill in a sufficiently short time due to the load torque or friction or where the unguided coasting of the drive, the so-called “coasting down”, has no safety relevance (STOP category 0).

The STO safety function does not correspond to the “Safe off” safety function of IEC 60204-1:2016 because it does not provide galvanic isolation. This means that the motor terminals can still have dangerous voltage in the STO state.


Two-channel STO in the DM1 variable frequency drives
Power Board
Control Board
EMC
SMPS
IGBT gate logic IC
Up side IGBT driver
Down side IGBT driver
PWM_Down
PWM_UP
Enable_Down
Enable_Up
VCC
+5 V
STO 1'
STO 2'
Or Logic
Over current fault
INVERTER_PWM_ENABLE
Or Logic
DSP
MCU
STO 1
STO 2
STO channel 1
STO channel 2
Communication
L1
L2
L3
PE
STO1+
STO2+
STO CM
U
V
W
M
3
PE
Note: STO channel 1 is marked in black. STO channel 2 is marked in blue.

Safe Stop 1 (SS1)

The SS1 function is a safe stop of the motor. It can be used where a drive needs to be shut down in a monitored manner via a braking ramp. When the function is initiated, the drive initially shuts down in a controlled manner. The STO function is then activated, e. g. by a safety relay, either after a delay time or after the drive has come to a standstill (STOP category 1).

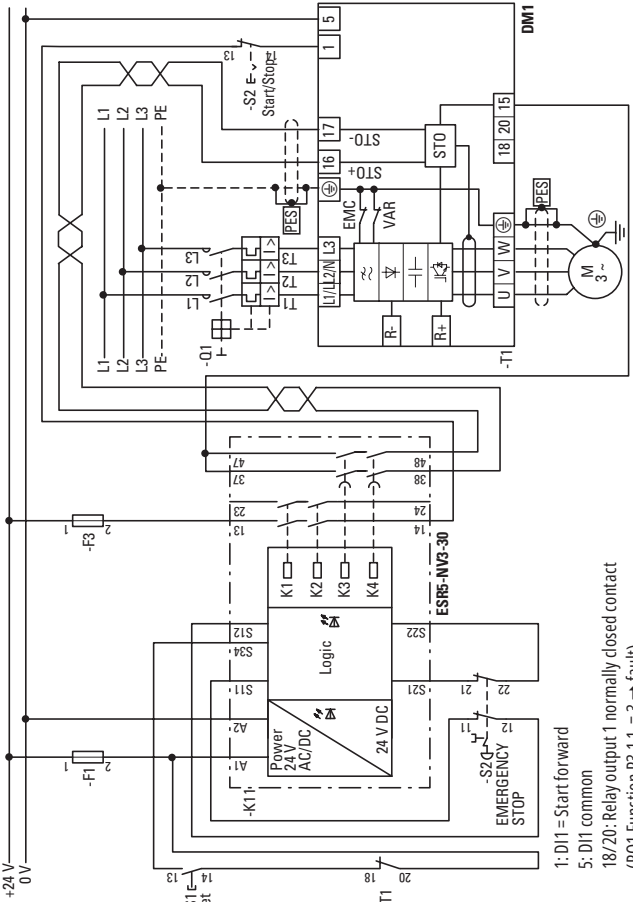
The following example shows an SS1-t function. Here, the STO is executed after a parameterized time, which should take into account the worst case scenario for a machine standstill. This function is classified as purely functional and not safety-related, as the machine standstill is not monitored.

The function should therefore only be used if a machine movement is clearly visible to the operator.

Electronic motor starter and variable frequency drives

Variable frequency drives basic information

Two-channel emergency stop via STO on DM1 with safety relay ESR5



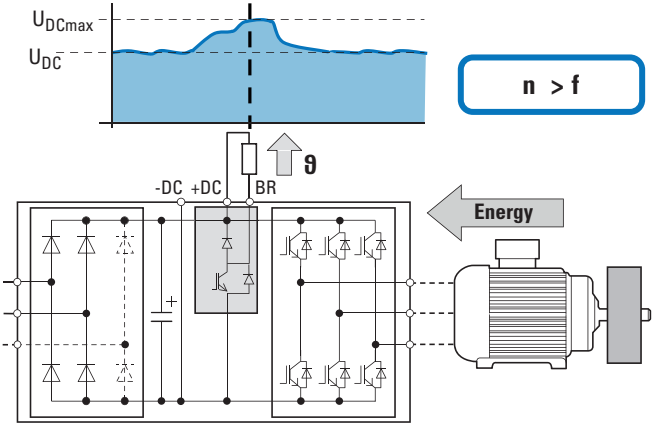
5

Braking resistors

A braking resistor is a high-load resistor through which the motor's regenerative energy, which is generated, for example, by a braking process, can be converted into heat.

This energy initially flows into the DC link of the variable frequency drives and causes that the voltage level increases.

The variable frequency drives then chops the DC link voltage via a brake IGBT from a defined switch-on limit to the resistor.



When selecting and designing, the following must be taken into account:

- The variable frequency drives must have a brake chopper connection.
- The resistance value "R" must be within the minimum and maximum resistance values from the manual or technical data sheet of the variable frequency drives.
- The load cycle and the braking performance should be known or determined.

Example of determining a braking resistor

The voltage threshold in the DC link for switching on the brake choppers for the Eaton PowerXL variable frequency drives are 780 V DC. For a 400 V device with 7.5 KW nominal power R_{min} for the braking resistor is specified as 40 Ω.

The maximum braking power is therefore

$$P = \frac{U^2}{R} = \frac{780\,V^2}{40\,\Omega} = 15210\,W$$

The deceleration time in the frequency converter is set to 5 seconds, which results in a braking energy of

$$\triangle E = P \times t = 15210\,W \times 5\,s = 76050\,WS$$

The braking cycle can be assumed to be ≦ 120 s. If the maximum value of 120 s is used, the braking resistor has a power of

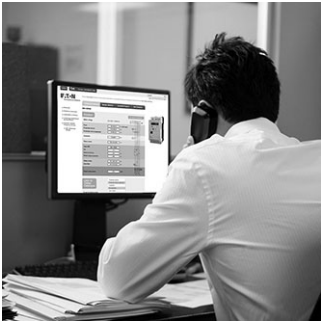
$$P_{br} = \frac{\triangle E}{t} = \frac{76050\,W}{120\,s} = 633.75\,W$$

The next larger resistor with 42 Ω and 720 W continuous braking power is therefore selected.

If a braking resistor with 50 Ω is selected, the above formula results in a power for the braking resistor of 507 W, so the resistor with 50 Ω and 600 W continuous braking power can also be selected

Selection aid for PowerXL variable frequency drives

Simple planning and project engineering



More efficient planning is achieved with the help of the electronic selection aid. This enables a quick selection of the drive required for the respective application as well as the corresponding switching and protective devices, chokes and filters. Everything with the corresponding article numbers.

Eaton.com/config/powerxl

Electronic motor starter and variable frequency drives

Measures to improve network quality

EMC compliance in PDS

The electrical components of a system (machine) are subject to reciprocal interference. Each device not only exerts interference on other devices but is also adversely affected by it. This occurs as a result of galvanic, capacitive and/or inductive coupling or through electromagnetic radiation. The border between line-conducted interference and radiated interference is around 30 MHz. Above 30 MHz the lines and cables act like antennas and radiate the electromagnetic waves.

The electromagnetic compatibility (EMC) for variable speed drives is implemented in accordance with product standard IEC/EN 61800-3.

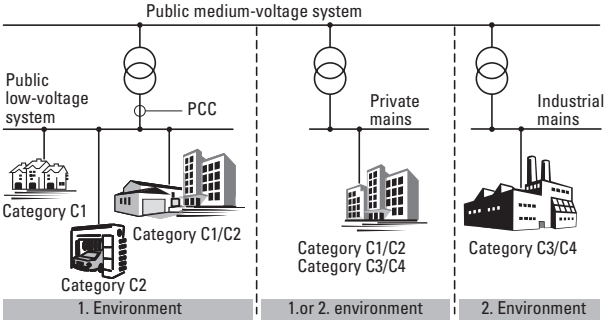
This covers the entire drive system (PDS = Power Drives System) from the mains end supply to the motor, including all components and cables. This type of drive system can also consist of several individual drives.

The generic standards of the individual components in a PDS compliant with IEC/EN 61800-3 do not apply. These component manufacturers, however, must offer solutions that ensure standards-compliant use.

In Europe, maintaining the EMC Directive is mandatory.

A declaration of conformity (CE) refers always to a "typical" power drives system (PDS). The responsibility to comply with the legally stipulated limit values and thus the provision of electromagnetic compatibility is ultimately the responsibility of the end user or system operator.

Measures must be taken to remove or minimize emission in the associated environment. It must also be ensured that the immunity of the devices or systems is increased.



EMC environment and categories

PDS categories

Drive systems (PDS) are divided into the following four categories.

PDS category C1

- PDS for use in the first environment
- Rated operating voltage < 1000 V

PDS category C2

- PDS for use in the first environment
- Rated operating voltage < 1000 V
- Not connected via plug-in devices
- No plug or movable equipment
- Connection and commissioning must be carried out by persons with suitable technical knowledge
- Hazard warning required ("This product may cause malfunctions in a domestic environment; in this case additional measures may be necessary.")

PDS category C3

- PDS for use in the second environment
- Not intended for use in the first environment
- Rated operating voltage < 1000 V
- Hazard warning required ("This PDS is not intended for connection to the public utility grid. Connection to these networks may cause electromagnetic interference.")

PDS category C4

- PDS for use in the second environment which fulfills at least one of the following criteria:
- Rated operating voltage > 1000 V
- Rated operational current > 400 A
- Connection to IT networks
- The required dynamic properties are not achieved due to EMC filter measures.
- EMC plan required

PDS environment

The environment refers to the installation location of the drive system.

First environment

Residential buildings or locations where the drive system is connected directly to the public low-voltage grid without an intermediate transformer.

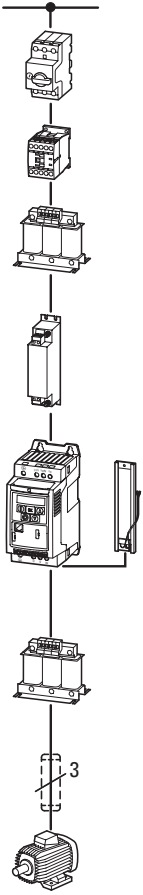
Second environment

Locations outside the residential area that are supplied from the medium-voltage grid via their own transformers.

Electronic motor starter and variable frequency drives

Measures to improve network quality

PDS components



Fuses (circuit-breakers) allow the protection of lines and electrical apparatus. For the protection of persons, AC/DC-sensitive residual current devices (RCD type B for three-phase variable frequency drives and type F for single-phase variable frequency drives) are required in addition.

Contactors are used for the on/off switching of the mains voltage.

Mains chokes suppress any current harmonics and peaks and limit the inrush current.

Passive harmonic filters reduce the current harmonics (THDi) to comply with standardized limiting values. This protects the connected grid from grid perturbations and increases the interference immunity of the facility.

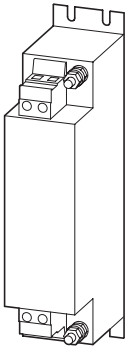
EMC filters are mains side filters that reduce the power-related interference between the mains and the variable frequency drive. They ensure that the limit values specified in the applicable product standards are observed.

Variable frequency drives enable the infinitely variable speed control of three-phase motors. To do this, the variable frequency drive converts the voltage of the supplying AC grid with constant voltage and constant frequency into a new AC voltage with variable amplitude and variable frequency.
A **braking resistor** converts the variable frequency drives's regenerative braking energy into heat. The variable frequency drives must be equipped with a brake chopper, which connects the braking resistor parallel to the internal DC link.

Motor chokes compensate for the capacitive recharging currents in long motor cables, thus reducing the current ripple and current change noise in the motor. They attenuate the retroaction on parallel connection of several motors. (All-pole) **Sine filter** smoothen the output voltage sinusoidally. They reduce motor noise through du/dt reduction, and thereby increase the motor insulation's lifespan. Reduce the leakage currents to allow better motor performance at improved EMC values.

Shielded motor cables attenuate emitted and conducted high-frequency emissions within the limit values specified in the applicable product standard (EMC).

EMC filter



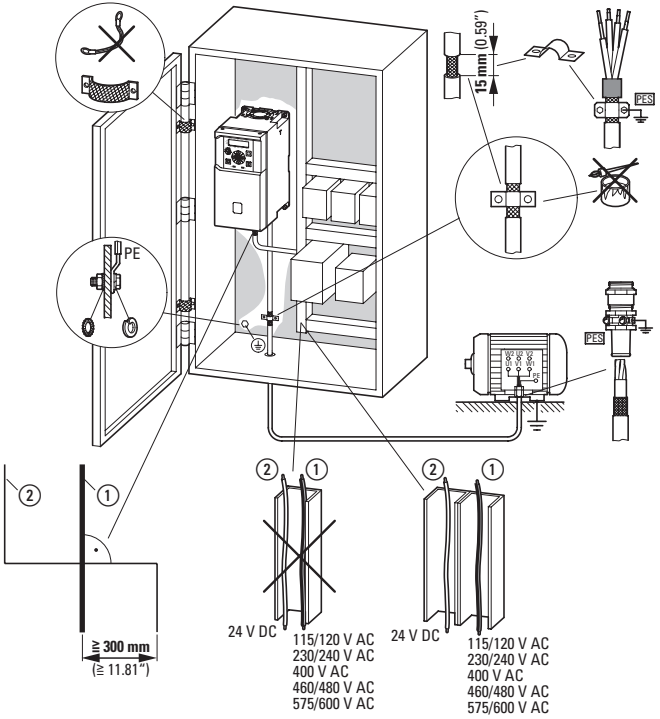
EMC filters are filters on the mains side that reduce power-related interference. Many variable frequency drives have internal EMC filters. These are designed to suit a wide range of applications. The maximum length of the motor cable that can be realized with the internal filter while complying with the standard depends on the EMC category or place of use. If a longer cable length is required, an external EMC filter must be connected between the mains and the variable frequency drive, and the internal filter must be disabled to prevent the filters from influencing each other.

EMC filters usually dissipate the interference currents to earth via capacitors, thereby generating leakage currents. Please note that the leakage current (touch current) must not exceed 3.5 mA AC or 10 mA DC (IEC/EN 61800-5-1 and IEC/EN 62477-1) for a plugged connection (earthed plug) to supply a frequency inverter. In this context, a plug connector for industrial applications in accordance with IEC 60309 (CE connector) counts as a fixed connection. If the leakage current is too high, it can be reduced with special low leakage current filters (DX-EMC...-L) of 6 - 8 mA or extra low leakage current filters (DX-EMC...SL) of < 0.4 mA.

Electronic motor starter and variable frequency drives

Measures to improve network quality

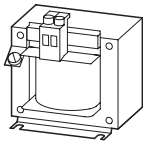
EMC-compliant mounting and connection



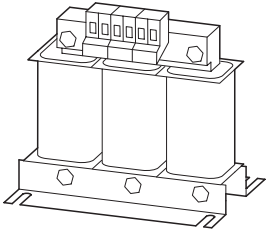
① Mains and motor cables
② Control circuits

Electronic motor starter and variable frequency drives

Measures to improve network quality



Single-phase chokes



Three-phase chokes

Mains chokes

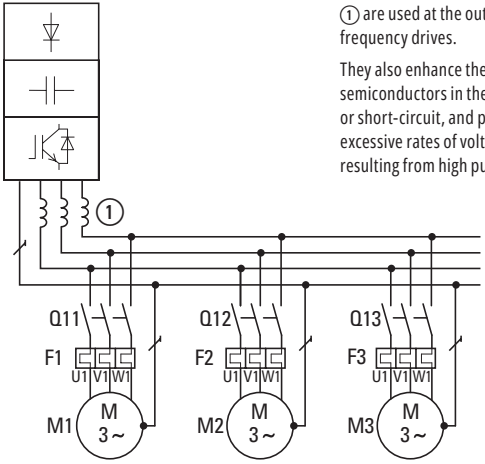
Fitted on the variable frequency drives's input side, chokes reduce the current-dependent mains feedback and improve the power factor. This reduces the current harmonics and improves the mains quality. The use of mains chokes is especially recommended when several variable frequency drives are connected to a single mains supply point and when other electronic devices are also connected on the network.

A reduction of the mains current interference is also achieved by installing DC chokes in the variable frequency drives's DC link. This eliminates the need for mains chokes.

Motor chokes

With long motor cables or the parallel connection of several motors, motor chokes ① are used at the output of the variable frequency drives.

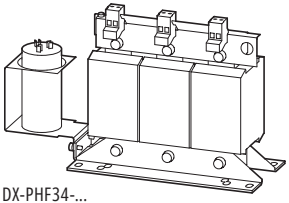
They also enhance the protection of the power semiconductors in the event of an earth fault or short-circuit, and protect the motors from excessive rates of voltage rise (> 500 V/µs) resulting from high pulse frequencies.



Electronic motor starter and variable frequency drives

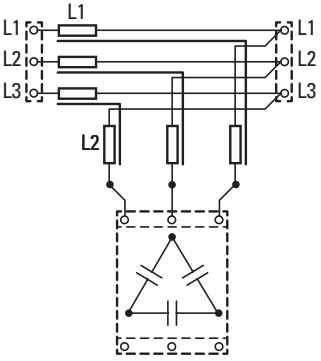
Measures to improve network quality

Passive Harmonic Filter



DX-PHF34-...

Like a sine filter, a passive harmonic filter is a combination of a choke and capacitor. They ensure sinusoidal current consumption from the mains, thus reducing the Total Harmonic Distortion current (THDi) to less than 8 % over the typical operating range. Above a speed of 50 %, the value drops to 5 %.



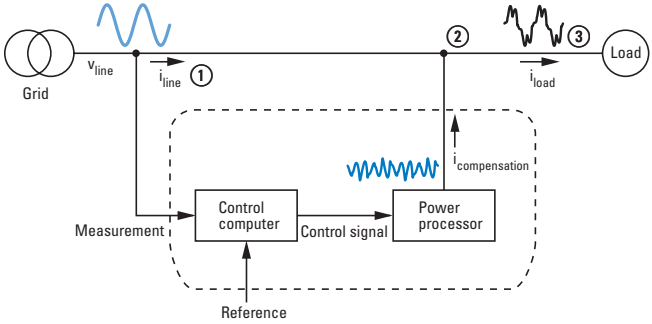
Advantages

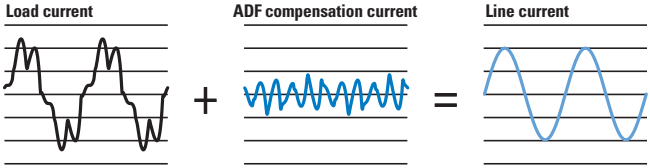
- Compliance with EN 61000-3-2, EN 61000-3-12
- Cos(phi) > 0.95 at nominal current
- Almost no DC link voltage drop compared with a 4 % uK mains choke
- Harmonic filter with minimum capacitive idle power
- Excellent corrosion protection and low noise levels due to vacuum impregnation
- Operation at 50 - 60 Hz possible
- The PHF can be used as a central sum filter for several inverters

Electronic motor starter and variable frequency drives

Measures to improve network quality

Active Harmonic Filter





The Active Harmonic Filter is a computer-controlled current generator that can generate any form of current with little to no delay time. The AHF is connected in parallel with the original load.

This measures the electrical currents between the load in a system and the mains and analyzes them for harmonics ① to determine whether interference currents such as displacement reactive power and/or harmonics are present.

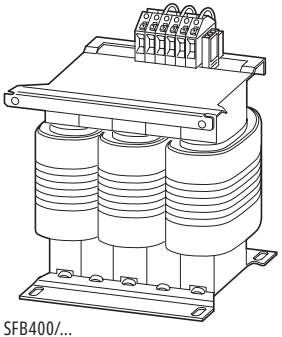
If there are interference currents, the ADF feeds in compensation currents ② that are precisely the opposite of the harmonics and/or the reactive power. This takes place to balance the load behavior ③.

The result is an ideal load with a minimum of power loss and interference. The energy profile then appears ideal to the transformer.

Electronic motor starter and variable frequency drives

Measures to improve network quality

Sine filters



SFB400/...

Sine filters are a combination of choke and capacitor (low pass filter). The differential mode interference (phase against phase) is then filtered by the sine filter. They improve the sinusoidal shape of the variable frequency drives output voltage, thus reducing the noise and the temperature rise of the motor.

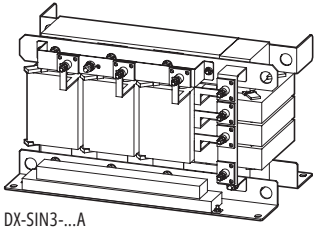
Advantages of sine filters

- Long shielded motor supply cables possible
  - max. 400 m on supply voltages up to 240 V +10 %
  - max. 200 m on supply voltages up to 480 V +10 %
- Extended lifespan – like that of a mains-operated motor
- Low noise generation of the motor
- Low motor temperature rise
- Reduced du/dt values (< 500 V/µs)

Disadvantages of a sine filters

- Up to 30 V voltage drop
- Operation only with fixed pulse frequency possible

All-pole sinus filters



DX-SIN3-...A

In addition to the normal sine filter, there is also the all-pole sine filter.

The all-pole sine filter filters not only the reverse current interference (phase to phase), but also the common-mode interference (phase to PE (N)). It can also be operated with unshielded motor cables.

Another advantage of the all-pole sine filter is less noise due to the du/dt reduction. It increases the durability of the motor insulation.

The filter is installed between the variable frequency drive and the motor and has a feedback to the DC link.

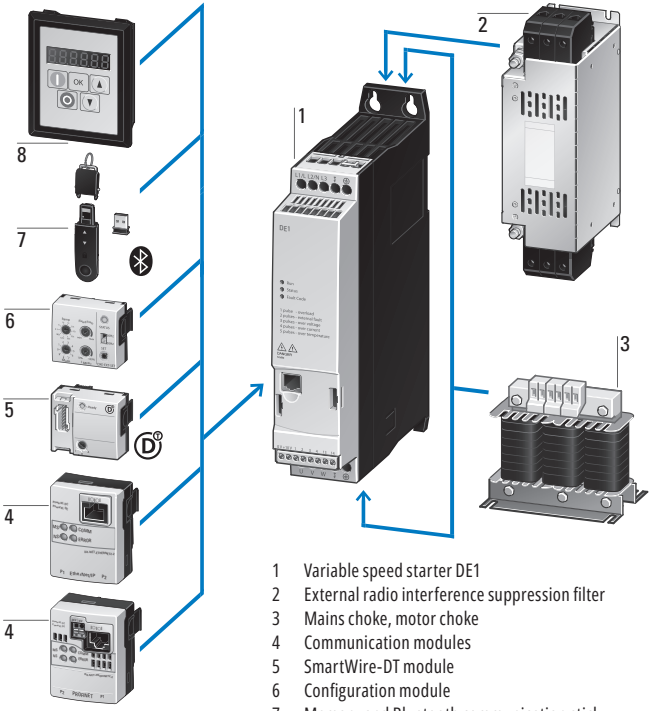
Electronic motor starter and variable frequency drives

Application of a variable speed starter (DE1)

System overview variable speed starter DE1

The PowerXL™ DE1... series variable speed starters close the gap between conventional DOL starters and variable frequency drives.

The DE1 variable speed starter combines the advantages of both device types in a single device by providing the ease of use of a DOL starter and the variable motor speed of a variable frequency drive.

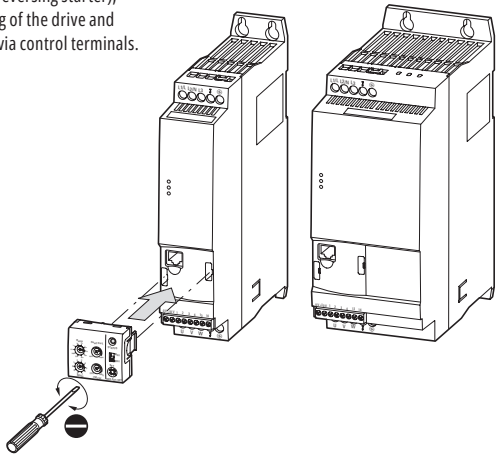


1 Variable speed starter DE1
2 External radio interference suppression filter
3 Mains choke, motor choke
4 Communication modules
5 SmartWire-DT module
6 Configuration module
7 Memory and Bluetooth communication stick
8 External keypad

Electronic motor starter and variable frequency drives
Application of a variable speed starter (DE1)

Product features DE1

The smooth and time-controlled motor starter at a preset speed with full torque without inrush current peaks enables the user to achieve the required energy efficiency (ErP directive) for the application. In addition to the variable speed setting (V/f control), other features of the DE1 variable speed starter include reversing duty (reversing starter), time-controlled stopping of the drive and simple function change via control terminals.



The basic functions, speed setpoint, acceleration and deceleration time as well as motor protection can be set with a screwdriver, as is usual with a conventional DOL starter.

Electronic motor starter and variable frequency drives
Application of a variable speed starter (DE1)

Functions

A comprehensive range of protection functions allow safe operation and the protection of variable frequency drives, motor and application. They offer protection against:

- Overcurrent, earth fault
- Overload (electronic motor protection)
- Overtemperature
- Overvoltage, undervoltage

Further functions

- Compact: 45 mm width
- Out-of-box commissioning without any configuration
- No special drive technology knowledge required
- Screwdriver parameterization with configuration module DXE-EXT-SET
- Trip-free design for maximum machine availability
- Suitable for ambient temperatures up to 60 °C
- DE11 with CANopen on-board, removable control terminal strip and programmable relay output
- Optionally expandable with plug-in Profinet or Ethernet/IP communication module
- International standards (CE, UKCA, UL, cUL, cTick, RoHS)

Application

The PowerXL variable speed starter allow the continuously variable speed control of three-phase asynchronous motors. They are especially suitable for applications where simple operation and profitability are important.

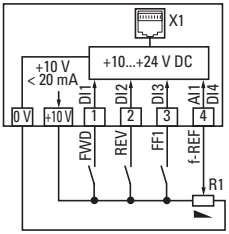
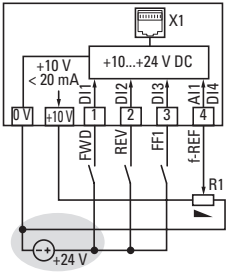
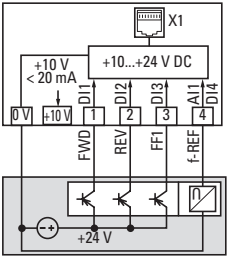
Rated operating currents from 1.3 to 16 A allow the operation of standard 4 pole asynchronous motors in an assigned performance range of:

- 0.25 up to 2.2 kW at 230 V (single-phase mains connection),
- 0.37 up to 7.5 kW at 400 V (three-phase mains connection).

Electronic motor starter and variable frequency drives

Application of a variable speed starter (DE1)

Connection examples for the digital inputs (mode 0)

Connection terminals	Description
	**Default settings** The digital inputs (DI1 - DI3) and the setpoint value (AI1) are driven with the internal +10 V control voltage through potentiometer R1 (0 - 10 V).
	**External control voltage 24 V** The digital inputs (DI1 - DI3) are driven with an external control voltage (+24 V). The setpoint value is set with the internal +10 V control voltage through potentiometer R1 (0 - 10 V).
	**External control voltage via PLC** The digital inputs (DI1 - DI3) are driven with an external control voltage (+24 V). The setpoint value is set with an external signal (0 - 10 V). **Note** The signal common for the PLC's analog and digital outputs is 0 V.

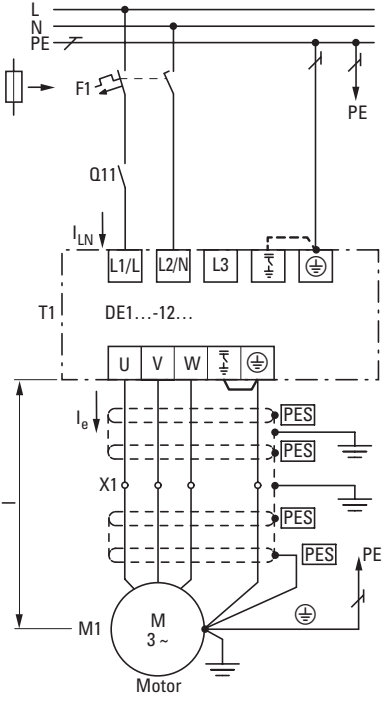
Electronic motor starter and variable frequency drives

Application of a variable speed starter (DE1)

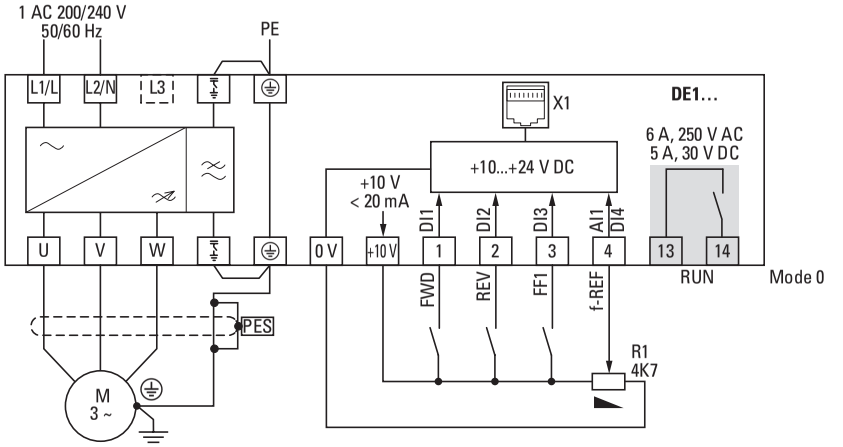
The following block diagrams show all of the DE1 variable speed starter's connection terminals and their functions when the device is used with its default settings.

Variable speed starter with single-phase mains supply voltage and internal radio interference suppression filter

Mains
1 ~ 200 V - 240 V ±10 %, 50/60 Hz (DE1…-12…)



Block diagram DE1-12...FN-...



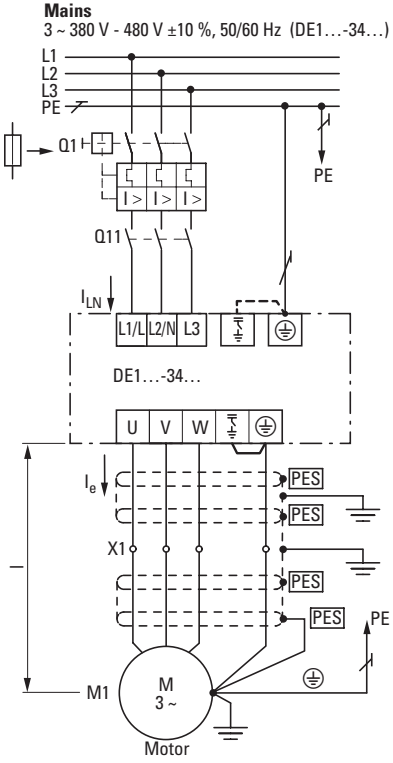
Variable speed starter with single-phase mains supply voltage and internal radio interference suppression filter

Electronic motor starter and variable frequency drives

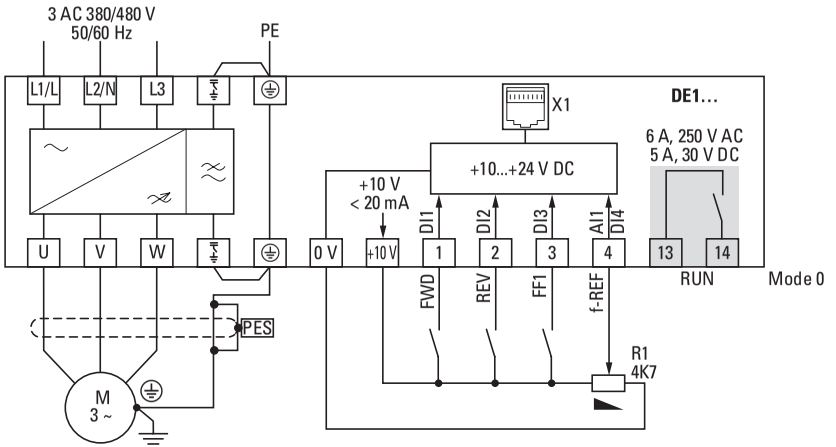
Application of a variable speed starter (DE1)

The following block diagrams show all of the DE1 variable speed starter's connection terminals and their functions when the device is used with its default settings.

Variable speed starter with three-phase mains supply voltage and internal radio interference suppression filter



Block diagram DE1-34...FN-...



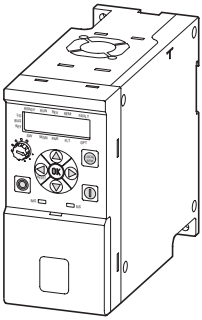
Variable speed starter with three-phase mains supply voltage and internal radio interference suppression filter

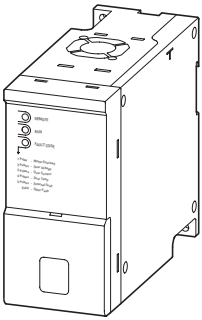
Electronic motor starter and variable frequency drives

Application of variable frequency drives IP20 (DM1/DG1)

DM1 and DM1 Pro – Compact universal

The PowerXL DM1 variable frequency drive combines maximum functionality with the smallest of footprints. It can be used wherever space is limited, but where the functionality of a standard multi-purpose drive is nevertheless required. These include pump functions, HVAC functions, and the control of standard motors such as asynchronous motors or PM motors.





