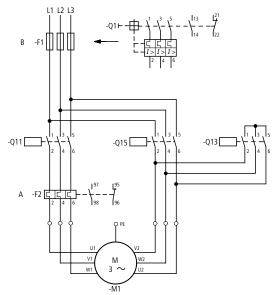
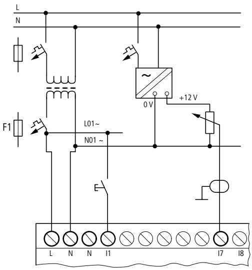
Wiring Manual

Automation and Power Distribution





Think future. Switch to green.

1st edition 2000, 12/99

2nd updated edition 2006, publication date 02/05

Editor: Heidrun Riege
Translators: Uli Wright, Nigel Green, Dominik Kreuzer, David Long, Terence Osborn

All the circuits are designed according to our best expertise and have been carefully tested. They serve as practical examples. Moeller GmbH refuses to accept liability for any errors.

Printed on bleached cellulose, 100 % free from chlorine and acid.

The Moeller Wiring Manual

Automation Systems

Automation Systems
Programmable Logic Controllers, PLCs

Programmable logic controllers

The programmable (logic) controller (PLC) is an electronic device for machine or process control. The PLC receives signals via inputs, processes them according to the instructions of a program, and transfers signals to the outputs.

The program is created using programming software which is able to link inputs and outputs in any required sequence, to measure time, or even carry out arithmetic operations.

The most important specifications of a PLC are its maximum number of inputs/outputs, its memory size and its processing speed.

The PS40 Series and the new xSystem are the two automation systems offered by Moeller. These are described below.

PS40 Series

Compact PLCs

The PS4 compact PLCs have the following system characteristics:

- Standard programming
- Remote and local expansion options
- Integrated fieldbus interface (Suconet)
- Plug-in screw terminals
- Small, compact in size

The controllers in this range are very versatile with a wide range of features, such as integrated setpoint potentiometers, analog inputs/outputs or memory expansion modules (from PS4-150).

Moellers' entire PLC range is described in the Main Catalogue for Automation Systems and Drives, as well as in the Product overview for automation.

Modular PLCs

The PS416 modular PLC has the following key features:

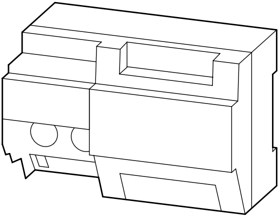
- High processing speed
- Compact size
- Wide range of networking options
- Extensive memory

Sucosoft programming software

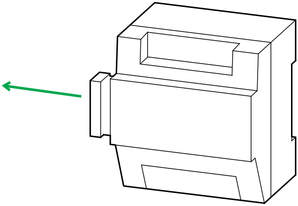
Sucosoft is the name of the software for programming the PS40 PLCs.

Program examples are provided in the PLC Beginners' Guide “Automation with Programmable Logic Controllers” (FB2700-017).

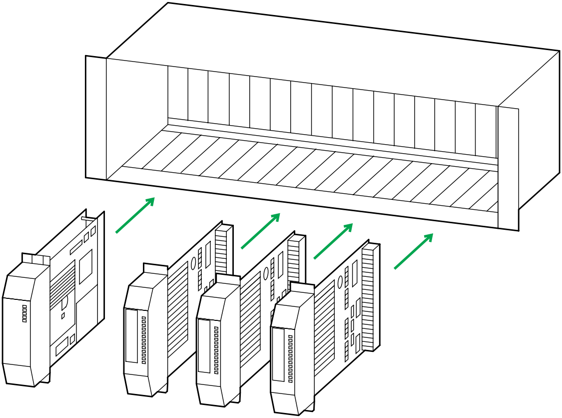
Automation Systems
Programmable Logic Controllers, PLCs



PS4/EM4:
Compact PLC or expansion module



LE4:
Local expansion



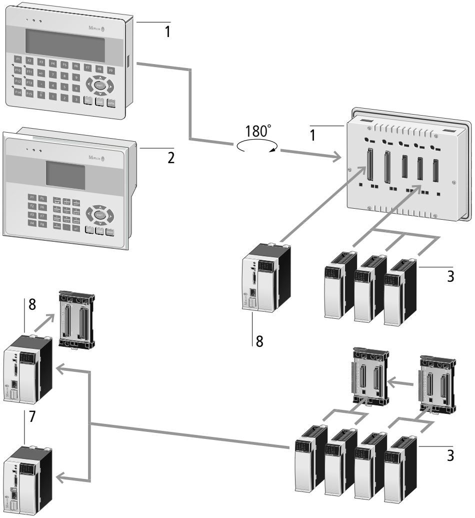
PS416:
Modular PLC

Automation Systems
xSystem

xSystem

xSystem is Moeller's latest modular automation system. It can be configured for the individual requirements of small or large applications. xSystem reduces the hardware and software interfaces required. The system features IT functions that are already integrated.

The XSoft software combines programming, configuring, testing, commissioning and visualization functions in a single tool designed for the entire xSystem product range.



Automation Systems

xSystem

System components

- Modular PLCs
  - XC100 ⑧
    8 DI, 6 DO, CANopen, RS 232, 4 interrupt inputs
    Slot for multimedia memory card,
    64 – 256 KByte program/data memory,
    4/8 KByte for retentive data,
    0.5 ms/1000 instructions
  - XC200 ⑦
    8 DI, 6 DO, CANopen, RS 232, Ethernet, 2 counters, 2 interrupt inputs, WEB/OPC server, USB, locally expandable with XI/OC I/O modules, 256 – 512 KByte program/data memory, 0.05 ms/1000 instructions
- Text display PLCs
  - Modular text display PLCs ①
    Consisting of XC100, up to 3 XI/OC modules and LCD text display with 4 × 20 or 8 × 40 lines/characters
  - Compact text display PLC ②
    Minimum mounting dimensions and high interface integration density (10 DI, 8 DO, 8 DIO, 2 AI, 2 AO, 2 counter inputs, 2 interrupt inputs, 1 encoder input)
- XI/OC input/output modules ③
  - Can be fitted to the XC100/200 (max. 15 modules)
  - Plug-in terminals with screw or springloaded terminal
- XSoft
  - Programming, configuring, testing/commissioning in a single tool

Refer to the following product overview and manuals for further information:

- Automation product overview (AWB2700-7546)
- XC100 hardware and engineering (AWB2724-1453)
- XC200 hardware and engineering (AWB2724-1491)
- XI/OC hardware and engineering (AWB2725-1452)
- XV100 hardware and engineering (AWB2726-1461)
- xStart-XS1 hardware and engineering (AWB2700-1426)
- XSoft PLC programming (AWB2700-1437)
- Function blocks for XSoft (AWB2786-1456); including data handling function blocks for text display PLCs

The latest edition is available from http://www.moeller.net/support: Enter the numbers shown in brackets, e.g. "AWB2725-1452G", as a search term.

Automation Systems
Modular I/O System XI/ON

XI/ON – the concept

XI/ON is a modular I/O system for use in industrial automation applications. It links sensors and actuators on the field level with the higher-level controller. Fieldbus protocols PROFIBUS-DP, CANopen and DeviceNet are supported.

XI/ON offers modules for virtually every application:

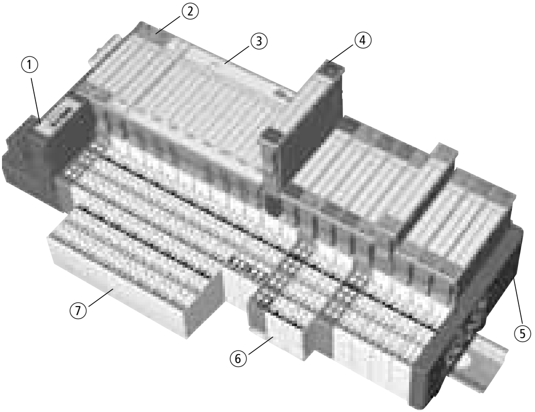
- Digital input and output modules
- Analog input and output modules
- Technology modules

A XI/ON station consists of a gateway, power supply modules and I/O modules.

A complete XI/ON structure counts as a single bus station in any fieldbus structure and therefore only requires one bus address. The individual XI/ON peripheral modules are therefore independent of the higher-level fieldbus.

The I/O modules consist of a combination of a base module designed as a terminal block, and a plug-in electronics module.

The XI/ON peripheral modules are linked to the fieldbus via the XI/ON gateway. This is used for the communication between the XI/ON station and the other fieldbus stations.



1 Gateway
2 Power supply module
3 Electronics module in block design
4 Electronics module in slice design
5 End plate
6 Base module in slice design
7 Base module in block design

Automation Systems
Modular I/O System XI/ON

Flexibility
Each XI/ON station can be adapted exactly for the required number of channels since the modules are available in different levels of granularity.

For example, digital input modules with 2, 4, 16 or 32 channels are available in slice or block design.

A XI/ON station can contain modules in any combination. This enables the system to be adapted to virtually any application in industrial automation.

Compact design
The narrow mounting width of the XI/ON modules (gateway 50.4 mm; slice 12.6 mm, block 100.8 mm) and the low mounting height make the system ideal for use in applications where space is at a premium.

Simple handling
Apart from the gateway, all XI/ON modules consist of a base module and an electronics module.

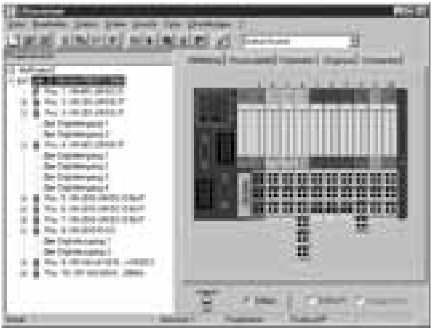
The gateway and the base modules can be snap-fitted on mounting rails. The electronics modules can then be plugged simply onto the assigned base module.

The base modules are available as terminal blocks. They are wired either with spring-loaded or screw terminals. The electronic modules can be fitted or removed during commissioning or for maintenance without disturbing the wiring.

A design coding feature ensures that the electronic modules can only be fitted at the correct locations provided.

I/Oassistant diagnostics and engineering software
The I/Oassistant provides support during the entire planning and implementation phase of an I/O system. It provides help for engineering the stations, the configuration and for setting the parameters. The software is used for commissioning systems and carrying out tests and diagnostics on the stations.

The entire documentation for the station, including a parts list for ordering, can be generated after the engineering phase.



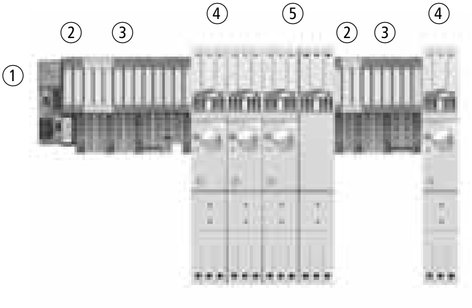
Automation Systems
Networkable Motor Starters xStart-XS1

xStart-XS1

xStart-XS1 is the modular, networkable version of the tried and tested motor starter from Moeller. It connects the motors with the XI/ON system and thus ensures flexible availability between systems, irrespective of the fieldbus in use.

xStart-XS1 offers DOL and reversing starters in different ratings and available with or without a trip-indicating auxiliary contact (AGM).

The xStart-XS1 modules consist of a base module and a power module that contains the tried and tested PKZM0 motor-protective circuit-breaker and one or two DILEM contactors. They enable the connection of assigned motor ratings up to 4.0 kW at a rated operational voltage U_e of 400 V AC.



1. XI/ON gateway
2. Supply module
3. XI/ON I/O modules
4. xStart-XS1 DOL starter module
5. xStart-XS1 reversing starter module

Flexibility

You can adapt xStart-XS1 exactly to the requirements of the system used.

xStart-XS1 can be used at any position on a XI/ON station so that you can organise your station conveniently into system areas.

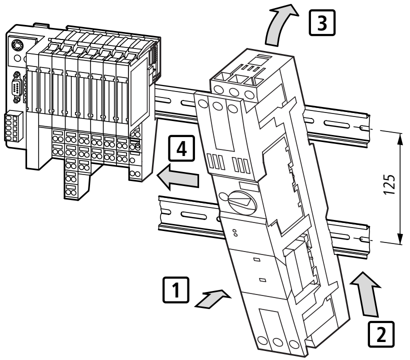
The motor can be disconnected at the machine by using the rotary handle.

Mounting

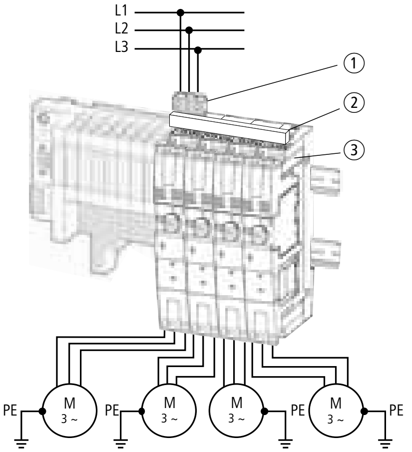
The complete module is mounted by simply snap-fitting it onto two top-hat rails. You can also simply mount the base module and add the power section at a later time. Mounting and removal are carried out without any tools.

Automation Systems

Networkable Motor Starters xStart-XS1

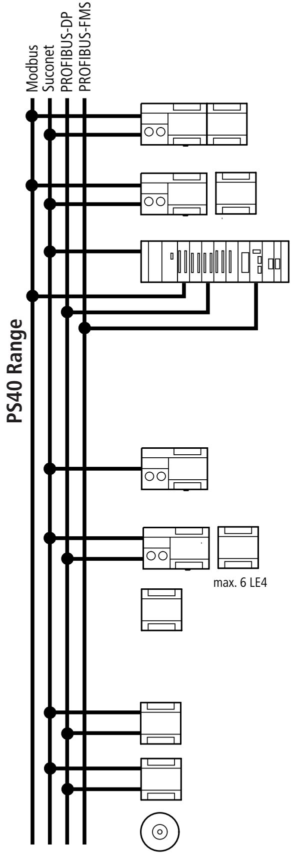


Power supply accessories are available for reducing wiring costs. If several xStart-XS1 modules are mounted next to each other, the power can be fed via a distribution system. This power distribution is available for an operating current of up to 63 A.