Safe (DM1 Pro)

Thanks to the built-in two-channel STO (SIL2, PLd, Cat. 3), no external contactor is required to safely switch the drive torque-free. This is especially important for material handling applications.

Power range

- 0.25 - 1.5 kW (115 V)
- 0.55 - 15 kW (230 V)
- 0.75 - 22 kW (400 V)
- 5 - 25 HP (575 V)

Integrated web server (DM1 Pro)

The integrated web server makes it possible to configure and operate the device without the need to install any additional software.

Bluetooth integrated

The DM1 can also communicate with PowerXpert inControl via Bluetooth, without opening the control panel.

Multi-pump functions

For booster pumps in which several pumps run in a network, the DM1 offers all the basic functions for controlling the activation and deactivation or uniform control of all pumps.

Robust

- Degree of protection IP20, with optional Kit IP21/NEMA1
- Ambient temperature up to -30 °C with cold weather function, up to +50 °C (up to +60 °C with derating)

Measuring

- Energy metering and energy savings cost calculator on board

Short-circuit protection without any upstream devices

For short-circuit protection up to 100 kA, no additional upstream devices are required, such as a mains choke. The achievable short-circuit current depends only on the protective device used:

- FAZ up to 14 kA
- PKZ up to 65 kA
- Fuses up to 100 kA

Options

- Profibus connection
- CANopen connection
- IP21/NEMA1 Kit
- DG1-Remote keypad

Applications

- Multi-pump applications
- Booster pumps
- Sprinkler
- Inlet and exhaust fans
- Conveyors
- Compressors
- Roller and chain conveyors
- Screw conveyors
- Centrifuges
- Saws
- Drilling
- Water jet cutting

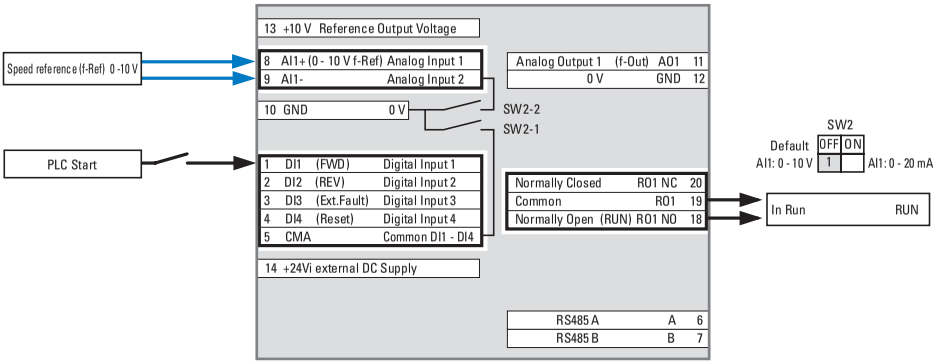
Further documents about DM1

For more information on the use of the DM1 Basic and DM1 Pro in various applications, visit Eaton.com/dm1.

Basic connection: controller section for V/f open loop

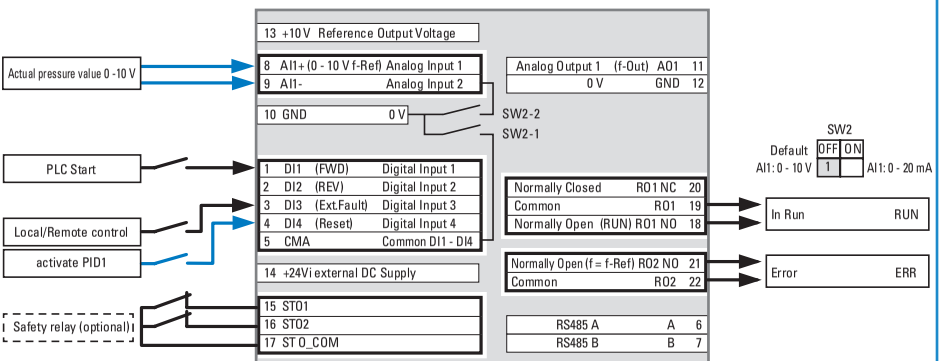
In open-loop operation, the DM1 is controlled with a setpoint and start/stop commands.

Example circuit diagram DM1 Basic



If there is a process feedback (speed or pressure), this can be connected to the DM1 via Modbus or, as a second option, the setpoint is specified via the internal potentiometer and the feedback is fed in via the analog input.
The PI controller can be used to optimize the control process in this case.

Example circuit diagram DM1 Pro



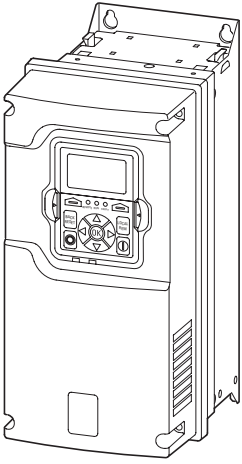
While the DM1 Basic has no STO input, this can be used on the DM1 Pro for a safe shutdown (SIL2, PLd, Cat.2).

Electronic motor starter and variable frequency drives

Application of variable frequency drives IP20 (DM1/DG1)

DG1 General purpose inverter

PowerXL DG1general purpose drives are inverters of the "Next generation" PowerXL series from Eaton. Designed especially for modern and sophisticated applications. With Energy saving algorithms and high short-circuit ratings in a robust design they offer increased efficiency, safety and reliability.



Safe and reliable

Functional safety with single channel STO (SIL1, PLc, Cat.1) saves external contactor. Important for the material handling segment.

Power range

- 0.75 - 90 kW (230 V)
- 0.75 - 132 kW (400 V)
- 1 - 250 HP (575 V)

Simple commissioning

- 19 parameters for all settings including language and time
- Plain-text menus and messages

Communication

- Best in class on-board: Modbus RTU, Modbus TCP, BACnet MSTP, Ethernet/IP
- Optional: Profibus, CANopen, DeviceNet, SmartWire-DT

Multi-pump functions

For booster pumps in which several pumps run in a network, the DG1 offers all the basic functions for controlling the activation and deactivation or uniform control of all pumps.

Robust and reliable

- Degree of protection:
  FS0: IP20, FS1-6: IP21, IP54, FS7-8: IP00
- Ambient temperature up to -30 °C with cold weather function, up to +50 °C (up to +60 °C with Derating)

Extensive onboarding communication and many I/Os. Small footprint with integrated DC link choke removes the need for a mains choke and switch cabinets.

Measuring

- Energy metering and energy savings cost calculator on board

Flexible

- Brake control, bypass, synchronization
- 2 PID: internal, external and cashable
- Programmable DI, DO, RO, AI, AO
- V/f, SLV, Torque, PM motor
- Real Time Clock and Timer
- 2 extension slots

Options

- Profibus connection
- CANopen connection
- Profinet connection
- IP21/NEMA1 Kit
- DG1-Remote keypad

Applications

- Multi-pump applications
- Booster pumps
- Sprinkler
- Inlet and exhaust fans
- Conveyors
- Compressors
- Roller and chain conveyors
- Screw conveyors
- Centrifuges
- Saws
- Drilling
- Water jet cutting

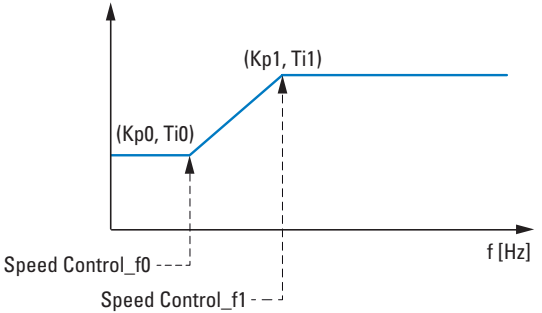
Further documents about DG1

More information on the use of the DG1 in various applications and the parameter settings required for the functions described are available for download from Eaton.com.

Enter the term "AP...EN" in the search and you will find the application notes for the use of the DG1.

Vector operation and PM motors

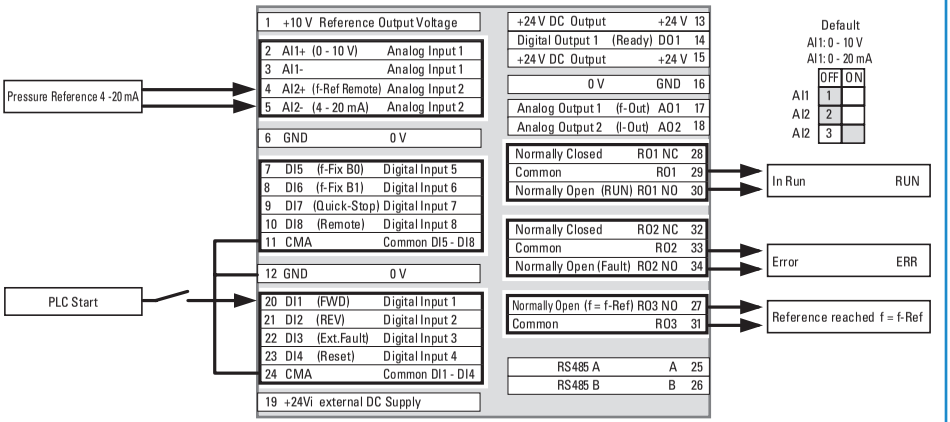
To guarantee optimum operation over a wide operation frequency and speed range, the DG1 has a motor current controller with an adaptive PI controller:



A pair of Kp and Ti can be specified for two different operation frequencies. Between the nodes, the values for Kp and Ti are interpolated depending on the speed; above and below these points, the corresponding pairs of entered values are used. This ensures an optimum response even at extremely low speeds.

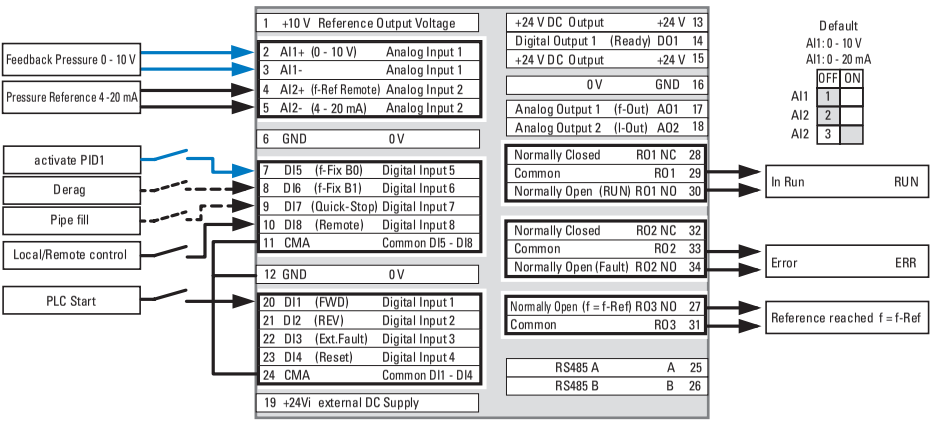
Basic connection: controller section for V/f open loop

The start command is displayed as “Level-Control”; if the command is there, it is interpreted as a start, without a signal it is stopped with a ramp. There are other variants for the start command (including three-wire connection with edge control).



Simple pressure control

The DG1 is capable of extensive pump functions. The image shows the optional “fill pipe” functions, which slowly fill a pipe system until the liquid to be pumped is present in all valves and only then starts the PID controller. The PID controller may overreact without this function, depending on the system. Another optional function is “pipe cleaning”. Using a special routine, soiling and deposits are loosened in the pipe system and then rinsed out. With the “Local/Remote” change-over switching shown, for example, the control system can be switched from a PLC to local on-site operation (e. g., during routine maintenance).

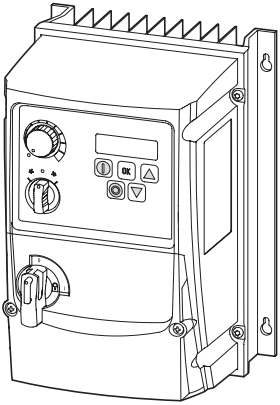


Electronic motor starter and variable frequency drives

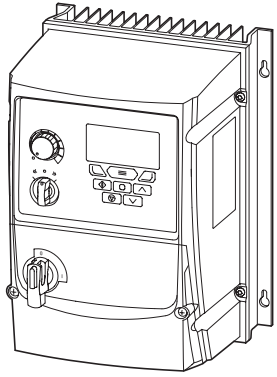
Application of variable frequency drives IP66 (DC1/DA1)

Product features

The PowerXL DC1 and DA1 frequency inverter series are also available with IP66/NEMA 4x degree of protection up to a motor output of 22 kW (400 V). This means that the drives can be used in areas with moisture, dust, or contaminants without hesitation. The water-tight ABS housing and corrosion-resistant heat sink also make it possible to clean the units with pressure washers, making them ideal for use in landscaping and agricultural applications, in the food industry, in concrete and cement equipment, and in drive-through and self-service car washes. Protected from environmental conditions, DC1 and DA1 devices (IP66/NEMA 4X) can be installed directly at the processing location. With an integrated setpoint potentiometer, selector switch, and main switch, these versions enable direct operation on site.



DC1 (IP66)

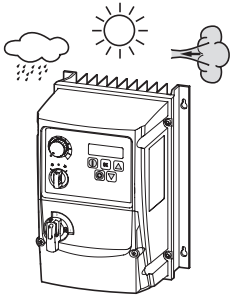


DA1 (IP66)

Electronic motor starter and variable frequency drives

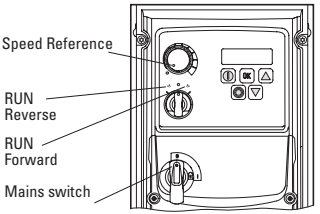
Application of variable frequency drives IP66 (DC1/DA1)

Application



Installation directly in the application

- Weatherproof and robust in IP66/NEMA 4X
- Outdoor rating (UV-resistant)
- Dust and splashproof
- Coated heat sink for facilities that require rinsing (food and beverage industry)



Operation of inverter on-board without wiring effort

- Local speed potentiometer for setting speed
- Local start/rotation direction selector switch
- Repair switch

Electronic motor starter and variable frequency drives
Application of variable frequency drives IP66 (DC1/DA1)

Functions

A comprehensive range of protection functions allow safe operation and the protection of variable frequency drives, motor and application. They offer protection against:

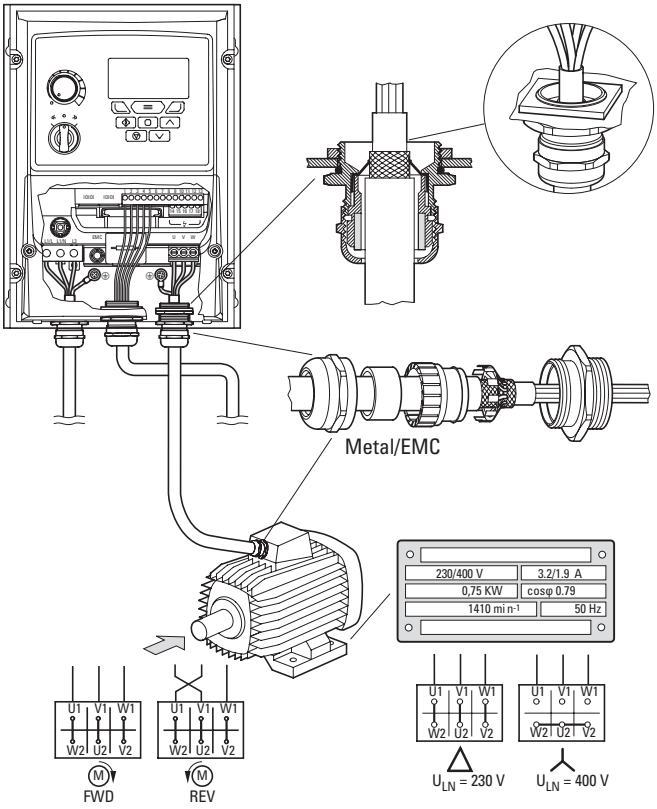
- Overcurrent, earth fault
- Overload (electronic motor protection)
- Overtemperature
- Overvoltage, undervoltage

Further functions

- High overload capacity: 150 % for 60 seconds, 200 % for 4 seconds.
- Modbus RTU and CANopen integrated
- Ambient temperature up to 50 °C without Derating
- Integrated EMC filter
- Integrated brake transistor
- V/f control, sensorless and closed-loop vector control, PM motors, BLDC motors, SynRel motors
- Optional fieldbus modules
- Integrated function block editor, optional (Profinet, Ethernet/IP, Profibus, EtherCAT, BACnet, Modbus TCP)
- Safe Torque Off (STO, SIL 2/PI d)
- High-resolution OLED display, optional
- International standards (CE, UKCA, UL, cUL, RCM, RoHS, EAC, UkrSEPRO

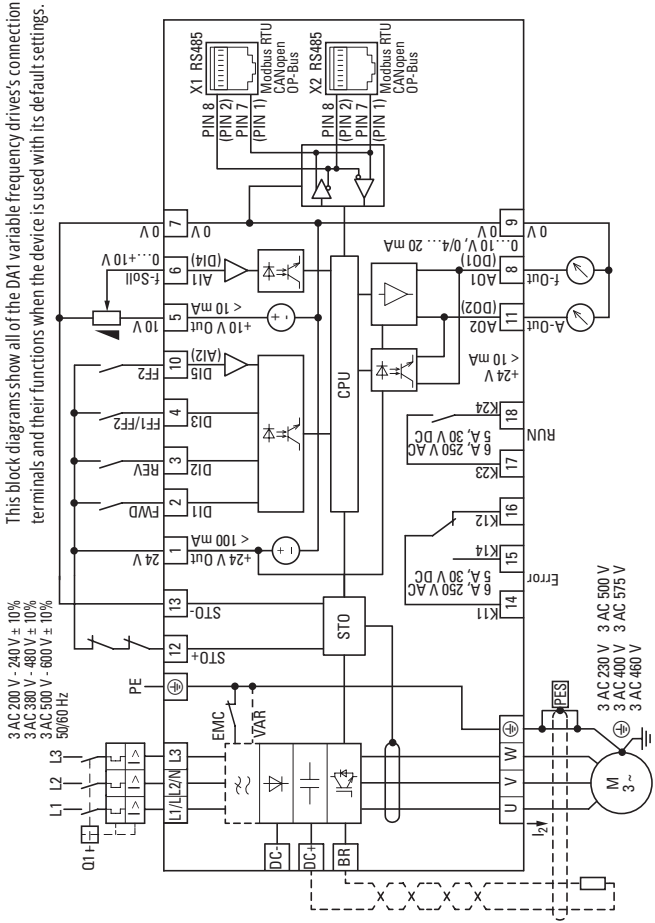
Electronic motor starter and variable frequency drives

Application of variable frequency drives IP66 (DC1/DA1)



Electronic motor starter and variable frequency drives

Application of variable frequency drives IP66 (DC1/DA1)



Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

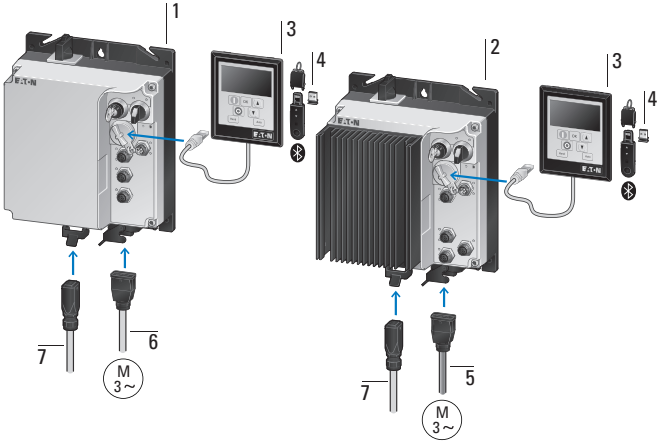
System overview Rapid Link 5

Rapid Link is a remote switching and installation for system material handling systems. Thanks to its compact design and its high degree of protection to IP65 these motor starters and variable frequency drives can be installed in the direct vicinity of the motor.

Pluggable connection cables with standard terminals reduce the wiring requirement and provide the preferred installation technology for conveying system.

Product features

Thanks to a power bus and a data bus that are plugged into every Rapid Link 5 module, the system is quick and easy to install. Customer-specific and sector-specific requirements for material handling systems are the main focus of the Rapid Link 5 system design.

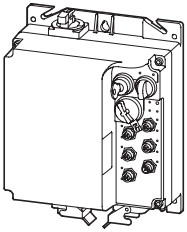


1 Motor starter RAMO5 three-phase, electronic DOL starter or reversing starter
2 Variable frequency drives RASP5 three-phase, frequency controlled motor starter
3 Operating unit for parameterization
4 Communication stick for parameterization
5 Energy connection cable for connection to a power bus
6 Unshielded motor cable
7 Shielded motor cable (EMC)

Electronic motor starter and variable frequency drives

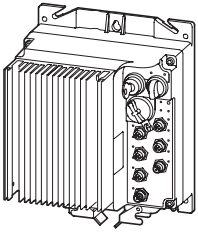
Application of a decentralised drive system (Rapid Link 5)

Rapid Link 5 has the following features



Motor starter RAMO5

- DOL starter and Reversing starter
- 90 W up to 3.0 kW (400 V) with one device
- 2/4 sensor inputs, 0/1/2 actuator outputs
- Programmable motor protection
- Electronic hybrid switch
- more than 10 million switching cycles



Variable frequency drives RAPS5

- Power range 0.75 kW up to 4 kW for one size
- 2/4 sensor inputs, 0/2 actuator outputs
- Control of IE2, IE3 and high-efficiency IE4 motors
- V/f, smart vector and sensorless vector control
- Integrated EMC filter up to 25 m motor cable length
- Optional with integrated brake resistor
- Integrated safety function
- "Safe Torque Off" (SIL3, PLe)

System features RAMO5 and RASP5

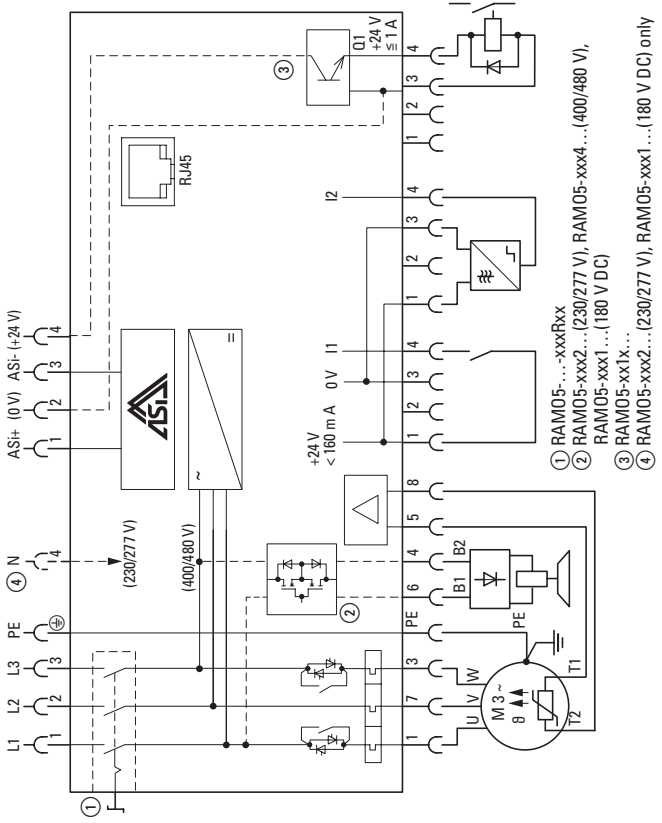
- AS-Interface, Profinet, Ethernet/IP
- Manual/automatic operation on-board
- Integrated functions for material handling systems
- One drilling template for all types and outputs
- Plug-in connections
- Parameterization with OLED operating units, drivesConnect or drivesConnect as a mobile App
- Integrated thermistor monitoring
- Control for electromechanical motor brakes (180 V DC, 230 V AC, 400 V AC)
- Optional repair switch
- Protection class: IP65/NEMA 12
- Approvals: CE, cUL, CCC (RAMO5)

Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

Block diagram RAMO5-D...

Electronic DOL starter with AS-Interface®

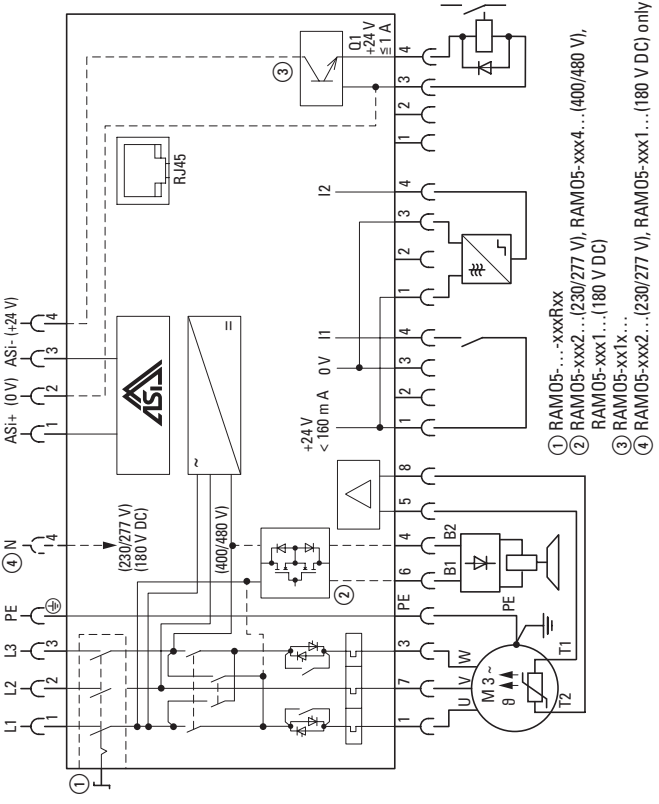


Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

Block diagram RAMO5-W...

Electronic reversing starter with AS-Interface®

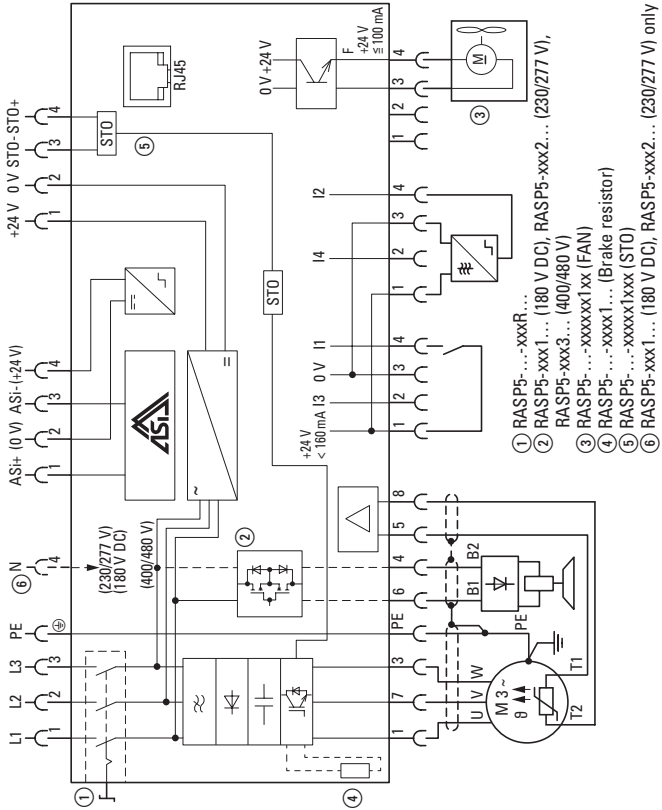


Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

Block diagram RASP5-...

Variable frequency drives with AS-Interface®

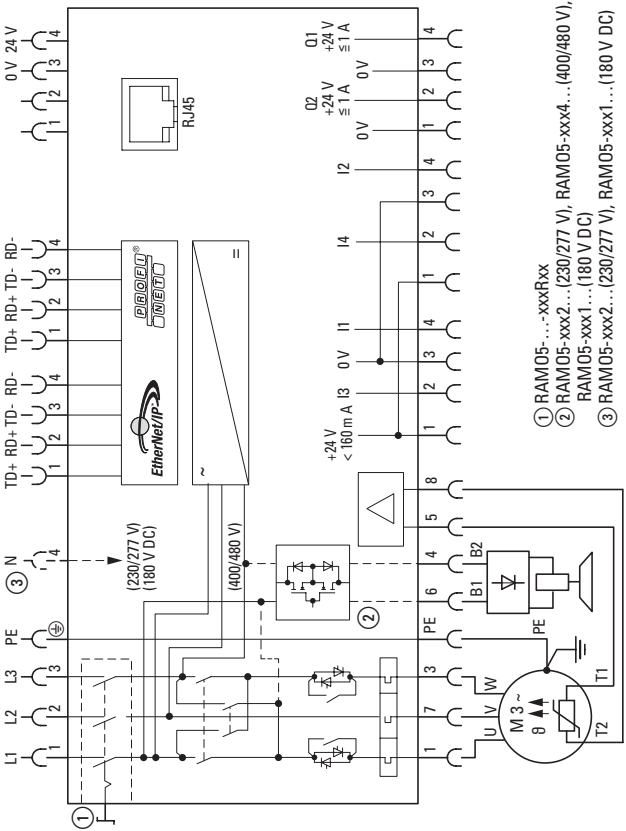


Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

Block diagram RAMO5-W...

Electronic reversing starter with Ethernet/IP or Profinet

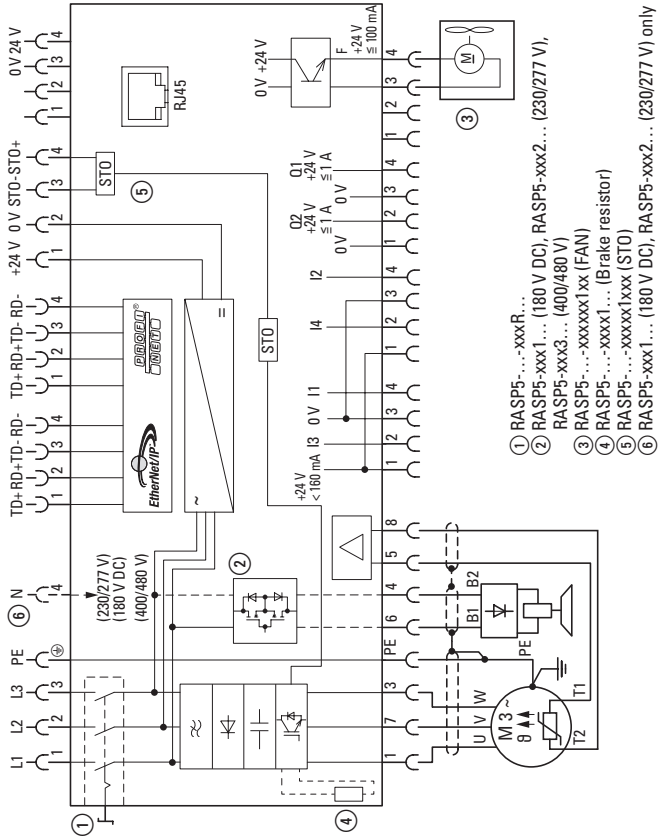


Electronic motor starter and variable frequency drives

Application of a decentralised drive system (Rapid Link 5)

Block diagram RASP5-...

Variable frequency drives with Ethernet/IP or Profinet



Cam switches

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On-Off switches, main switches, maintenance switches	6-3
Changeover switches, reversing switches	6-5
(Reversing) star-delta switches	6-6
Multi-speed switches	6-7
Interlock circuits	6-11
Single-phase approach circuits	6-12
Meter changeover switches	6-13
Heater switches	6-14
Step switches	6-15

Cam switches
Overview

Use and designs

Eaton cam switches and switch-disconnectors are used as:

① Main switches, main switches used as Emergency-stop devices,
② On-Off switches,
③ Safety switches,
④ Changeover switches,
⑤ Reversing switches, star-delta switches, multi-speed switches,
⑥ Step switches, control switches, coding switches, meter selector switches.

The following designs are available:

⑦ Flush mounting,
⑧ Centre mounting,
⑨ Surface mounting,
⑩ Service distribution board mounting,
⑪ Rear mounting.

Refer to the latest issue of our catalog "P Switch-disconnectors and T Rotary cam switches" CA042001EN for technical details and standards. In addition to the switches listed in this catalog, you will find an overview of all products relevant for machine builders in the catalog "Solutions for machinery and systems" CA08103003Z-EN.

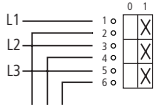
Basic part number	I_u	Use as						Design				
	[A]	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
TM	10	–	x	–	x	–	x	○	○	–	○	–
T0	20	x	x	–	x	x	x	+	○	○	○	+
T3	32	x	x	–	x	x	–	+	○	○	○	+
T5B	63	x	x	x	x	x	–	+	–	○	–	+
T5	100	x	–	x	x	–	–	+	–	○	–	+
T6	160	x	–	–	x	–	–	–	–	+	–	+
T8	315[1)]	x	–	–	x	–	–	–	–	+	–	+
P1-25	25	x	x	x	–	–	–	+	○	+	○	+
P1-32	32	x	x	x	–	–	–	+	○	+	○	+
P1-40	40	x	x	x	–	–	–	+	○	+	○	+
P3-63	63	x	x	x	–	–	–	+	–	+	○	+
P3-100	100	x	x	x	–	–	–	+	–	+	○	+
P5-125	125	x	x	–	–	–	–	+	–	–	–	+
P5-160	160	x	x	–	–	–	–	+	–	–	–	+
P5-250	250	x	x	–	–	–	–	+	–	–	–	+
P5-315	315	x	x	–	–	–	–	+	–	–	–	+

I_u = max. rated uninterrupted current
1) In enclosed version (surface mounting), max. 275 A.
○ Irrespective of the number of contact units, function and process.
+ Irrespective of the number of contact units, function and contact sequence.

Cam switches
On-Off switches, main switches, maintenance switches

On-Off switches, main switches

T0-2-1
P1-25
P1-32
P1-40
P3-63
P3-100
P5-125
P5-160
P5-250
P5-315



FS 908

These switches can also be used as switch-disconnectors for lighting, heating or combined loads.

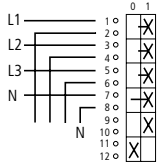
Main switches to IEC/EN 60204; for rear mounting switches with door interlock, padlocking feature, finger proof incoming terminals, N and PE terminal, red thumb-grip handle (black, if required), warning label.

If it is not clear which drive is associated with which main switch, an additional maintenance switch is required close to each drive.

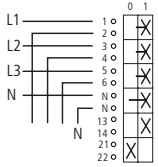
Maintenance switches (safety switches) with auxiliary contacts

T0-3-15680

FS 908



P1-25/.../
P1-32/.../
P1-40/.../
P3-63/.../
P3-100/.../
...N/NHI11



FS 908

Maintenance switches are fitted to electrical machines or installations to provide safe working conditions in accordance with the safety regulations.

By attaching a padlock to the SVB padlocking feature, the electrician can protect themselves against anyone switching on without authorization (→ Section "Circuit diagram example for maintenance switches with a load shedding contact and (or) switch position indicator", page 6-4).

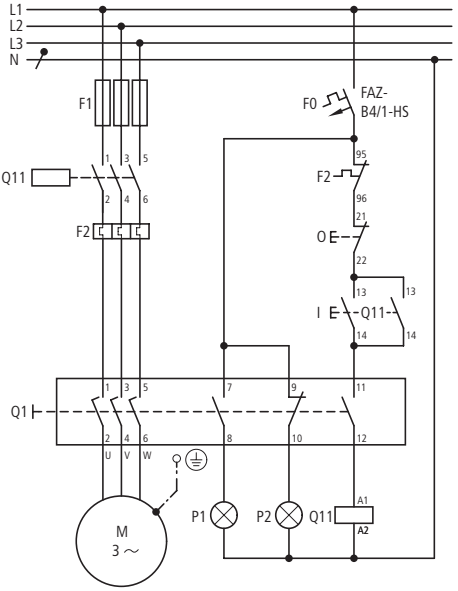
1) Load shedding contact

Cam switches

On-Off switches, main switches, maintenance switches

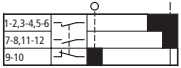
Circuit diagram example for maintenance switches with a load shedding contact and (or) switch position indicator

T0(3)-3-15683 maintenance switch



P1: On
P2: Off
Q11: Load shedding

T0(3)-3-15683 circuit symbol



Function

Load shedding: When switching on, the main current contacts close first, then the contactor is activated via the late-make N/O contact. When switching off, the contactor is first disconnected by opening the early-make contact, then the main contacts isolate the motor supply.

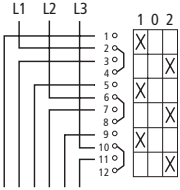
Switch position indication: The position of the switch can be signalled to the control panel or control room via additional NO and NC contacts.

Cam switches
Changeover switches, reversing switches

Changeover switch

T0-3-8212
T3-3-8212
T5B-3-8212
T5-3-8212
T6-3-8212
T8-3-8212

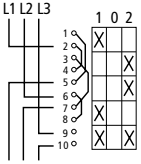
FS 684



Reversing switches

T0-3-8401
T3-3-8401
T5B-3-8401
T5-3-8401

FS 684



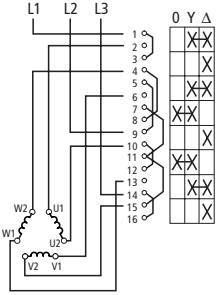
Cam switches
(Reversing) star-delta switches

Star-delta switches

T0-4-8410
T3-4-8410

T5B-4-8410
T5-4-8410

FS 635

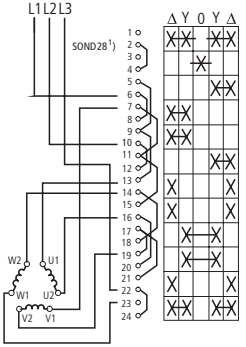


6

Reversing star-delta switches

T0-6-15877
T3-6-15877

FS 638



1) Standard contactor interlock
→Section "Interlock circuits", page 6-11

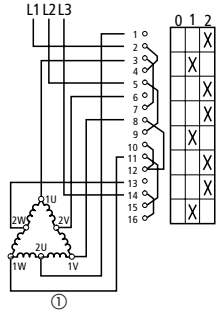
Cam switches
Multi-speed switches

2 speeds, 1 operating direction

Tapped winding

T0-4-8440
T3-4-8440
T5B-4-8440
T5-4-8440

FS 644

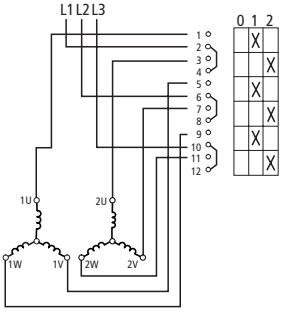


① without connections

2 separate windings

T0-3-8451
T3-3-8451
T5B-3-8451
T5-3-8451

FS 644



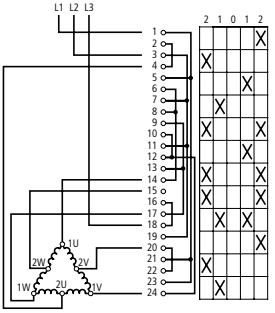
Cam switches
Multi-speed switches

2 speeds, 2 operating directions

Tapped winding

T0-6-15866
T3-6-15866

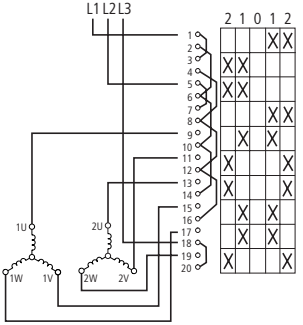
FS 629



2 separate windings, 2 operating directions

T0-5-8453
T3-5-8453

FS 629



6

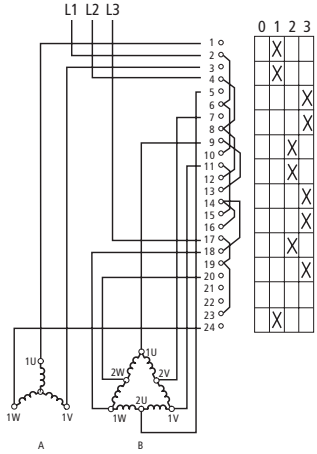
Cam switches
Multi-speed switches

3 speeds, 1 operating direction

Tapped winding arrangement, single winding for low speed

T0-6-8455
T3-6-8455
T5B-6-8455
T5-6-8455

FS 616



0-(A)Y- (B)△ = (B)YY

6

Cam switches
Multi-speed switches

3 speeds, 1 operating direction

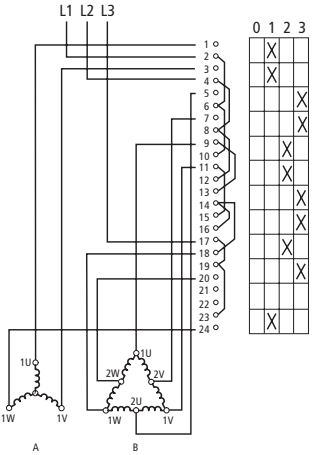
Tapped winding arrangement, single winding for high speed

T0-6-8459
T3-6-8459

FS 616

T5B-6-8459
T5-6-8459

FS 420



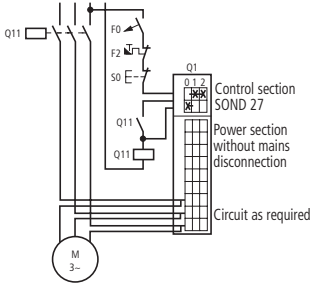
0-(B)△-(B)ᛉᛉ-(A)ᛉ

Cam switches
Interlock circuits

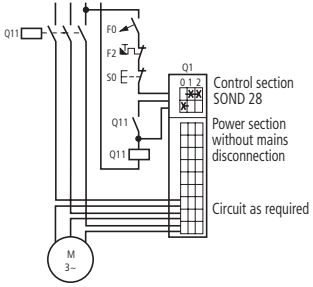
Interlock circuits between cam switches and contactors with overload relays provide neat and economical solutions for many switching drive tasks. The following points are common to all interlock circuits:

- Protection against automatic restarting after a motor overload or voltage failure
- The facility for remote disconnection (e.g. emergency-stop) can be provided by one or more Off pushbuttons.

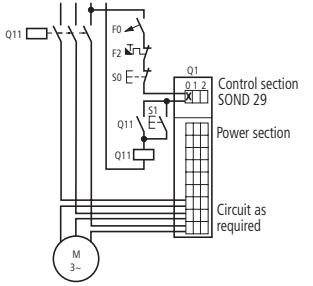
Without mains disconnection (SOND 27)
Mains disconnection only by contactor primarily for star-delta connection



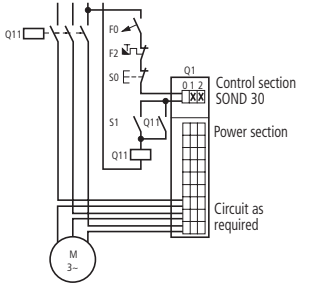
With mains disconnection (SOND 28)
Mains disconnection by contactor and switch



Interlock with contactor (SOND 29)
Contactor can be energized only when switch is in an operating position



Interlock with contactor (SOND 30)
Contactor can be energized only when switch is in an operating position



Cam switches
Single-phase approach circuits

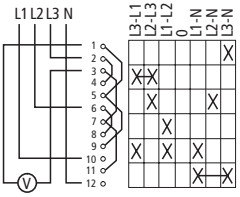
Meter changeover switches enable you to measure currents, voltages and power in three-phase systems with only one measuring device.

Numerous connections are possible for the different measurements. Some of the most common ones being shown below.

Voltmeter changeover switches

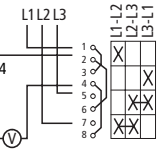
T0-3-8007
3 x phase to phase
3 x phase to neutral with off position

FS 1410759



T0-2-15922
3 x phase to neutral without off position

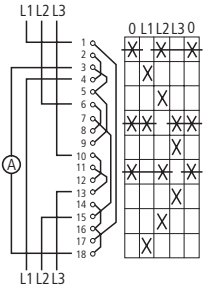
FS 164854



Ammeter changeover switches

T0-5-15925
T3-5-15925
For direct measurement

FS 9440

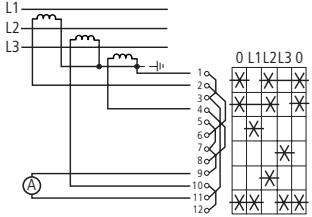


Cam switches
Meter changeover switches

Ammeter changeover switch

T0-3-8048
T3-3-8048
For measurement via transformers, complete rotation possible

FS 9440

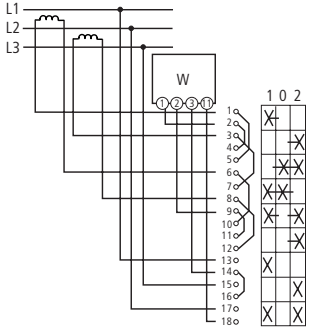


Power monitoring-changeover switches

T0-5-8043
T3-5-8043
Two-phase method (Aron circuit) for three-cable installations loaded as required. The total wattage is calculated by adding together the two wattages.

The Aron circuit will give a correct result for four-cable systems only when the sum of the currents equals zero, i.e. only when the four-cable system is balanced.

FS 953

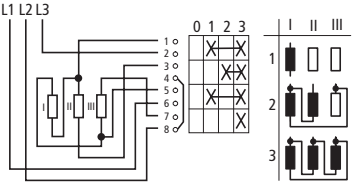


Cam switches
Heater switches

1-pole disconnection, 3 steps

T0-2-8316
T3-2-8316
T5B-2-8316

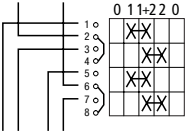
FS 420



6

T0-2-15114, complete rotation possible

FS 193840



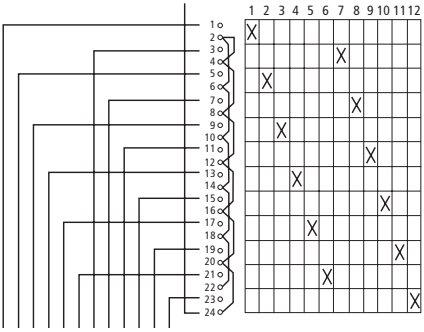
Further heater switches, 2-pole and 3-pole, with alternative circuitry, output stages, and number of steps are described in the catalog “P Switch-disconnectors and T Rotary cam switches” CA042001EN and in the special catalog “Solutions for machinery and systems” CA08103003Z-EN.

Cam switches
Step switches

One step closed in each position, complete rotation possible

T0-6-8239
T3-6-8239

FS 301



Cam switches
Step switches

Stay-put switches

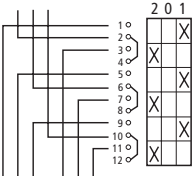
On-Off stay-put switch
1-pole: T0-1-15401
2-pole: T0-1-15402
3-pole: T0-2-15403

FS 415

Changeover switches

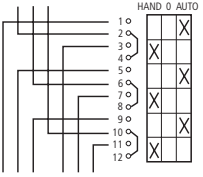
1-pole: T0-1-15421
2-pole: T0-2-15422
3-pole: T0-3-15423

FS 429



1-pole: T0-1-15431
2-pole: T0-2-15432
3-pole: T0-3-15433

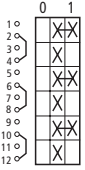
FS 1401



On-Off stay-put switches

1-pole: T0-1-15521
2-pole: T0-2-15522
3-pole: T0-3-15523
With pulsed contact in the intermediate position

FS 908



Circuit-breakers

	Page
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Undervoltage releases	7-5
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Internal circuit diagrams NZM	7-8
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Applications of the undervoltage release	7-11
Switch off of the undervoltage release	7-12
Indication of the contactor state	7-13
Short-time delayed circuit-breaker – internal circuit diagrams	7-14
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Circuit-breaker with residual current device	7-18
Terminal assignments of IZMX circuit-breakers	7-23

Circuit-breakers
Overview

NZM circuit-breakers

Circuit-breakers are mechanical switching devices that switch currents in the circuit on or off and control them under normal operating conditions. These circuit-breakers protect electrical equipment from thermal overloads and in the event of a short-circuit.

The NZM circuit-breakers cover the rated current range from 20 to 1600 A.

Depending on the version, they have additional protective functions such as residual current device, earth-fault protection or the capability for energy management by detecting load peaks, and selective load shedding.
NZM circuit-breakers stand on account of their compact shape and their current-limiting characteristics.

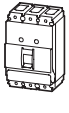
Switch-disconnectors without overload or tripping units are available in the same sizes as the circuit-breakers and can be fitted with additional shunt or undervoltage release to suit the versions concerned.

NZM circuit-breakers and switch-disconnectors are built and tested to the specifications in standard IEC/EN 60947.

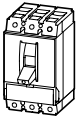
They feature isolating characteristics. In conjunction with a locking facility, they are suitable for use as main switches to IEC/EN 60204/VDE 0113, part 1.

The electronic release of frame sizes NZM2, NZM3 and NZM4 feature communication capabilities. The current status of the circuit-breakers on site can be forwarded to the control room or PLC via an internal Modbus RTU module or external communication modules.

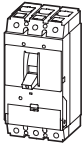
NZM1



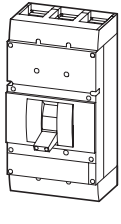
NZM2



NZM3



NZM4



Information on the above devices is provided in this chapter.

Circuit-breakers
Overview

IZMX circuit-breakers

The IZMX circuit-breakers are designed for use in the high rated current range from 630 A. IZMX circuit-breakers and INX switch-disconnectors provide the main switch isolation functions required by the IEC/EN 60204-1 standard as they are lockable in the OFF position. They can therefore be used as mains switches. IZM circuit-breakers are built and tested in accordance with IEC/EN 60947.

Depending on the type of equipment protected, the following main areas of application are possible with different settings to the release electronics:

- System protection,
- Motor protection,
- Transformer protection,
- Generator protection.

IZMX circuit-breakers with high-resolution dot matrix display offer different electronic units from simple system protection with overload and short-circuit release right through selective protection and the possibility to create time selective networks.

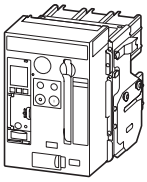
They can be adapted to a wide range of requirements with a comprehensive range of mounted accessories such as auxiliary contacts, trip-indicating auxiliary contacts, motor operators or voltage release, fixed-mounted or withdrawable units.

With their communication capability, the IZMX circuit-breakers open up new possibilities in power distribution. Important information can be passed on, collected and evaluated, also for preventative maintenance. For example, by enabling rapid intervention in processes, system downtimes can be reduced or even prevented.

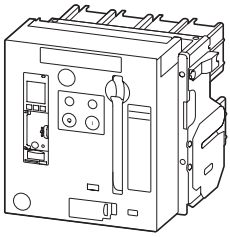
Selection criteria of an IZM circuit-breaker are:

- Rated operating current I_n,
- Ambient temperature,
- 3- or 4-pole design,
- Fixed mounting or withdrawable units,
- Protective function,
- Max. short-circuit current I_{kmax}.

IZMX16

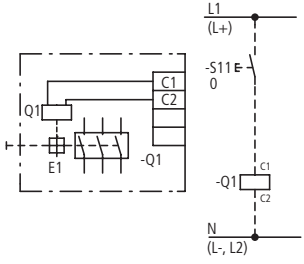


IZMX40



Circuit-breakers
Shunt release

Shunt release A



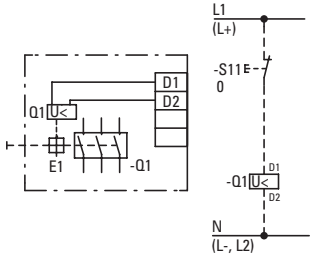
Module (Q1, solenoid) of a circuit-breaker or motor-protective circuit-breaker that actuates a release mechanism when voltage is applied. When de-energized, the system is in the rest position.

A normally open contact actuates the system. If the shunt release is rated for intermittent duty (overexcited shunt release with 5 % DF), the intermittent operation must be ensured by connecting an appropriate auxiliary contact of the circuit-breaker upstream. This measure is not required when using a shunt release with 100 % DF.

Shunt releases are used for remote tripping when an interruption in the voltage is not intended to lead to automatic disconnection. Tripping does not occur in the event of wire breakage, loose contacts or undervoltage.

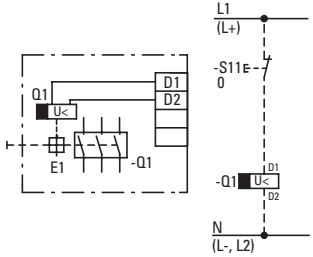
Circuit-breakers
Undervoltage releases

Undervoltage release U



A passive electromagnetic relay (Q1) which actuates a release mechanism when the supply voltage drops or is interrupted, in order, for example, to prevent the automatic restarting of motors. Undervoltage releases are also suitable for very reliable interlocking and remote off switching since disconnection always occurs in the event of a fault (e.g. wire breakage in the control circuit). The circuit-breakers cannot be reclosed when the undervoltage releases are de-energized.
The system is in the rest position when energized. Actuation is produced by a normally closed contact. Undervoltage releases are always designed for uninterrupted operation. These are the ideal tripping elements for totally reliable interlocking tasks (e.g. emergency offswitching).

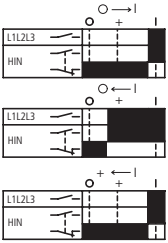
Off-delayed undervoltage release UV



The off-delayed undervoltage release (Q1) is a combination of a separate delay unit (UVU) and the respective release. This release is used to prevent brief interruptions in power leading to disconnection of the circuit-breaker. The delay time can be set between 0.06 and 16 s.

Circuit-breakers
Contact diagrams of the auxiliary contacts

Auxiliary contact – standard HIN

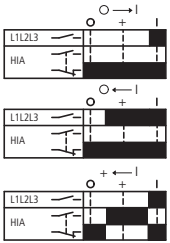


Auxiliary contacts are used to provide command or signal outputs from processes which are governed by the position of the contacts. They can be used for interlocking with other switches, and for the remote indication of the switching state. Auxiliary contacts have the following properties:

- Standard auxiliary contacts behave like main switch contacts
- Switch position indication
- Interlocking
- Disconnection of the shunt release

7

Auxiliary contact – trip-indicating HIA



Used to provide command and signal output relating to electrical tripping of the circuit-breaker (trip position +) as is required, for example, for mesh network circuit-breakers. No pulse is produced when the switch is opened or closed manually or by a motor operator.

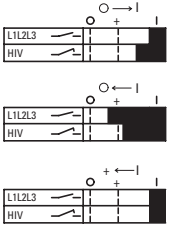
- Indication that the switch is in the tripped position
- Switch position indication only if tripping is caused by, for example, overcurrent, short-circuit, test or voltage release. No fleeting contact when switched on or off manually or switched off with the motor (exception: manual switch off with motor operator NZM2, NZM3, NZM4).

0 → I
Switch on
0 ← I
Switch off
+← I
Trip
■ Contact closed
□ Contact open

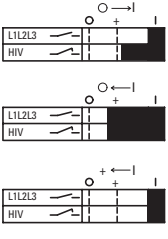
Circuit-breakers
Contact diagrams of the auxiliary contacts

Auxiliary contact – early make HIV

NZM1, NZM2, NZM3



NZM4



Early-make auxiliary contacts are used to provide command or signal outputs for processes which are initiated before the closure or opening of the main contact system. Because they close early, they can be used for interlocks with other switches. Furthermore, they allow a switch position indication.
With the circuit-breaker in the tripped position, the HIV is in the same position as it is at OFF.
Because of its early-make characteristics, it can be used to apply voltage to the undervoltage release.
→ Section "Undervoltage releases", page 7-5,
→ Section "Remote switch-off with voltage release", page 7-10,
→ Section "Applications of the undervoltage release", page 7-11.

0 → I
Switch on
0 ← I
Switch off
+← I
Trip
■ Contact closed
□ Contact open

Circuit-breakers
Internal circuit diagrams NZM

Maximum configuration

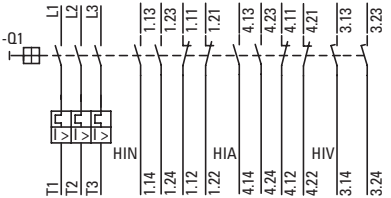
	NZM...			
	1	2	3	4
HIN: 1 NO, 1 NC, 2 NO, 2 NC or 1NO/1NC	1	2	3	3
HIA: 1 NO, 1 NC, 2 NO, 2 NC or 1NO/1NC	1	1	1	2
HIV: 2 S	1	1	1	1

If a motor operator is used at the same time, a configuration with 2 NO, 2 NC or 1NO/1NC (double auxiliary contact) is restricted on the NZM3 circuit-breaker.

For this observe the latest installation instructions.

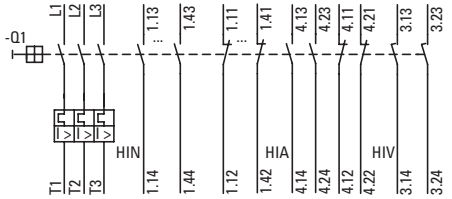
7

NZM1



Contact elements M22-K10 (K01, K20, K02, K11) from the RMQ-Titan range from Eaton are used for the auxiliary contacts. Two early-make auxiliary contacts (2 NO) are also available.

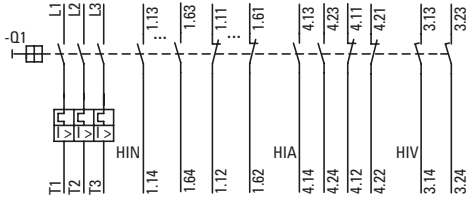
NZM2



Information on the auxiliary contacts
→ Section "Maximum configuration", page 7-8

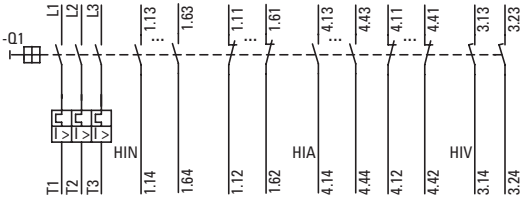
Circuit-breakers
Internal circuit diagrams NZM

NZM3



Details about the auxiliary contacts → Section "Maximum configuration", page 7-8

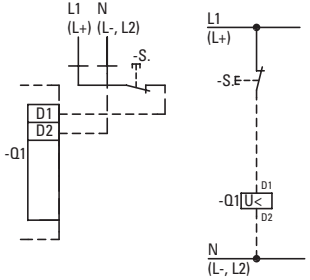
NZM4



Details about the auxiliary contacts → Section "Maximum configuration", page 7-8

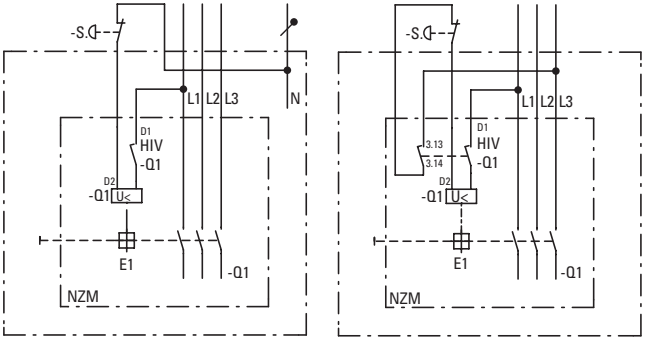
Circuit-breakers
Remote switch-off with voltage release

Remote switch-off with undervoltage releases



7

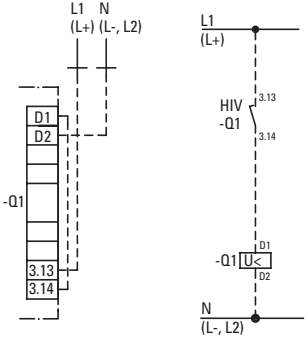
Main switch application in processing machines with emergency-stop function conform to the IEC/EN 60204-1, VDE 0113 part 1



In the OFF position of the main switch all control elements and control cables which exit the control panel are de-energized. The only live components are the control-voltage tap-offs with the control lines to the early-make auxiliary contacts.

Circuit-breakers
Applications of the undervoltage release

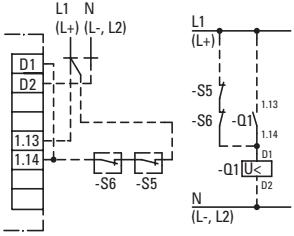
Switch off of the undervoltage release



The early-make auxiliary contact HIV (Q1) can – as shown above – disconnect the undervoltage release from the control voltage when the circuit-breaker is in the Off position. If the undervoltage release is to be disconnected in 2 poles, then a further normally open contact of Q1 must be connected between terminals D2 and N. The early-make auxiliary contact HIV (Q1) will always apply voltage to the undervoltage release in time to permit closure.

7

Starting interlock of the undervoltage release

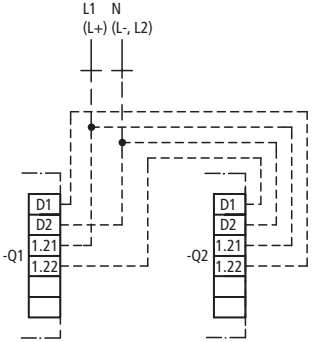


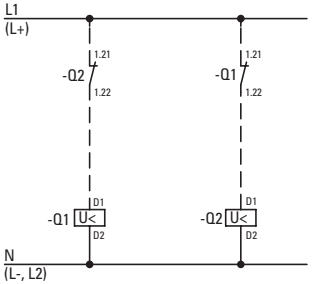
Circuit-breakers with an undervoltage release produce a positive Off position in conjunction with an interlocking auxiliary contact on the starter (S5), ancillary devices on the motor (e.g. brush lifting, S6) or on all switches in multi-motor drives.

The circuit-breaker can only be closed if the starter or switch is in the zero or OFF position.

Circuit-breakers
Switch off of the undervoltage release

Interlocking of several circuit-breakers using an undervoltage release

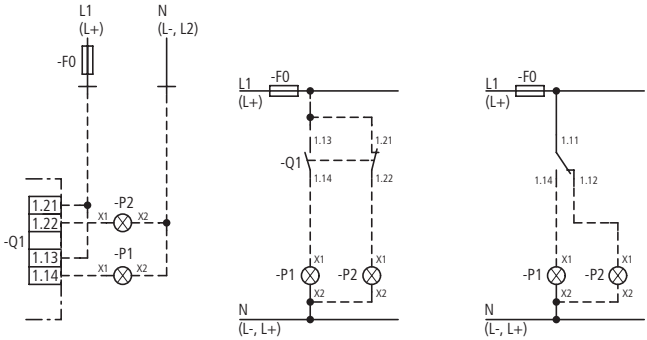




When interlocking 3 or more circuit-breakers, each circuit-breaker must be interlocked with the series-connected normally closed contacts of the auxiliary contacts on the other circuit-breakers using one contactor relay – for contact duplication – per auxiliary contact. If one of the circuit-breakers is closed, the others cannot be closed.

Circuit-breakers
Indication of the contactor state

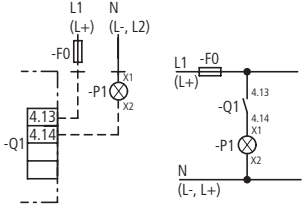
ON and OFF indication with auxiliary contact – standard HIN (Q1)



P1: On
P2: Off

Tripped indication using trip-indicating auxiliary contact HIA (Q1)

Trip-indicating auxiliary contacts for mesh network circuit-breaker



P1: Tripped

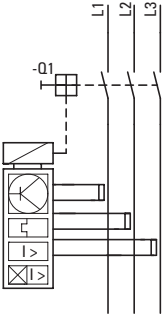
7

Circuit-breakers
Short-time delayed circuit-breaker – internal circuit diagrams

Time-discriminating network topology

Short-time delayed circuit-breakers NZM2(3)(4)/VX(VE) enable a time-discriminating network design with variable stagger times.

Where the prospective short-circuit currents are extremely high, additional installation protection is achieved by instantaneous releases, which respond without any delay.



NZM2(3)(4)...-VX(VE)...
Trip block VX(VE)

Adjustable short-time delay:

0, 20, 60, 100, 200, 300, 500, 750, 1000 ms

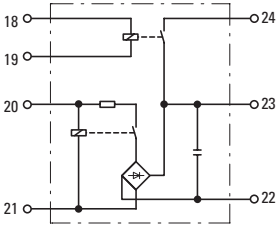
Circuit-breakers
Mesh network circuit-breakers

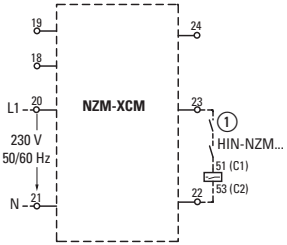
NZM1, NZM2, NZM3, NZM4

Circuit with capacitor unit and shunt release 230 V, 50 Hz.

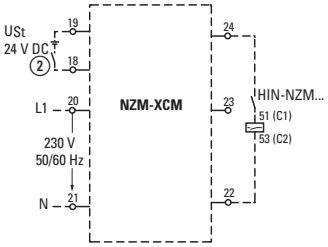
The configuration of the capacitor unit which provides the energy for the shunt release of the mesh network circuit-breaker can be undertaken independently of the circuit-breaker.

Connect NZM-XCM to the supply side!





① Mesh network relay



② Mesh network relay with low power contacts

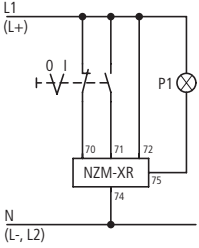
Circuit-breakers
Remote operation with motor operator

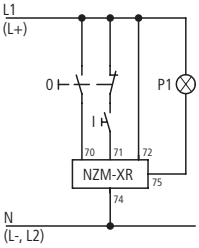
Two-wire control (continuous contact)

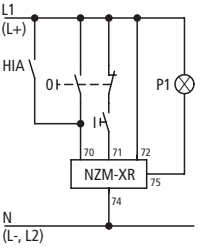
Three-wire control (pulse contact)

Three-wire control with automatic return to the Off position after tripping

NZM2, NZM3, NZM4







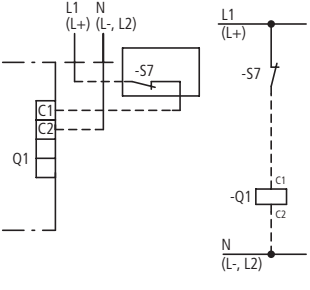
Circuit-breakers
Circuit-breaker as transfomer switch

Faults upstream of the low-voltage circuit-breaker, e.g. in the transformer itself, are disconnected by suitable protective devices (e.g. a Buchholz relay) on the high-voltage side. The S7 auxiliary contact of the high-voltage circuit-breaker trips out the NZM transformer switch on the low-voltage side in order to prevent feedback to the high-voltage network.