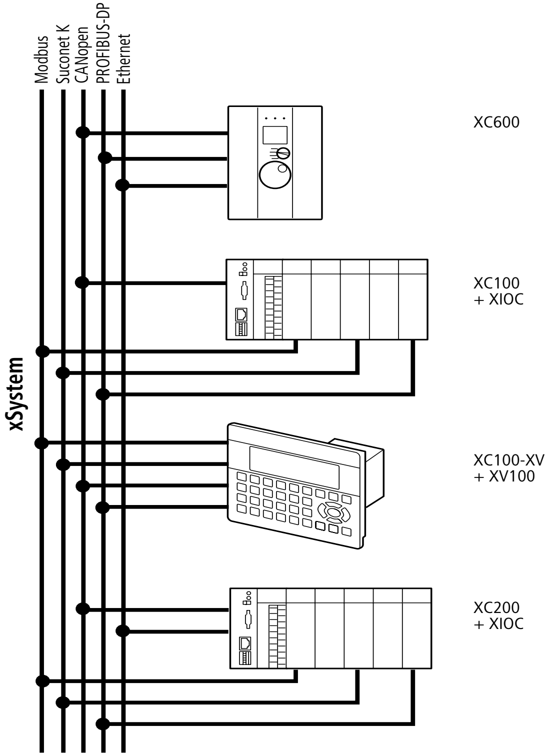
1. Incoming terminal for three-phase commoning link
2. Three-phase commoning link for up to 4 DOL starters without trip-indicating auxiliary contact AGM
3. DOL starter without AGM trip-indicating auxiliary contact

Automation Systems
Networking PS40 Series



Part No.	Interface	Memory
PS4-141-MM1	Suconet K + RS 232	64 kByte
PS4-151-MM1	Suconet K + RS 232	64 kByte
PS4-201-MM1	Suconet K + RS 232	64 kByte
PS4-271-MM1	Suconet K + RS 232	64 kByte
PS4-341-MM1	Suconet K + RS 232	512 kByte
PS416-BGT...		
PS416-CPU...		
PS416-POW...		
PS416-INP...		
PS416-OUT...		
PS416-AIN...		
PS416-AIO...		
PS416-CNT-200		
PS416-TCS-200		
PS416-NET...	Suconet K (M/S)	
PS416-COM-200	serial interface	
PS416-MOD-200	Modbus(SI)	
EM4-101-...	Suconet K/K1	
EM4-111-...	Suconet K/K1	
EM4-201-DX2	Suconet K	
EM4-204-DX1	PROFIBUS-DP	
LE4-104-XP1		
LE4-108-...		
LE4-116-...		
LE4-206-...		
LE4-308-...		
LE4-622-CX1	2 × 3 counter	
LE4-633-CX1	3 × 3 path measurement	
LE4-501-BS1	Suconet K	
LE4-503-BS1	PROFIBUS-FMS (Slave)	
CM4-504-GS1	Suconet K, PROFIBUS-DP	
CM4-505-GS1	Gateway	
ZB4-501-UM4	interface converter	
S40	Programming software	

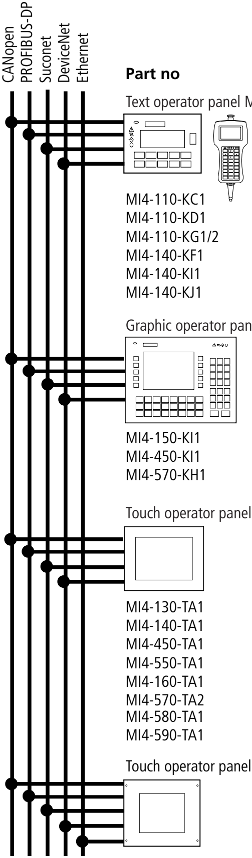
Automation Systems
Networking xSystem



Automation Systems

Networking Display and Operator Devices

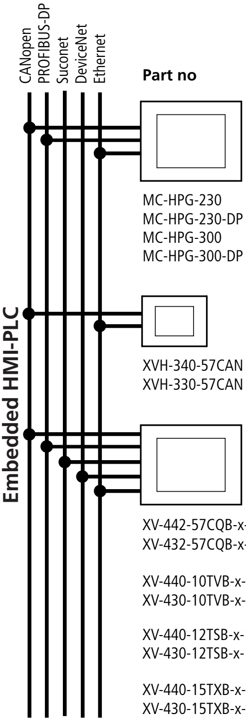
HMI (Display and operating device)



Part no	Resolution	Code	Display
Text operator panel M14			
MI4-110-KC1	120 × 32	11	LCD monochrome
MI4-110-KD1	120 × 32	19	LCD monochrome
MI4-110-KG1/2	120 × 32	35	LCD monochrome
MI4-140-KF1	120 × 64	27	LCD monochrome
MI4-140-KI1	240 × 64	46	LCD monochrome
MI4-140-KJ1	240 × 64	46	LCD monochrome
Graphic operator panel M14			
MI4-150-KI1	320 × 240	56	Monochrome
MI4-450-KI1	320 × 240	56	STN colour
MI4-570-KH1	640 × 480	50	TFT
Touch operator panel M14 (Resistive)			
MI4-130-TA1	320 × 240	–	Monochrome
MI4-140-TA1	320 × 240	–	Monochrome
MI4-450-TA1	320 × 240	–	STN colour
MI4-550-TA1	320 × 240	–	TFT colour
MI4-160-TA1	640 × 480	–	Monochrome
MI4-570-TA2	640 × 480	–	TFT
MI4-580-TA1	800 × 600	–	TFT
MI4-590-TA1	1024 × 768	–	TFT
Touch operator panel MV4 (Infra-red)			

Automation Systems

Networking Embedded HMI-PLC



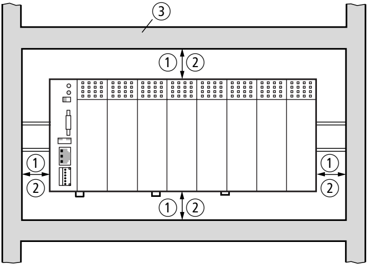
Part no	Resolution	Touch	Display
MC-HPG-230	320 × 240	Infra-red	STN colour
MC-HPG-230-DP			
MC-HPG-300	640 × 480	Infra-red	TFT
MC-HPG-300-DP			
XVH-340-57CAN	320 × 240	Infra-red	STN colour
XVH-330-57CAN	320 × 240	Resistive	STN colour
XV-442-57CQB-x-13-1	320 × 240	Infra-red	STN colour
XV-432-57CQB-x-13-1	320 × 240	Resistive	STN colour
XV-440-10TVB-x-13-1	640 × 480	Infra-red	TFT
XV-430-10TVB-x-13-1	640 × 480	Resistive	TFT
XV-440-12TSB-x-13-1	800 × 600	Infra-red	TFT
XV-430-12TSB-x-13-1	800 × 600	Resistive	TFT
XV-440-15TXB-x-13-1	1024 × 768	Infra-red	TFT
XV-430-15TXB-x-13-1	1024 × 768	Resistive	TFT

Note: The XVH- ... devices are also available with RS 232 or MPI interface.

Automation Systems
Engineering XC100/XC200

Device arrangement

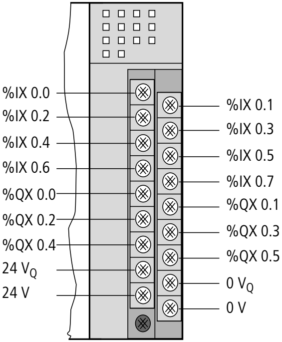
Install the rack and the PLC horizontally in the control cabinet – as shown in the following figure.



1. Clearance > 50 mm
2. Clearance > 75 mm from active elements
3. Cable duct

Terminal assignment

The terminals for the power supply and the local I/O have the following assignment:



Wiring example of power supply unit

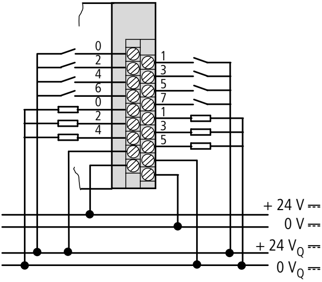
The voltage terminal 0VQ/24VQ is only used for the power supply of the local 8 inputs and 6 outputs, and is potentially isolated from the bus.

The outputs 0 to 3 can be loaded with 500 mA and the outputs 4 and 5 with 1 A, each with a 100 % duty factor (DF) and a simultaneity factor of 1.

The wiring example shows the wiring with a separate power supply for the PLC and the IO terminals. If only one power supply is used, the following terminals must be connected:

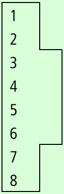
24 V to 24VQ and 0 V to 0VQ.

Automation Systems
Engineering XC100/XC200



RS 232 serial interface

This interface is used by the XC100 to communicate with the PC. The physical connection is implemented via an RJ 45 interface. The interface is not isolated. The connector has the following assignment:



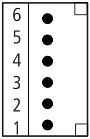
Pin	Designation	Description
4	GND	Ground
5	TxD	Transmit Data
7	GND	Ground
8	RxD	Receive Data

You can use the COM1 or COM2 interface on the PC.

You use the XT-SUB-D/RJ45 programming cable for the physical connection.

CANopen interface

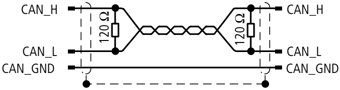
Assignment of the 6-pole Combicon connector:



Terminal	Signal
6	GND
5	CAN_L
4	CAN_H
3	GND
2	CAN_L
1	CAN_H

Only use a cable that is permissible for CANopen with the following properties:

- Surge impedance 108 to 132 Ω
- Capacitance per unit length < 50 pF/m

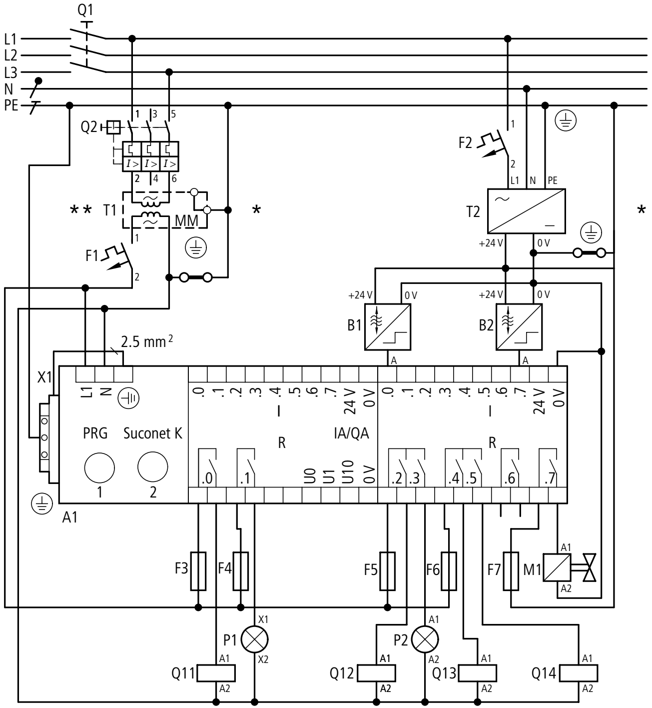


Baud rate [Kbit/s]	Length [m]	Cable cross section [mm^2]	Loop resistance [Ω/km]
20	1000	0.75 – 0.80	16
125	500	0.50 – 0.60	40
250	250	0.50 – 0.60	40
500	100	0.34 – 0.60	60
1000	40	0.25 – 0.34	70

Automation Systems
Engineering PS4

PS4-151-MM1 compact PLC

- Wiring for a 230 V AC supply circuit
- Relay contacts with different potentials: 230 V AC and 24 V DC
- 24 V DC inputs from an external power supply unit, earthed operation



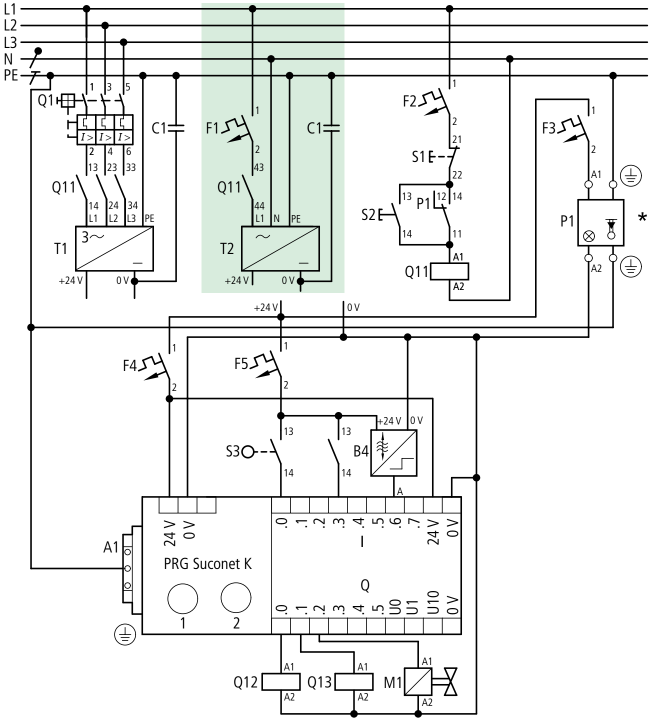
* Insulation monitoring must be provided where the control circuits are not earthed. (EN 60204-1 and VDE 0100-725)

** IEC/EN 60204-1 specifies that a control transformer is required.

Automation Systems
Engineering PS4

PS4-201-MM1 compact PLC

- Shared power supply for PLC and inputs/outputs
- Non-earthed operation with insulation monitoring

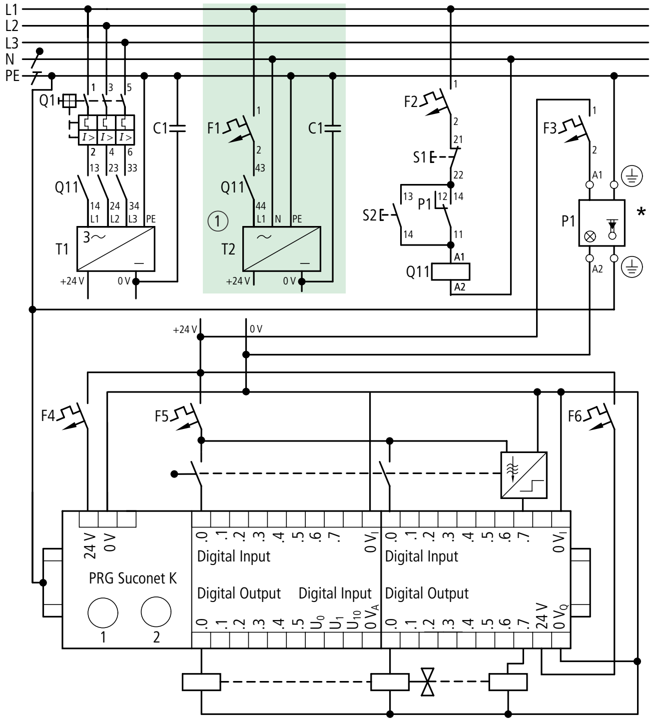


* For operation without insulation monitoring, 0 V must be linked with the PE potential in the control circuits.