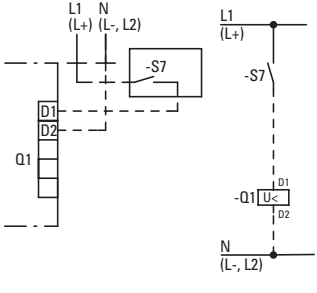
S7 thus isolates the transformer from the network on both sides. This interlocking with the high-voltage circuit-breaker must always be provided when transformers are being operated in parallel.

If only one normally open contact is available as the auxiliary contact, an undervoltage release must be used instead of the shunt release. At the same time, this provides protection against undervoltage.

Circuit-breakers with shunt release (Q1)



Circuit-breakers with undervoltage release (Q1)



Circuit-breakers
Circuit-breaker with residual current device

Residual current releases combined with circuit-breakers are used for protection against the effects of fault currents. These device combinations fulfill the following tasks:

- Overload protection,
- Short-circuit protection,
- Fault-current protection.

Depending on type the earth-fault releases protect the following:

- Persons against direct contact (basic protection),
- Persons against indirect contact (fault protection),
- Dangers of an earth fault (fire etc).

These kinds of earth-fault releases can be attached to the NZM1 and NZM2 circuit-breakers. No auxiliary voltage is required. In the event of a fault, the earth-fault release trips the circuit-breaker, i.e. the main contacts are opened. The circuit-breaker and the earth-fault release must be reset to restore the supply.

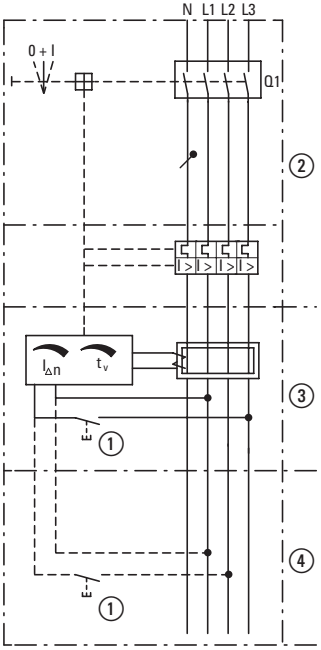
Part no.	Rated current range A	Rated operational voltage U_e V	Response value of earth fault release $I_{\Delta n}$ A	Delay time t_v ms	Sensitivity
NZM1(-4)-XFI30(R)(U)	15 – 125	200 – 415	0.03	–	Pulsating current
NZM1(-4)-XFI300(R)(U)	15 – 125	200 – 415	0.3	–	
NZM1(-4)-XFI(R)(U)	15 – 125	200 – 415	0.03; 0.1; 0.3; 0.5; 1; 3	10; 60; 150; 300; 450	
NZM2-4-XFI30[1)]	15 – 250	280 – 690	0.03	–	
NZM2-4-XFI[1)]	15 – 250	280 – 690	0.1; 0.3; 1; 3	60; 150; 300; 450	
NZM2-4-XFI30A[1)]	15 – 250	50 – 400	0.03	–	AC/DC
NZM2-4-XFIA[1)]	15 – 250	50 – 400	0.1; 0.3; 1	60; 150; 300; 450	

[1)] Devices are not dependent on the supply voltage.

Circuit-breakers
Circuit-breaker with residual current device

Circuit-breakers can be used together with residual current releases in three-phase and single-phase systems.

With 2-pole operation it must be ensured that voltage is applied to both terminals required for test functions.



① Test button (T)
② NZM1-(4)..., NZM2-4...
③ +NZM2-4-XFI
④ NZM1-(4)-XFI

Trip indication is implemented via auxiliary contacts. Circuit-breaker NZM2-4 -XFI... has fixed contacts. The NZM1(-4)-XFI... allows two M22-K... contact elements from the Eaton RMQ-Titan range to be clipped in.

Contact representation for "not released"

NZM1(-4)-XFI...

M22-K10 M22-K02

NZM2-4-XFI...

7

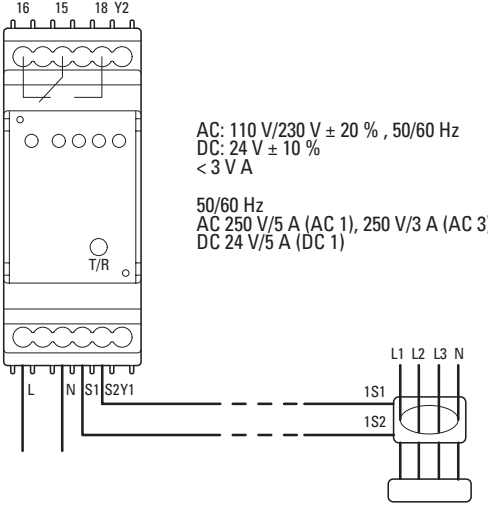
Circuit-breakers
Circuit-breaker with residual current device

Residual-current relays ELR with ring-type transformers

The area of application for the relay/transformer combination ranges – depending on the standards involved – from personnel protection to fire prevention to general protection of systems for 1- to 4-pole electrical power networks. There are four different relay types and five different transformer types available. They cover operating currents ranging from 1 to 2000 A. The four relay types have the following features:

- Rated fault current 30 mA, permanently set,
- Rated fault current 300 mA, permanently set,
- Rated fault current from 30 mA to 30 A and a delay time from 15 ms to 9 s which is variable in stages.

The residual current relay indicates when a fault current has exceeded the predefined fault current by using a changeover contact. The contact signal can be processed further as a signal in programmable logic controllers or can initiate a trip via the undervoltage release of a circuit-breaker/switch-disconnector. The compact ring-type transformer is placed without any particular space requirement at a suitable position in the power chain.

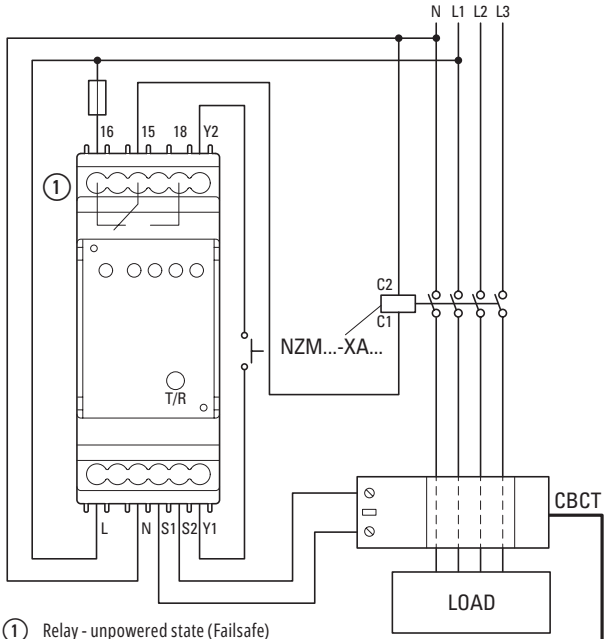


AC: 110 V/230 V ± 20 % , 50/60 Hz
DC: 24 V ± 10 %
< 3 V A

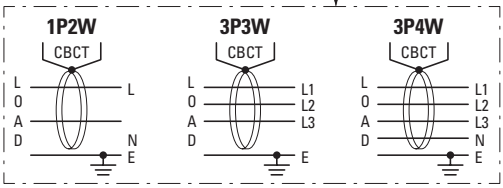
50/60 Hz
AC 250 V/5 A (AC 1), 250 V/3 A (AC 3)
DC 24 V/5 A (DC 1)

Circuit-breakers
Circuit-breaker with residual current device

Trip of circuit-breakers with shunt release and possible external reset of the relay by a pushbutton (NC contact)



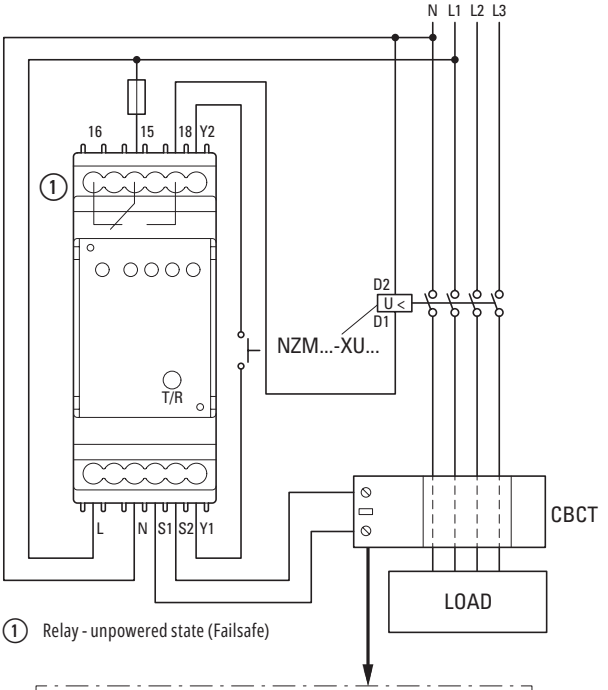
1 Relay - unpowered state (Failsafe)



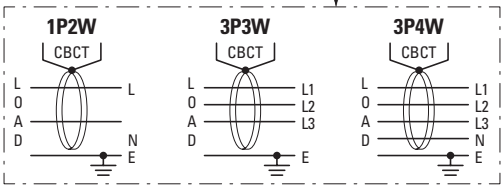
Circuit-breakers

Circuit-breaker with residual current device

Trip of circuit-breakers with undervoltage release and possible external reset of the relay by a pushbutton (NC contact)



1 Relay - unpowered state (Failsafe)



Circuit-breakers
Terminal assignments of IZMX circuit-breakers

Terminal assignment IZMX16

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55
ST1 +	UV1 +	OT1C	OT1B	ACCY2	N1	ALMC	ALM2	G1	+24V	ZIN	ZCOM	CMM1	CMM3	PTA	PTVC	MODBA	MODBG	ACCY5	ACCY7	E01	SR1	C1	B1	C2	C3	B3	C4
–	–	OT1M	ACCY1	ACCY3	N2	ALM1	ALM3	G2	AGND	ARMSIN	ZOUT	CMM2	CMM4	PTVB	PTVN	MODBB	ACCY4	ACCY6	SC	E02	SR2	A1	B2	A2	A3	B4	A4
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56

1, 2	Shunt trip
3, 4	Undervoltage release/2nd shunt trip
5 ~ 7	Overload trip switch 1 (OTS) (5-COM, 6-N.O, 7-N.C.)
8 ~ 10	Overload trip switch 2 (OTS)/Remote reset (8-N.C., 9-COM, 10-N.O./9-RR1, 10-RR2)
11, 12	External neutral sensor
13 ~ 16	Alarm
17,18	Ground fault source sensor
19, 20	Control voltage supply 24 V DC
21, 23, 24	Zone selectivity ZSI
20, 22	ARMS
25 ~ 28	External CAM module
29 ~ 32	PT module (external voltage measurement)
35 ~ 33	Onboard ModBus
36	ACCY4 (Reserved)
37 ~ 39	Latch check switch (37-COM, 38-N.O, 39-N.C.)
40	Message: Spring energy store tensioned
41, 42	Motor operator
43, 44	Spring closing release
45 ~ 56	Auxiliary contact on/off, C-COM, A-N.O., B-N.C.

7

Terminal assignment IZMX40

1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47
ST1 +	UV1 +	OT1C	OT1B	OT2C	N1	ALMC	ALM2	G1	+24V	ZIN	ZCOM	CMM1	CMM3	PTVA	PTVC	MODBA	MODBG	2CMM3	2CMM1	ARCON2	RR1		
–	–	OT1M	OT2B	OT2M	N2	ALM1	ALM3	G2	AGND	ARMSIN	ZOUT	CMM2	CMM4	PTVB	PTVN	MODBB	2CMM2	2CMM4	ARCON1	ARCON3	RR2		
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48

1, 2	Shunt trip
3, 4	Undervoltage release/2nd shunt trip
5 ~ 7	Overload trip switch 1 (OTS) (5-COM, 6-N.O, 7-N.C.)
8 ~ 10	Overload trip switch 2 (OTS) (8-N.C., 9-COM, 10-N.O.)
11, 12	External neutral sensor
13 ~ 16	Alarm
17, 18	Ground fault source sensor
19, 20	Control voltage supply 24 V DC
21, 22, 24	Zone selectivity ZSI
20, 22	ARMS
25 - 28	External CAM module
29 ~ 132	PT module (external voltage measurement)
33 ~ 35	Onboard ModBus
36 ~ 39	External CAM module (future)
40 ~ 42	ARCON
43, 44	Remote reset
45 ~ 48	Reserved

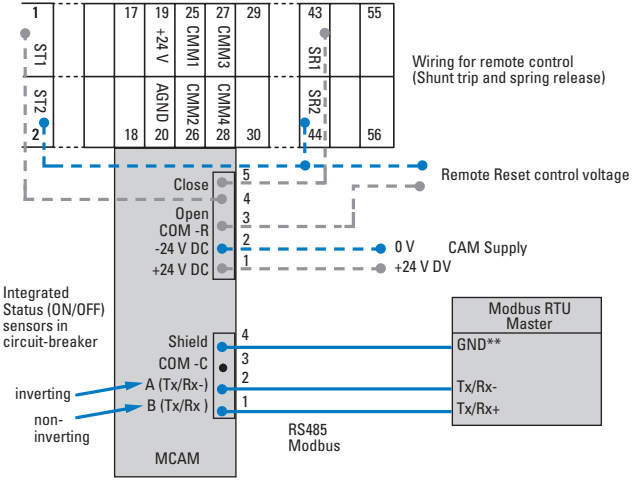
49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95
LCC	LCB	E01 +	SR1	C1	B1	C2	C3	B3	C4	C5	B5	C6	C7	B7	C8	B9		C10	C11	B11	C12		
LCM	SC	B02 –	SR2	A1	B2	A2	A3	B4	A4	A5	B6	A6	A7	B8	A8	A9	B10	A10	A11	B12	A12		
50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96

49 ~ 51	Latch check switch (49-COM, 50-N.O., 51-N.C.)
52	Message: Spring energy store tensioned
53, 54	Motor operator
55 ~ 56	Spring closing release
57 ~ 92	Auxiliary contact on/off, C-COM, A-N.O., B-N.C.

Circuit-breakers
Terminal assignments of IZMX circuit-breakers

Plan view of a mounted MCAM on IZMX...

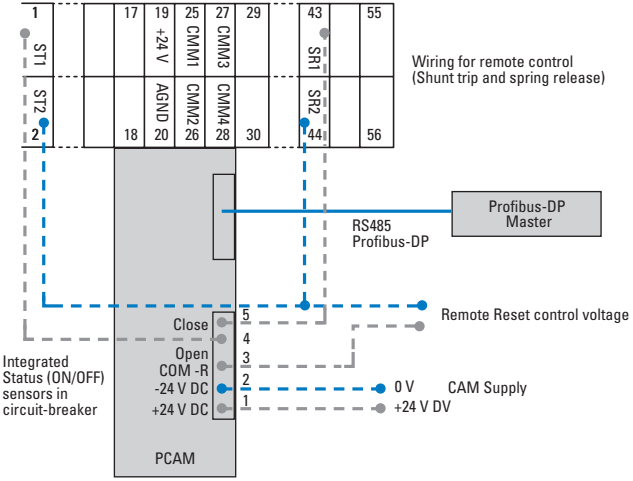
Terminal diagram Modbus



Circuit-breakers
Terminal assignments of IZMX circuit-breakers

Plan view of a mounted PCAM on IZMX...

Terminal diagram PROFIBUS DP

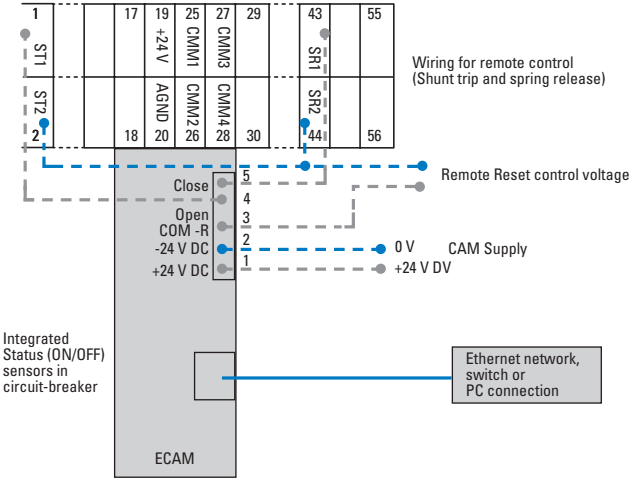


Circuit-breakers

Terminal assignments of IZMX circuit-breakers

Plan view of a mounted ECAM on IZMX...

Terminal diagram Ethernet



7

Power distribution equipment

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Power distribution equipment
xEnergy Main

xEnergy Main – Safe energy distribution up to 7100 A

The modular system consists of perfectly fitting function modules that are type tested to IEC/EN 61439 with form 1 to form 4 internal partitioning, and which take European and local (DIN, VDE, CEI, NF, UNE) installation practice into account.

xEnergy Main provides the panel builder with a flexibly combinable product range for power distribution systems up to 7100 A.

The operation of the system could not be simpler, despite its complexity. The modular design enables the creation of intelligent combinations.

Switching and protective devices, as well as the associated mounting technology and extensive housing components are perfectly matched and form both a technical as well as an economic unit.

This practically oriented system platform enables individual project design, maximum flexibility and fast production in the workshop. On the one hand, this saves time, money and space, whilst type tested mounting units offer a higher level of safety. The modular system can furthermore be extended with little effort to meet future requirements.

The panel builder is provided with efficient tools for tasks ranging from planning to quotations, right through to ordering. The entire range is supplied in functional flat packs or as pre-assembled switch cabinets.

Power distribution equipment
xEnergy Main

System features:

- Main busbar at the back or top
- Rated operational voltage 400 to 690 V AC
- Rated operational current 630 to 7100 A
- Rated short-time withstand current to 100 kA (1 s)
- Main busbar current to 7100 A
- Dropper bar current up to 2000 A
- Sheet steel housing for combination and separate mounting
- Degree of protection IP31, IP42, IP43 and IP55
- Color RAL 7035 (special colors possible)
- Internal separation up to form 4b
- Dimensions:
  - Height 2000, 2200 mm
  - Width 300, 425, 600, 800, 1000, 1100, 1200, 1350 mm
  - Depth 600, 800, 1000 mm

Available technologies

- Fixed mounting (XF)
- Removable compartments (XR)
- Withdrawable compartments (XW)

Standards

- IEC 61439-1/2
- IEC TR 61641
- IEC TS 63107 (ARCON®)
- IEC 60068-3-3: level AG2 and AG5

xEnergy Main XP (Power)

- Incoming units/feeder units, outgoers and couplings with NZM or IZM(X) circuit-breakers up to 6300 A
- Circuit-breakers in fixed mounting or withdrawable units
- 3- or 4-pole circuit-breakers
- Internal separation up to form 4b
- Cable connection from top or bottom
- Connection of busbar systems
- Incomer system for drill-free cable connection

Power distribution equipment
xEnergy Main

xEnergy Main XF (Fixed) compartment design

- Outgoers with PKZ or NZM circuit-breakers up to 1250 A
- Circuit-breakers in fixed mounting or withdrawable units
- 3- or 4-pole circuit-breakers
- Outgoers with SL fuse-strip units up to 630 A
- Outgoers with switch-disconnectors up to 630 A (SL)
- Individual outgoers, e. g. controllers, motor starters, small energy outgoers, ...
- Internal separation up to form 4b
- Cable connection from top or bottom

xEnergy Main XR (Removable) removable compartment design

- Outgoers with PKZ and NZM circuit-breakers up to 630 A
- Outgoers with strip-type switch-fuse units up to 630 A (PIFT)
- Outgoers with switch-disconnectors up to 630 A
- Flexible surface mounting using plug-in contacts
- Plug-in modules and switch-fuse units exchangeable under conditions
- Straightforward maintenance, minimal downtime
- Internal separation up to form 4b
- Cable connection from top or bottom

Power distribution equipment
xEnergy Main

xEnergy Main XW (Withdrawable) withdrawable compartment design

- Outgoers with PKZ and NZM circuit-breakers up to 630 A
- Outgoers for motor starters up to 250 kW
- Empty drawer-units for every application
- Uniform, straightforward operation for all drawer-unit sizes
- No special tool required
- Flexible assembly with plug-in contacts (incoming and outgoing)
- Withdrawable modules exchangeable whilst live
- Unambiguous position indication for operation, test, de-energized
- Straightforward maintenance, minimal downtime
- Internal separation up to form 4b
- Cable connection from top or bottom

xEnergy Main XG (General) empty sections

- Power factor correction
- Mounting system for subdistribution system with modular installation devices
- Control technology with Sasy60i and xStart
- Individual fixed mounted components on mounting plate

Power distribution equipment
xEnergy Light flexible main distribution board

xEnergy Light flexible main distribution board up to 1600 A

The xEnergy Light side-by-side distribution system is designed to take switchgear for applications up to 1600 A.

Typical uses are as power distribution systems in utility buildings or as control panel enclosures in industry. This is where the xEnergy Light can demonstrate the benefits of its rugged design.

The xEnergy Light is a stable, side-by-side mountable distributor made of sheet steel that is also best suited for stand-alone installation. It protects persons from coming into direct contact with conducting parts and even from possible electric shock, and reliably fends off damaging exterior influences. It carries out these functions according to the specific requirements, with protection degrees of IP31, IP42 or IP55. While the former is suited to diverse uses in functional buildings such as schools or hospitals, it is also recommended for harsher conditions such as wind energy systems, or in industry, in a foam-type polyurethane sealing design. Abrasion-proof protection against corrosion is guaranteed thanks to structured paint finish using a powder coating RAL 7035.

Overall, the technical design of the xEnergy Light complies with the IEC/EN 62208 standard, as well as with IEC 61439-1, as long as it is used as a low-voltage energy distribution system.

Power distribution equipment
xEnergy Light flexible main distribution board

System features:

- Common platform with xEnergy: Several design elements such as mounting frames, bottom and top plates, as well as side and rear panels can be used for both systems.
- Installation mounting systems: Profi+ and EP
- Rated operational voltage 415 V AC
- Rated operational current to 1600 A
- Rated short-time withstand current to 65 kA (1 s)
- Sheet steel housing for combination and separate mounting
- Degree of protection: IP31, IP42 and IP55
- Color RAL 7035 (Special colors possible)
- Internal separation up to form 4b
- Dimensions:
  - Height 1400, 1600, 1800, 2000 mm
  - Width 425, 600, 800, 850, 1000, 1100, 1200, 1350 mm
  - Depth 400, 600, 800 mm

xEnergy Light low-voltage energy distribution system

- Incoming units/feeder units, outgoers and couplings with NZM, PDE and IZM(X) circuit-breakers up to 1600 A
- Outgoers with SL fuse-strip units up to 630 A
- Incoming units, Outgoers with switch-disconnectors up to 1600 A
- Internal separation up to form 4b
- Circuit-breakers in fixed mounting or withdrawable units
- 3- or 4-pole circuit-breakers
- Cable connection from top or bottom
- Incomer system for drill-free cable connection
- Outgoers with NZM circuit-breakers
- Outgoers with switch-disconnectors Dumeco/QSA
- Individual fixed mounted components on mounting plate

Power distribution equipment
xEnergy Light flexible main distribution board

xEnergy Light subdistribution system

- Installation mounting systems Profi+ and EP
- Mounting modules for
  - NZM
  - NH switch-disconnectors
  - Low-voltage h.b.c. fuse switch disconnectors
  - Busbar mounting fuses
  - Modular installation devices
  - Individual devices

xEnergy Light control centres

- Control technology with Sasy60i and xStart
- Individual fixed mounted components on mounting plate
- Air conditioning and ventilation
- Automation engineering

Power distribution equipment
xEnergy Elite high-performance motor control center

xEnergy Elite – high-performance motor control center up to 7500 A

The xEnergy Elite is a type-tested modular power distribution system in compliance with IEC/EN 61439-1. It is used wherever large amounts of energy have to be distributed safely and reliably or where motor controllers have to be integrated into processes.

xEnergy Elite combines the greatest possible flexibility with safety and reliability, as well as profitability for the long term. Straightforward engineering, effective commissioning and fault-free operation by the modular construction using Eaton products for switching, protection, control and visualization.

Full and comprehensive integration of the primary control is implemented on the basis of networked functional groups.

For personnel and system protection, the arc fault protection system ARCON® 3G can be integrated without problems. The Eaton motor management relay C445 can be fully integrated. Fully insulated busbar for the highest safety requirements available as an option.

Power distribution equipment

xEnergy Elite high-performance motor control center

System features:

- Main busbar at the back or top
- Rated operational voltage 400 to 690 V AC
- Rated operational current 630 to 7500 A
- Rated short-time withstand current to 100 kA (1 s)
- Main busbar current to 7500 A
- Dropper bar current up to 1800 A
- Sheet steel housing
- Degree of protection IP30, IP31, IP40, IP42 and IP54
- Color RAL 7035 (special colors possible)
- Internal separation up to form 4b
- Dimensions:
  - Height 2200 mm
  - Width 400, 600, 800, 1000, 1200, 1350, 1400 mm
  - Depth 600 up to 1400 mm

Available technologies

- Removable compartments (R)
- Withdrawable compartments (W)

Standards

- IEC 61439-1/2
- IEC TR 61641
- IEC TS 63107 (ARCON® 3G)
- IEC 60068-3-3: level AG2 and AG5

xEnergy Elite P – Power

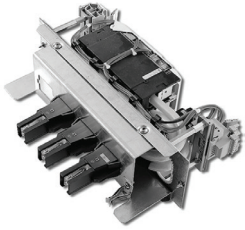
- Operating voltage 400 to 690 V AC
- Rated operational current 630 to 6300 A
- Short-circuit strength to 100 kA (1 s)
- Incoming units/feeder units, outgoers and couplings with NZM or IZM(X) circuit-breakers up to 6300 A
- Incoming units/feeder units, outgoers and couplings with switch-disconnectors Dumeco up to 3150 A
- Circuit-breakers in fixed mounting or withdrawable units
- 3- or 4-pole circuit-breakers
- Internal partitioning up to form 4b
- Cable connection from top or bottom
- Connection of busbar systems
- Installation of quenching device ARCON® 3G device optionally possible

Power distribution equipment

xEnergy Elite high-performance motor control center

xEnergy Elite R – Removable

- Section for up to 15 removable compartments for power outgoers and motor starters or
- Section for up to 27 switch-fuse units (PIFT)
- Flexible surface mounting using plug-in contacts
- Plug-in modules exchangeable whilst live
- Straightforward maintenance and reduced downtime



Removable compartments

- Power outgoers up to 630 A
- Motor starters up to 90 kW
- Module is for plugging in, i. e. the incoming unit is removable

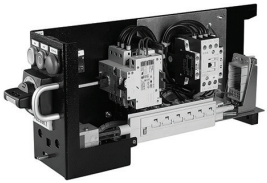
Fuse-switch disconnector

- 4 sizes up to 630 A
- Safe protection against contact
- Easy fuse replacement

Power distribution equipment
xEnergy Elite high-performance motor control center

xEnergy Elite W – Withdrawable

- Section for up to 32 drawer units for power outgoers and motor starters
- High packing density
- Uniform, straightforward operation for all drawer-unit sizes
- No special tool required
- Withdrawable modules exchangeable whilst live
- Straightforward maintenance and minimal downtime
- Internal partitioning up to form 4b



Withdrawable units

- Power outgoers up to 630 A
- Motor starters up to 315 kW
- Micro drawer units (1/4 and 1/2)
- Withdrawable units
- Drawer-unit is withdrawable, i. e. all electrical connections are plug connections
- Exchangeable whilst live
- All drawer units positions lockable
- Unambiguous and clearly visible indication for all possible drawer unit positions (operation, test, de-energized)
- C445 fully integrated

Power distribution equipment
ARCON® 3G arc fault protective system

ARCON® 3G arc fault protective system

Maximum personnel and system safety, especially during continuous production processes, made possible using the ARCON® 3G arc-fault protection system. ARCON® 3G is suitable for low-voltage switchgear assemblies up to 690 V AC/50 Hz. The system offers protection from 7.5 to 100 kArms arc fault current. The ARCON® arc-fault protection system is used wherever enhanced personal protection is required that goes above and beyond the requirements of the relevant standards.

The effects of an arc fault will put a low-voltage switchboard systems out of operation for several weeks. If a redundant power supply is not available, this will also result in unplanned downtime. The only solution is effective system protection to minimize the effects of an arc fault and get your system back up and running. ARCON® restricts the effects of the arc fault to its foot points, and after the cause of the fault has been rectified and the quenching device has been replaced, the system can be back up and running in the shortest possible time in order to ensure the required level of availability.

- System arc mitigation time (t_{mtA}) ≦ 2 ms
- At the lowest threshold setting, ARCON® 3G protects against arcs at a pick-up level of Ipc arc = 7.5 kA (Ipc arc max. = 100 kA)
  Rated short-time withstand current Icw of the quenching device (at operating voltage of 415 V AC):
  - 85 kA/1 s
  - 105 kA/500 ms
  - 150 kA/200 ms
- Integrated self-monitoring of the entire system to prevent unplanned downtime
- Low-voltage switchgear and control gear assembly xEnergy with integrated ARCON® 3G meets criteria 1-7 of IEC/TR 61641:2014 Ed.3 for personnel and assembly protection
- Full personnel protection even if the doors are open, e. g. during maintenance
- The arc quenching device (ARC-AT) has been tested and verified acc. to IEC 60947-9-1:2019 (latest standard for active arc-fault mitigation systems – Arc quenching devices)

ARCON® 3G – Quenching device

Power distribution equipment
xEffect CS

xEffect CS Sheet steel wall-mounting enclosure with mounting plate

Eaton's latest generation of CS sheet steel enclosures is especially rugged and can be used wherever a high level of protection is required, both to effectively protect against direct contact with live parts and to prevent damage to components due to ingress of liquids or dust. The enclosures come with IP66 degree of protection (UL/CSA types 1, 4, 12) thanks to a continuous CNC-foamed polyurethane gasket that prevents the ingress of water, oil and dirt.

This is only one of the features that makes the CS series of enclosures the perfect match for sub-distribution boards in control systems for industrial buildings and machine building applications. In addition, these heavy-duty sheet steel enclosures meet the requirement set forth in IEC/EN 62208 and UL508A, meaning they are approved for use in switchgear assemblies as defined in IEC/EN 61439-2.

Shock resistance rating is IK09 according to EN 62262, hence the inside equipment of the enclosures is also protected against mechanical impacts. CS enclosures can be installed as wall-mounted enclosures. A roughtype paint applied in the powder-coating method provides for non-abrasive corrosion protection. The door of the enclosure is easy to remove in case any further mechanical work needs to be carried out.

Concealed inside hinges according quick-change technology are easy to remove for this purpose and provide for quick and easy reversal of the hinging from left to right and vice-versa.

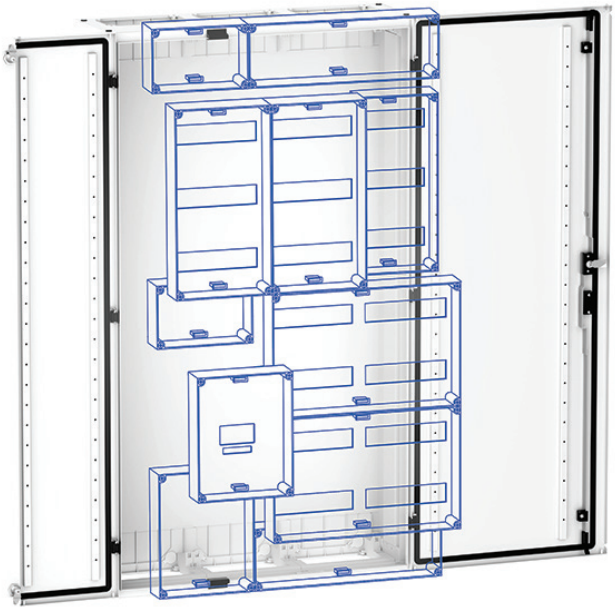
The xEffect CS enclosure with mounting plate (2/3 mm) is also available in 45 different dimensions. Eaton offers a wide range of standardized products from the smallest (250 x 200 x 150 mm) to the largest enclosure (1200 x 1200 x 250 mm).

Power distribution equipment
xEnergy Basic

Our xEnergy Basic range offers various certified distribution boards for all types of applications up to 630 A. Their robust and flexible design allows them to be used in residential and commercial buildings, as well as in harsh environments.

To meet the needs of each individual customer, we have developed different systems with their own features and benefits:

- xEnergy Basic BP
- xEnergy Basic EWK
- xEnergy Basic EMC2



Power distribution equipment

xEnergy Elite high-performance motor control center

xEnergy Basic BP

xEnergy Basic BP is not only the smallest distribution board of the whole xEnergy family, but also the most flexible and versatile one. By offering certified systems with various mounting methods, we can provide customized solutions for all kinds of applications.

- Flush-mounted, surface-mounted, and floor standing versions
- For electrical systems up to 630 A
- Two systems for various applications: EP and Profi+

Certified as a low-voltage distribution board that may be operated by non-experts in accordance with IEC/EN 61439-1/-2/-3 and IEC/EN 62208, xEnergy Basic BP is the ideal choice for electrical distribution systems in residential and functional buildings.

xEnergy Basic EWK

EWK is a surface-mounted distribution board with its own unique installation system as well as individual installation sections. Each of its sections can be easily pre-assembled and integrated into the board. Large contact-protective plastic covers and insulated interior linings meet the requirements of protection class II, which makes the xEnergy EWK especially suitable for use in public buildings.