Automation Systems
Engineering PS4

PS4-341-MM1 compact PLC

- Shared power supply for PLC and inputs/outputs
- Non-earthed operation with insulation monitoring

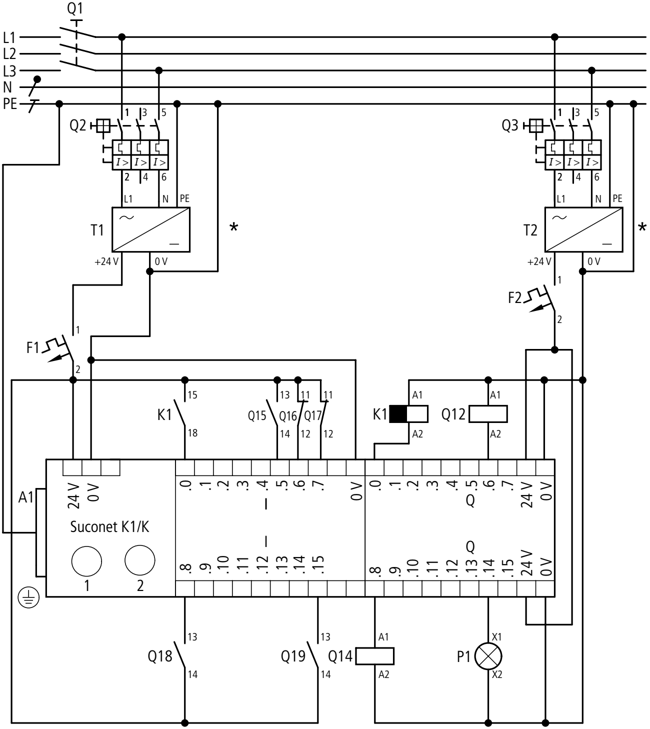


* For operation without insulation monitoring, 0 V must be linked with the PE potential in the control circuits.

Automation Systems
Engineering EM4 and LE4

EM4-201-DX2 expansion module and LE4-116-XD1 local expansion

- Inputs and outputs have a separate power supply
- Earthed operation



* Insulation monitoring must be provided where the control circuits are not earthed.

Notes

Electronic motor starters and drives

Electronic motor starters and drives

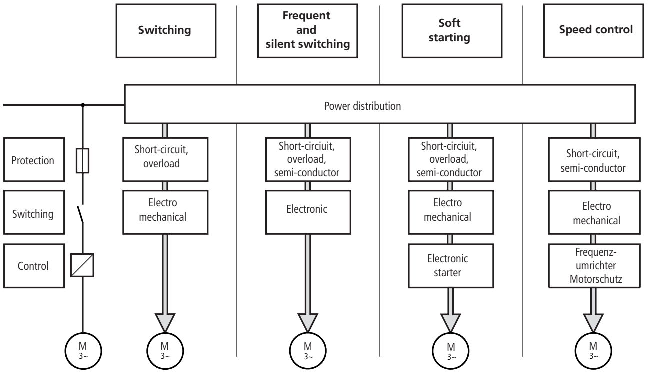
General

The complete power supply and control programme for motors

As the applications differ, so do the requirements made of the electric drives:

- In the simplest case, the motor is switched with an electromechanical contactor. Combinations consisting of motor protection and line protection are termed motor starter.
- If frequent and/or silent switching is required, contactless semiconductor contactors are used. In addition to conventional line, short-circuit and overload protection, superfast semiconductor fuses are required for type "2" coordination and may be needed for type "1" coordination.
- During DOL starting (star-delta, reversing starter or pole-switching), unwanted current and torque peaks occur. Soft starters eliminate these to ensure gentle starting and prevent an excessive burden on the power source.
- Where an infinitely adjustable speed or a torque adjustment is necessary, frequency inverters (U/f inverters, vector frequency inverters, servo) are used today.

As a general rule, the application determines the drive.



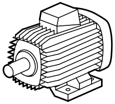
Three-phase asynchronous motors

A drive task first requires a drive motor whose characteristics with regard to speed, torque and control options are in accord with the set task.

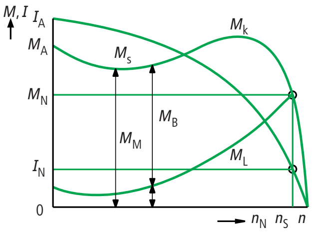
Electronic motor starters and drives

General

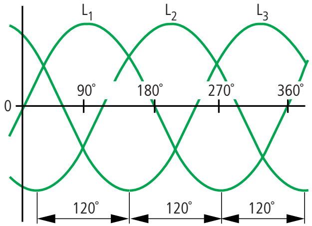
The three-phase asynchronous motor is the world's most common electric motor. Its popularity is the result of a rugged, simple construction, high degrees of protection, standardized sizes and low cost.



Three-phase motors have typical starting characteristics, with tightening torque M_A, pull-out torque M_K and rated-load torque M_N.



The three-phase motor contains three phase windings that are offset from one another by 120 °/p (p = number of pole pairs). To generate a rotating field in the motor, a voltage is applied to each phase in turn at a time delay of 120 °.



The effect of induction produces the rotating field and a torque in the rotor winding. The motor speed is determined by the number of pole pairs and the frequency of the supply voltage. The direction of rotation can be reversed by swapping over two of the supply phases:

$$n_s = \frac{f \times 60}{p}$$

n_s = Revolutions per minute
f = Frequency of voltage in Hz
p = Number of pole pairs

Example: 4-pole motor (number of pole pairs = 2), mains frequency = 50 Hz, n = 1 500 r.p.m. (synchronous speed, speed of rotating field)
Because of the induction effect, the asynchronous motor's rotor can not reach the rotating field's synchronous speed even at idle. The difference between synchronous speed and rotor speed is termed *slip*.

Slip speed:

$$S = \frac{n_s - n}{n_s}$$

Speed of an asynchronous machine:

$$n = \frac{f \times 60}{p}(1 - s)$$

The output power is as follows:

$$P_2 = \frac{M \times n}{9550} \qquad \eta = \frac{P_2}{P_2}$$

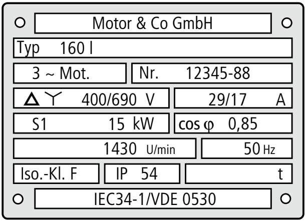
$$P_1 = U \times I \times \sqrt{3} - \text{p.f.}$$

P_2 = Shaft rating in kW
M = Torque in Nm
n = Speed in r.p.m.

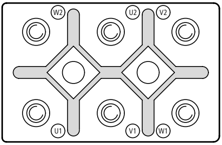
2

Electronic motor starters and drives
General

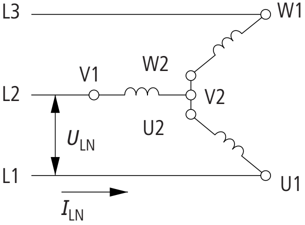
The motor's electrical and mechanical rating are recorded on its nameplate.



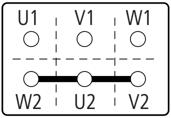
As a rule, three-phase asynchronous motors are connected to their power supply with six terminal bolts. There are basically two connection configurations: star and delta.



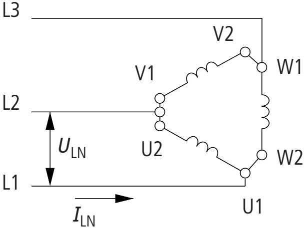
Star connection



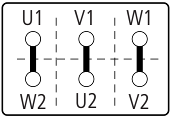
$U_{LN} = \sqrt{3} \times U_W$ $I_{LN} = I_W$



Delta connection



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



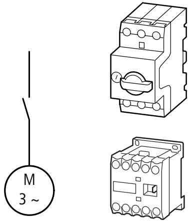
Note:
In continuous operation, the mains voltage must be the same as the motor's rated voltage.

Electronic motor starters and drives
General

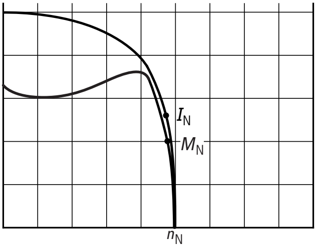
Starting and operating methods

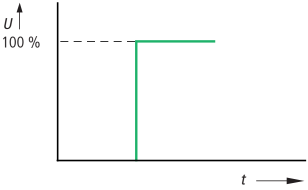
The most important starting and operating methods for three-phase asynchronous motors include:

DOL starting (electromechanical)

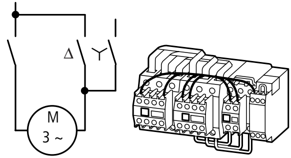


$M \sim I$, n = constant

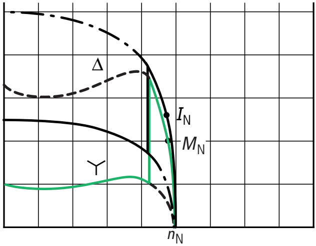


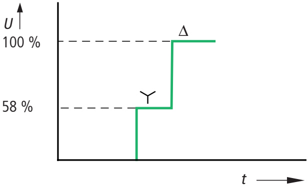


Star-delta circuit (electromechanical)



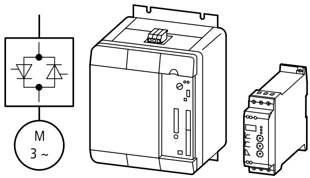
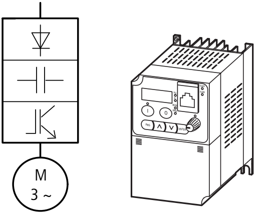
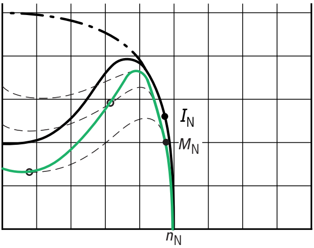
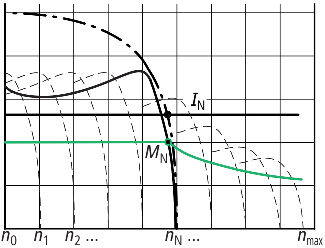
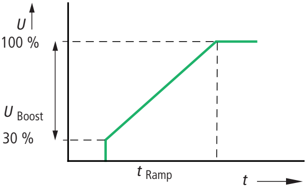
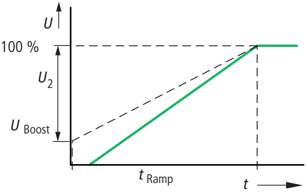
$M_{\curlyvee} \sim \frac{1}{3} M_{\triangle}$, n = constant





Electronic motor starters and drives

General

Soft starter and semiconductor contactor (electronic)	**Frequency inverter (electronic)**
	
$M \sim U^2$, n = constant	$M \sim U/f$, n = variable
	
	
U_{Boost} = Start pedestal (adjustable) t_{Ramp} = Ramp time (adjustable)	U_2 = Output voltage (adjustable) U_{Boost} = Start pedestal (adjustable) t_{Ramp} = Ramp time (adjustable)

Electronic motor starters and drives

Basics of drives engineering

Power electronics devices

The power electronics devices provide infinitely variable adjustment of physical variables – such as speed or torque – to the application process. The power is drawn from the electrical mains, converted in the power electronics apparatus and fed to the consumer (i.e. the motor).

Semiconductor contactors
Semiconductor contactor allow fast, silent switching of three-phase motors and resistive loads. Switching takes place automatically at the ideal point in time and suppresses unwanted current and voltage peaks.

Soft starters
Soft starters ramp the voltage fed to the motor up to mains voltage, so that the motor starts almost jolt-free. The voltage reduction leads to a square-law torque reduction in relation to the motor's normal starting torque. Soft starter are therefore especially well suited to starting loads with a square-law speed or torque characteristic (such as pumps or fans).

Frequency inverters
Frequency inverters convert the AC or three-phase system with its constant voltage and frequency into a new, three-phase system with variable voltage and frequency. This voltage/frequency control enables stepless speed control of three-phase motors. The controlled drive can be operated at rated-load torque even at low speeds.

Vector frequency inverters
While conventional frequency inverters control three-phase motors using a charactieristic-controlled *U/f* (voltage/frequency) relationship, vector frequency inverters work using a sensorless, flow-oriented control of the motor's magnetic field. The controlled variable is the motor current. This allows an opimized control of the torque for demanding applications (mixers and agitators, extruders, transport and conveying installations).

Electronic motor starters and drives

Basics of drives engineering

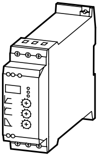
2

Moeller drives

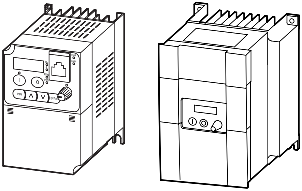
Designation	Model	Rated current [A]	Mains supply voltage [V]	Assigned motor rating [kW]
Semiconductor contactor for resistive and inductive load	DS4-140-H	10–50	1 AC 110–500	–
Soft starter	DS4-340-M	6–23	3 AC 110–500	2.2–11 (400 V)
Soft starter with bidirectional operation	DS4-340-MR	6–23	3 AC 110–500	2.2–11 (400 V)
Soft starter with bypass relay	DS4-340-MX, DS4-340-M + DIL	16–46	3 AC 110–500	7.5–22 (400 V)
Soft starter with bypass relay and bidirectional operation	DS4-340-MXR	16–31	3 AC 110–500	7.5–15 (400 V)
Soft starters (in-line connection type)	DM4-340...	16–900	3 AC 230 – 460	7.5–500 (400 V)
Soft starters (delta connection type)	DM4-340...	16–900	3 AC 230 – 460	11–900 (400 V)
Frequency inverters	DF5-322...	1.4–10	1 AC 230 3 AC 230	0.18–2.2 (230 V)
Frequency inverters	DF5-340...	1.5–16	3 AC 400	0.37–7.5 (400 V)
Frequency inverters	DF6-340...	22–230	3 AC 400	11–132 (400 V)
Vector frequency inverters	DV5-322...	1.4–11	1 AC 230 3 AC 230	0.18–2.2 (230 V)
Vector frequency inverters	DV5-340...	1.5–16	3 AC 400	0.37–7.5 (400 V)
Vector frequency inverters	DV6-340...	2.5–260	3 AC 400	0.75–132 (400 V)

Electronic motor starters and drives

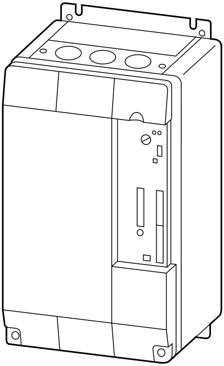
Basics of drives engineering



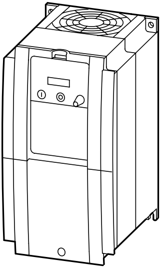
Semiconductor contactors DS4-…



Frequency inverters DF5-…
Vector frequency inverters DV5-…



Soft starters DM4-…



Frequency inverters DF6-320-…
Vector frequency inverters DV6-320-…

Electronic motor starters and drives

Basics of drives engineering

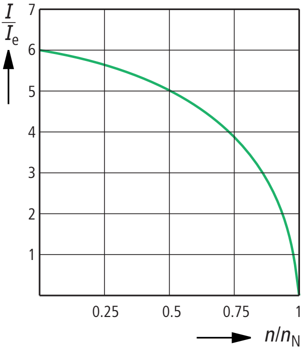
DOL starting

In the simplest case, and especially at low rated output (up to about 2.2 kW), the three-phase motor is connected directly to mains voltage. In most applications, the connection is made with an electromechanical contactor.