- Depth 230 mm
- 14 preconfigured enclosure sizes

xEnergy Basic EMC2

xEnergy Basic EMC2 combines the modularity of the EP installation system with user-friendly features, and is fully compatible with EP. Its robust design makes it suitable for a wide variety of applications, including industrial power distribution.

Thanks to their robust design and welded construction, the series comes with a mechanical impact rating of IK10. Due to the high protection class of IP55, these enclosures are suitable for a variety of applications, including industrial power distribution.

- Wall-mounted and floor-standing versions
- For electrical systems up to 630 A
- Protection class II

Power distribution equipment
xEffect K-type terminals

The modular connection terminal consists of a combination of several highly stable terminal blocks. It is used for connecting two or more conductors, such as cables, flexible copper strips or copper bars, inside a power or control panel.

We offer a wide range of options as standard, with six frame sizes (connection cross-sections from 10 mm^2 to 3 x 240 mm^2) that cover the current range from 40 to 1000 A.

Optional accessories include IP2X finger protection as well as conversion kits.

Due to their extraordinary stability and robustness, the xEffect K-type terminal blocks can be used as feed or output terminals in low-voltage distribution systems according to IEC/EN 61439-2.

The copper or aluminum conductors can be easily and quickly inserted into the box terminals from above and do not require any bending.

- Proven technology:
  Each individual terminal in the series is based on field-proven design features.
- Flexibility:
  Different conductor types, such as flat copper strips or copper bars, can be connected to each other.
- Modular:
  Individual terminal blocks can be combined with each other, regardless of the size.
- Safety:
  Thanks to their modular structure, the protective covers offer a high degree of protection (IP2X).
- Easy installation:
  Connecting cables can be quickly and easily inserted into the box terminal.
- Integration:
  Integration into Eaton's xEnergy power distributions boards and configurator tool.

Power distribution equipment
xEnergy Safety Ci

Ci insulated distribution boards, totally insulated

Eaton's xEnergy Safety modular power distribution system is a multi-box-type, low-voltage switchgear assembly according to IEC/EN 61439-2. Made from polycarbonate, it has been designed to meet the most stringent requirements, including corrosion protection, for applications up to 1600 A. These fully insulated distribution enclosures provide IP65 degree of protection and can withstand almost any type of environmental impact, such as dust, moisture, and water.

Thanks to the spring-loaded fittings in the cover, the CI enclosure offers special protection against extreme switching arcs. This mechanism provides pressure relief by lifting the cover by a few millimeters and then closing it again immediately.

Thanks to the transparent smoke gray covers, operators can check the status of the switchgear at a glance.
In addition, non-transparent covers and covers with integrated cylinder lock are also available.

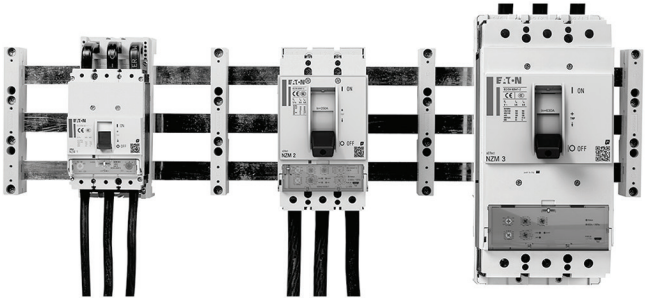
This type of enclosure offers additional protection against mechanical impacts and caustic substances.

- Design-approved system modules ensure that the switchgear complies with the IEC/EN 61439-2 standard
- Maximum safety – the cover rests on spring-loaded fittings to ensure pressure relief in case of a switching arc
- Thanks to the modular structure/system, the devices can be adapted to their surroundings
- The fully insulated encapsulation provides personal and operational safety as well as corrosion protection
- High degree of protection (IP65/IK10) for easy, universal use
- Transparent covers for simplified maintenance and control
- Integrated system for up to 1600 A
- Stable carrier frame profiles, whether used as a wall-mounted or floor-standing distribution system

Power distribution equipment
SASY60i busbar system

SASY60i busbar system for the world market

SASY 60i connects safety and reliability in a single product. SASY 60i is a comprehensive UL-certified solution for switching, controlling, protecting and distributing power that is designed for use with our motor-protective circuit breakers and NZM molded-case circuit breakers.



The SASY60i modular busbar system is designed for effective power distribution in the control panel.

Thanks to its innovative busbar adapter, the feeders and outgoing circuit breakers can be quickly and easily mounted directly on the busbar system in a space-saving manner.

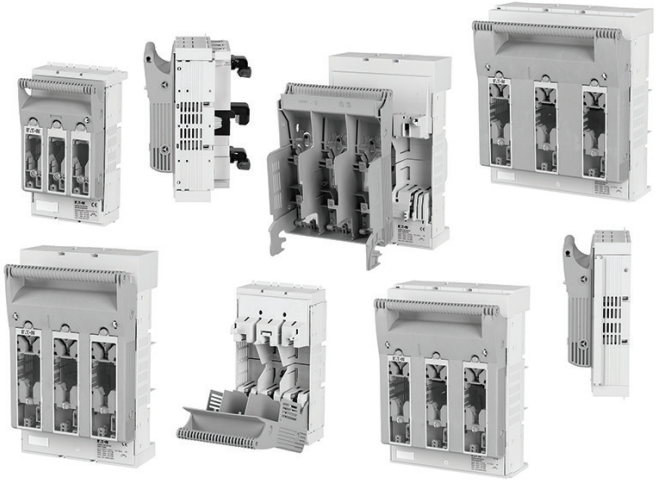
In addition, the SASY 60i system's double-T profile busbars reduce the amount of work required for preparing contact points. They also combine an extremely high rated peak withstand current with a small number of busbar supports, meaning they take full advantage of every inch of control cabinet space available.

The SASY 60i busbar system and the associated components are designed for control cabinets in the machine-building sector and can be used worldwide.

The larger clearances and creepage distances required in compliance with the UL 508A in America have been considered in the construction of the busbar components.

Power distribution equipment
xEffect XNH fuse-switch disconnector

In machines and systems, safety is a decisive factor.



The latest generation of Eaton's XNH fuse-switch disconnectors provides even more safety functions than the IEC/EN 60947-3 standard requires.

Thanks to the wide range of models and the extensive accessories, the series meets the requirements of even the most demanding machine-building and energy distribution applications.

Export to World Markets and North America

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Export to World Markets and North America
Approvals and certifications

Approval of electrical equipment is based on the conformity and certification of components and assemblies to regional and country specific product and installation standards that are geared towards the proper application of these products in those markets.

- Product testing conducted by nationally recognized certification agencies is often required, and product certification is also subject to periodic review and auditing by the certification agency.
- In the majority of cases, product certification is tied to the display of respective certification marks on the product themselves.
- Product certification ratings may differ from IEC based technical data and ratings.
- Product certifications are sometimes subject to additional and specific conditions of acceptability.
- Design flexibility on the part of manufacturers can sometimes be impacted by the possible need to re-certify each subsequent product modification.

Successful exports are based on more than just using certified equipment. In addition to product certifications, a firm understanding of the standards and market conventions involved is necessary to insure that electrical components and assemblies are also properly applied.

A checklist is a useful tool to clarify important issues and minimize costs during the engineering phase. Special requirements that are overlooked during the initial stages, and need to be remedied after the fact, will not only be costly but very time consuming as well.

Export to World Markets and North America
Approvals and certifications

Special characteristics for the export to North America (USA, Canada)

Technologies that have proven themselves reliable the world over are not guaranteed automatic acceptance in North America. Exports to North America must take into consideration the following:

- North American certification of electrical equipment,
- North American product, application, and installation standards,
- Particular and specialized market conventions,
- Approval of electrical installations by local inspectors (AHJ = **A**uthority **H**aving **J**urisdiction).

Particular aspects of the North American market, which are not readily known in the IEC world:

- Product specific differences and ratings based on certification
- Differentiation of power circuits (Feeder and Branch Circuits)
- Equipment limitations based on particular supply network configurations
- Application related differences affecting product selection

Electrical equipment groupings in North America

There is a differentiation made in North America between products used in Energy Distribution, such as molded-case circuit-breakers certified per the UL 489 product standard, and those found in Industrial Control, typically falling under UL 508.

Product standards such as UL 489 and CSA C22.2 No. 5-09 require significantly larger air and creepage clearances in component construction than do the IEC standards and their harmonized European counterparts (EN norms).

An example of its impact on component construction would be the European motor protective switch which, in North America, needs to be equipped with a large spacings terminal on its supply side whenever it is applied as a stand-alone protective device in individual motor branch circuits.

Electrical components used in energy distribution

- Molded-case circuit-breakers
  UL 489, CSA C22.2 No. 5-09
- Molded-case switches
  UL 489, CSA C22.2 No. 5-09
- Enclosed switches
  UL 98, CSA C 22.2 No. 4
- Fusible disconnect switches
  UL 98, CSA C 22.2 No. 4
- Fuses
  UL 248, CSA C22.2 No. 248

Industrial Control Equipment

UL 508 and CSA-C22.2 No. 14/UL60947-4-1 and CSA-C22.2 No. 60947-4-1

- Contactors
- Control relays
- Overload relays
- Cam switches
- Pilot devices and limit switches
- Solid State relays and equipment
- Programmable controllers

Export to World Markets and North America
Approvals and certifications

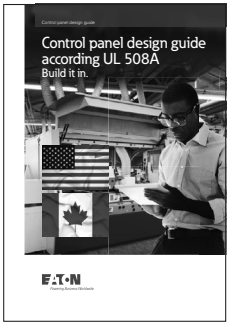
Criteria for equipment selection particular to North American conventions

- Knowing the type of load and circuit is especially important in selecting the right equipment for the application. Motor starters are used exclusively for the protection and switching of motor loads.
- Motor starters mounted on busbar adapters that are supplied from a feeder must have the larger electrical clearances on their incoming supply side.[1)]
- Motor starters mounted on busbar adapters within a branch circuit are permitted to have industrial control electrical clearances on their field terminations.[1)]
- Supplementary handles are necessary for supply circuit disconnect switches equipped with door mounted rotary handles in applications such as industrial machinery.

[1)] Circuit examples: Refer to diagrams on page 9-35.

Comprehensive information and tips on exporting electrical equipment and controls to North America can be downloaded free of charge from the Internet.

Eaton.com/export-na



Export to World Markets and North America

Fuse classifications in North America

Additional comments on table → page 9-8

Suitable for use in: USA	Canad	UL/CSA Standards	Charac-teristics	SCCR	Typical ranges in Amps
Class **H**, “Code”	Class **H**, No. 59 “Code”	UL 248-6/7, C22.2 248-6/7	Fast-Acting	10 kA, 250 V AC 10 kA, 600 V AC	0...600
Class **CC**	Class **CC**	UL 248-4, C22.2 248-4	Fast-Acting Time Delay	200 kA, 600 V AC	0.5...30
Class **G**	Class **G**	UL 248-5, C22.2 248-5	Fast-Acting Time Delay	100 kA, 480 V AC 100 kA, 600 V AC	21...60 0.5...20
Class **J**	Class **J** HRCI-J	UL 248-8, C22.2 248-8	Fast-Acting Time Delay	200 kA, 600 V AC	1...600
Class **K** K1, K5	Class **K** K1, K5	UL 248-9, C22.2 248-9	Fast-Acting Time Delay	50 kA/100 kA/ 200 kA, 600 V AC	0...600
Class **L**	Class **L**	UL 248-10, C22.2 248-10	Fast-Acting Time Delay	200 kA, 600 V AC	601...6000
Class **R** RK1, RK5	Class **R** HRCI-R RK1, RK5	UL 248-12, C22.2 248-12	Fast-Acting Time Delay	50 kA/100 kA/ 200 kA, 600 V AC	0...600
Class **T**	Class **T**	UL 248-15, C22.2 248-15	Fast-Acting	200 kA, 300 V AC 200 kA, 600 V AC	0...1200

Export to World Markets and North America

Fuse classifications in North America

Applications		Comments
Residential, Commercial, Industrial		Class H, K and No. 59 "Code" fuses are physically interchangeable and fit in the same fuseholders. Refer to comments below under Class K.
Fast-Acting: Protection of resistive and inductive loads. Appliances, Heaters, Lighting, Mixed loads in Feeders and Branch Circuits.	**Time Delay:** Protection of inductive and highly inductive loads. Electrical Motors, Transformers, Lighting...	Extremely compact size! **Current limiting** per UL/CSA Standards!
		Compact size! **Current limiting** per UL/CSA Standards! Non-interchangeable with any other fuse class.
		Compact size! **Current limiting** per UL/CSA Standards! Non-interchangeable with any other fuse class.
		Not marked current limiting per UL/CSA Standards! That's why Class K fuses are often substituted by rejection -type Class RK... fuses.
		Current limiting per UL/CSA Standards! Non-interchangeable with any other fuse class.
		Current limiting per UL/CSA Standards! Types RK1, RK5 and HRCI-R fit in the same rejection-type fuseholders, and are non-interchangeable with any other fuse class.RK1 fuses have lower let through values than RK5 fuses.
	–	Extremely compact size! **Current limiting** per UL/CSA Standards! Non-interchangeable with any other fuse class.

Export to World Markets and North America
Fuse classifications in North America

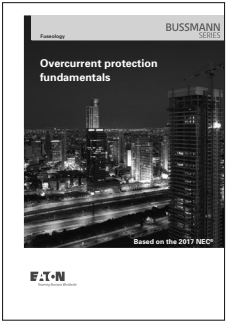
The table contains selection and application information for feeder and branch circuit fuses commonly used in North America.

The fuse characteristics and application guidelines mentioned in the table provide a general overview only.

Most North American power circuit fuses also carry DC ratings per UL and CSA product certification standards.

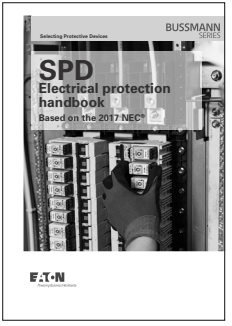
More detailed information on the selection and use of fuses can be found in the Eaton Bussmann "Fuseology"

Eaton.com/bus-fuseology



and inside the Eaton Bussmann "Electrical Protection Handbook"

Eaton.com/bus-ep-handbook



Export to World Markets and North America

Global Codes and Standards Authorities

Code	Full title	Country
ABS	**A**merican **B**ureau of **S**hipping Ship classification association	USA
AEI	**A**ssoziazione **E**lettrotechnica ed Elettronica **I**taliana Italian electrotechnical industry organisation	Italy
AENOR	**A**sociacion **E**spañola de **Nor**malización y Certificación, Spanish organisation for standards and certification	Spain
ALPHA	Gesellschaft zur Prüfung und Zertifizierung von Niederspannungsgeräten German test laboratories association	Germany
ANSI	**A**merican **N**ational **S**tandards **I**nstitute	USA
AS	**A**ustralian **S**tandard	Australia
ASA	**A**merican **S**tandards **A**ssociation American association for standards	USA
ASTA	**A**ssociation of **S**hort-Circuit **T**esting **A**uthorities Association of the testing authorities	Great Britain
BS	**B**ritish **S**tandard	Great Britain
BV	**B**ureau **V**eritas, Ship´s classification association	France
CEBEC	**C**omité **E**lectrotechnique **Be**lge, Belgian electro-technical product quality mark	Belgium
CEC	**C**anadian **E**lectrical **C**ode	Canada
CEI	**C**omitato **E**lettrotecnico **I**taliano Italian standards organisation	Italy
CEI	**C**ommission **E**lectrotechnique **I**nternationale International electrotechnical commission	Switzerland
CEN	**C**omité **E**uropéen de **N**ormalisation European standards committee	Europe
CENELEC	**C**omité **E**uropéen de coordination de **N**ormalisation **Élec**trotechnique, European committee for electro-technical standards	Europe
CSA	**C**anadian **S**tandards **A**ssociation Canadian standards association, Canadian standard	Canada

Export to World Markets and North America

Global Codes and Standards Authorities

Code	Full title	Country
DEMKO	**D**anmarks **E**lektriske Materiel**ko**ntrol Danish material control for electrotechnical products	Denmark
DIN	**D**eutsches **I**nstitut für **N**ormung German institute for standardisation	Germany
DNA	**D**eutscher **N**ormen**a**usschuss German standards committee	Germany
DNV	**D**et **N**orsk **V**eritas Ship classification association	Norway
EN	European standard	Europe
ECQAC	**E**lectronic **C**omponents **Q**uality **A**ssurance **C**ommittee Committee for components with a verified quality	Europe
EEMAC	**E**lectrical **E**quipment **M**anufacturers **A**ssociation of **C**anada	Canada
ELOT	Hellenic Organization for Standardization Greek organization for standardization	Greece
EOTC	**E**uropean **O**rganization for **T**esting and **C**ertification	Europe
ETCI	**E**lectro**t**echnical **C**ouncil of **I**reland Irish organization for standardization	Ireland
GL	**G**ermanischer **L**loyd Ship classification association	Germany
HD	Harmonization document	Europe
IEC	**I**nternational **E**lectrotechnical **C**ommission	–
IEEE	**I**nstitute of **E**lectrical and **E**lectronics **E**ngineers	USA
IPQ	**I**nstituto **P**ortoguês da **Q**ualidade Portuguese quality institute	Portugal
ISO	**I**nternational **O**rganization for **S**tandardization	–
JEM	**J**apanese **E**lectrical **M**anufacturers Association Electrical industry association	Japan
JIC	**J**oint **I**ndustry **C**onference Gesamtverband der Industrie	USA

Export to World Markets and North America

Global Codes and Standards Authorities

Code	Full title	Country
JIS	**J**apanese **I**ndustrial **S**tandard	Japan
KEMA	**K**euring van **E**lektrotechnische **M**aterialen Testing institute for electrotechnical products	Netherlands
LOVAG	**L**ow **V**oltage Agreement Group	–
LRS	**L**loyd's **R**egister of **S**hipping Ship classification association	Great Britain
MITI	**M**inistry of **I**nternational **T**rade and **I**ndustry	Japan
NBN	**N**orme **B**elge, Belgian standard	Belgium
NEC	**N**ational **E**lectrical **C**ode	USA
NEMA	**N**ational **E**lectrical **M**anufacturers **A**ssociation Electrical industry association	USA
NEMKO	**N**orges **E**lektrische **M**ateriell**ko**ntroll Norwegian testing institute for electrotechnical products	Norway
NEN	**Ne**derlands **N**orm, Dutch standard	Netherlands
NFPA	**N**ational **F**ire **P**rotection **A**ssociation	USA
NKK	**N**ippon **K**aiji **K**yakai Japanese classification association	Japan
OSHA	**O**ccupational **S**afety and **H**ealth **A**dministration	USA
ÖVE	**Ö**sterreichischer **V**erband für **E**lektrotechnik Austrian electrotechnical association	Austria
PEHLA	**P**rüfstelle **e**lektrischer **H**ochleistungs**a**pparate der Gesellschaft für elektrische Hochleistungsprüfungen Electrical high-performance apparatus test laboratory of the association for electrical high-performance testing	Germany
PRS	**P**olski **R**ejestr **S**tatków Ship classification association	Poland
PTB	**P**hysikalisch-**T**echnische **B**undesanstalt German physical/technical federal agency	Germany

Export to World Markets and North America

Global Codes and Standards Authorities

Code	Full title	Country
RINA	**R**egistro **I**taliano **N**avale Italian ship classification association	Italy
SAA	**S**tandards **A**ssociation of **A**ustralia	Australia
SABS	**S**outh **A**frican **B**ureau of **S**tandards	South Africa
SEE	**S**ervice de l'**E**nergie de l'**E**tat Luxemburg authority for standardisation, testing and certification	Luxemburg
SEMKO	**S**venska **E**lektriska **M**ateriel**k**ontrollanstalten Swedish test institute for electrotechnical products	Sweden
SEV	**S**chweizerischer **E**lektrotechnischer **V**erein Swiss electro-technical association	Switzerland
SFS	Suomen Standardisoimisliitlo r.y. Finnish standardisation association, Finnish standard	Finland
SUVA	**S**chweizerische **U**nfallversicherungs-**A**nstalt Swiss accident insurance federal agency	Switzerland
TÜV	**T**echnischer **Ü**berwachungsverein Technical inspection association	Germany
UL	**U**nderwriters' **L**aboratories Inc.	USA
UTE	**U**nion **T**echnique de l'**E**lectricité Electrotechnical federation	France
VDE	Verband der Elektrotechnik, Elektronik, Informationstechnik (**V**erband **D**eutscher **E**lektrotechniker) Association of electrical, electronics and information technology	Germany
ZVEI	**Z**entralverband **E**lektrotechnik- und Elektronikindustrie Central association of the electrical and electronic industry	Germany

Export to World Markets and North America

Testing Agencies and Certification Marks

Testing agencies and certification marks encountered in Europe and North America

Nearly all of Eaton's electrical components in the Moeller line are compliant with global standards, including those in the USA and Canada.

Some components, like e.g. circuit-breakers, meet all relevant international standards in their base model versions and can be universally applied, except in the USA and Canada. A special line of circuit breakers, certified to UL and CSA standards, is available for export to North America.

An up-to-date listing of all component certifications and classifications can be accessed via the Internet:
Eaton.com/approvals

In some cases, certain country specific installation and operational requirements, wiring materials and practices, as well as special circumstances such as unusual environmental conditions, must be taken into consideration.

As of January 1997, all electrical equipment built in accordance with the European Low Voltage

Directive and destined for sale in the European Union must bear a CE mark.

The CE mark verifies that the marked component meets all the provisions of the relevant standards and requirements pertaining to that product. The marking obligation thus enables components to gain unfettered access to the European market place.

Because CE marked components are constructed in accordance with harmonized standards, certification in individual countries within the European Union is no longer necessary.

An exception would be components that could also be installed in non-industrial environments. Accordingly, components such as miniature circuit breakers and residual current protective devices are often expected to bear national certification marks. The following table provides a selection of the most commonly encountered certification marks from international testing authorities.

Export to World Markets and North America

Testing Agencies and Certification Marks

Country	Testing Authority	Certification Mark
Austria	Österreichischer Verband für Elektrotechnik (ÖVE)	
Belgium	Comité Electrotechnique Belge Belgisch Elektrotechnisch Comité (CEBEC)	
Canada	Canadian Standards Association (CSA)	
China	China Compulsory Certification (CCC)	
Denmark	Danmarks Elektriske Materielkontrol (DEMKO)	
Finland	FIMKO	
France	Union Technique de l'Electricité (UTE)	
Germany	Association of electical, electronics and information technology	
Great Britain	UK Conformity Assessed	
Netherlands	Naamloze Vennootschap tot Keuring van Electrotechnische Materialien (KEMA)	
Norway	Norges Elektriske Materiellkontrol (NEMKO)	
Russia	Eurasian Economic Union	
Sweden	Svenska Elektriska Materielkontrollanstalten (SEMKO)	
Switzerland	Schweizerischer Elektrotechnischer Verein (SEV)	
Ukraine	UkrSEPRO Certificate of Conformity Ukraine	
USA	Underwriters Laboratories Listing Recognition	

Device designations in the USA and Canada to NEMA ICS 19-2002 (R 2021), ANSI Y32.2/IEEE 315/315 A

Suitable prefix numbers and/or letters, and suffix letters may be added to the basic device designations to differentiate between components performing similar functions.

Where two or more basic device designations are combined, the function designation is normally given first.

Example:

The first control relay initiating a jog function is designated: "1JCR", where:

1 = number prefix

J = Jogging function of the component

CR = The type of component is a Control Relay (Contactor Relay).

Device or function designation letters in accordance with NEMA ICS 19-2002 (R 2021)

Designation	Device or function
A	Accelerating
AM	Ammeter
B	Braking
C or CAP	Capacitor, capacitance
CB	Circuit-breaker
CR	Control relay
CT	Current transformer
DM	Demand meter
D	Diode
DS or DISC	Disconnect switch
DB	Dynamic braking
FA	Field accelerating
FC	Field contactor
FD	Field decelerating
FL	Field-loss
F or FWD	Forward
FM	Frequency meter
FU	Fuse
GP	Ground protective
H	Hoist
J	Jog
LS	Limit switch
L	Lower
M	Main contactor
MCR	Master control relay

Export to World Markets and North America

Identification of electrical equipment in North America

Designation	Device or function
MS	Master switch
OC	Overcurrent
OL	Overload
P	Plugging, potentiometer
PFM	Power factor meter
PB	Pushbutton
PS	Pressure switch
REC	Rectifier
R or RES	Resistor, resistance
REV	Reverse
RH	Rheostat
SS	Selector switch
SCR	Silicon controlled rectifier
SV	Solenoid valve
SC	Squirrel cage
S	Starting contactor
SU	Suppressor
TACH	Tachometer generator
TB	Terminal block, board
TR	Time-delay relay
Q	Transistor
UV	Undervoltage
VM	Voltmeter
WHM	Watthour meter
WM	Wattmeter
X	Reactor, reactance

The use of class designation code letters to appropriate ANSI/IEEE standards is permissible as an alternative to device designations per NEMA ICS19-2002 (R 2021). Class designation code letters should simplify harmonization with international standards. The code letters are, in part, similar to those of IEC 81346-1:2022 .

Class designation code letter to ANSI Y32.2/IEEE 315, 315 A

Code letter	Device or function
A	Separate Assembly
B	Induction Machine, Squirrel Cage Induction Motor Synchro, General • Control Transformer • Control Transmitter • Control Receiver • Differential Receiver • Differential Transmitter • Receiver • Torque Receiver • Torque Transmitter Synchronous Motor Wound-Rotor Induction Motor or Induction Frequency Converter
BT	Battery
C	Capacitor • Capacitor, General • Polarized Capacitor Shielded Capacitor
CB	Circuit-Breaker (all)

Export to World Markets and North America

Identification of electrical equipment in North America

Code letter	Device or function
D, CR	Diode • Bidirectional Breakdown Diode • Full Wave Bridge Rectifier • Metallic Rectifier • Semiconductor Photosensitive • Cell • Semiconductor Rectifier • Tunnel Diode • Unidirectional Breakdown Diode
D, VR	Zener Diode
DS	Annunciator Light Emitting Diode Lamp • Fluorescent Lamp • Incandescent Lamp • Indicating Lamp
E	Armature (Commutor and Brushes) Lightning Arrester Contact • Electrical Contact • Fixed Contact • Momentary Contact Core • Magnetic Core Horn Gap Permanent Magnet Terminal Not Connected Conductor

Export to World Markets and North America

Identification of electrical equipment in North America

Code letter	Device or function
F	Fuse
G	Rotary Amplifier (all) A.C. Generator Induction Machine, Squirrel Cage Induction Generator
HR	Thermal Element Actuating Device
J	Female Disconnecting Device Female Receptacle
K	Contactor, Relay
L	Coil • Blowout Coil • Brake Coil • Operating Coil Field • Commutating Field • Compensating Field • Generator or Motor Field • Separately Excited Field • Series Field • Shunt Field Inductor Saturable Core Reactor Winding, General
LS	Audible Signal Device • Bell • Buzzer • Horn
M	Meter, Instrument

Export to World Markets and North America

Identification of electrical equipment in North America

Code letter	Device or function
P	• Male Disconnecting Device • Male Receptable
Q	Thyristor • NPN Transistor • PNP Transistor
R	Resistor • Adjustable Resistor • Heating Resistor • Tapped Resistor • Rheostat Shunt • Instrumental Shunt • Relay Shunt
S	Contact • Time Closing Contact • Time Opening Contact • Time Sequence Contact • Transfer Contact • Basic Contact Assembly • Flasher

Code letter	Device or function
S	Switch • Combination Locking and Non-locking Switch • Disconnect Switch • Double Throw Switch • Drum Switch • Flow-Actuated Switch • Foot Operated Switch • Key-Type Switch • Knife Switch • Limit Switch • Liquid-Level Actuated Switch • Locking Switch • Master Switch • Mushroom Head • Operated Switch • Pressure or Vacuum • Operated Switch • Pushbutton Switch • Pushbutton Illuminated Switch, Rotary Switch • Selector Switch • Single-Throw Switch • Speed Switch Stepping Switch • Temperature-Actuated Switch • Time Delay Switch • Toggle Switch • Transfer Switch • Wobble Stick Switch Thermostat

Export to World Markets and North America

Identification of electrical equipment in North America

Code letter	Device or function
T	Transformer • Current Transformer • Transformer, General • Polyphase Transformer • Potential Transformer
TB	Terminal Board
TC	Thermocouple
U	Inseparable Assembly
V	Pentode, Equipotential Cathode Phototube, Single Unit, Vacuum Type Triode Tube, Mercury Pool
W	Conductor • Associated • Multiconductor • Shielded Conductor, General
X	Tube Socket

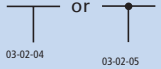
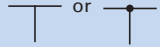
Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Electrical circuit symbols to DIN EN, NEMA ICS/ANSI/IEEE/CSA

The following comparison of electrical circuit symbols is based on the following international/national specifications:

- IEC 60617 graphic symbol database (DIN EN 60617-2 to DIN EN 60617-12)
- NEMA ICS 19-2002 (R 2021), ANSI Y32.2/ IEEE 315/315 A, CSA Z99

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Conductors, connectors		
Junction of conductors	 03-02-04 03-02-05	
Connection of conductors (node)	03-02-01	
Terminal	03-02-02	
Terminal strip/block	03-02-03	
Conductors	03-01-01	

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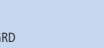
Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Conductor (for later expansion)	103-01-01	
Line of application, general symbol	02-12-01	
Line of application, optional, denoting small interval	02-12-04	
Separation between two fields	02-01-06	
Line of separation between functional units	02-01-06	
Shielding	02-01-07	
Earth, general symbol ground, general symbol	02-15-01	 GRD
Protective earth protective ground	02-15-03	
Connector with plug and socket	or 03-03-05 03-03-06	
Isolating point, lug, closed	03-03-18	

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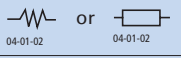
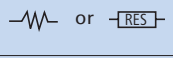
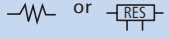
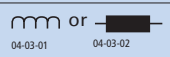
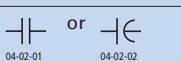
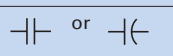
Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Passive components		
Resistor, general symbol		
Resistor with fixed tappings		
Variable resistor, general		
Adjustable resistor		
Resistor with sliding contact, potentiometer		
Winding, inductance, general		
Winding with fixed tapping		
Capacitor, general symbol		
Variable capacitor		

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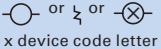
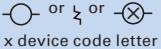
Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Control circuit devices		
Visual indicator, general symbol		*with color stated
Indicator light, general symbol	08-10-01	or or *with color stated
Buzzers	or 08-10-11 08-10-10	ABU
Horn, claxon	08-10-05	HN
Drives		
Manual operation, general use	02-13-01	
Operated by pushing	02-13-05	
Operated by pulling	02-13-03	
Operated by turning	02-13-04	
Operated by key	02-13-13	
Operated by rollers, sensors	02-13-15	

Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Stored energy mechanism, general symbol	02-13-20	
Switch mechanism with mechanical release	102-05-04	
Operated by motor	02-13-26	
Emergency switch	02-13-08	
Operated by electromagnetic overcurrent protection	02-13-24	
Operated by thermal overcurrent protection	02-13-25	
Electromagnetic operation	02-13-23	
Control by fluid level	02-14-01	
Electromechanical, electromagnetic operating devices		
Electromechanical operating device, general symbol, relay coil, general symbol	07-15-01	 x device code letter → table, page 9-16
Operating device with special features, general symbol		 x device code letter → table, page 9-16

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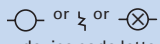
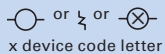
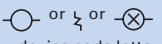
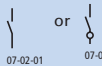
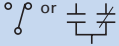
Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Electromechanical operating device with On-delay	07-15-08	 x device code letter →table, page 9-16
Electromechanical device with Off-delay	07-15-07	 x device code letter →table, page 9-16
Electromechanical device with On- and Off-delay	07-15-09	 x device code letter →table, page 9-16
Electromechanical device of a thermal relay	07-15-21	
Contacts		
N/O contact	 07-02-01 07-02-02	
N/C contact	07-02-03	
Changeover contact with interruption	07-02-04	
Early-make N/O contact of a contact assembly	07-04-01	
Late-break N/C contact of a contact assembly	07-04-03	

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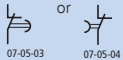
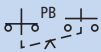
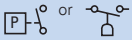
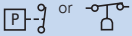
Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
N/O contact, delayed when closing		
N/C contact, delayed when reclosing		
Control devices		
Push-button (not stay-put)		
Spring-return switches with N/C contact, manually operated by pushing, e.g. push-button		
Spring-return switches with N/O and N/C contacts, manually operated by pushing		
Spring-return switches with latching position and one N/O contact, manually operated by pushing		
Spring-return switches with latching position and one N/C contact, manually operated by striking (e.g. mushroom button)		
Position switches (N/O contacts) Limit switches (N/O contacts)		
Position switches (N/C contacts) Limit switches (N/C contacts)		
Spring-return switches with N/O contacts, mechanically operated, N/O contacts closed		

Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Spring-return switches with N/C contacts, mechanically operated, N/C contacts open		
Proximity switches (N/C contacts), actuated by the proximity of iron		
Proximity switches, inductive, N/O contacts		
Proximity switches, block diagram		
Under-pressure relays, N/O contacts		
Pressure switches, N/C contact		
Float switches, N/O contact		
Float switches, N/C contact		