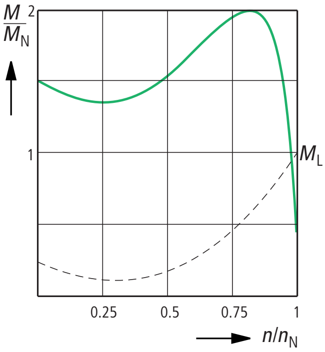
In this control mode, – on the mains at fixed voltage and frequency – the asynchronous motor's speed is only slightly below the synchronous speed [$n_s \sim f$].

Due to rotor slippage, The operating speed [n] deviates from this value in relation to the rotating field [$n = n_s \times (1 - s)$], slippage being [$s = (n_s - n)/n_s$].

On starting (s = 1), a high starting current occurs, reaching up to ten times the rated current I_e.



I/I_e: 6...10



M/M_N: 0.25...2.5

Features of DOL starting

- For low- and medium-power three-phase motors
- Three connection lines (circuit layout: star or delta)
- High starting torque
- Very high mechanical load
- High current peaks
- Voltage dips
- Simple switching devices

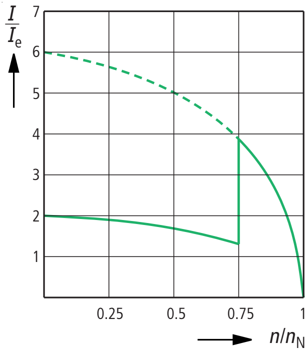
If an application demands frequent and/or silent switching, or if adverse environmental conditions prevent the effective use of electromechanical switching elements, electronic semiconductor contactors are required. In addition to short-circuit and overload protection, the semiconductor contactor must be protected with a superfast fuse. According to IEC/EN 60947, type "2" coordination requires the use of a superfast semiconductor fuse. For type "1" coordination, – the majority of cases – a superfast semiconductor fuse is not necessary. Here are a few examples:

- Building services management:
  - Reversing drive for lift doors
  - Starting heat-exchanger units
  - Starting conveyor belts
- In critical atmospheres:
  - Controlling filling station petrol pump motors
  - Controlling pumps in paint processing plants.
- Other applications: Non-motor-driven loads, such as
  - Heater elements in extruders
  - Heater elements in kilns
  - Controlling lighting systems.

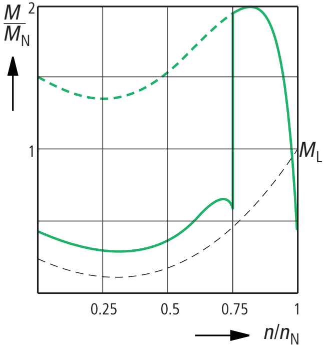
Motor start in star-delta configuration

The star-delta circuit layout is the most commonly used configuration for starting three-phase motors.

The completely factory prewired SDAINL star-delta combination from Moeller provides convenient motor control. The customer saves on expensive wiring and installation time and reduces the likelihood of faults.



I/I_e: 1.5...2.5



M/M_N: 0.5

Features of star-delta starting

- For low- to high-power three-phase motors
- Reduced starting current
- Six connection cables
- Reduced starting torque
- Current peak on changeover from star to delta
- Mechanical load on changeover from star to delta

Electronic motor starters and drives

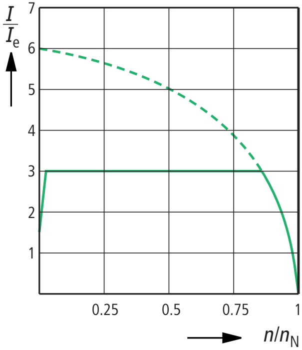
Basics of drives engineering

Soft starters (electronic motor start)

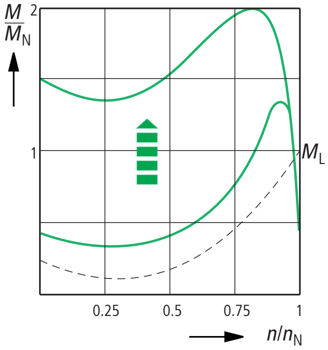
The characteristic curves for DOL and star-delta starting show current and torque step changes, which have a number of negative effects, especially at medium and high motor ratings:

- High mechanical machine loads
- Rapid wear
- Increased servicing costs
- High supply costs from the power supply companies (peak current calculation)
- High mains and generator load
- Voltage dips with a negative effect in other consumers

The ideal scenario of a smooth torque build-up and a controlled current reduction in the starting phase is made possible by the electronic soft starter. Providing infinitely variable control of the three-phase motor's supply voltage in the starting phase, it matches the motor to the load behaviour of the driven machine and accelerates it smoothly. This avoids mechanical jolting and suppresses current peaks. Soft starters present an electronic alternative to the conventional star-delta switch.



I/I_e: 1...5



M/M_N: 0.15...1

Features of the soft starters

- For low- to high-power three-phase motors
- No current peaks
- Zero maintenance
- Reduced adjustable starting torque

Electronic motor starters and drives

Basics of drives engineering

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 behaviour of the individual motors to be controlled. Each motor must be separately fitted with suitable overload protection.

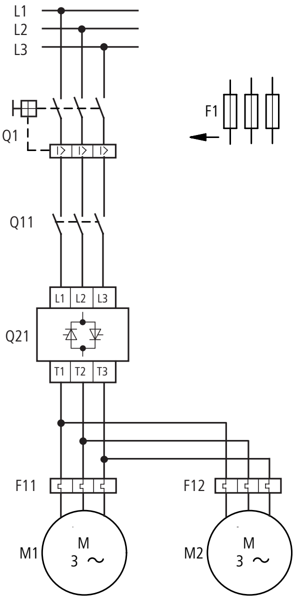
Note:
The total current consumption of the connected motors must not exceed the soft starter's rated operational current I_e.

Note:
Each motor must be individually protected with a thermistor and/or overload relay.

Caution!
Switching must not take place in the soft starter's output as the resulting voltage peaks can damage the thyristors in the power section.

Problems may arise during starting if there are significant differences in the connected motors' ratings (for example 1.5 kW and 11 kW): The lower-rated motors may not be able to reach the required torque due to the relatively large ohmic resistance of these motors' stators, requiring a higher voltage during starting.

It is advisable to use this circuit type only with motors of a similar rating.



Electronic motor starters and drives

Basics of drives engineering

Using soft starters with pole-changing motors

Soft starters can be connected in the supply line before pole-changing, → section "Pole-changing motors", page 8-51).

Note:

All changeovers (high/low speed) must take place at standstill.

The start signal must be issued only when a contact sequence has been selected and a start signal for pole-changing was set.

Control is comparable to cascade control with the difference that the changeover is made not to the next motor but to the other winding (TOR = top-of-ramp signal).

Using soft starters with three-phase slipring 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 sliprings of the motor's rotor. The soft starter is then connected into the incomer and provides stepless starting of the motor. (→ page 2-15).

Using soft starters for motors with power-factor correction

Caution!

No capacitive loads must be connected at the soft starter's output.

Power-factor corrected motors or motor groups must not be started with soft starters. Mains-side compensation is permissible when the ramp time (starting phase) has completed (i.e. the TOR (Top of Ramp) signal has been issued) and the capacitors exhibit a series inductance.

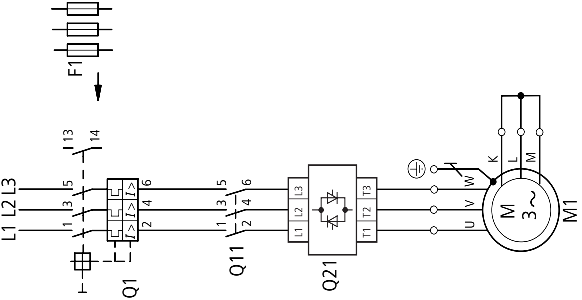
Note:

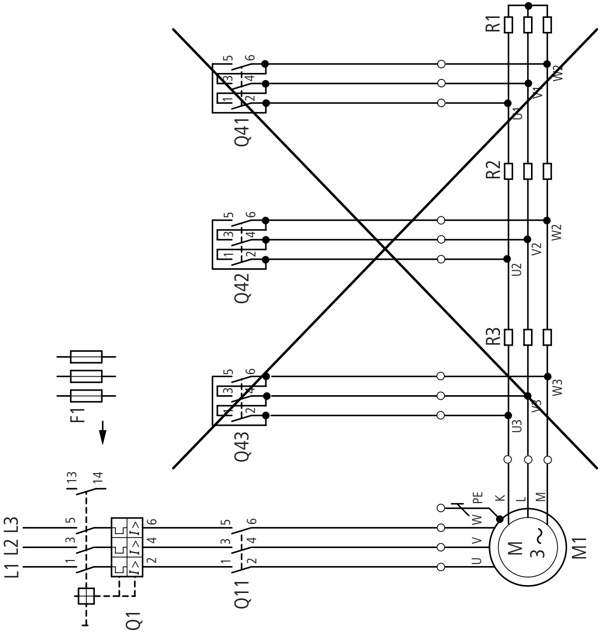
If electronic devices (such as, soft starters, frequency inverters or UPS), use capacitors and correction circuits only with a choke fitted upstream.

→ page 2-16.

Electronic motor starters and drives

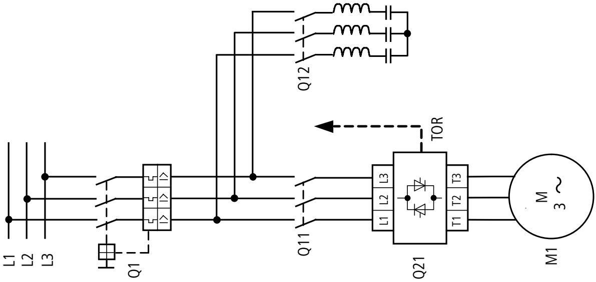
Basics of drives engineering

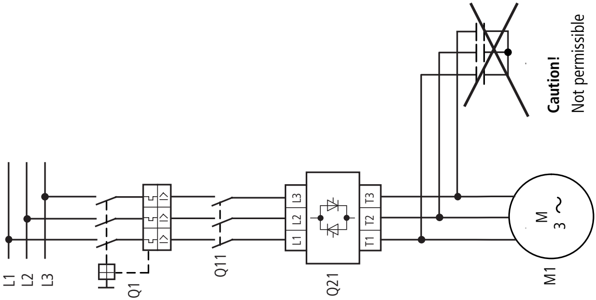


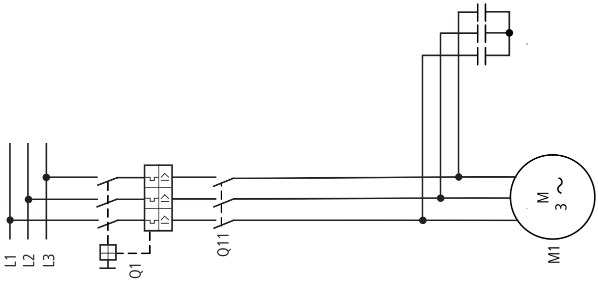


Electronic motor starters and drives

Basics of drives engineering







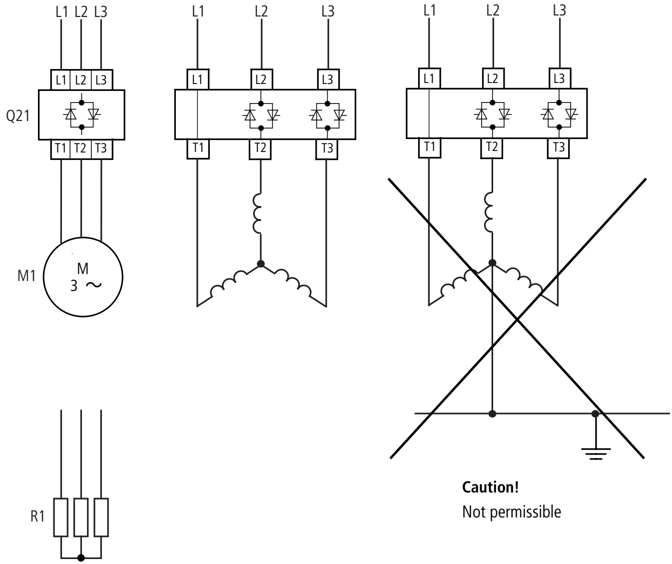
Electronic motor starters and drives

Basics of drives engineering

Connecting star points when using soft starters or semiconductor contactors

Caution!

The connection of the star point to the PE or N conductor is not permissible when using controlled semiconductor contactors or soft starters. This applies especially to two-phase-controlled starters.



Caution!