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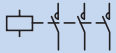
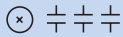
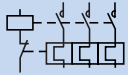
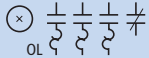
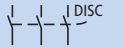
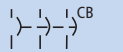
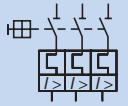
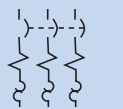
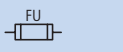
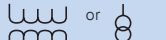
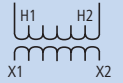
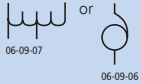
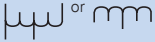
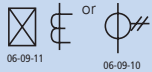
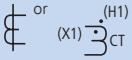
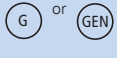
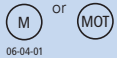
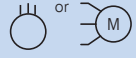
Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Switchgear		
Contactors (N/O contacts)	 07-13-02	 x code letter
Three-pole contactor with bimetal relay (3 thermal elements)		 OL x code letter
Three-pole switch-disconnector	07-13-06	 DISC
Three-pole circuit-breaker	07-13-05	 CB
Three-pole breaker with switch mechanism with three thermoelectric overcurrent releases, three electromagnetic overcurrent releases, motor-protective circuit-breaker	 107-05-01	
Fuse, general symbol	07-21-01	 FU
Transformers, current transformers		
Transformers with two windings	 06-09-02 or 06-09-01	 H1 H2 X1 X2

Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Autotransformer		
Current transformer		
Machines		
Generator		
Motor, general symbol		
DC motor, general symbol		
AC motor, general symbol		
Three-phase asynchronous motor with squirrel-cage rotor		
Three-phase asynchronous motor with slip-ring rotor		

Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Semiconductor components		
Static input		
Static output		
Static input with negation	12-07-01	
Static output with negation	12-07-02	
Dynamic input, change of status from 0 to 1 (L/H)	12-07-07	
Dynamic input with negation, change of status from 1 to 0 (H/L)	12-07-08	
AND gate, general symbol	12-27-02	
OR gate, general symbol	12-27-01	
NOT gate, inverter	12-27-11	
AND with negated output, NAND		
OR with negated output, NOR		

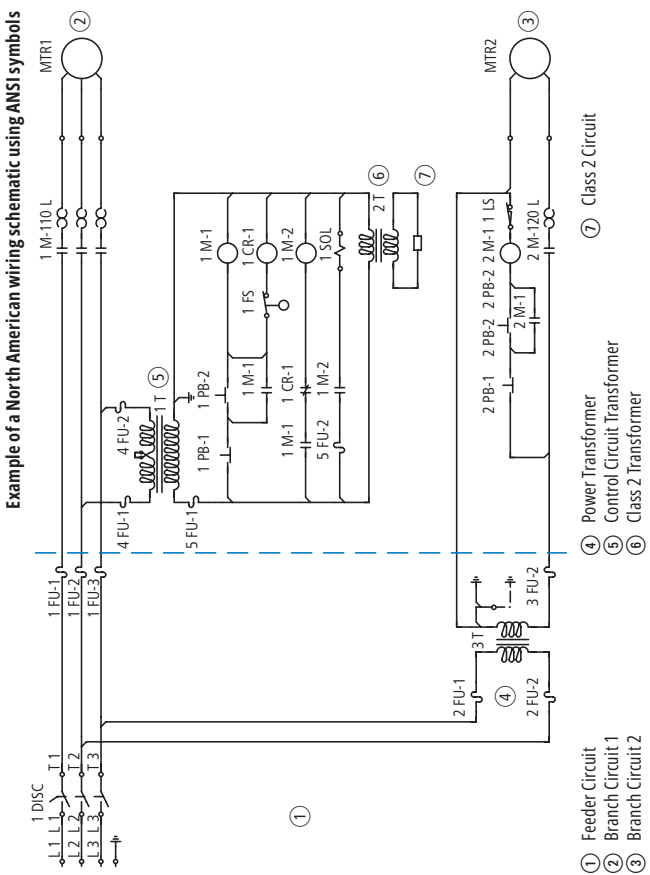
Export to World Markets and North America

Electrical circuit symbols, Europe – North America

Description	IEC (DIN EN)	NEMA ICS/ANSI/IEEE
Exclusive OR gate, general	12-27-09	
RS flip-flop	12-42-01	
Monostable gate, cannot be triggered during the output pulse, general symbol	12-44-02	
Delay, variable with indication of delay values	02-08-05	
Semiconductor diode, general symbol	05-03-01	
Limiting diode Zener diode	05-03-06	
Light-emitting diode (LED), general symbol	05-03-02	
Bi-directional diode, diac	05-03-09	
Thyristor, general symbol	05-04-04	
PNP transistor	05-05-01	
NPN transistor, in which the collector is connected to the enclosure	05-05-02	

Export to World Markets and North America

Circuit diagram examples using North American graphic symbols



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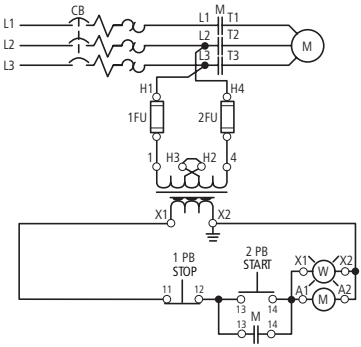
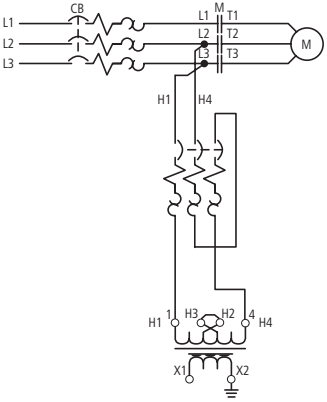
Circuit diagram examples using North American graphic symbols

Direct motor starters, fuseless with circuit-breakers

Control circuit with fuse



Control circuit, fuseless



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Export to World Markets and North America

North American classification for control circuit contact ratings

Classification	Designation At maximum rated voltage of			Thermal uninterrupted current
AC voltage	600 V	300 V	150 V	A
Heavy duty	A600 A600 A600 A600	A300 A300 – –	A150 – – –	10 10 10 10
Standard duty	B600 B600 B600 B600	B300 B300 – –	B150 – – –	5 5 5 5
	C600 C600 C600 C600	C300 C300 – –	C150 – – –	2.5 2.5 2.5 2.5
	– –	D300 D300	D150 –	1 1
DC voltage				
Heavy duty	N600 N600 N600	N300 N300 –	N150 – –	10 10 10
Standard duty	P600 P600 P600	P300 P300 –	P150 – –	5 5 5
	Q600 Q600 Q600	Q300 Q300 –	Q150 – –	2.5 2.5 2.5
	– – –	R300 R300 –	R150 – –	1.0 1.0 –

to UL 508, CSA C 22.2-14 and NEMA ICS 5

Export to World Markets and North America

North American classification for control circuit contact ratings

Switching capacity				
Rated voltage V	Make A	Break A	Make VA	Break VA
120	60	6	7200	720
240	30	3	7200	720
480	15	1.5	7200	720
600	12	1.2	7200	720
120	30	3	3600	360
240	15	1.5	3600	360
480	7.5	0.75	3600	360
600	6	0.6	3600	360
120	15	1.5	1800	180
240	7.5	0.75	1800	180
480	3.75	0.375	1800	180
600	3	0.3	1800	180
120	3.6	0.6	432	72
240	1.8	0.3	432	72
125	2.2	2.2	275	275
250	1.1	1.1	275	275
301 – 600	0.4	0.4	275	275
125	1.1	1.1	138	138
250	0.55	0.55	138	138
301 – 600	0.2	0.2	138	138
125	0.55	0.55	69	69
250	0.27	0.27	69	69
301 – 600	0.10	0.10	69	69
125	0.22	0.22	28	28
250	0.11	0.11	28	28
301 – 600	–	–	–	–

Export to World Markets and North America

North American motor full load current ratings (FLC)

Full Load Currents, North American Three-Phase Alternating-Current Motors[1)]

Motor rating	Motor full load currents in amperes[2)]			
HP	115 V 120 V	230 V 240 V	460 V 480 V	575 V 600 V
½	4.4	2.2	1.1	0.9
¾	6.4	3.2	1.6	1.3
1	8.4	4.2	2.1	1.7
1½	12	6.0	3.0	2.4
2	13.6	6.8	3.4	2.7
3		9.6	4.8	3.9
5		15.2	7.6	6.1
7½		22	11	9
10		28	14	11
15		42	21	17
20		54	27	22
25		68	34	27
30		80	40	32
40		104	52	41
50		130	65	52
60		154	77	62
75		192	96	77
100		248	124	99
125		312	156	125
150		360	180	144
200		480	240	192
250			302	242
300			361	289
350			414	336
400			477	382
450			515	412
500			590	472

[1)] Source: NEC Code, table 430-250, with additional full load current values for 208 V and 200 V motors.

[2)] The full load current values provided in the tables are used as guidelines for equipment selection. Also consult motor manufacturer data and actual motor nameplate ratings.

Export to World Markets and North America

North American environmental type ratings for electrical equipment

Comparison of North American and IEC/EN environmental ratings for electrical equipment

IP ratings per IEC/EN standards cannot be used as a substitute for North American Type ratings. **The IP ratings shown represent a rough comparison only**. A precise conversion is not possible since tests and evaluation criteria in the relevant standards differ greatly from one another. UL/CSA and NEMA type ratings are often used interchangeably. The significant difference between the two is that a

UL/CSA type rating represents third party certification by an approved testing agency, which is the preferred manner in which ratings are verified in North America.

North American environmental type ratings are referenced in the following standards:

- NFPA 70 (National Electrical Code),
- CEC (Canadian Electrical Code),
- UL 50E, UL 508A,
- CSA-C22.2 No. 94-M91 (2011),
- NEMA 250-2008 (National Electrical Manufacturers Association).

North American environmental Type ratings	Application	Rough equivalency to IP ratings per IEC/EN 60529, DIN 40050
UL/CSA Type 1 Incidental contact with enclosed equipment; falling dirt	Indoor use	IP20
UL/CSA Type 2 Driptight	Indoor use	IP22
UL/CSA Type 3 Dusttight, raintight, degree of protection against rain, snow and sleet	Outdoor use	IP55
UL/CSA Type 3 R Rainproof, degree of protection against rain, snow and sleet	Outdoor use	IP24
UL/CSA Type 3 S Dust-tight, rain-tight, protection against sleet and ice	Outdoor use	IP55

Export to World Markets and North America

North American environmental type ratings for electrical equipment

North American environmental Type ratings	Application	Rough equivalency to IP ratings per IEC/EN 60529, DIN 40050
UL/CSA Type 3 X, 3 RX, 3 SX same as 3, 3 R and 3 S, but with corrosion resistance	Outdoor use	IP55
UL/CSA Type 4 Watertight, raintight, dusttight	Indoor or Outdoor use[1)]	IP66
UL/CSA Type 4 X Watertight, raintight, dusttight, corrosion resistant	Indoor or Outdoor use[1)]	IP66
UL/CSA Type 5 Driptight, dusttight	Indoor use	IP53
UL/CSA Type 6 Raintight, watertight, temporarily submersible	Indoor or Outdoor use[1)]	IP67
UL/CSA Type 12 Common industrial rating, driptight, dusttight	Indoor use	IP54
UL/CSA Type 13 driptight, dusttight, oiltight	Indoor use	IP54

[1)] Take note of manufacturer instructions!

Export to World Markets and North America

North American environmental type ratings for electrical equipment

Terms German/English:

General purpose	general purpose
tropfdicht	drip-tight
staubdicht	dust-tight
regendicht	rain-tight
regensicher	rain-proof
wettersicher	weather-proof
wasserdicht	water-tight
eintauchbar	submersible
eisbeständig	ice resistant
hagelbeständig	sleet resistant
korrosionsbeständig	corrosion resistant
öldicht	oil-tight

Export to World Markets and North America

North American conductor cross-sections

Conversion of North American cable cross sections into mm²

USA/Canada	Europe	
AWG	**mm² (exact)**	**mm² (nearest standard size)**
22	0.324	0.4
20	0.519	0.5
18	0.823	0.75
16	1.31	1.5
14	2.08	
12	3.31	4
10	5.261	6
8	8.367	10
6	13.30	16
4	21.15	25
3	26.67	
2	33.62	35
1	42.41	
1/0 (0)	53.49	50
2/0 (00)	67.43	70
3/0 (000)	85.01	
4/0 (0000)	107.2	95

Export to World Markets and North America

North American conductor cross-sections

USA/Canada	Europe	
kcmil	mm^2 (exact)	mm^2 (nearest standard size)
250	127	120
300	152	150
350	177	185
400	203	
450	228	
500	253	240
550	279	
600	304	300
650	329	
700	355	
750	380	
800	405	
900	456	
1,000	507	500

In addition to “circular mills”, cable sizes are often given in “MCM”:
250 000 circular mills = 250 MCM

Notes

Standards, formulae, tables

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Standards, formulae, tables
Marking of electrical equipment

General

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Marking of the devices in wiring diagrams to DIN EN IEC 81346-2

10

Eaton uses the above international standard.

Example of a resistor

- Normal current limiter: R
- Heater resistor: E
- Measurement resistor: B

Additional equipment

- Circuit-breakers with the main function of protection are marked with Q. They are numbered from 1 to 10 from the top left.
- Contactors are marked with Q and numbered from 11 to nn.
- Contactor are marked with K and are numbered from 1 to n.

The marking appears in a suitable position as close as possible to the circuit symbol.

The marking forms the link between the equipment in the installation and the various circuit documents (wiring diagrams, parts lists, circuit diagrams, instructions).

Selected equipment of the Eaton used code letters →Table, page 10-3

Standards, formulae, tables
Marking of electrical equipment

Code letter	Purpose	Examples for electrical equipment
A	(several purposes)	(without main purpose)
B	Signal generation	Pressure switches; limit switches
C	Storage	Capacitors
D	(reserved for later)	
E	Energy supply	Heating resistor, lamps
F	Protection	Bimetal releases, fuses
G	Power supply	Generator, UPS
H	(reserved for later)	
I	(must not be used)	
J	(reserved for later)	
KP	Signal processing	Contactor relay, timing relays
L	(reserved for later)	
M	Drive energy	Motor
N	(reserved for later)	
O	(must not be used)	
P	Information display	Signalling and measuring devices
Q	Switching energy/ signal flow	Soft starter, contactor, motor starter
R	Energy flow limitation	Reactor coils, diodes
S	Manual signal generation	Control circuit devices
T	Energy conversion	Frequency inverters, transformer
U	Object fixing	
V	Material processing	Electro filter
W	Power transmission	
X	Object connection	Terminal, plug connector
Y, Z	(reserved for later)	

Standards, formulae, tables
Protective measures

Protection against electrical shock to DIN IEC 60364-1 (DIN VDE 0100-100)

This divides between different types of protection:

- **Basic protection**
  These are all the measures for the protection of personnel and working animals from dangers which may arise from contact with live parts of electrical equipment.
- **Fault protection**
  This is the protection of personnel and working animals from fault scenarios which may arise from accidental contact with components or extraneous conductive parts.
- **Additional protection**
  If basic or fault protection fails or there is a greater potential danger, residual current protective devices with $I_{\triangle n} \leqq 30$ mA offer additional protection.

Protection must be ensured by either
a) the equipment itself or
b) the use of protective measures when erecting the installation or
c) a combination of a) and b).

If basic, fault and additional protection is combined in a suitable manner the following protective measures result and are covered in section 410 of DIN VDE 0100:

- Automatic disconnection of the power supply (DIN VDE 0100-411)
- Double or reinforced insulation (DIN VDE 0100-412)
- Protective separation (DIN VDE 0100-413)
- Safety extra low voltage SELV or PELV (DIN VDE 0100-414)

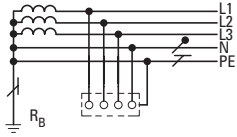
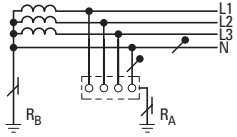
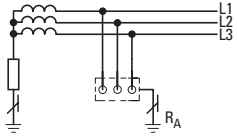
One of the key amendments to DIN VDE 0100-410 was the additional protection for final circuits for outdoor areas and sockets (section 411.3.3). This stipulates that an additional protection must be provided by means of residual current devices (RCDs) with $I_{\triangle n} \leqq 30$ mA for sockets, as well as final current circuits for portable equipment $\leqq 32$ A used outdoors.

Standards, formulae, tables
Protective measures

Protection against indirect contact by means of disconnection or indication

The conditions for disconnection are determined by the type of system in use and the protective device selected.

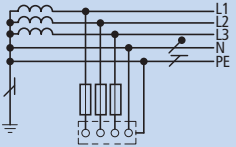
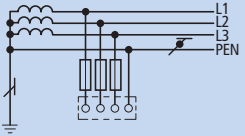
Systems to DIN IEC 60364-1 (DIN VDE 0100-100)

Earth continuity type systems	Meaning of designation
TN system 	T: Direct earthing of a point N: Chassis (of electrical equipment) directly connected with the power supply system earth
TT system 	T: Direct earthing of a point T: Direct electrical connection of chassis to earth, independent of any existing earthing of the power supply system
IT system 	I: All live parts isolated from earth or one point connected to earth via a high impedance T: Direct electrical connection of chassis to earth, independent of any existing earthing of the power supply system

R_B Earthing on the current source
R_A Earthing on chassis of electrical equipment

Standards, formulae, tables
Protective measures

Protective devices and conditions for disconnection to DIN IEC 60364-1 (DIN VDE 0100-100)

Type of distribution system	**TN system**	
Protection with	Circuit principle	Condition for disconnection
Overcurrent protective device	TN-S system separated neutral and protective conductors throughout the system  	$Z_s \times I_a \leqq U_0$ with Z_s = Impedance of the fault circuit I_a = Current, which causes switch off in (conform to DIN VDE 0100-411.3.2): • ≦ 5 s • ≦ 0.2 s U_0 = rated voltage against earthed conductor
Fuses, miniature circuit-breakers, circuit-breakers	TN-C system Neutral conductor and protection functions are combined throughout the system in a single PEN conductor.  	

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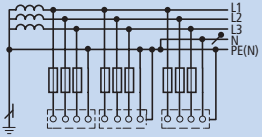
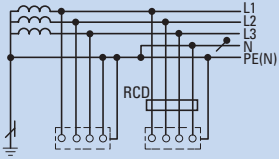
Standards, formulae, tables
Protective measures

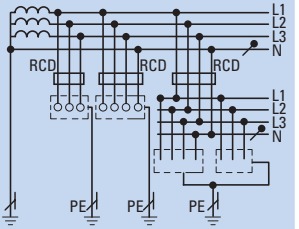
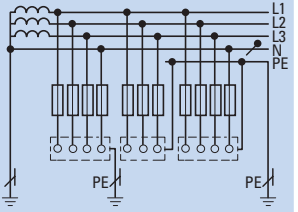
Protective devices and conditions for disconnection to DIN IEC 60364-1 (DIN VDE 0100-100) or DIN IEC 60364-4-41 (DIN VDE 0100-410)

Type of distribution system	**TN system**	
Protection with	Circuit principle	Condition for disconnection
Overcurrent protective device	TN-C-S system Neutral conductor and protective conductor functions are in a part of the system combined in a single PEN conductor. 	
Fault current protective device		$Z_s \times I_{\triangle n} \leqq U_0$ with $I_{\triangle n}$ = Rated fault current U_0 = Maximum permissible touch voltage[1]: (≦ 50 V AC, ≦ 120 V DC)

[1] →Table, page 10-11

Standards, formulae, tables
Protective measures

Protective devices and conditions for disconnection to DIN IEC 60364-1 (DIN VDE 0100-100) or DIN IEC 60364-4-41 (DIN VDE 0100-410)

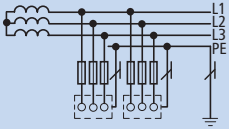
Type of distribution system	**TT system**	
Protection with	Circuit principle	Conditions for indication/disconnection
Residual current device (General case)		$R_A \times I_{\triangle n} \leqq U_L$ with R_A = Earthing resistance of conductive parts of the chassis (total) $I_{\triangle n}$ = Rated fault current U_L = Maximum permissible touch voltage[1]: (≦ 50 V AC, ≦ 120 V DC)
Overcurrent protective device Fuses, miniature circuit-breakers, circuit-breakers (special case)		$R_A \times I_a \leqq U_L$ with I_a = Current which causes automatic disconnection in ≦ 5 s

[1] → Table, page 10-11

10

Standards, formulae, tables
Protective measures

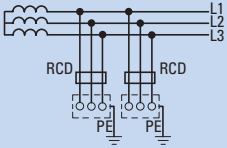
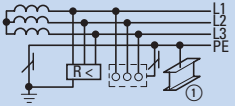
Protective devices and conditions for disconnection to DIN IEC 60364-1 (DIN VDE 0100-100)

Type of distribution system	**TN system**	
Protection with	Circuit principle	Conditions for indication/ disconnection
Overcurrent protective device (always with additional insulation monitoring device, see below)		$R_A \times I_d \leqq U_L$ (1) $Z_S \times I_a \leqq Uo$ (2) R_A = Earthing resistance of all conductive parts connected to an earth I_d = Fault current in the event of the first fault with a negligible impedance between a phase conductor and the protective conductor or element connected to it U_L = Maximum permissible touch voltage[1]: ≦ 50 V AC, ≦ 120 V DC

[1] →Table, page 10-11

Standards, formulae, tables
Protective measures

Protective devices and conditions for disconnection to DIN IEC 60364-1 (DIN VDE 0100-100) or DIN IEC 60364-4-41 (DIN VDE 0100-410)

Type of distribution system	**IT system**	
Protection with	Circuit principle	Conditions for indication/disconnection
Residual current device (RCD) (always with additional insulation monitoring device, see below)		$R_A \times I_{\triangle n} \leqq U_L$ $I_{\triangle n}$ = Rated fault current
Insulation monitoring device (IMD)	 ① additional potential equalization	The insulation monitoring device is used to display the insulation state of all live parts to earth. An indication (visual/acoustic) is generated if the resistance goes below a specific value (R). The system is not disconnected but remains operational until a second earth fault occurs and the automatic disconnection takes place.

Standards, formulae, tables
Protective measures

The protective device must automatically disconnect the faulty part of the installation. At no part of the installation may there be a touch voltage or an effective duration greater than that specified in the table below.

Maximum disconnection times (s) as a function of the rated voltage. Phase conductors to earth and the system in accordance with DIN IEC 60364-4-41 (DIN VDE 0100-410)

		System	
		TN Max. permissible disconnection time [s]	**DD** Max. permissible disconnection time [s]
50 V < U_0 ≦ 120 V	AC	0.8	0.3
	DC	(see note)	(see note)
120 V < U_0 ≦ 230 V	AC	0.4	0.2
	DC	1.0	0.4
230 V < U_0 ≦ 400 V	AC	0.2	0.07
	DC	0.4	0.2
U_0 > 400 V	AC	0.1	0.04
	DC	0.1	0.1

U_0 is the rated operating voltage phase conductor to earth.

Note:

A disconnection may be necessary for different reasons than the protection from electric shock.

Standards, formulae, tables
Overcurrent protection of cables and conductors

Cables and conductors must be protected by means of overcurrent protective devices against excessive temperature rises, which may result both from operational overloading and from short-circuit.

Overload protection

Overload protection involves the provision of protective devices which will interrupt overload currents in the conductors of a circuit before they can cause temperature rises which may damage the conductor insulation, the terminals and connections or the area around the conductors.

For the protection of conductors against overload the following conditions must be fulfilled (source: DIN IEC 60364-4-43 (DIN VDE 0100-430))

$I_B \leqq I_n \leqq I_Z$

$I_2 \leqq 1.45\ I_Z$

I_B Anticipated operating current of the circuit

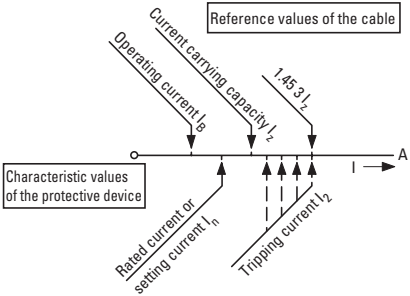
I_Z Current carrying capacity of conductor or cable

I_n Rated operational current of the protective device

Remark:

For adjustable protective devices, I_n corresponds to the value set.

I_2 The current which causes tripping of the protective device under the conditions specified in the equipment regulations.



Arrangement of overload protective devices

Protection devices for overload protection must be fitted at the start of every circuit and at every point where the current carrying capacity is reduced unless an upstream protection device can ensure protection.

Standards, formulae, tables
Overcurrent protection of cables and conductors

Note:

Reasons for the current carrying capacity being reduced:

Reduction of the conductor cross-section, a different installation method, different conductor insulation, a different number of conductors.

Protective devices for overload protection should not be fitted if interruption of the circuit could prove hazardous. The circuits must be laid out in such a way that no possibility of overload currents occurring need be considered.

Examples:
Timing relay = function relay with contacts and coils
Time switch = function relay with contacts

- Energizing circuits for rotating machines
- Feeder circuits of solenoids
- Secondary circuits of current transformers
- Circuits for safety purposes

Short-circuit protection

Short-circuit protection means providing protective devices which will interrupt short-circuit currents in the conductors of a circuit before they can cause a temperature rise which may damage the conductor insulation, the terminals and connections, or the area around the cables and conductors. In general, the permissible disconnection time t for short circuits of up to 5 s duration can be specified approximately using the following equation:

$$t = \left(k \times \frac{S}{I}\right)^2 \quad \text{or} \quad I^2 \times t = k^2 \times S^2$$

The meaning of the symbols is as follows:

t: Permissible disconnection time in the event of short-circuit in s
S: Conductor cross-section in mm2
I: r.m.s. value of the current with a maximum short-circuit in A
k: Constants with the values, if not stated different by cable manufacturer
- 115 for PVC-insulated copper conductors
- 76 for PVC-insulated aluminum conductors
- 141 for rubber-insulated copper conductors
- 93 for rubber-insulated aluminum conductors
- 115 for soft-solder connections in copper conductors
- Other values for k are given in Table 43A of DIN IEC 60364-4-43 (DIN VDE 0100-430).

With very short permissible disconnection times (< 0.1 s) the product from the equation $k^2 \times S^2$ must be greater than the $I^2 \times t$ value of the current-limiting device stated by manufacturer.

Arrangement of protective devices for protection in the event of a short-circuit.
Protective devices for protection in the event of a short-circuit must be fitted at the start of every circuit and at every point at which the short-circuit current-carrying capacity is reduced (reduction of the conductor cross-section), unless a protective device fitted upstream can no longer ensure the necessary protection in the event of a short circuit.

Note:

Reasons for the reduction in the shortcircuit current-carrying capacity can be:
Reduction of the conductor cross-section, other conductor insulation.

Short-circuit protection must not be provided where an interruption of the circuit could prove hazardous. In these cases two requirements must be fulfilled:

- The cable must be laid so that the risk of short-circuits is reduced to a minimum.
- The cable must not be laid in the vicinity of flammable materials.

Protection of the main poles and the neutral conductors

Protection of the main poles

Overcurrent protection devices must be provided in every main pole: they must disconnect the conductor in which the overcurrent occurs, but not necessarily also disconnect the other live conductors.

Note:

Where the disconnection of an individual main pole could prove hazardous, as for example, with three-phase motors, suitable precautions must be taken. Motorprotective circuit-breakers and circuit-breakers disconnect in 3 poles as standard.

Protection of the neutral conductor:

1. In installations with a directly earthed neutral point (**TN** or **TT systems**)

Where the cross-section of the neutral conductor is less than that of the main poles, an overcurrent monitoring device appropriate to its cross-section is to be provided in the neutral conductor; this overcurrent monitoring device must result in the disconnection of the phase conductors but not necessarily that of the neutral conductor.

An overcurrent monitoring device in the neutral conductor is not necessary where:

- the neutral conductor is protected in the event of a short-circuit by the protective device for the main poles
- the largest current which can flow through the neutral conductor is, in normal operation, considerably less than the current carrying capacity of this conductor.

Note:

This second condition is met provided that the power transferred is divided as evenly as possible among the main poles, for example where the total power consumption of the load connected between phase and neutral conductors, lamps and socket outlets is much less than the total power transferred via the circuit.

Standards, formulae, tables
Overcurrent protection of cables and conductors

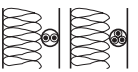
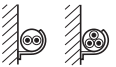
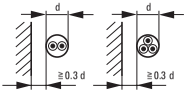
2. In installations without a directly earthed neutral point **(IT system)**

Where it is necessary for the neutral conductor to be included, **an overcurrent monitoring device must be provided in the neutral conductor of each circuit**, to cause disconnection of all live conductors in the relevant circuit (including the neutral conductor).

The overcurrent monitoring device may however be omitted where the neutral conductor in question is protected against short-circuit by an upstream protective device, such as in the incoming unit of the installation.

Disconnection of the neutral conductor
Where disconnection of the neutral conductor is specified, the protective device used must be designed in such a way that the neutral conductor cannot under any circumstances be disconnected before the phase conductors and reconnected again after them.
4-pole NZM circuit-breakers always meet these conditions.

Current carrying capacity and protection of cables and conductors with PVC insulation to DIN VDE 0298-4, at 25 °C ambient air temperature

Type of cable or conductor	NYM, NYBUY, NHYRUZY, NYIF, H07V-U, H07V-R, H07V-K, NYIFY								NYY, NYCWY, NYKY, NYM, NYMZ, NYMT, NYBUY, NHYRUZY	
Type of installation	A1 In heat-insulating walls, in cable conduit under the surface		B1 In cable conduits Single-core cables		B2 Multi-core cable		C On a wall		E Exposed	
										
	Multi-core cable under the surface		Cable cores in cable conduit on the wall		Multi-core cable in cable conduit on the wall surface		Single or multi-core cables or insulated cables		Multi-core cables or insulated cables with a minimum clearance of 0.3 x diameter d to wall	
Number of cores	2	3	2	3	2	3	2	3	2	3
	Current-carrying capacity Iz in A for 25 °C ambient air temperature and 70 °C operating temperature.									

Standards, formulae, tables

Overcurrent protection of cables and conductors

Continued

Type of installation	A1				B1				B2				C				E			
Number of cores	2		3		2		3		2		3		2		3		2		3	
Copper conductor cross-section in mm²	I_z	I_n	I_t	I_n	I_z	I_n	I_z	I_n	I_t	I_n	I_z	I_n	I_z	I_n	I_t	I_n	I_t	I_n	I_t	I_n
1.5	16.5	16	14.5	13	18.5	16	16.5	16	17.5	16	16	13	21	20	18.5	16	23	20	19.5	16
2.5	21	20	19.5	16	25	25	22	20	24	20	21	20	29	25	25	25	32	32	27	25
4	28	25	25	25	34	32	30	25	32	25	29	25	38	35	34	32	42	40	36	35
6	36	35	33	32	43	40	38	35	40	35	36	35	49	40	43	40	54	50	46	40
10	49	40	45	40	60	50	53	50	55	50	49	50	67	63	60	63	74	63	64	63
16	65	63	59	50	81	80	72	63	73	63	66	63	90	80	81	80	100	100	85	80
25	85	80	77	63	107	100	94	80	95	80	85	80	119	100	102	100	126	125	107	100
35	105	100	94	80	133	125	117	100	118	100	105	100	146	125	126	125	157	125	134	125
50	126	125	114	100	160	160	142	125	141	125	125	125	178	160	153	125	191	160	162	160
70	160	160	144	125	204	200	181	160	178	160	158	125	226	224	195	160	246	224	208	200
95	193	160	174	160	246	224	219	200	213	200	190	160	273	250	236	224	299	250	252	250
120	223	200	199	160	285	250	253	250	246	224	218	200	317	315	275	250	348	315	293	250

For overcurrent protective devices with a rated operational current In that does not conform to the values given in the table, select the next lower available rated operational current value.

Standards, formulae, tables

Overcurrent protection of cables and conductors

Minimum cross-sections for protective conductors to DIN IEC 60364-5-54 (DIN VDE 0100-540)

Main poles		Protective conductor or PEN conductor[1]		Protective conductor[3] laid seperately		
		Insulated power cables	0.6/1-kV cable with 4 conductors	Protected		Unprotected[2]
mm^2		mm^2	mm^2	mm^2 Cu	Al	mm^2 Cu
To	0.5	0.5	–	2.5	4	4
	0.75	0.75	–	2.5	4	4
	1	1	–	2.5	4	4
	1.5	1.5	1.5	2.5	4	4
	2.5	2.5	2.5	2.5	4	4
	4	4	4	4	4	4
	6	6	6	6	6	6
	10	10	10	10	10	10
	16	16	16	16	16	16
	25	16	16	16	16	16
	35	16	16	16	16	16
	50	25	25	25	25	25
	70	35	35	35	35	35
	95	50	50	50	50	50
	120	70	70	70	70	70
	150	70	70	70	70	70
	185	95	95	95	95	95
	240	–	120	120	120	120
	300	–	150	150	150	150
	400	–	185	185	185	185

[1] PEN conductor ≧ 10 mm^2 Cu or 18 mm^2 Al

[2] It is not permissible to lay aluminum conductors without protection.

[3] With main poles of ≧ 95 mm^2 or more, it is advisable to use non-insulted conductors.

Standards, formulae, tables
Overcurrent protection of cables and conductors

Conversion factors

When the ambient temperature is not 30 °C; to be used for the current carrying capacity of wiring or cables in air to VDE 0298-4 Table 17.

Insulation material[1)]	NR/SR	PVC	EPR
Permissible operating temperature	60 °C	70 °C	80 °C
Ambient air temperature °C	Conversion factors		
10	1.29	1.22	1.18
15	1.22	1.17	1.14
20	1.15	1.12	1.10
25	1.08	1.06	1.05
30	1.00	1.00	1.00
35	0.91	0.94	0.95
40	0.82	0.87	0.89
45	0.71	0.79	0.84
50	0.58	0.71	0.77
55	0.41	0.61	0.71
60	–	0.50	0.63
65	–	0.35	0.55
70	–	–	0.45
75	–	–	0.32

[1)] Higher ambient air temperatures in accordance with information given by the manufacturer

Standards, formulae, tables
Overcurrent protection of cables and conductors

Conversion factors to DIN VDE 0298-4, Table 21

Grouping of several circuits

Arrangement	Number of circuits								
	1	2	3	4	6	9	12	16	20
1 Embedded or enclosed	1.00	0.80	0.70	0.65	0.57	0.50	0.45	0.41	0.38
2 Fixed to walls or floors	1.00	0.85	0.79	0.75	0.72	0.70	0.70	0.70	0.70
3 Fixed under ceilings	0.95	0.81	0.72	0.68	0.64	0.61	0.61	0.61	0.61

Conversion factors for the grouping of multi-core cables or cables on cable troughs or trays as well as for other cases are provided in DIN VDE 0298-4, tables 22 to 27.

Standards, formulae, tables
Electrical equipment of machines

Extract from DIN EN 60204-1 (VDE 0113-1)

This standard is used for the electrical equipment of machines, unless there is a product standard (Type C according to the European Machinery Safety Directive/Regulation) for the type of machine to be equipped.

Safety requirements regarding the protection of personnel, machines and material according to the European Machinery Safety Directive/Regulation are highlighted under the heading "Safety of machines". The degree of possible danger is to be estimated and to document by risk assessment. The standard also includes requirements for equipment, engineering and construction, as well as tests to ensure faultless function and the effectiveness of protective measures. The following paragraphs are an extract from the standard.

Mains isolating device (main switches)

Every machine must be equipped with a manually-operated mains isolating device. It must be possible to isolate the entire electrical equipment of the machine from the mains using the mains isolating device. The breaking capacity must be sufficient to simultaneously disconnect the stalled current of the largest motor in the machine and the total current drawn by all the other loads in normal operation.

Its Off position must be lockable and must not be indicated until the specified clearances and creepage distances between all contacts have been achieved. It must have only one On and one Off position with associated stops.

Star-delta, reversing and multi-speed switches are not permissible for use as mains isolating devices.

The tripped position of circuit-breakers is not regarded as a switch position, therefore there is no restriction on their use as mains isolating devices.

Where there are several incomers, each one must have a mains isolating device. Mutual interlocking must be provided where a hazard may result from only one mains isolating device being switched off. Only circuit-breakers may be used as remotely-operated switches. They must be provided with an additional handle and be lockable in the Off position.

Standards, formulae, tables
Electrical equipment of machines

Protection against electric shock

The following measures must be taken to protect personnel against electric shock.

Basic protection/protection against direct contact

This is understood as meaning protection by means of an enclosure which can only be opened by qualified personnel using a key or special tool. Such personnel is not obliged to disable the mains isolating device before opening the enclosure. Live parts must be protected against direct contact in accordance with DIN EN 50274 or VDE 0660-514.

Where the mains isolating device is interlocked with the door, the restrictions mentioned in the previous paragraph cease to apply because the door can only be opened when the mains isolating device is switched off. It is permissible for an interlock to be removable by an electrician using a tool, e. g. in order to search for a fault. Where an interlock has been removed, it must still be possible to switch off the mains isolating device.

Where it is possible for an enclosure to be opened without using a key and without disconnection of the mains isolating device, all live parts must at the very least comply with IP2X or IPXXB degree of protection in accordance with DIN EN 60529; DIN VDE 0470-1.

Fault protection – Protection against indirect contact

This involves prevention of a dangerous touch voltage resulting from faulty insulation. To meet this requirement, protective measures in accordance with DIN IEC 60364-4-410 (DIN VDE 0100-410) must be used.

Protection of equipment

Protection in the event of power failure

When the power returns following a failure in the supply, machines or parts of machines must not start automatically where this would result in a dangerous situation or damage to property. With contactor controls this requirement can easily be met via self-maintaining circuits.

For circuits with two-wire control, an additional contactor relay with three-wire control in the input wiring to the actuating circuit can carry out this function. Mains isolating devices and motor-protective circuit-breakers with undervoltage releases also reliably prevent automatic restarting on return of voltage.

Overcurrent protection

No overcurrent protective device is normally required for the mains supply cable. Overcurrent protection is provided by the protective device at the head of the input wiring. All other circuits must be protected by means of fuses or circuitbreakers.

For fuses there is the requirement that they may be used in the country of use and can be replaced there. This difficulty can be avoided by using circuit-breakers, with the added benefits of all-pole disconnection, rapid operational readiness and prevention of single-phasing.

Standards, formulae, tables
Electrical equipment of machines

Overload protection of motors

Continuously operating motors above 0.5 kW must be protected against overload, ideally also against phase failure. Overload protection is recommended for all other motors. Motors which are frequently starting and braking are difficult to protect and often require a special protective device. Built-in thermal sensors are particularly suitable for motors with restricted cooling. In addition, the fitting of overload relays is always recommended, particularly as protection in the event of a stalled rotor.

Control functions in the event of a fault

A fault in the electrical equipment must not result in a dangerous situation or in damage. Suitable measures must be taken to prevent danger from arising. The expense of using appropriate measures can be extremely high if applied generally. To permit a better assessment of the magnitude of the risk in conjunction with the respective application, the standard DIN EN ISO 13849-1 has been published: “Safety-related parts of control systems Part 1: General rules for design”. The use of risk assessment to DIN EN ISO 13849-1 is dealt with in the Eaton safety manual “Safety Technology for Machines and Systems” (PU05907001Z).

Download Safety Manual:
Eaton.com/shb

Standards, formulae, tables
Electrical equipment of machines

Device for handling in case of emergency

Every machine which could potentially cause danger must be equipped with a device for handling in case of emergency. Shutdown can be achieved by means of a main current switching device or control current by means of a command and control device.

Actuation of the Emergency-stop device must result in all current loads which could directly result in danger, being disconnected by de-energization via another device or circuit, i. e. electromechanical devices such as contactors, contactor relays or the undervoltage release of the mains isolating device.

Once the circuit device has been actuated, it must only be possible to restart the machine after local resetting. Resetting alone must not allow restarting.

Furthermore, the following apply for both Emergency-stop switches and Emergency switching off devices:

- The handle must be red with a yellow background.
- Emergency-stop switches and Emergency switching off devices must be quickly and easily accessible in the event of danger.
- The Emergency-stop function and the Emergency switching off function must take precedence over all other functions and operations.
- It must be possible to determine functional capability by means of tests, especially in severe environmental conditions.
- Where there is separation into several Emergency switching off areas, it must be clearly discernible to which area an Emergency-stop device applies.

Emergency operations

In order to be able to give a more precise definition here, DIN EN 60204-1 describes two specific functions:

1. Devices for Emergency-stop
This involves the possibility of stopping hazardous motion as quickly as possible.

2. Devices for Emergency switching off
Where there is a risk of an electric shock by direct contact, e. g. with live parts in electrical operating areas, then an Emergency-off device shall be provided.

Standards, formulae, tables
Electrical equipment of machines

Colors of pushbuttons and their meanings

to DIN EN 60073; VDE 0199
DIN EN 60204-1; VDE 0113-1, Table 2

Color	Meaning	Typical application
RED	Emergency	• Emergency switching off • Fire fighting
YELLOW	Abnormal condition	Intervention, to suppress abnormal conditions or to avoid unwanted changes
BLUE	Enforced action	Resetting function
GREEN	Normal	Start from safe condition
WHITE	No specific meaning assigned	• Start/ON (preferred) • Stop/OFF
GREY		• Start/ON • Stop/OFF
BLACK		• Start/ON • Stop/Off (preferred)

Standards, formulae, tables
Electrical equipment of machines

Colors of indicator lights and their meanings

to DIN EN 60073; VDE 0199
DIN EN 60204-1; VDE 0113-1, Table 4

Color	Meaning	Description	Typical application
RED	Emergency	Warning of potential danger or a situation which requires immediate action	• Failure of pressure in the lubricating system • Temperature outside specified (safe) limits • Essential equipment stopped by action of a protective device
YELLOW	Abnormal condition	Impending critical condition	• Temperature (or pressure) different from normal level • Overload, which is permissible for a limited time
BLUE	Enforced action	Operator action essential	• Remove obstacle • Switch over to Advance
GREEN	Normal	Indication of safe operating conditions or authorization to proceed, clear way	• Cooling liquid circulating • Automatic tank control switched on • Machine ready to be started
WHITE	Neutral	Any meaning: may be used whenever doubt exists about the applicability of the colors RED, YELLOW or GREEN; or as confirmation	• Motor running • Indication of operating modes

Colors of illuminated pushbutton actuators and their meanings

Both tables are valid for illuminated pushbutton actuators, Table 1 relating to the function of the actuators.

Safety-related characteristic values to DIN EN ISO 13849-1 and DIN EN IEC 62061 (VDE 0113-50)

A safety-related system can consist of one or several components. The assessment of the safety-related parts of a control system to DIN EN ISO 13849-1 and DIN EN IEC 62061 require the use of characteristic values provided by the component manufacturer. Eaton provides the characteristic values of safety-related components in the area of "Machine building".
Eaton.com/safety

Reliability values to DIN EN ISO 13849-1

B10d	Number of operations until 10 % of the tested components fail dangerously.
MTTFd	Mean Time To Dangerous Failure. Average of the time expected up to a dangerous failure.
PL	Performance Level

Reliability values to DIN EN IEC 62061

B10	Number of operations until 10 % of the tested components fail.
PFHd	Probability of a Dangerous Failure per Hour.
SIL CL	Safety Integrity Level Claim Limit. SIL claim limit (for a subsystem).

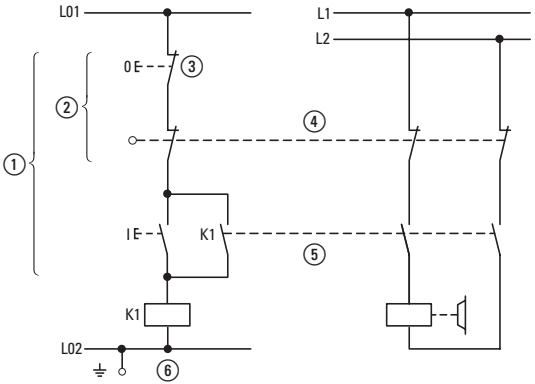
Standards, formulae, tables
Measures for risk reduction

Risk reduction in the fault scenario

A fault in the electrical equipment must not result in a dangerous situation or in damage.

Suitable measures must be taken to prevent danger from arising.

The use of proven circuits and components



1. All switching functions on the non-earthed side
2. Use of break devices with positively opening contacts (not to be confused with interlocked opposing contacts)
3. Shut-down by de-excitation (fail-safe in the event of wire breakage)
4. Circuit engineering measures which make undesirable operating states in the fault scenario unlikely (in this instance, simultaneous interruption via contactor and position switch)
5. Switching of all live conductors to the device to be controlled
6. Chassis earth connection of the actuating circuit for operational purposes (not used as a protective measure)

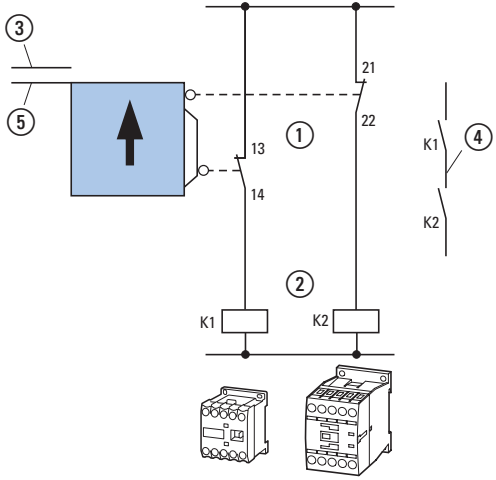
Redundancy

This means the existence of an additional device or system which takes over the function in the fault scenario.

Standards, formulae, tables
Measures for risk reduction

Diversity

The construction of control circuits according to a range of function principles or using various types of device.



① Functional diversity by combination of N/O and N/C contacts
② Diversity of devices due to use of various types of device (here, various types of contactor relay)
③ Safety barrier open
④ Feedback circuit
⑤ Safety barrier closed

Performance tests

The correct functioning of the equipment can be tested either manually or automatically.

Standards, formulae, tables
Protection types for electrical equipment

Protection types for electrical equipment by enclosures, covers and similar to DIN EN 60529; VDE 0470-1

The degree of protection that an electrical equipment fulfils, consists of the characteristic letters **IP** (Ingress Protection) followed by two characteristic numerals.

The first numeral indicates the degree of protection of persons against contact with live parts and of equipment against ingress of solid foreign bodies and dust, the second numeral the degree of protection against the ingress of water.

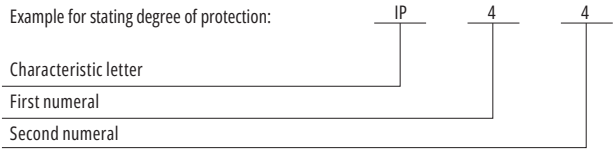
Protection against contact and foreign bodies

First numeral	Degree of protection	
	Description	Explanation
0	Not protected	No special protection of persons against accidental contact with live or moving parts. No protection of the equipment against ingress of solid foreign bodies.
1	Protection against solid objects ≧ 50 mm	Protection against contact with live parts with back of hand. The access probe, sphere 50 mm diameter, must have enough distance from dangerous parts. The probe, sphere 50 mm diameter, must not fully penetrate.
2	Protection against solid objects ≧ 12.5 mm	Protection against contact with live parts with a finger. The articulated test finger, 12 mm diameter and 80 mm length, must have sufficient distance from dangerous parts. The probe, sphere 12.5 mm diameter, must not fully penetrate.

Standards, formulae, tables
Protection types for electrical equipment

Protection against contact and foreign bodies

First numeral	Degree of protection	
	Description	Explanation
3	Protection against solid objects ≧ 2.5 mm	Protection against contact with live parts with a tool. The entry probe, 2.5 mm diameter, must not penetrate. The probe, 2.5 mm diameter, must not penetrate.
4	Protection against solid objects ≧ 1 mm	Protection against contact with live parts with a conductor. The entry probe, 1.0 mm diameter, must not penetrate. The probe, 1.0 mm diameter, must not penetrate.
5	Protection against accumulation of dust	Protection against contact with live parts with a conductor. The entry probe, 1.0 mm diameter, must not penetrate. The ingress of dust is not totally prevented, but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment or with safety.
6	Protection against the ingress of dust Dust-tight	Protection against contact with live parts with a conductor. The entry probe, 1.0 mm diameter, must not penetrate. No entry of dust.



Standards, formulae, tables
Protection types for electrical equipment

Protection against water

Second numeral	Degree of protection	
	Description	Explanation
0	Not protected	No special protection
1	Protected against vertically dripping water	Dripping water (vertically falling drops) shall have no harmful effect.
2	Protected against dripping water when enclosure tilted up to 15°	Dripping water shall have no harmful effect when the enclosure is tilted at any angle up to 15° from the vertical.
3	Protected against sprayed water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect.
5	Protected against water jets	Water projected by a nozzle against the equipment from any direction shall have no harmful effect.
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effect.
7	Protected against the effects of occasional submersion	Ingress of water in harmful quantities shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.

Standards, formulae, tables

Protection types for electrical equipment

Second numeral	Degree of protection	
	Description	Explanation
8	Protected against the effects of submersion	Ingress of water in harmful quantities must not be possible when the equipment is continuously submerged in water under conditions which are subject to agreement between manufacturer and user. These conditions must be more stringent than those for characteristic numeral 7.
9	Protected during cleaning using highpressure/ steam jets	Water which is directed against the enclosure under extremely high pressure from any direction must not have any harmful effects. Water pressure of 100 bar Water temperature of 80 °C

Standards, formulae, tables
Use of electrical equipment in explosive atmospheres

Global reference guide on the marking of electrical equipment for use in explosive atmospheres (EU/ATEX/IECEx/CSA)

Typical marking of electrical equipment for use in explosive gas atmospheres (EU/ATEX/IECEx)

Marking according to directive 2014/34/EU (previously 94/9/EG) (ATEX)

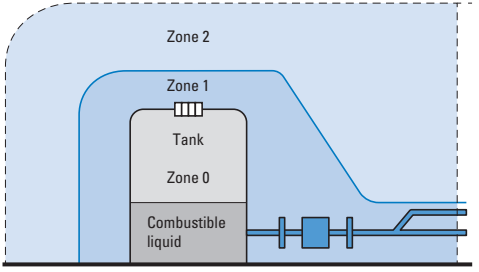
CE 0158 Ex II 2 G

- **CE** CE-marking and number of the notified (monitoring) body (0158 = DEKRA EXAM GmbH) (not for equipment category 3)
- Ex Explosion protection symbol
- **II** Equipment group (equipment for use in hazardous areas, other than mines susceptible to firedamp)
- **2** Equipment category (category 2)
- **G** Explosive atmosphere (gas, vapour or mist)

Marking according to IEC/CENELEC/CSA standard 60079-0

Ex db eb IIC T4 Gb

- **Ex** Explosion protection marking
- **db** Type of protection (flameproof enclosure, level of protection “db”)
- **eb** Type of protection (Increased safety, level of protection “eb”)
- **IIC** Equipment group (Electrical equipment group II, subgroup IIC (typical gas: hydrogen), intended for use in areas where an explosive gas atmosphere is to be expected, other than mines susceptible to firedamp)
- **T4** Temperature class (max. surface temperature 135 °C)
- **Gb** Equipment protection level (EPL Gb; equipment with high protection level)



Example of classification of explosive gas atmospheres into zones
Ex gas atmosphere according to IEC/EN 60079-10-1

Typical marking of electrical equipment for use in explosive dust atmospheres (EU/ATEX/IECEx)

Marking according to directive 2014/34/EU (previously 94/9/EG) (ATEX)

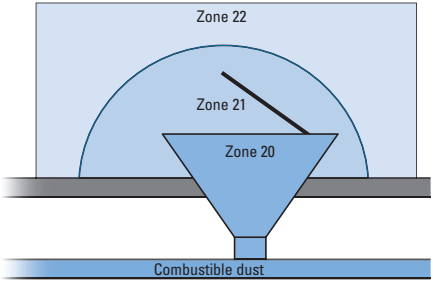
CE 0158 Ex II 2 D

- **CE** CE-marking and number of the notified (monitoring) body (0158 = DEKRA EXAM GmbH) (not for equipment category 3)
- Ex Explosion protection symbol
- **II** Equipment group (equipment for use in hazardous areas, other than mines susceptible to firedamp)
- **2** Equipment category (category 2)
- **D** Explosive atmosphere (dust)

Marking according to IEC/CENELEC/CSA standard 60079-0

Ex tb IIIC T80 °C Db

- **Ex** Explosion protection marking
- **tb** Type of protection (protection by enclosure "tb")
- **IIIC** Equipment group (Electrical apparatus group III, subgroup IIIC (conductive dust), intended for use in areas where an explosive dust atmosphere is to be expected, other than mines susceptible to firedamp)
- **T80 °C** Surface temperature (max. 80 °C)
- **Db** Equipment protection level (EPL Db; equipment with high protection level)



Example of classification of explosive dust atmospheres into zones
Ex dust atmosphere according to IEC/EN 60079-10-2

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Explosion groups

Explosive atmosphere		Typical combustible material	Group
Gas, Vapour, Mist		Acetylene	IIC
		Hydrogen	IIC/IIB+H2
		Ethylene/Formaldehyde	IIB
		Methane/Octane	IIA
Dust	Conductive	Metal dust	IIIC
		Coal dust	
	Non-conductive	Grain dust	IIIB
	Fibres, Flyings	Wood, paper or cotton processing	IIIA

Temperature class

Maximum surface temperature	IEC/EN 60079-0
450 °C	T1
300 °C	T2
200 °C	T3
135 °C	T4
100 °C	T5
85 °C	T6

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Electrical types of protection for explosive atmospheres due to flammable gases, vapours and mists

Type	Protection level	Type of protection	Group	Equipment category
d	da	Flameproof enclosure	II	1 G
d	db	Flameproof enclosure	II	2 G
d	dc	Flameproof enclosure	II	3 G
p	pxb pyb	Pressurized enclosure	II	2 G
p	pzc	Pressurized enclosure	II	3 G
q		Powder filling	II	2 G
o	ob	Liquid immersion	II	2 G
o	oc	Liquid immersion	II	3 G
e	eb	Increased safety	II	2 G
e	ec	Increased safety	II	3 G
i	ia	Intrinsic safety	II	1 G
i	ib	Intrinsic safety	II	2 G
i	ic	Intrinsic safety	II	3 G
p/v		Pressurized enclosure/Ventilation	II	2 G
nA		Non-sparking equipment	II	3 G
nC		Enclosed equipment	II	3 G

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Equipment protection level (EPL)	CENELEC/IEC/CSA Standards	Protection concept
Ga	EN/IEC/CSA 60079-1	Explosion containment, prevention of flame transmission
Gb	EN/IEC/CSA 60079-1	Explosion containment, prevention of flame transmission
Gc	EN/IEC/CSA 60079-1	Explosion containment, prevention of flame transmission
Gb	EN/IEC/CSA 60079-2	Exclusion of Ex-atmospher
Gc	EN/IEC/CSA 60079-2	Exclusion of Ex-atmospher
Gb	EN/IEC/CSA 60079-5	Prevention of explosion diffusion
Gb	EN/IEC/CSA 60079-6	Exclusion of Ex-atmospher
Gc	EN/IEC/CSA 60079-6	Exclusion of Ex-atmospher
Gb	EN/IEC/CSA 60079-7	No arcs, sparks or hot surfaces
Gc	EN/IEC/CSA 60079-7	No arcs, sparks or hot surfaces
Ga	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Gb	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Gc	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Gb	EN/IEC/CSA 60079-13	Exclusion of Ex-atmospher/Dilution
Gc	EN/IEC/CSA 60079-15	No arcs, sparks or hot surfaces
Gc	EN/IEC/CSA 60079-15	Prevention of flame transmission

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Type	Protection level	Type of protection	Group	Equipment category
nR		Restricted breathing enclosure	II	3 G
m	ma	Encapsulation	II	1 G
m	mb	Encapsulation	II	2 G
m	mc	Encapsulation	II	3 G
i		Intrinsic system	II	2 G
		Equipment with protection level (EPL) Ga	II	1 G 1 G/2 G
op is		Inherent safe optical radiation	II	1 G
op is		Inherent safe optical radiation	II	2 G
op is		Inherent safe optical radiation	II	3 G
op pr op sh		Safe/interlocked optical radiation	II	2 G
op pr op sh		Safe/interlocked optical radiation	II	3 G
s	sa	Special protection	n.a.	n.a.
s	sb	Special protection	n.a.	n.a.
s	sc	Special protection	n.a.	n.a.

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Equipment protection level (EPL)	CENELEC/IEC/CSA Standards	Protection concept
Gc	EN/IEC/CSA 60079-15	Exclusion of Ex-atmosphere for a limited period
Ga	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Gb	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Gc	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Gb	EN/IEC/CSA 60079-25	Limitation of spark energy and surface temperature
Ga Ga/ Gb	EN/IEC/CSA 60079-26	Double protection concept
Ga	EN/IEC/CSA 60079-28	Limitation of radiation energy
Gb	EN/IEC/CSA 60079-28	Limitation of radiation energy
Gc	EN/IEC/CSA 60079-28	Limitation of radiation energy
Gb	EN/IEC/CSA 60079-28	Limitation or containment of radiation energy
Gc	EN/IEC/CSA 60079-28	Limitation or containment of radiation energy
Ga	IEC 60079-33	Special measures
Gb	IEC 60079-33	Special measures
Gc	IEC 60079-33	Special measures

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Electrical types of protection for explosive atmospheres due to combustible dust

Type	Protection level	Type of protection	Group Directive	Standard	Equipment category
p	pxb	Pressurized enclosure	II	III	2 D
p	pzc	Pressurized enclosure	II	III	3 D
i	ia	Intrinsic safety	II	III	1 D
i	ib	Intrinsic safety	II	III	2 D
i	ic	Intrinsic safety	II	III	3 D
m	ma	Encapsulation	II	III	1 D
m	mb	Encapsulation	II	III	2 D
m	mc	Encapsulation	II	III	3 D
op is		Inherent safe optical radiation	II	III	1 D
op is		Inherent safe optical radiation	II	III	2 D
op is		Inherent safe optical radiation	II	III	3 D
op pr op sh		Safe/interlocked optical radiation	II	III	2 D
op pr op sh		Safe/interlocked optical radiation	II	III	3 D
t	ta	Protection by enclosure	II	III	1 D
t	tb	Protection by enclosure	II	III	2 D
t	tc	Protection by enclosure	II	III	3 D
s	sa	Special protection		III	n.a.
s	sb	Special protection		III	n.a.
s	sb	Special protection		III	n.a.

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Equipment protection level (EPL)	CENELEC/IEC/CSA Standards	Protection concept
Db	EN/IEC/CSA 60079-2	Exclusion of Ex-atmospher
Dc	EN/IEC/CSA 60079-2	Exclusion of Ex-atmospher
Da	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Db	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Dc	EN/IEC/CSA 60079-11	Limitation of spark energy and surface temperature
Da	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Db	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Dc	EN/IEC/CSA 60079-18	Exclusion of Ex-atmospher
Da	EN/IEC/CSA 60079-28	Limitation of radiation energy
Db	EN/IEC/CSA 60079-28	Limitation of radiation energy
Dc	EN/IEC/CSA 60079-28	Limitation of radiation energy
Db	EN/IEC/CSA 60079-28	Limitation or containment of radiation energy
Dc	EN/IEC/CSA 60079-28	Limitation or containment of radiation energy
Da	EN/IEC/CSA 60079-31	Exclusion of dust
Db	EN/IEC/CSA 60079-31	Exclusion of dust
Dc	EN/IEC/CSA 60079-31	Exclusion of dust
Da	IEC 60079-33	Special measures
Db	IEC 60079-33	Special measures
Dc	IEC 60079-33	Special measures

Standards, formulae, tables

Use of electrical equipment in explosive atmospheres

Zone classification/Equipment protection level

Substance	Period of presence of the combustible substances	Zone	Minimum device requirements				Protection level
			Directive 2014/34/EU		Standard IEC/EN/CSA 60079-0		
			Equipment group	Equipment category	Group	Equipment protection level EPL	
Gas, Mist, Vapour	Continuously for long periods or frequently	Zone 0	II	1 G	II	Ga	very high
	Occasional occurrence	Zone 1	II	2 G	II	Gb	high
	Not likely, but if it occurs only rarely and for a short period	Zone 2	II	3 G	II	Gc	enhanced
Dust	Continuously for long periods or frequently	Zone 20	II	1 D	III	Da	very high
	Occasional occurrence	Zone 21	II	2 D	III	Db	high
	Not likely, but if it occurs only rarely and for a short period	Zone 22	II	3 D	III	Dc	enhanced
Methane, Coal dust		Mining	I	M1	I	Ma	very high
		Mining	I	M2	I	Mb	high

Standards, formulae, tables
Use of electrical equipment in explosive atmospheres

Classification of explosion-protected equipment into equipment groups and categories in accordance with directive 2014/34/EU

Equipment group I for mines endangered by firedamp.

The equipment group I is subdivided into the categories M1 and M2.

Equipment category M1

The equipment in this category is intended for use in both underground parts of mines and those parts of surface installations of such mines that are endangered by firedamp and/or combustible dust. The equipment shall continue to remain functional even in the event of rare incidents relating to the equipment with an explosive atmosphere present, and feature such protective measures that in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection, or the requisite level of protection is assured in the event of two faults occurring independently of each other.

Equipment category M2

The equipment in this category is intended for use in both underground parts of mines and those parts of surface installations of such mines that are endangered by firedamp and/or combustible dust. If an explosive atmosphere occurs, it must be possible to switch off the equipment. The constructional explosion-protection measures ensure the required degree of safety during normal operation, even under severe operating conditions and, in particular, in cases of rough handling and changing environmental influences.

Equipment group II for all other hazardous areas.

The equipment group II is subdivided into the categories 1, 2 and 3.

Equipment category 1

The equipment in this category is intended for use in areas in which an explosive atmosphere is present continuously or for long periods or frequently. Even if equipment failures only occur infrequently, the equipment must ensure the required degree of safety and feature such explosion protection measures that

- if one constructional protective measure fails, at least one other independent constructional protective measure ensures the required degree of safety, or
- if two independent faults occur in combination, the required degree of safety is still ensured.

Equipment category 2

The equipment in this category is intended for use in areas in which an explosive atmosphere occurs occasionally. Even in the case of frequent equipment failures or faulty conditions that are normally to be expected, the constructional explosionprotection measures ensure the required degree of safety.

Standards, formulae, tables

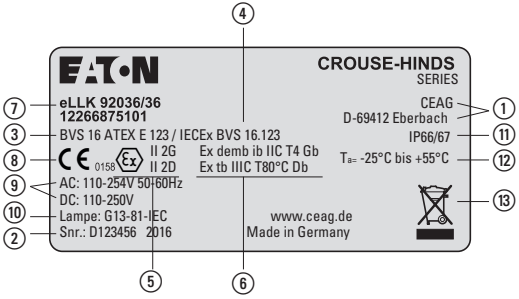
Use of electrical equipment in explosive atmospheres

Equipment category 3

The equipment in this category is intended for use in areas in which no occurrence of an explosive atmosphere due to gases, vapours, mists or whirled-up dust is to be expected.

If, however, it occurs, then in all probability only rarely or for a short period. During normal operation the equipment ensures the required degree of safety.

Example of type label: CEAG product



1. Name or registered trade mark (CEAG) and address of the manufacturer
2. Serial number including year of manufacture
3. Certificate number, may end with "X" or "U"
   - "X" indicates that special conditions for safe use apply
   - "U" is used for component certificates
4. Additional IECEx certification
5. Marking according to directive: Equipment group (II) and equipment category (2); type of explosive atmosphere G (gas, vapour or mist) – D (dust)
6. Marking according to standard: IEC/EN
7. Equipment name/type
8. CE marking and number of the "notified body" responsible for monitoring the quality system (0158 = EXAM Germany)
9. Electrical parameters
10. Other essential information (depends on the standard, e. g. lamp)
11. Other optional information (e. g. degree of protection)
12. Permissible ambient temperature (-25 °C to +55 °C); no marking required for temperatures from -20 °C to +40 °C (standard values for all equipment)
13. Marking according to EU-directive 2002/96/EG (WEEE-directive: **W**aste of **E**lectrical and **E**lectronic **E**quipment)

Standards, formulae, tables

Utilization categories for switching elements

To DIN EN 60947-5-1 (VDE 0660-200, Table 1, 4 and 5)

Type of current	Utilization category	Typical applications	Usual conditions of use	
		I = Inrush current, I_c = Breaking current, I_e = Rated operational current, U = Voltage, U_e = Rated operational voltage, U_r = Recovery voltage, $t_{0.95}$ = Time in ms, until 95 % of the steadystate current has been reached. P = U_e x I_e = Rated power in Watts	Switch on $\frac{I}{I_e}$	$\frac{U}{U_e}$
Alternating current	AC-12	Control of resistive and solid state loads as in optocoupler input circuits	1	1
	AC-13	Control of solid state loads with transformer isolation	2	1
	AC-14	Control of small electromagnetic loads (max. 72 VA)	6	1
	AC-15	Control of electromagnetic loads (above 72 VA)	10	1
			$\frac{I}{I_e}$	$\frac{U}{U_e}$
DC current	DC-12	Control of resistive and solid state loads as in optocoupler input circuits	1	1
	DC-13	Control of electromagnets	1	1
	DC-14	Control of electromagnetic loads with economy resistors in the circuit	10	1

Standards, formulae, tables

Utilization categories for switching elements

				Unusual conditions of use					
Switch off				Switch on			Switch off		
cos φ	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ
0.9	1	1	0.9	–	–	–	–	–	–
0.65	1	1	0.65	10	1.1	0.65	1.1	1.1	0.65
0.3	1	1	0.3	6	1.1	0.7	6	1.1	0.7
0.3	1	1	0.3	10	1.1	0.3	10	1.1	0.3
$t_{0.95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$t_{0.95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$t_{0.95}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$t_{0.95}$
1 ms	1	1	1 ms	–	–	–	–	–	–
6 x P[1)]	1	1	6 x P[1)]	1.1	1.1	6 x P[1)]	1.1	1.1	6 x P[1)]
15 ms	1	1	15 ms	10	1.1	15 ms	10	1.1	15 ms

[1)] The value “6 x P” results from an empirical relationship that represents most DC magnetic loads to an upper limit of P = 50 W, i. e. 6 [ms]/[W] = 300 [ms]. Loads having a power consumption greater than 50 W are assumed to consist of smaller loads in parallel. Therefore, 300 ms is to be an upper limit, irrespective of the power consumption.