Not permissible

Electronic motor starters and drives

Basics of drives engineering

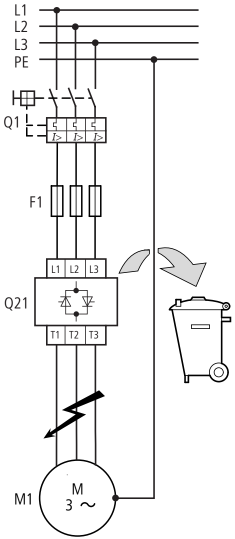
Soft starters and classification type to IEC/EN 60947-4-3

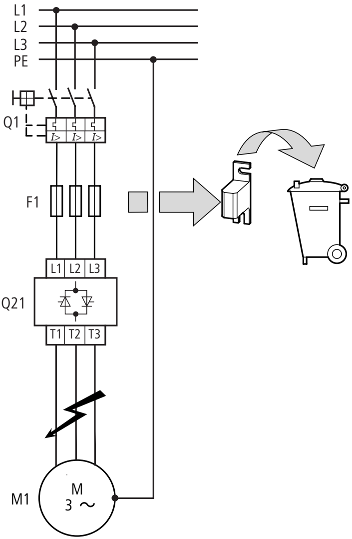
The following classification types are defined in IEC/EN 60947-4-3, 8.2.5.1:

Type "1" coordination
In type "1" coordination, the contactor or soft starter must not endanger persons or the installation in the event of a short-circuit and **does not** have to be capable of continued use without repairs or parts replacements.

Type "2" coordination
In type "2" coordination, the contactor or soft starter 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. In this case the manufacturer must provide appropriate maintenance instructions.

The coordinated short-circuit protection device (SCPD) must trip in the event of a short-circuit. Blown fuses must be replaced. This is part of normal operation (for the fuse), also for type "2" coordination.



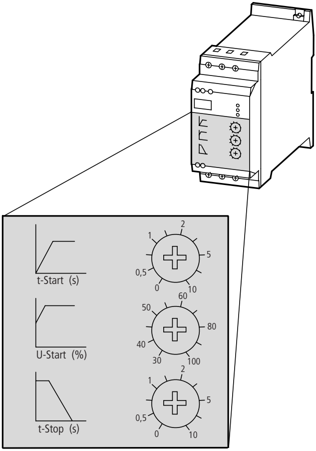


Electronic motor starters and drives

Soft starters DS4

Product attributes

- Construction, mounting and connection as for contactor
- Automatic control voltage detection
  – 24 V DC ± 15 % 110 to 240 V AC ± 15 %
  – Safe starting at 85 % U_{min}
- Operation indication by LED
- Individually adjustable start and stop ramps (0.5 to 10 s)
- Adjustable start pedestal (30 to 100 %)
- Relay contact (N/O contact): operating signal, TOR (top of ramp)



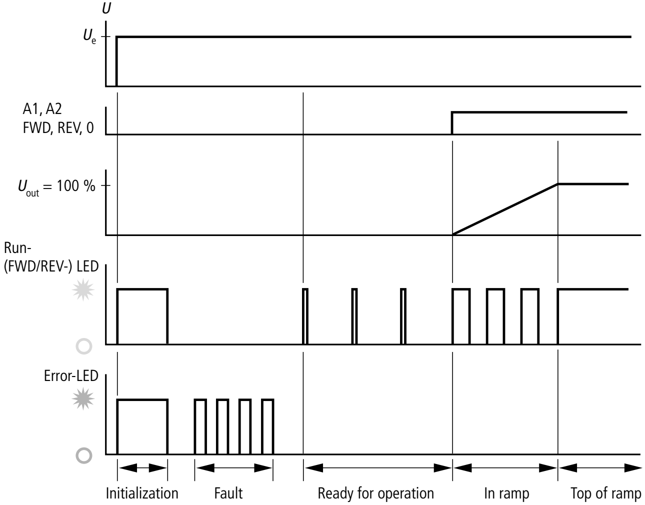
Electronic motor starters and drives

Soft starters DS4

LED displays

The LEDs indicate the operational states as follows:

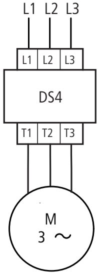
Red LED	Green LED	Function
Lit	Lit	Init, LEDs lit only briefly, Init itself takes about 2 seconds Depending on device: – All devices: LED briefly lit once – DC devices: after a brief pause, the LEDs briefly light up again
Off	Off	Device is off
Off	Flashing at 2 s intervals	Ready for operation, power supply OK, but no start signal
Off	Flashing at 0.5 s interval	Device in operation, ramp is active (soft start or soft stop); on M(X)R the current rotating field direction is also indicated.
Off	Lit	Device in operation, top-of-ramp reached; on M(X)R the current rotating field direction is also indicated.
Flashing at 0.5 s interval	Off	Fault

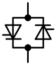
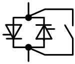
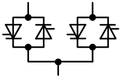
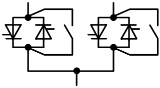
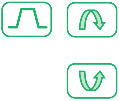


Electronic motor starters and drives

Soft starters DS4

Power section versions



	DOL starters	DOL starters with bypass	Reversing starters	Reversing starters with bypass
	DS4-340-...-M	DS4-340-...-MX	DS4-340-...-MR	DS4-340-...-MXR
				
				

Electronic motor starters and drives

Soft starters DM4

Product attributes

- Configurable, communications-capable soft starter with plug-in control signal terminals and interface for optional units:
  - Operator control and programming unit
  - Serial interface
  - Fieldbus module
- Application selector switch with user-programmable parameter sets for 10 standard applications
- I^2t controller
  - Current limitation
  - Overload protection
  - Idle/undercurrent detection (e.g. belt breakage)
- Kickstarting and heavy starting
- Automatic control voltage detection
- 3 relays, e.g. fault signal, TOR (top of ramp)

Ten default parameter sets for typical applications can be simply called up with a selector switch.

Additional plant-specific settings can be defined with an optional keypad.

In three-phase regulator control mode, for example, three-phase resistive and inductive loads – heaters, lighting systems, transformers – can be controlled with the DM4. Both open-loop and – with measured value feedback – closed-loop control are possible.

Instead of the keypad, intelligent interfaces can also be used:

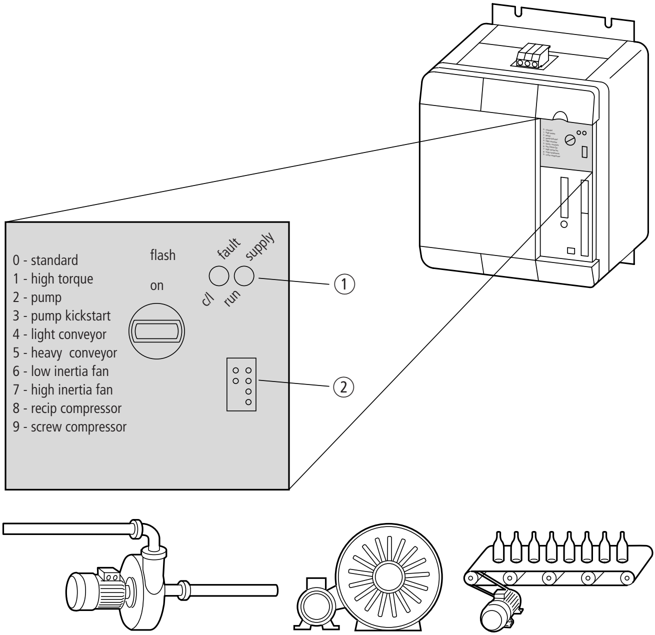
- Serial RS 232/RS 485 interface (configuration through PC software)
- Suconet K fieldbus module (interface on every Moeller PLC)
- PROFIBUS DP fieldbus module

The DM4 soft starters provide the most convenient method of implementing soft starting. Because – in addition to phase failure and motor current monitoring – the motor winding temperature is signalled through the built-in thermistor input, the soft starters eliminate the need for additional, external components, such as motor protective relays. DM4 conforms to the IEC/EN 60947-4-2 standard.

With the soft starter, reducing the voltage results in a reduction of the high starting currents of the three-phase motor, although the torque is also reduced [$I_{startup} \sim U$] and [$M \sim U^2$]. After starting, the motor reaches its rated speed with all of the solutions described above. For starting motors at rated-load torque and/or for motor operation at a motor speed that is independent of the supply frequency, a frequency inverter is required.

Electronic motor starters and drives

Soft starters DM4



Electronic motor starters and drives

Soft starters DM4

Standard applications (selector switch)

Labelling on device	Indication on keypad	Meaning	Notes
Standard	Standard	Standard	Default settings, suitable without adaptation for most applications
High torque[1)]	High Torque	High breakaway torque	Drives with higher friction torque at standstill
Pump	Pump	Small pump	Pump drives up to 15 kW
Pump Kickstart	Pump.w.Kick	Large pump	Pump drives over 15 kW Longer deceleration times.
Light conveyor	LightConvey	Light conveyor	
Heavy conveyor	HeavyConvey	Heavy-duty conveyor	
Low inertia fan	LowInert.fan	Low-inertia fan	Fan drive with relatively small mass inertia moment of up to 15 times the motor's inertia moment
High inertia fan	HighInertfan	High-inertia fan	Fan drive with relatively large mass inertia moment of over 15 times the motor's inertia moment Longer ramp-up times.
Recip compressor	RecipCompres	Reciprocal compressor	Higher start pedestal, p.f. optimization matched
Screw compressor	ScrewCompres	Screw compressor	Increased current consumption, no current limitation

1) For the "High Torque" setting, the soft starter must be able to supply 1.5 times the motor's rated current.

Delta circuit

Normally, soft starters are connected directly in series (in-line) with the motor. The DM4 soft starters also allow a delta connection.

Advantage:

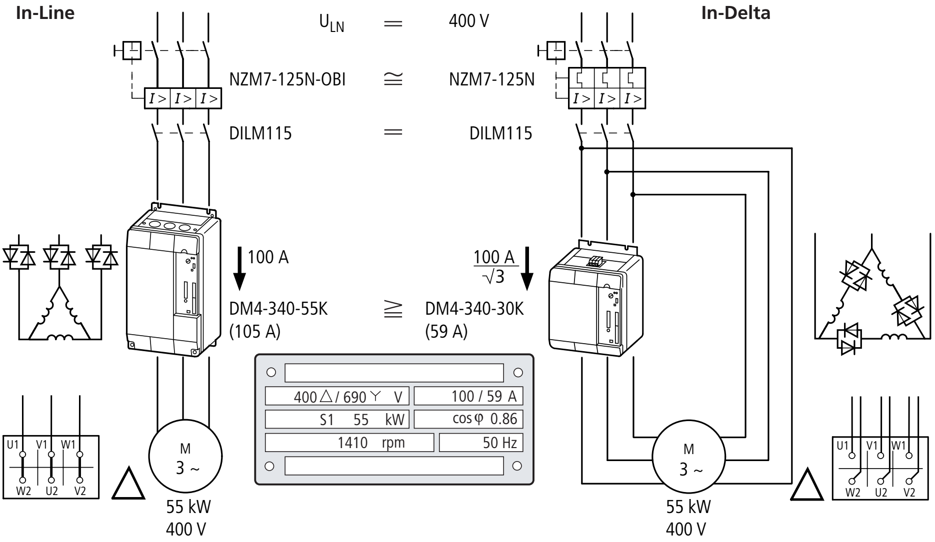
- This is a less expensive alternative since the soft starter has to deliver only 58 % of the motor's rated current.

Disadvantages over in-line connection:

- As in a star-delta circuit, the motor must be connected with six conductors.
- The DM4's overload protection is active only in one phase, so that additional motor protection must be fitted in the parallel phase or in the supply cable.

Note:

The delta connection is more cost-effective at motor ratings over 30 kW and when replacing star-delta switches.

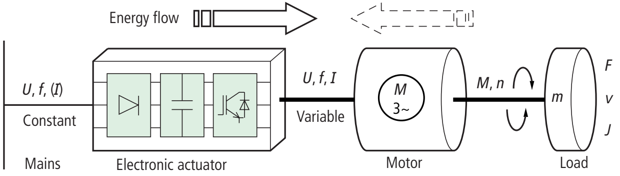

In-Line
In-Delta
ULN
=
400 V
NZM7-125N-OBI
≅
NZM7-125N
I > I > I >
DILM115
=
DILM115
100 A
100 A / √3
DM4-340-55K
(105 A)
≧
DM4-340-30K
(59 A)
400 △ / 690 Y V
100 / 59 A
S1 55 kW
cos φ 0.86
1410 rpm
50 Hz
U1 V1 W1
W2 U2 V2
M
3 ~
55 kW
400 V

Electronic motor starters and drives

Frequency inverters DF5, DV5, DF6, DV6

Design and mode of operation

Frequency inverters provide variable, stepless speed control of three-phase motors.

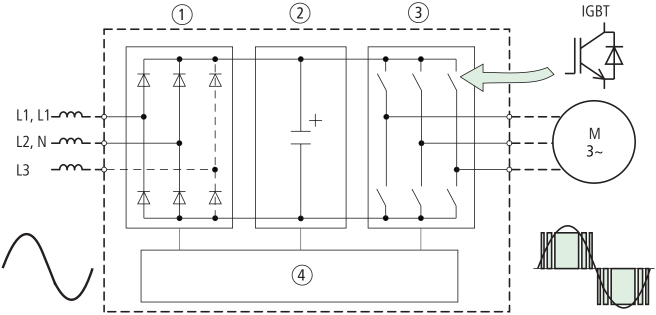


$$P_{el} = U \times I \times \sqrt{3} \times \cos\varphi$$

$$I \sim M$$
$$f \sim n$$

$$P_L = \frac{M \times n}{9550}$$

Frequency inverters convert 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 frequency inverter draws almost only active power (p.f. ~ 1) from the supplying mains. The reactive power needed for motor operation is supplied by the DC link. This eliminates the need for p.f. correction on the mains side.

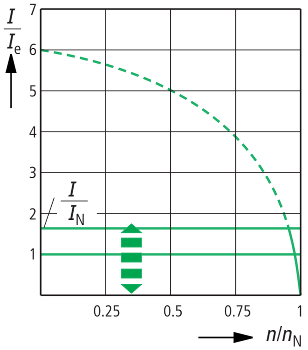


1 Rectifier
2 DC link
3 Inverter with IGBT
4 Open-/closed-loop control

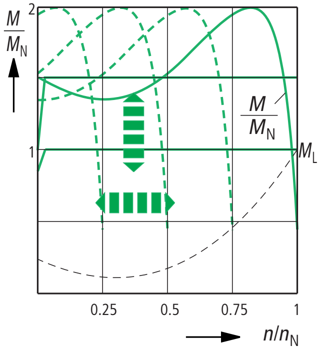
Electronic motor starters and drives
Frequency inverters DF5, DV5, DF6, DV6

The frequency-controlled three-phase motor is today a standard component for infinitely variable speed and torque regulation, providing efficient, energy-saving power either as an individual drive or as part of an automated installation.

The possibilities for individual or plant-specific coordination are determined by the specific features of the inverters and by the modulation procedure used.