Standards, formulae, tables

Utilization categories for contactors and motor starters

To DIN EN IEC 60947-4-1 (VDE 0660-102, Table 1, B1 and 7)

Type of current	Utilization category	Typical applications: I = Inrush current, I_c = Breaking current, I_e = Rated operational current, U = Voltage, U_e = Rated operational voltage, U_r = Recovery voltage	Verification of electrical lifespan		
			Switch on		
			I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$
Alternating current	AC-1	Non-inductive or slightly inductive loads, resistance furnaces	All values	1	1
	AC-2	Slip-ring motors: starting, switch off	All values	2.5	1
	AC-3	Normal AC induction motors: starting, switch off during running[4]	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-3e	Normal AC induction motors with higher starting current: starting, switch off during running	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-4	Normal AC induction motors: starting, plugging, reversing, inching	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-5a	Switching of electric discharge lamp controls			
	AC-5b	Switching of filament lamps			
	AC-6a[3]	Switching of transformers			
	AC-6b[3]	Switching of capacitor banks			
	AC-7a	Slightly inductive loads in household appliances and similar applications	Data as supplied by the manufacturer		
	AC-7b	Motor load for domestic applications			
	AC-8a	Switching of hermetically enclosed refrigerant compressor motors with manual reset of overload releases[5]			
	AC-8b	Switching of hermetically enclosed refrigerant compressor motors with automatic reset of overload eleases[5]			

Standards, formulae, tables

Utilization categories for contactors and motor starters

				Verification of switching capacity						
	Switch off			Switch on				Switch off		
cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ	I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ
0.95	1	1	0.95	All values	1.5	1.05	0.8	1.5	1.05	0.8
0.65	2.5	1	0.65	All values	4	1.05	0.65	4	1.05	0.8
0.65	1	0.17	0.65	$I_e \leqq 100$	8	1.05	0.45	8	1.05	0.45
0.35	1	0.17	0.35	$I_e > 100$	8	1.05	0.35	8	1.05	0.45
0.65	1	0.17	0.65	$I_e \leqq 100$	8	1.05	0.45	8.5	1.05	0.45
0.35	1	0.17	0.35	$I_e > 100$	8	1.05	0.35	8.5	1.05	0.45
0.65	6	1	0.65	$I_e \leqq 100$	10	1.05	0.45	10	1.05	0.45
0.35	6	1	0.35	$I_e > 100$	10	1.05	0.35	10	1.05	0.35
					3.0	1.05	0.45	3.0	1.05	0.45
					1.5[2)]	1.05	[2)]	1.5[2)]	1.05	[2)]
					1.5	1.05	0.8	1.5	1.05	0.8
					8.0	1.05	[1)]	8.0	1.05	[1)]
					6.0	1.05	[1)]	6.0	1.05	[1)]
					6.0	1.05	[1)]	6.0	1.05	[1)]

Standards, formulae, tables

Utilization categories for contactors and motor starters

To DIN EN IEC 60947-4-1 (VDE 0660-102, Table 1, B1 and 7)

Type of current	Utilization category	Typical applications: I = Inrush current, I_c = Breaking current, I_e = Rated operational current, U = Voltage, U_e = Rated operational voltage, U_r = Recovery voltage	Verification of electrical lifespan		
			Switch on		
			I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$
DC current	DC-1	Non-inductive or slightly inductive loads, resistance furnaces	All values	1	1
	DC-3	Shunt motors: starting, plugging, reversing, inching, dynamic braking	All values	2.5	1
	DC-5	Series motors: starting, plugging, reversing, inching, dynamic braking	All values	2.5	1
	DC-6	Switching of filament lamps			

[1] $\cos \varphi = 0.45$ for $I_e \leqq 100$ A; $\cos \varphi = 0.35$ for $I_e > 100$ A

[2] Tests must be carried out with an filament bulb load connected.

[3] Here, the test data are to be derived from the AC-3 or AC-4 test values in accordance with particular table.

Standards, formulae, tables

Utilization categories for contactors and motor starters

				Verification of switching capacity						
	Switch off			Switch on				Switch off		
L/R [ms]	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R [ms]	I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$	L/R [ms]	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R [ms]
1	1	1	1	All values	1.5	1.05	1	1.5	1.05	1
2	2.5	1	2	All values	4	1.05	2.5	4	1.05	2.5
7.5	2.5	1	7.5	All values	4	1.05	15	4	1.05	15
					1.5[2)]	1.05	[2)]	1.5[2)]	1.05	[2)]

[4)] Devices for utilization category AC-3 may be used for occasional inching or plugging during a limited period such as for setting up a machine; during this limited time period, the number of operations must not exceed a total of five per minute or more than ten in a ten minute period.

[5)] Hermetically enclosed refrigerant compressor motor means a combination of a compressor and a motor both of which are housed in the same enclosure with no external shaft or shaft seals, the motor running in the coolant.

Standards, formulae, tables

Utilization categories for switch-disconnectors

For switches, switch-disconnectors and fuse-combination units to DIN EN IEC 60947-3 (VDE 0660-107, Table 2 and 4)

Type of current	Utilization category	Typical applications: I = Inrush current, I_c = Breaking current, I_e = Rated operational current, U = Voltage, U_e = Rated operational voltage, U_r = Recovery voltage
Alternating current	AC-20 A(B)[1)]	Making and breaking without load
	AC-21 A(B)[1)]	Switching resistive loads including low overloads
	AC-22 A(B)[1)]	Switching mixed resistive and inductive loads including low overloads
	AC-23 A(B)[1)]	Switching motors and other highly inductive loads
DC current	DC-20 A(B)[1)]	Making and breaking without load
	DC-21 A(B)[1)]	Switching resistive loads including low overloads
	DC-22 A(B)[1)]	Switching mixed resistive and inductive loads, including low overloads (e. g. shunt motors) overloads
	DC-23 A(B)[1)]	Switching highly inductive loads (e. g. series motors)

[1)] A: Frequent actuation, B: Occasional actuation

Switch-disconnectors that are suitable for switching motors are also tested according to the criteria stated in →Section "Utilization categories for contactors and motor starters", page 10-48.

Standards, formulae, tables

Utilization categories for switch-disconnectors

Verification of switching capacity						
Switch on				Switch on		
I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$	cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ
All values	1)		1)	1)		1)
All values	1.5	1.05	0.95	1.5	1.05	0.95
All values	3	1.05	0.65	3	1.05	0.65
$I_e \leqq 100$ $I_e > 100$	10 10	1.05 1.05	0.45 0.35	8 8	1.05 1.05	0.45 0.35
I_e [A]	$\frac{I}{I_e}$	$\frac{U}{U_e}$	L/R [ms]	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R [ms]
All values	1)	1)	1)	1)	1)	1)
All values	1.5	1.05	1	1.5	1.05	1
All values	4	1.05	2.5	4	1.05	2.5
All values	4	1.05	15	4	1.05	15

Notes

Standards, formulae, tables

Rated motor currents (recommended value for Standard motor IE1/IE2)

Rated motor currents for three-phase motors (recommended value for squirrel cage motors)

Minimum fuse size for short-circuit protection of three-phase motors

The maximum value is determined by the switching device or overload relay.

The rated motor currents are for standard 1500 r.p.m. three-phase motors with normal inner and outer surface cooling.

D.O.L. starting: Maximum starting current: 6 x rated motor current, maximum starting time: 5 sec.

Y/△ starting: Maximum starting current: 2 x rated motor current, maximum starting time: 15 sec. Motor overload relay in phase current: set to 0.58 x rated motor current.

Rated fuse currents for Y/△ starting also apply to three-phase motors with slip-ring rotors.

For higher rated currents, starting currents and/or longer starting times, larger fuses will be required.

This table applies to “slow” or “gL” fuses (VDE 0636).

In the case of NH fuses with aM characteristics, fuses are to be selected according to their rated operational current.

Standards, formulae, tables

Rated motor currents (recommended value for Standard motor IE1/IE2)

Motor power			230 V			400 V		
			Rated motor current	Fuse		Rated motor current	Fuse	
				Direct starting	Y/Δ		Direct starting	Y/Δ
kW	cos φ	η [%]	A	A	A	A	A	A
0.06	0.7	58	0.37	2	–	0.21	2	–
0.09	0.7	60	0.54	2	–	0.31	2	–
0.12	0.7	60	0.72	4	2	0.41	2	–
0.18	0.7	62	1.04	4	2	0.6	2	–
0.25	0.7	62	1.4	4	2	0.8	4	2
0.37	0.72	66	2	6	4	1.1	4	2
0.55	0.75	69	2.7	10	4	1.5	4	2
0.75	0.79	74	3.2	10	4	1.9	6	4
1.1	0.81	74	4.6	10	6	2.6	6	4
1.5	0.81	74	6.3	16	10	3.6	6	4
2.2	0.81	78	8.7	20	10	5	10	6
3	0.82	80	11.5	25	16	6.6	16	10
4	0.82	83	14.8	32	16	8.5	20	10
5.5	0.82	86	19.6	32	25	11.3	25	16
7.5	0.82	87	26.4	50	32	15.2	32	16
11	0.84	87	38	80	40	21.7	40	25
15	0.84	88	51	100	63	29.3	63	32
18.5	0.84	88	63	125	80	36	63	40
22	0.84	92	71	125	80	41	80	50
30	0.85	92	96	200	100	55	100	63
37	0.86	92	117	200	125	68	125	80
45	0.86	93	141	250	160	81	160	100
55	0.86	93	173	250	200	99	200	125
75	0.86	94	233	315	250	134	200	160
90	0.86	94	279	400	315	161	250	200
110	0.86	94	342	500	400	196	315	200
132	0.87	95	401	630	500	231	400	250
160	0.87	95	486	630	630	279	400	315
200	0.87	95	607	800	630	349	500	400
250	0.87	95	–	–	–	437	630	500
315	0.87	96	–	–	–	544	800	630
400	0.88	96	–	–	–	683	1000	800
450	0.88	96	–	–	–	769	1000	800
500	0.88	97	–	–	–	–	–	–
560	0.88	97	–	–	–	–	–	–
630	0.88	97	–	–	–	–	–	–

Standards, formulae, tables

Rated motor currents (recommended value for Standard motor IE1/IE2)

440 V			500 V			690 V		
Rated motor current	Fuse		Rated motor current	Fuse		Rated motor current	Fuse	
	Direct starting	Y/Δ		Direct starting	Y/Δ		Direct starting	Y/Δ
A	A	A	A	A	A	A	A	A
0.19	2	–	0.17	2	–	0.12	2	–
0.28	2	–	0.25	2	–	0.18	2	–
0.37	2	–	0.33	2	–	0.24	2	–
0.54	2	–	0.48	2	–	0.35	2	–
0.76	2	–	0.7	2	–	0.5	2	–
1	4	2	0.9	2	2	0.7	2	–
1.4	4	2	1.2	4	2	0.9	4	2
1.7	4	2	1.5	4	2	1.1	4	2
2.4	4	2	2.1	6	4	1.5	4	2
3.3	6	4	2.9	6	4	2.1	6	4
4.6	10	6	4	10	4	2.9	10	4
6	16	10	5.3	16	6	3.8	10	4
7.7	16	10	6.8	16	10	4.9	16	6
10.2	20	10	9	20	16	6.5	16	10
13.8	25	16	12.1	25	16	8.8	20	10
19.8	32	25	17.4	32	20	12.6	25	16
26.6	50	32	23.4	50	25	17	32	20
32.8	63	32	28.9	50	32	20.9	32	25
37	80	40	33	63	32	23.8	50	25
50	100	63	44	80	50	32	63	32
61	125	80	54	100	63	39	80	50
74	125	100	65	125	80	47	80	63
90	125	100	79	160	80	58	100	63
122	160	125	107	200	125	78	160	100
146	200	160	129	200	160	93	160	100
179	250	200	157	250	160	114	200	125
210	250	250	184	250	200	134	250	160
254	315	250	224	315	250	162	250	200
318	400	315	279	400	315	202	315	250
397	630	400	349	500	400	253	400	315
495	630	630	436	630	500	316	500	400
621	800	800	547	800	630	396	630	400
699	800	800	615	800	630	446	630	630
–	–	–	–	–	–	491	630	630
–	–	–	–	–	–	550	800	630
–	–	–	–	–	–	618	800	630

Standards, formulae, tables
Conductors

Wiring and cable entries with grommets

Cable entry into closed devices is considerably simplified and improved by using cable grommets.

Cable grommets

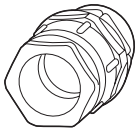
For direct and quick cable entry into an enclosure and as a plug.

Membrane grommets metric	Cable entry	Hole diameter mm	Cable external diameter mm	For use with NYM/NYY cables, 4-core mm^2	Cable grommet part no.
 • IP66 with built-in push-through membrane • PE and thermoplastic elastomer, halogen free	M16	16.5	1 - 9	H03VV-F3 x 0.75 NYM 1 x 16/3 x 1.5	KT-M16
	M20	20.5	1 - 13	H03VV-F3 x 0.75 NYM 5 x 1.5/5 x 2.5	KT-M20
	M25	25.5	1 - 18	H03VV-F3 x 0.75 NYM 4x 10	KT-M25
	M32	32.5	1 - 25	H03VV-F3 x 0.75 NYM 4 x 16/5 x 10	KT-M32

Standards, formulae, tables
Conductors

Wiring and cable entries with cable glands

Metric cable glands to DIN EN 62444; VDE 0619

Cable glands	Cable entry	Hole diameter mm	Cable external diameter mm	For use with NYM/NYY cables, 4-core mm²	Cable grommet part no.
 • With lock nut and built-in strain relief • IP68 up to 5 bar, polyamide, halogen free	M12	12.5	3 –7	H03VV-F3 x 0.75 NYM 1 x 2.5	V-M12
	M16	16.5	4.5 - 10	H05VV-F3 x 1.5 NYM 1 x 16/3 x 1.5	V-M16
	M20	20.5	6 - 13	H05VV-F4 x 2.5/3 x 4 NYM 5 x 1.5/5 x 2.5	V-M20
	M25	25.5	9 - 17	H05VV-F5 x 2.5/5 x 4 NYM 5 x 2.5/5 x 6	V-M25
	M32	32.5	13 - 21	NYM 5 x 10	V-M32
	M40	40.5	16 - 28	NYM 5 x 16	V-M40
	M50	50.5	21 - 35	NYM 4 x 35/5 x 25	V-M50
	M63	63.5	34 - 48	NYM 4 x 35	V-M63
 Ventilation cable glands IP69K	M20	20.5	6 - 13	H05VV-F 4 x 2.5/3 x 4 NYM 5 x 1.5/5 x 2.5	V-M20-VENT

Standards, formulae, tables
Conductors

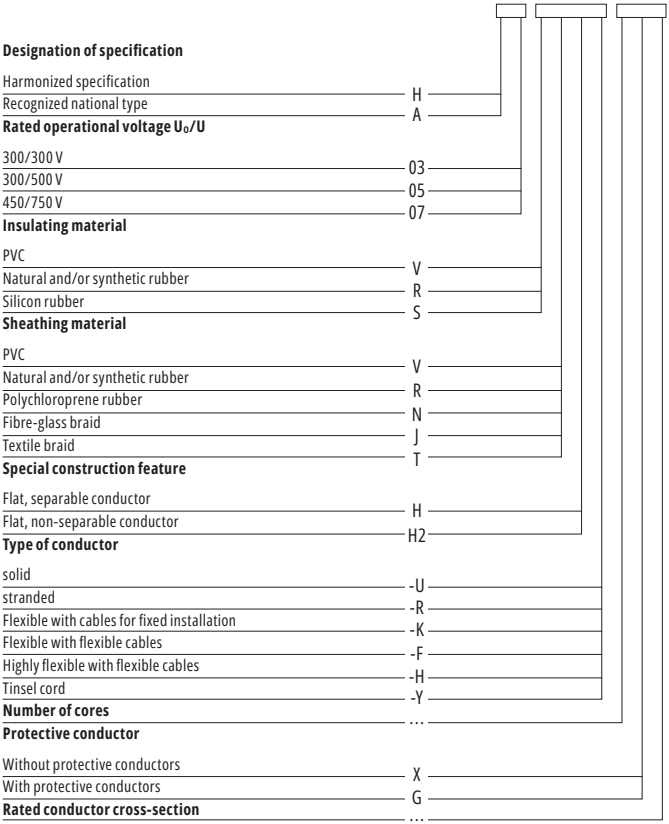
External diameter of conductors and cables

Number of conductors	Approximate external diameter (mean value of various makes)				
	NYM	NYY	H05 RR-F	H07 RN-F	NYCY NYCWY
Cross-section mm^2	mm max.	mm	mm max.	mm max.	mm
2 x 1.5	10	11	9	10	12
2 x 2.5	11	13	13	11	14
3 x 1.5	10	12	10	10	13
3 x 2.5	11	13	11	12	14
3 x 4	13	17	–	14	15
3 x 6	15	18	–	16	16
3 x 10	18	20	–	23	18
3 x 16	20	22	–	25	22
4 x 1.5	11	13	9	11	13
4 x 2.5	12	14	11	13	15
4 x 4	14	16	–	15	16
4 x 6	16	17	–	17	18
4 x 10	18	19	–	23	21
4 x 16	22	23	–	27	24
4 x 25	27	27	–	32	30
4 x 35	30	28	–	36	31
4 x 50	–	30	–	42	34
4 x 70	–	34	–	47	38
4 x 95	–	39	–	53	43
4 x 120	–	42	–	–	46
4 x 150	–	47	–	–	52
4 x 185	–	55	–	–	60
4 x 240	–	62	–	–	70
5 x 1.5	11	14	12	14	15
5 x 2.5	13	15	14	17	17
5 x 4	15	17	–	19	18
5 x 6	17	19	–	21	20
5 x 10	20	21	–	26	–
5 x 16	25	23	–	30	–
8 x 1.5	–	15	–	–	–
10 x 1.5	–	18	–	–	–
16 x 1.5	–	20	–	–	–
24 x 1.5	–	25	–	–	–

NYM: light plastic-sheated cable
NYY: plastic-sheathed cable
H05RR-F: light rubber-sheathed flexible cable (NLH + NSH)
NYCY: cable with concentric conductor and plastic sheath
NYCWY: cable with concentric wave-form conductor and plastic sheath

Standards, formulae, tables
Conductors

Cables and wiring, type abbreviation



Examples for complete cable designation

PVC-sheathed wire, 0.75 mm² flexible, H05V-K 0.75 black

Heavy rubber-sheathed cable, 3-core, 2.5 mm² without green/yellow protective conductor A07RN-F3 x 2.5

Recommended values for rated operational currents and short-circuit currents for standard transformers

Rated operating voltage				
U_n	**400/230 V**			**525 V**
Short-circuit voltage U_K		4 %	6 %	
Rating	Rated operational current	Short-circuit current		Rated operational current
	I_n	I_K''		I_n
kVA	A	A	A	A
50	72	1967	–	55
63	91	2478	1652	69
100	144	3933	2622	110
125	180	4916	3278	137
160	231	6293	4195	176
200	289	7866	5244	220
250	361	9833	6555	275
315	455	12390	8260	346
400	577	15733	10489	440
500	722	19666	13111	550
630	909	24779	16519	693
800	1155	–	20977	880
1000	1443	–	26221	1100
1250	1804	–	32777	1375
1600	2309	–	41954	1760
2000	2887	–	52443	2199
2500	3608	–	65553	2749

		690/400 V		
4 %	6 %		4 %	6 %
Short-circuit current		Rated operational current	Short-circuit current	
I_k''		I_n	I_k''	
A	A	A	A	A
1498	–	42	1140	–
1888	1259	53	1436	958
2997	1998	84	2280	1520
3746	2497	105	2850	1900
4795	3197	134	3648	2432
5993	3996	167	4560	3040
7492	4995	209	5700	3800
9440	6293	264	7182	4788
11987	7991	335	9120	6080
14984	9989	418	11401	7600
18879	12586	527	14365	9576
–	15983	669	–	12161
–	19978	837	–	15201
–	24973	1046	–	19001
–	31965	1339	–	24321
–	39956	1673	–	30402
–	49945	2092	–	38002

Standards, formulae, tables
Formulae

Ohm's Law

$U = I \times R$ [V]

$I = \frac{U}{R}$ [A]

$R = \frac{U}{I}$ [Ω]

Resistance of a piece of wire

$R = \frac{l}{\chi \times A}$ [Ω]

l = Length of conductor [m]

χ = Conductivity [m/Ωmm²]

A = Conductor cross-section [mm²]

Copper: $\chi = 57 \frac{m}{\Omega mm^2}$

Aluminum: $\chi = 33 \frac{m}{\Omega mm^2}$

Iron: $\chi = 8.3 \frac{m}{\Omega mm^2}$

Zinc: $\chi = 15.5 \frac{m}{\Omega mm^2}$

Resistances

Transformer: $X_L = 2 \times \pi \times f \times L$ [Ω]

Inductive impedance: $X_C = \frac{1}{2 \times \pi \times f \times C}$ [Ω]

Capacitive impedance: $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \frac{R}{\cos\varphi}$ [Ω]

L = Inductance [H]
C = Capacitance [F]
X_L = Inductive impedance [Ω]
X_C = Capacitive impedance [Ω]

f = Frequency [Hz]
φ = Phase angle

Parallel connection of resistances

With 2 parallel resistances:

$R_g = \frac{R_1 \times R_2}{R_1 + R_2}$ [Ω]

With 3 parallel resistances:

$R_g = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_2 \times R_3 + R_1 \times R_3}$ [Ω]

General calculation of resistances:

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...[1/\Omega]$

$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + ...[1/\Omega]$

$\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + ...[1/\Omega]$

Standards, formulae, tables
Formulae

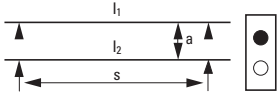
Electric power

	Power	Current consumption
DC current	$P = U \times I\ [W]$	$I = \frac{P}{U}[A]$
Single-phase AC	$P = U \times I \times \cos\varphi[W]$	$I = \frac{P}{U \times \cos\varphi}[A]$
Alternating current	$P = \sqrt{3} \times U \times I \times \cos\varphi[W]$	$I = \frac{P}{\sqrt{3} \times U \times \cos\varphi}[A]$

Mechanical force between 2 parallel conductors

2 conductors with currents I_1 and I_2

$F_2 = \frac{I_1 \times I_2 \times s}{a} \times K[N]$ $\quad K = 2 \times 10^{-7} \frac{N}{A^2}$



s = Distance between supports [cm]

a = Distance between conductors [cm]

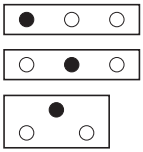
Mechanical force between 3 parallel conductors

3 conductors with current I

$F_3 = 0.808 \times F_2[N]$

$F_3 = 0.865 \times F_2[N]$

$F_3 = 0.865 \times F_2[N]$



Standards, formulae, tables
Formulae

Voltage drop

	Known power	Known current
DC current	$\Delta U = \frac{2 \times I \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times I \times I}{\chi \times A}$ [V]
Single-phase AC	$\Delta U = \frac{2 \times I \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times I \times I}{\chi \times A} \times \cos\varphi$ [V]
Alternating current	$\Delta U = \frac{I \times P}{\chi \times A \times U}$ [V]	$\Delta U = \sqrt{3} \times \frac{I \times I}{\chi \times A} \times \cos\varphi$ [V]

Calculation of cross-section from voltage drop

DC current	Single-phase AC	Alternating current
Known power		
$A = \frac{2 \times I \times P}{\chi \times \Delta U \times U}$ [mm²]	$A = \frac{2 \times I \times P}{\chi \times \Delta U \times U}$ [mm²]	$A = \frac{I \times P}{\chi \times \Delta U \times U}$ [mm²]
Known current		
$A = \frac{2 \times I \times I}{\chi \times \Delta U}$ [mm²]	$A = \frac{2 \times I \times I}{\chi \times \Delta U} \times \cos\varphi$ [mm²]	$A = \sqrt{3} \times \frac{I \times I}{\chi \times \Delta U} \times \cos\varphi$ [mm²]

Power loss

DC current	Single-phase AC
$P_{loss} = \frac{2 \times I \times P \times P}{\chi \times A \times U \times U}$ [W]	$P_{loss} = \frac{2 \times I \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi}$ [W]
Alternating current	
$P_{loss} = \frac{I \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi}$ [W]	

I = Single length of conductor [m];

A = Conductor cross-section [mm²];

X = Conductivity (copper: X = 57; aluminum: X = 33; iron: X = 8.3 $\frac{m}{\Omega mm^2}$)

△U = Voltage drop

Standards, formulae, tables
Formulae

Power of electric motors

	Output	Current consumption
DC current	$P_1 = U \times I \times \eta$ [W]	$I = \frac{P_1}{U \times \eta}$ [A]
Single-phase AC	$P_1 = U \times I \times \cos\varphi \times \eta$ [W]	$I = \frac{P_1}{U \times \cos\varphi \times \eta}$ [A]
Alternating current	$P_1 = 1.73 \times U \times I \times \cos\varphi \times \eta$ [W]	$I = \frac{P_1}{1.73 \times U \times \cos\varphi \times \eta}$ [A]

P_1 = Rated mechanical power at the motor shaft conform to rating plate
P_2 = Electrical power consumption

Efficiency	$\eta = \frac{P_1}{P_2} \times (100\ \%)$	$P_2 = \frac{P_1}{\eta}$ [W]

Amount of poles	Synchronous speed	Full load speed
2	3000	2800 - 2950
4	1500	1400 - 1470
6	1000	900 - 985
8	750	690 - 735
10	600	550 - 585

Synchronous speed = approx. no-load speed

Standards, formulae, tables
International Unit System

International Unit System (SI)

Basic parameters Physical parameters	Symbol	SI basic unit	Further related SI units
Length	l	m (Metre)	km, dm, cm, mm, µm, nm, pm
Mass	m	kg (Kilogram)	Mg, g, mg, µg
Time	t	s (Second)	ks, ms, µs, ns
Electrical current	I	A (Ampere)	kA, mA, µA, nA, pA
Thermo-dynamic temperature	T	K (Kelvin)	–
Amount of substance	n	mole (Mol)	Gmol, Mmol, kmol, mmol, µmol
Light intensity	I_v	cd (Candela)	Mcd, kcd, mcd

Conversion of SI units

Size	SI units name	Symbol	Basic unit	Conversion of SI units
Force	Newton	N	$1.\frac{kg \cdot m}{s^2}$	
Force momentum	Newton-metre	Nm	$1.\frac{kg \cdot m^2}{s^2}$	
Pressure	Bar	bar	$10^5\frac{kg}{m \cdot s^2}$	$1\ bar = 10^5 Pa = 10^5\ \frac{N}{m^2}$
	Pascal	Pa	$1.\frac{kg}{m \cdot s^2}$	$1\ Pa = 10^{-5}\ bar$
Energy, heat	Joule	J	$1.\frac{kg \cdot m^2}{s^2}$	1 J = 1 Ws = 1 Nm
Power	Watt	W	$1.\frac{kg \cdot m^2}{s^3}$	$W = 1\frac{J}{s} = 1\frac{N \cdot m}{s}$

Standards, formulae, tables
International Unit System

Conversion of SI units

Size	SI units name	Symbol	Basic unit	Conversion of SI units
Tension		$\frac{N}{mm^2}$	$10^6 \frac{kg}{m \cdot s^2}$	$1 \frac{N}{mm^2} = 10^2 \frac{N}{cm^2}$
Angle (flat)	Degree Gon	1 gon		360° = 1 pla = 2π rad 400 gon = 360°
	Radian	rad	$1 \frac{m}{m}$	
	Full circle	pla		1 pla = 2π rad = 360°
Voltage	Volts	V	$1 \cdot \frac{kg \cdot m^2}{s^3 \cdot A}$	$1\ V = 1 \cdot \frac{W}{A}$
Resistance	Ohm	Ω	$1 \cdot \frac{kg \cdot m^2}{s^3 \cdot A^2}$	$1\ \Omega = 1 \cdot \frac{V}{A} = 1 \cdot \frac{W}{A^2}$
Conductivity	Siemens	S	$1 \cdot \frac{s^3 \cdot A^2}{kg \cdot m^2}$	$1\ S = 1 \cdot \frac{A}{V} = 1 \cdot \frac{A^2}{W}$
Electric charge	Coulomb	C	$1 \cdot A \cdot s$	
Capacity	Farad	F	$1 \cdot \frac{s^4 \cdot A}{kg \cdot m^2}$	$1\ F = 1 \cdot \frac{C}{V} = 1 \cdot \frac{s \cdot A^2}{W}$
Electrical field		$\frac{V}{m}$	$1 \cdot \frac{kg \cdot m}{s^3 \cdot A}$	$1 \frac{V}{m} = 1 \cdot \frac{W}{A \cdot m}$
Flux	Weber	W_b	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A}$	$1\ W_b = 1 \cdot V \cdot s = 1 \cdot \frac{W \cdot s}{A}$
Flux density	Tesla	T	$1 \cdot \frac{kg}{s^2 \cdot A}$	$1\ T = \frac{W_b}{m^2} = 1 \cdot \frac{V \cdot s}{m^2} = 1 \cdot \frac{W \cdot s}{m^2 A}$
Reactor	Henry	H	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A^2}$	$1\ H = \frac{W_b}{A} = 1 \cdot \frac{V \cdot s}{A} = 1 \cdot \frac{W \cdot s}{A^2}$

Standards, formulae, tables
International Unit System

Decimal powers (parts and multiples of units)

Power	Prefix	Symbol	Power	Prefix	Symbol
10^{-18}	Atto	a	10^{-1}	Deci	d
10^{-15}	Femto	f	10	Deca	da
10^{-12}	Pico	p	10^{-2}	Hecto	h
10^{-9}	Nano	n	10^{-3}	Kilo	k
10^{-6}	Micro	µ	10^{-6}	Mega	M
10^{-3}	Milli	m	10^{-9}	Giga	G
10^{-2}	Centi	c	10^{-12}	Tera	T

Standards, formulae, tables
International Unit System

Conversion of Imperial/American units into SI units

Length	1 in	1 ft	1 yd	1 mile Land mile	1 mile Sea mile	
m	$25.4 \cdot 10^{-3}$	0.3048	0.9144	$1.609 \cdot 10^{3}$	$1.852 \cdot 10^{3}$	
Weight	1 lb	1 ton (UK) long ton	1 cwt (UK) long cwt	1 ton (US) short ton	1 ounce	1 grain
kg	0.4536	1016	50.80	907.2	$28.35 \cdot 10^{-3}$	$64.80 \cdot 10^{-6}$
Area	1 sq.in	1 sq.ft	1 sq.yd	1 acre	1 sq.mile	
m^2	$0.6452 \cdot 10^{-3}$	$92.90 \cdot 10^{-3}$	0.8361	$4.047 \cdot 10^{3}$	$2.590 \cdot 10^{3}$	
Volume	1 cu.in	1 cu.ft	1 cu.yd	1 gal (US)	1 gal (UK)	
m^3	$16.39 \cdot 10^{-6}$	$28.32 \cdot 10^{-3}$	0.7646	$3.785 \cdot 10^{-3}$	$4.546 \cdot 10^{-3}$	
Force	1 lb	1 ton (UK) long ton	1 ton (US) short ton	1 pdl (poundal)		
N	4.448	$9.964 \cdot 10^{3}$	$8.897 \cdot 10^{3}$	0.1383		
Momentum	1 lb-in					
Nm	0.112985					
Speed	$1 \frac{\text{mile}}{\text{h}}$	1 knot	$1 \frac{\text{ft}}{\text{s}}$	$1 \frac{\text{ft}}{\text{min}}$		
$\frac{\text{m}}{\text{s}}$	0.447	0.5144	0.3048	$5.080 \cdot 10^{-3}$		
Pressure		1 in Hg	1 ft H_2O	1 in H_2O		
bar	$65.95 \cdot 10^{-3}$	$33.86 \cdot 10^{-3}$	$29.89 \cdot 10^{-3}$	$2.491 \cdot 10^{-3}$		
Energy, Work	1 HPh	1 BTU	1 PCU			
J	$2.684 \cdot 10^{6}$	$1.055 \cdot 10^{3}$	$1.90 \cdot 10^{3}$			

Standards, formulae, tables
International Unit System

Conversion of Imperial/American units into SI units

Length	1 cm	1 m	1 m	1 km	1 km
	0.3937 in	3.2808 ft	1.0936 yd	0.6214 mile (land mile)	0.5399 mile (sea mile)
Weight	1 g	1 kg	1 kg	1 t	1 t
	15.43 grain	35.27 ounce	2.2046 lb.	0.9842 long ton	1.1023 short ton
Area	1 cm^2	1 m^2	1 m^2	1 m^2	1 km^2
	0.155 sq.in	10.7639 sq.ft	1.196 sq.yd	0.2471 · 10^{-3} acre	0.3861 sq.mile
Volume	1 cm^3	1 l	1 m^3	1 m^3	1 m^3
	0.06102 cu.in	0.03531 cu.ft	1.308 cu.yd	264.2 gal (US)	219.97 gal (UK)
Force	1 N	1 N		1 N	1 N
	0.2248 lb	0.1003 · 10^{-3} long ton (UK)		0.1123 · 10^{-3} short ton (US)	7.2306 pdl (poundal)
Momentum	1 Nm				
	8.8507 lb-in				
Speed	1 m/s	1 m/s	1 m/s	1 m/s	
	3.2808 ft/s	196.08 ft/min	1.944 knots	2.237 mph	
Pressure	1 bar	1 bar	1 bar	1 bar	
	14.50 psi	29.53 in Hg	33.45 ft H_2O	401.44 in H_2O	
Energy, Work	1 J	1 J		1 J	
	0.3725 · 10^{-6} HPh	0.9478 · 10^{-3} BTU		0.5263 · 10^{-3} PCU	

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Eaton is an intelligent power management company dedicated to improving the quality of life and protecting the environment for people everywhere. We are guided by our commitment to do business right, to operate sustainably and to help our customers manage power today and well into the future. By capitalizing on the global growth trends of electrification and digitalization, we're accelerating the planet's transition to renewable energy, helping to solve the world's most urgent power management challenges, and doing what's best for our stakeholders and all of society.

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