I/I_e: 0...1.8



M/M_N: 0.1...1.5

Modulation procedure of inverters

An inverter basically consists of six electronic switches and is today usually made with IGBTs (**i**nsulated **g**ate **b**ipolar **t**ransistors). The control circuit switches the IGBTs on and off according to various principles (modulation procedures) to change the frequency inverter's output frequency.

Sensorless vector control

The switching patterns for the inverter are calculated with the PWM (**p**ulse-**w**idth **m**odulation) switching patterns. In voltage vector control mode, the amplitude and frequency of the voltage vector are controlled in dependence of slippage and load current. This allows large speed ranges and highly accurate speeds to be achieved without speed feedback. This control method (*U*/*f* control) is the preferred method for parallel operation of several motors with one frequency inverter.

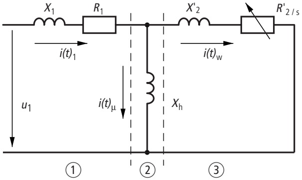
In flow-regulated vector control, the active and reactive current components are calculated from the measured motor currents, compared with the values from the motor model and, if necessary, corrected. The amplitude, frequency and inclination of the voltage vector are controlled directly. This allows operation at the current limit and the achievement of large speed ranges and highly accurate speeds. Especially noteworthy is the drive's dynamic output at low speeds, for example in lifting and winding applications.

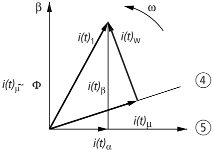
Electronic motor starters and drives

Frequency inverters DF5, DV5, DF6, DV6

The key advantage of sensorless vector technology is that the motor current can be regulated to match the motor's rated current. This allows dynamic torque regulation to be implemented for three-phase asynchronous motors.

The following illustration shows a simplified equivalent circuit diagram for the asynchronous motor and associated current vectors:





① Stator
② Air gap
③ Rotor
④ Rotor flow-oriented
⑤ Stator-oriented

i_1 = Stator current (phase current)
i_μ = Flux-generating current component
i_w = Torque-generating current component
R'_2 /s = Slip-dependent rotor resistance

In sensorless vector control, the flux-generating current i_μ and the torque-generating current i_w are calculated from the measured stator voltage u_1 and stator current i_1. The calculation is performed with a dynamic motor model (electrical equivalent circuit of the three-phase motor) with adaptive current regulators, taking into account the saturation of the main field and the iron loss. The two current components are set according to their value and phase in a rotating coordinate system (ω) to the stator reference system (α, β).

The physical motor data required for the model is formed from the entered and measured (self-tuning) parameters.

Electronic motor starters and drives
Frequency inverters DF5, DV5, DF6, DV6

Characteristics of frequency inverters DF5, DF6

- Infinitely variable speed control through voltage/frequency control (*U*/*f*)
- High starting and acceleration torque
- Constant torque in motor's rated range
- EMC measures (optional: radio interference filter, screened motor cable)

Additional features of sensorless vector control for frequency inverters DV5 and DV6

- Infinitely variable torque control, also at zero speed
- Low torque control time
- Increased concentricity and constancy of speed
- Speed control (options for DV6: control module, pulse generator)

The DF5, DF6, DV5 and DV6 frequency inverters are factory-preset for their assigned motor rating, allowing drives to be started immediately after installation.

Individual settings can be made with an optional keypad. Various control modes can be selected and configured in a number of layers,

For applications with pressure and flow control, all devices contain a built-in PID controller that can be matched to any system.

A further advantage of the frequency inverters is that they eliminate the need for external components for monitoring and motor protection. On the mains side, only a fuse or circuit-breaker (PHKZ) is needed for line and short-circuit protection. The frequency inverter's inputs and outputs are monitored internally by measurement and control circuits, such as overtemperature, earth fault, short-circuit, motor overload, motor blockage and drive belt monitoring. Temperature measurement in the motor winding can also be incorporated in the frequency inverter's control circuit through a thermistor input.

Electronic motor starters and drives

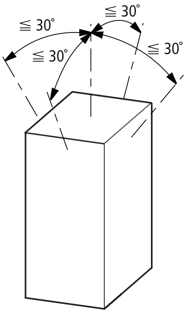
Frequency inverters DF5, DV5, DF6, DV6

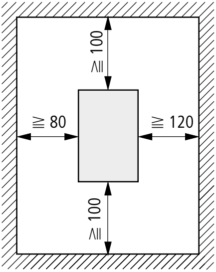
Frequency inverter, installing

Electronic devices such as soft starters and frequency inverters must normally be fitted vertically.

To ensure adequate air circulation for cooling, a clear space of at least 100 mm should be maintained both above and below the device. At the sides of the device, the clear space should be at least 10 mm for DF5 and DV5 and 50 mm for DF6 and DV6.

Note that the front enclosure elements of the DF5 and DV5 devices open to the side for electrical connection. Make sure that the free space in the area of the front hinged covers is at least 80 mm to the left side and at least 120 mm to the right side.

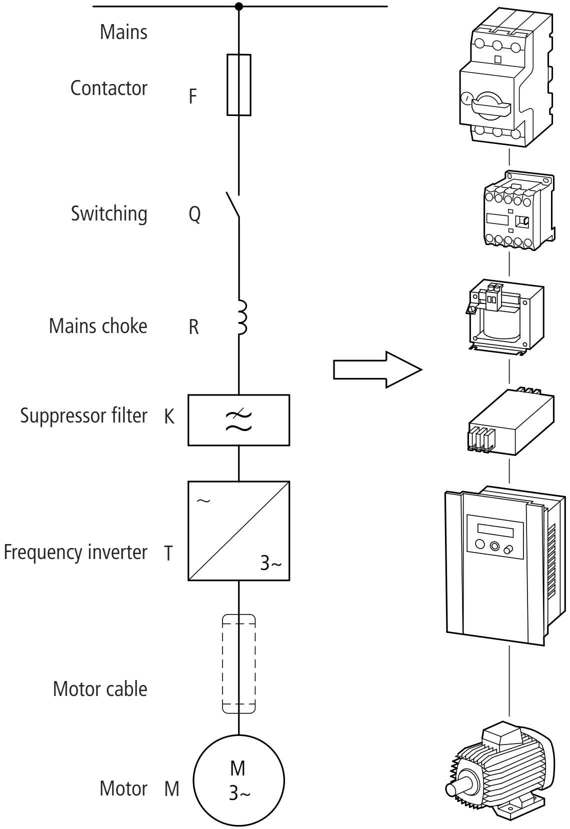




Electronic motor starters and drives

Frequency inverters DF5, DV5, DF6, DV6

EMC-compliant connection of frequency inverters



The EMC-compliant mounting and connection is described in detail in the respective devices' manuals (AWB).

Electronic motor starters and drives
Frequency inverters DF5, DV5, DF6, DV6

Notes about correct installation of frequency inverters

For an EMC-compliant installation, observe the following information. Electrical and magnetic disturbance fields can 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.

EMC measures

The EMC (**e**lectro**m**agnetic **c**ompatibility) of a device is its ability to withstand electrical interference (i.e. its immunity) while itself not emitting excessive electromagnetic interference into the environment.

The IEC/EN 61800-3 standard describes the limit values and test methods for emitted interference and noise immunity for variable-speed electrical drives (PDS = Power Drives System).

The tests and values are based not on individual components but on a typical complete drive system.

Measures for EMC-compliant installation are:

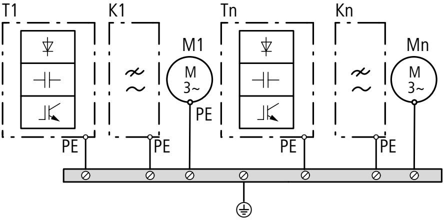
- Earthing measures
- Screening measures
- Filtering measures
- Chokes

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 screening. All conducting metallic enclosure sections must be electrically connected to the earth potential. For EMC, the important factor is not the cable’s cross-section, but its surface, since this is where high frequency current flows to earth. All earthing points must be low-impedance, highly conductive and routed directly to the central earthing point (potential equalization bar or star earth). The contact points must be free from paint and rust. Use galvanized mounting plates and materials.

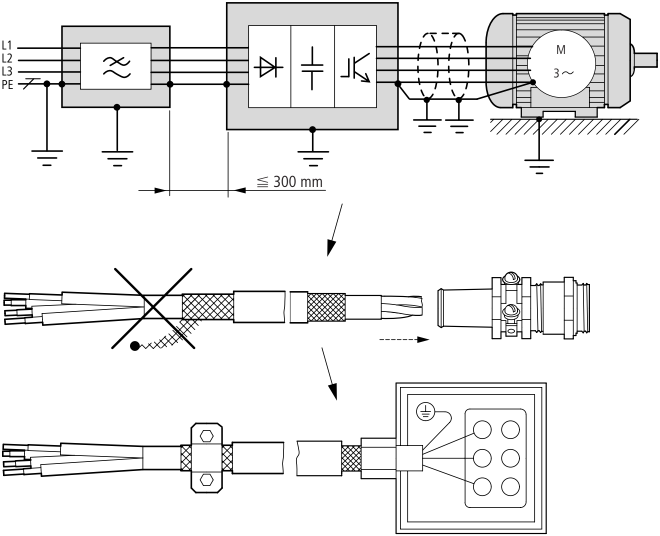
K1 = Radio interference filter
T1 = Frequency inverter

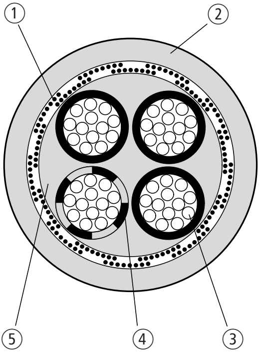


Electronic motor starters and drives

Frequency inverters DF5, DV5, DF6, DV6

Screening measures





Four-core screened motor supply cable:

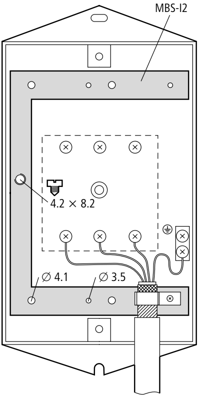
① Copper screen braid, earth at both ends with large-area connections
② PVC outer sheath
③ Drain wire (copper, U, V, W, PE)
④ PVC cable insulation 3 × black, 1 × green/yellow
⑤ Textile and PVC fillers

Electronic motor starters and drives
Frequency inverters DF5, DV5, DF6, DV6

Screening reduces emitted interference (noise immunity of neighbouring systems and devices against external influences). Cables laid between the frequency inverter and the motor must be screened, but the screen must not be considered a replacement for the PE cable. Four-wire motor cables are recommended (three phases plus PE). The screen must be connected to earth (PES) at both ends with a large-area connection. Do not connect the screen with pigtails. Interruptions in the screen, such as terminals, contactors, chokes, etc., must have a low impedance and be bridged with a large contact area.

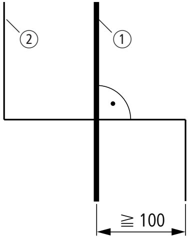
To do this, sever the screen near the module and establish a large-area contact with earth potential (PES, screen terminal). Free, unscreened cables should not be longer than about 100 mm.

Example: Screen attachment for maintenance switch



Note:
Maintenance switches at of frequency inverter outputs must be operated only at zero current.

Control and signal lines must be twisted and may be double-screened, the inner screen being connected to the voltage source at one end and the outer screen at both ends. The motor cable must be laid separately from the control and signal lines (>10 cm) and must not run parallel to any power cables.



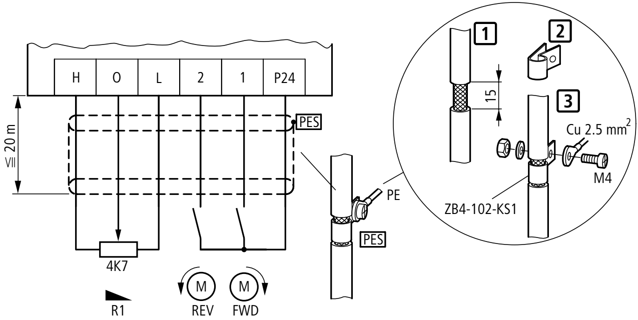
1. Power cables: mains, motor, internal DC link, braking resistance
2. Signal cables: analog and digital control signals

Inside control panels, too, cables should be screened if they are more than 30 cm long.

Electronic motor starters and drives

Frequency inverters DF5, DV5, DF6, DV6

Example for screening control and signal cables:



Example for a standard connection of frequency inverter DF5, with reference value potentiometer R1 (M22-4K7) and mounting accessories ZB4-102-KS1

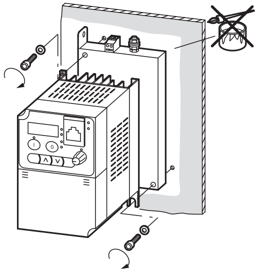
Filtering measures

Radio interference filters and line filters (combinations of radio interference filter and mains choke) protect against conducted high-frequency interference (noise immunity) and reduce the frequency inverter’s high-frequency interference, which is transmitted through or emitted from the mains cable, and which must be limited to a prescribed level (emitted interference).

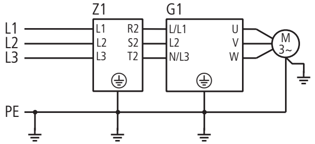
Filters should be installed as closely as possible to the frequency inverter to keep the length of the connecting cable between frequency inverter and filter short.

Note:

The mounting surfaces of frequency inverters and radio interference filters must be free from paint and must have good HF conductivity.



Filters produce leakage currents which, in the event of a fault (such as phase failure or load unbalance), can be much larger than the rated values. To prevent dangerous voltages, the filters must be earthed. As the leakage currents are high-frequency interference sources, the earthing connections and cables must have a low resistance and large contact surfaces.



For leakage currents above 3.5 mA, one of the following must be fulfilled according to EN 60335:

- the protective conductor must have a cross-section greater than 10 mm^2,
- the protective conductor must be open-circuit monitored, or
- an additional conductor must be fitted.

Chokes

Fitted on the frequency inverter's input side, chokes reduce the current-dependent phase effect and improve the power factor. This reduces the current harmonics and improves the mains quality. The use of mains chokes is especially recommended where several frequency inverters are connected to a single mains supply point when other electronic devices are also connected to the same supply network.

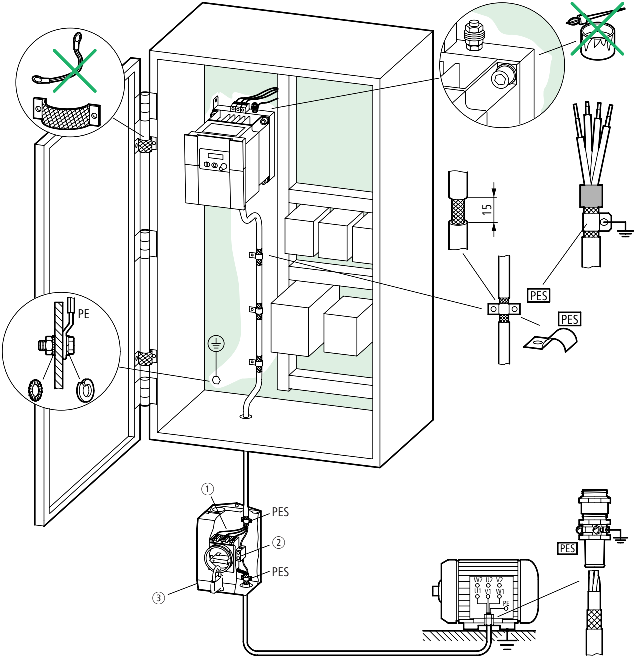
A reduction of the mains current interference is also achieved by installing DC chokes in the frequency inverter's DC link.

At the frequency inverter's output, chokes are used if the motor cables are long and if multiple motors are connected in parallel to the output. 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 starters and drives

Frequency inverters DF5, DV5, DF6, DV6

Example: EMC-compliant mounting and connection



① Metal plate, e.g. MSB-I2
② Earthing terminal
③ Maintenance switches

Electronic motor starters and drives
Connection examples, DS4

Linking the overload relay into the control system

We recommend using an external overload relay instead of a motor-protective circuit-breaker with built-in overload relay. This allows controlled ramping down of the soft starter through the control section in the event of an overload.

Note:
Connecting the motor directly to mains power can cause overvoltage and destruction of the soft starter's semiconductors.

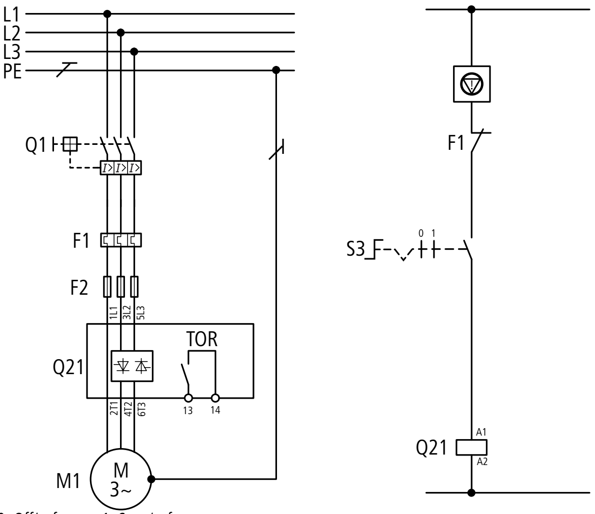
Note:
The overload relay's signalling contacts are linked into the On/Off circuit.

In the event of a fault, the soft starter decelerates for the set ramp time and stops.

Standard connection, unidirectional rotation

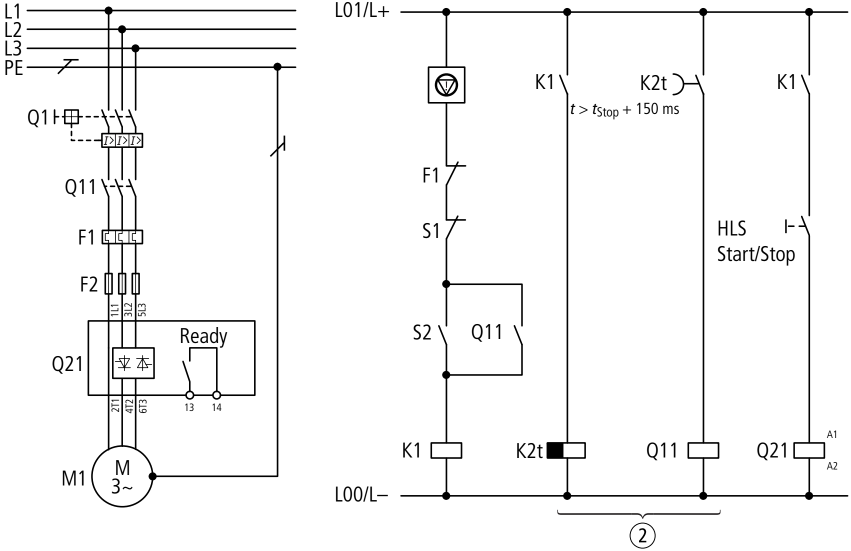
In standard operation the soft starter is connected into the motor supply line. A central switching element (contactor or main switch) with isolating properties to isolate the mains according to EN 60947-1 section 7.1.6 and for working on the motor is required according to EN 60204-1 section 5.3. No contactors are required to operate individual motor feeders.

Minimum connection of DS4-340-M(X)



0: Off/soft stop, 1: Start/soft start

Connection of DS4-340-M as semiconductor contactor



Q1 = Line protection
Q11 =Mains contactor (optional)
F1 = Motor-protective relay

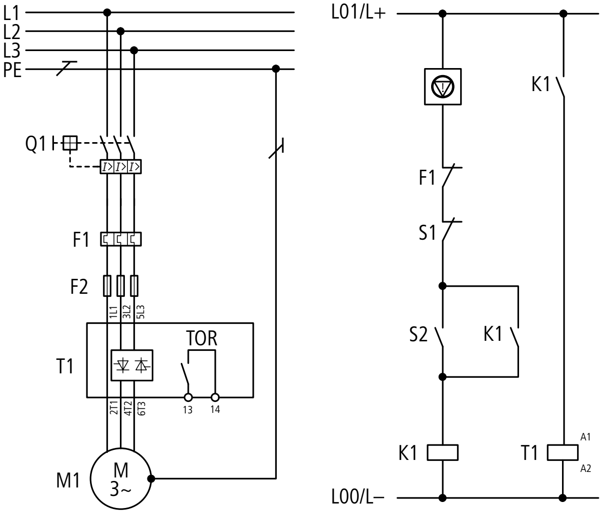
F2 = Semiconductor fuse for type “2” coordination, in addition to Q1
Q21 = Semiconductor contactor
M1 = Motor

S1: Q11 Off
S2: Q11 On
2: Control with Q11/K2t optional
HLS = Semiconductor contactor On/Off

Electronic motor starters and drives

Connection examples, DS4

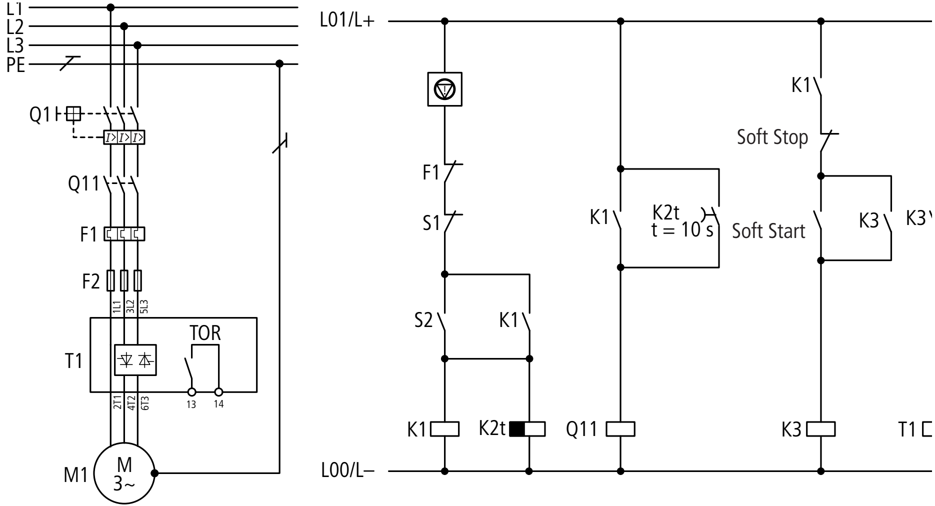
Connection as soft starter without separate mains contactor



Q1: Line protection
F1: Overload relay
F2: Semiconductor fuse for type "2" coordination, in addition to Q1
T1: Semiconductor contactor
M1: Motor

Emergency-Stop
S1: Soft stop
S2: Soft start

Connection of soft starter with mains contactor



Q1 = Line protection
Q11 = Mains contactor (optional)
F1 = Motor-protective relay

F2 = Semiconductor fuse for type “2” coordination, in addition to Q1
T1 = Soft starter
M1 = Motor

Emergency-Stop
S1: Q11 Off
S2: Q11 On

Electronic motor starters and drives

Connection examples, DS4

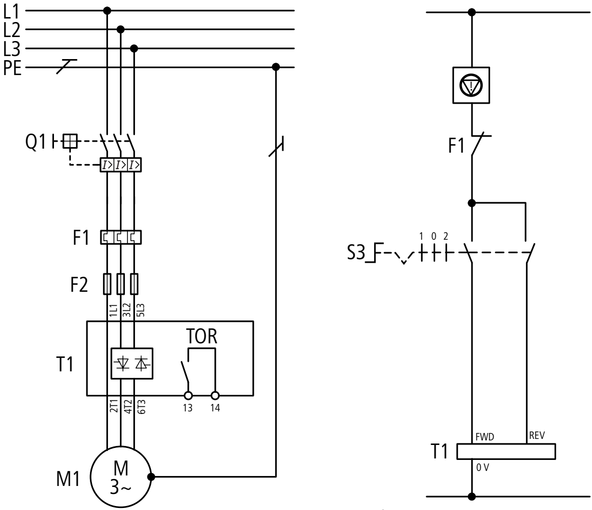
Reversing circuit standard connection, bidirectional rotation

Note:

The device of the DS4-...-M(X)R series have a built-in electronic reversing contactor function. You need to only specify the required direction of rotation. The DS4 then internally ensures the correct control sequence.

At ratings over 22 kW, a conventional reversing circuit layout must be used, because above this rating the DS4 is not available with built-in reversing contactor function. In this case make sure that direction reversal takes place only with the DS4 in stop state. Use an external controller to implement this functionality. In soft starter operation, you can use a TOR relay to control an off-delayed relay for this purpose, whereby the deceleration time must be t-Stop + 150 ms or higher.

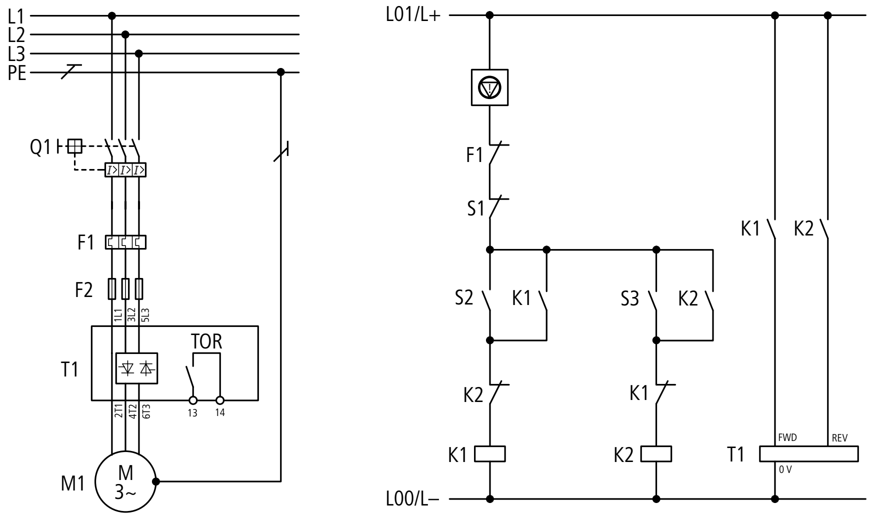
Minimum connection of DS4-340-M(X)R



Q1: Line protection
Q11: Mains contactor (optional)
F1: Overload relay
F2: Semiconductor fuse for type “2” coordination, in addition to Q1

T1: Soft starter
M1: Motor
: Emergency-Stop
0: Off/Soft stop
1: FWD
2: REV

Connection of reversing soft starter without mains contactor



Q1: Line protection
F1: Overload relay
F2: Semiconductor fuse for type "2" coordination, in addition to Q1

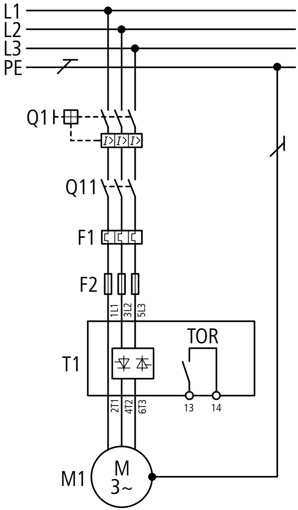
T1: Semiconductor contactor
M1: Motor

Ⓥ: Emergency-Stop
S1: Soft stop
S2: Soft start FWD
S2: Soft start REV

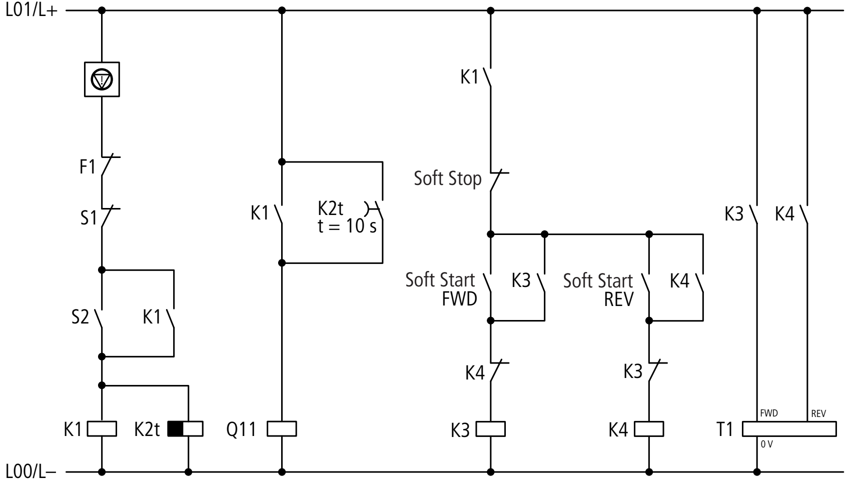
Electronic motor starters and drives

Connection examples, DS4

Connection of reversing soft starter with mains contactor



Q1: Line protection
Q11: Mains contactor (optional)
F1: Overload relay
F2: Semiconductor fuse for type "2" coordination, in addition to Q1
T1: Semiconductor contactor
M1: Motor



: Emergency-Stop
S1: Q11 Off
S2: Q11 On

Electronic motor starters and drives

Connection examples, DS4

Bypass connection, single direction of rotation

Caution!

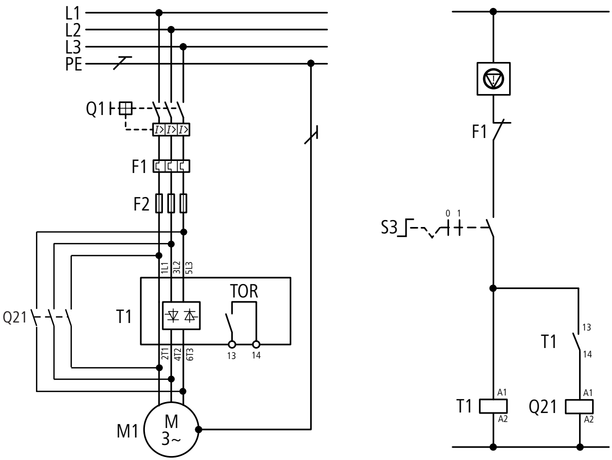
The DS4-...-MX(R) devices have built-in bypass contacts. The examples below therefore apply only for DS4-...-M. If an external bypass for devices with reversing function (DS4-...-MR) is to be fitted, you must include an additional bypass contactor is required the second direction of rotation as well as additional interlocks to prevent a short-circuit through the bypass contactors.

The bypass connection allows a direct connection of the motor to the mains to suppress heat dissipation through the soft starter. The bypass contactor is actuated once the soft starter has completed the acceleration phase (i.e. once mains voltage is reached). By default, the Top-of-Ramp function is mapped to relay 13/14. The soft starter controls the bypass contactor so that no further user action is required. Because the bypass contactor is switched only at zero current and does not, therefore, have to switch the motor load, an AC1 layout can be used. Suitable bypass contactors are listed in appendix "Technical data".

If an Emergency-Stop requires an immediate disconnection of the voltage, the bypass may have to switch under AC3 conditions (for example if the Enable signal is removed with a command or the soft stop ramp time is 0). In this case, the circuit must be laid out so that either a higher-priority isolating element trips first or the bypass must be laid out to AC3.

Electronic motor starters and drives

Connection examples, DS4



S3 = Soft start/stop
Q1 = Line protection
Q21 = Bypass contactor
F1 = Overload relay
F2 = Semiconductor fuse for type “2” coordination, in addition to Q1
T1 = Semiconductor contactor
M1 = Motor

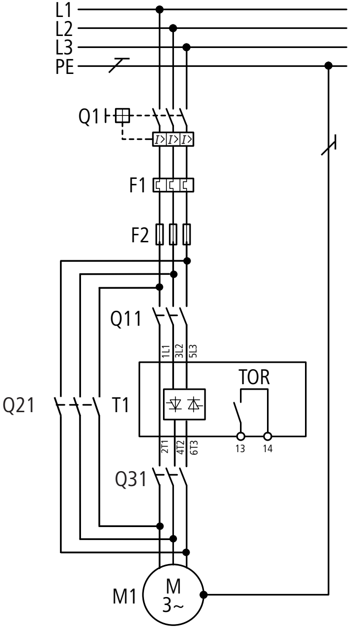
Electronic motor starters and drives
Connection examples, DS4

Pump connection, single direction of rotation

In pump applications the bypass contactor is often required to provide emergency operation capability. This is achieved with a service switch that allows a changeover from soft starter operation to DOL starting through the bypass contactor. In the latter setting the soft starter is fully bypassed. But because the output circuit must not be opened during operation, the interlocks ensure that changeovers take place only after a stop.

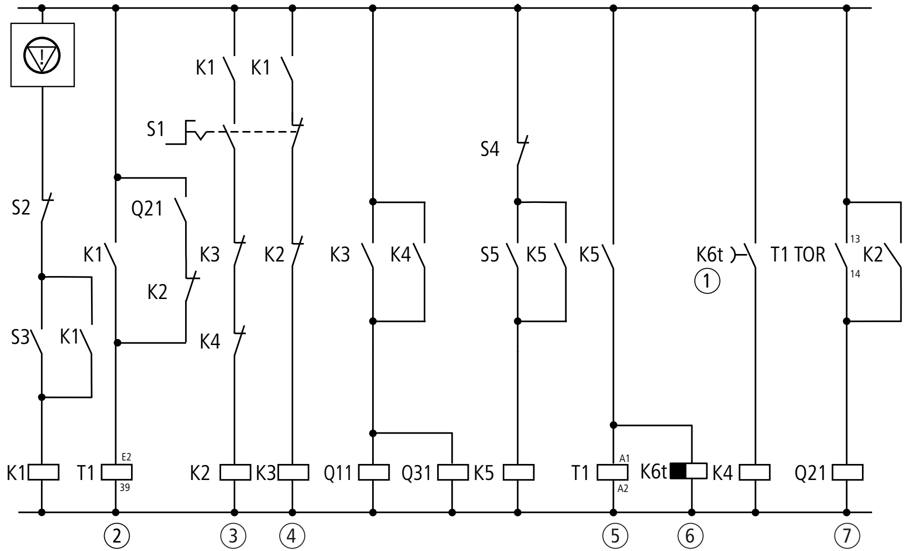
Note:
In contrast to simple bypass operation, the bypass contactor must be laid out to AC3 here. For a suitable contactor, see our recommended mains contactor in appendix “Technical data”.

Pump



Q1: Line protection
Q11: Mains contactor (optional)
Q21: Bypass contactor
Q31: Contactor
F1: Overload relay
F2: Semiconductor fuse for type “2” coordination, in addition to Q1
T1: Semiconductor contactor
M1: Motor

Pump control



Emergency-Stop
① t > t-Stop + 150 ms
② Enable
③ Hand
④ Auto
⑤ Soft start/soft stop
⑥ RUN
⑦ Bypass

Electronic motor starters and drives

Connection examples, DS4

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:

- Start using soft starter
- Switch on bypass contactor
- Disable soft starter
- Switch soft starter output to the next motor
- Restart

→ page 2-52

Emergency-Stop
S1: Q11 Off
S2: Q11 On
① Soft start/soft stop

② Simulation of RUN relay
Timing relay K2T simulates the RUN signal of the DS4. The set off-delay time must be greater than the ramp time. To be on the safe side, use 15 s.

③ RUN

④ Off-time monitoring
Set the timing relay K1T so that the soft starter is not thermally overloaded: calculate the time from the soft starter's permissible operating frequency or select a soft starter that allows the required time to be reached.

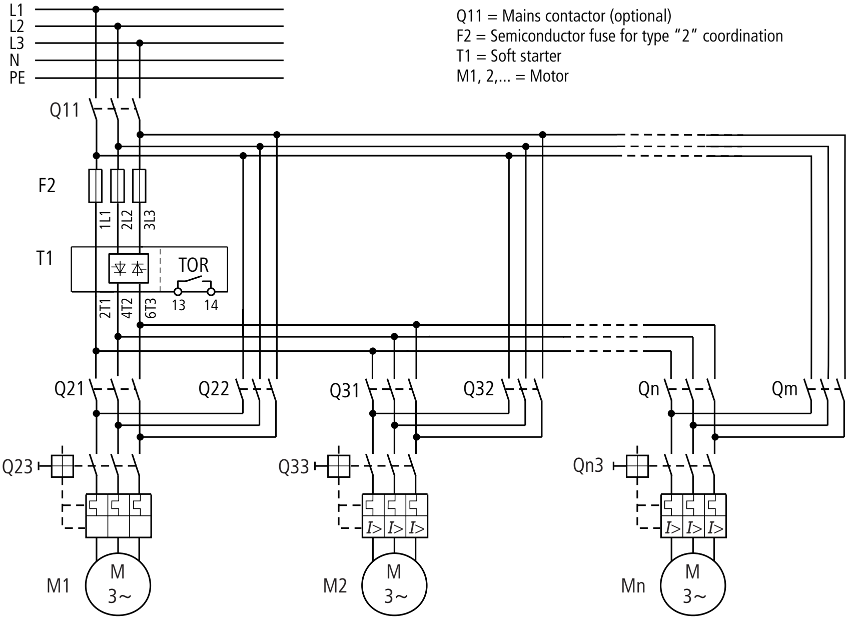
⑤ Changeover monitoring
Set the timing relay to a return time of about 2 s. This ensures that the next motor branch can not be connected as long as the soft starter is running.

→ page 2-53

⑨ Switching off individual motors
The Off switch results in all motors being switched off at the same time. To switch off individual motors, you need to make use of N/C contact ⑨.

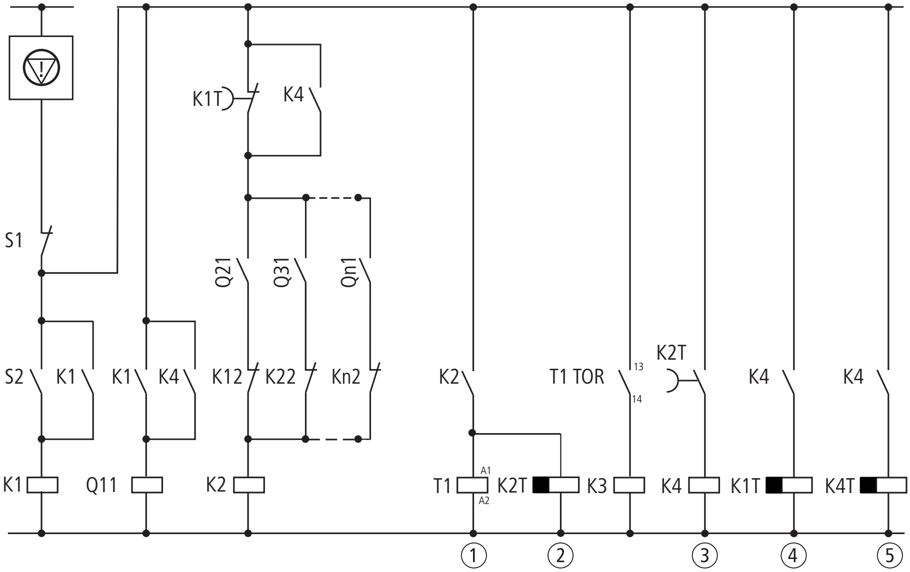
Observe the thermal load on the soft starter (starting frequency, current load). If motors are to be started at short intervals, you may have to select a soft starter with a higher load cycle.

Soft starters with motor cascade

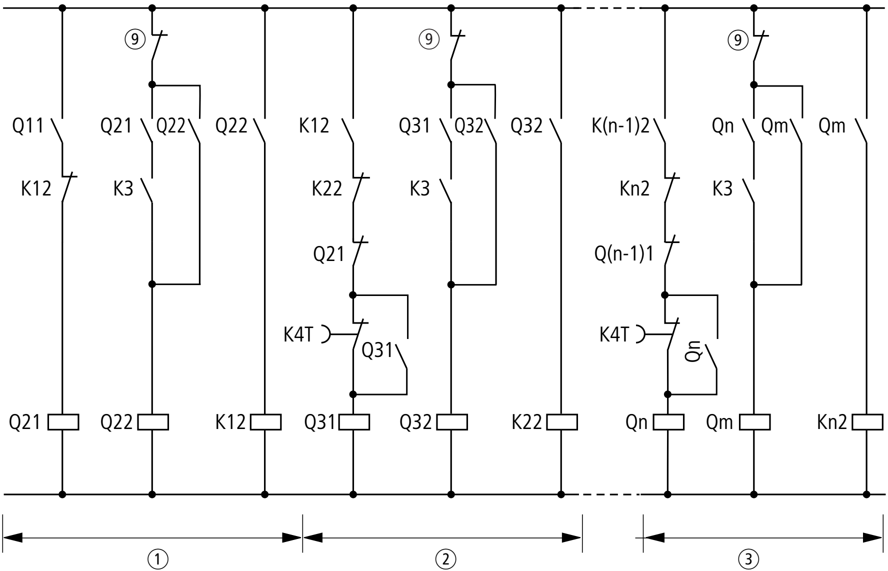


Q11 = Mains contactor (optional)
F2 = Semiconductor fuse for type "2" coordination
T1 = Soft starter
M1, 2,... = Motor

Soft starter with motor cascade, control section part 1



Soft starter with motor cascade, control section part 2



① Motor 1
② Motor 2
③ Motor n
⑨ → section “⑨ Switching off individual motors”, page 2-50

Electronic motor starters and drives

Connection examples, DM4

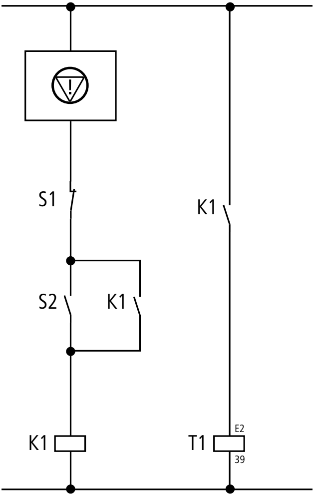
Enable/immediate stop without ramp function (e.g. for Emergency-Stop)

The digital input E2 is programmed in the factory so that it has the "Enable" function. The soft starter is enabled only when a High signal is applied to the terminal. The soft starter cannot be operated without enabling signal.

In the event of wire breakage or interruption of the signal by an Emergency-Stop circuit, the regulator in the soft starter is immediately blocked and the power circuit disconnected, and after that the "Run" relay drops out.

Normally the drive is always stopped via a ramp function. When the operating conditions require an immediate de-energization, this is effected via the enabling signal.

Caution!
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.



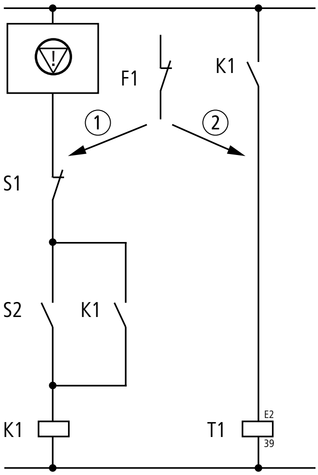
: Emergency-Stop
S1: Off
S2: On
T1: (E2 = 1 → enabled)

Electronic motor starters and drives

Connection examples, DM4

Linking the overload relay into the control system

We recommend using an external overload relay instead of a motor-protective circuit-breaker with built-in overload relay. This allows controlled ramping down of the soft starter through the control section in the event of an overload.



Caution!
Connecting the motor directly to mains power can cause overvoltage and destruction of the soft starter’s semiconductors.

There are two options, which are shown in the following diagram:

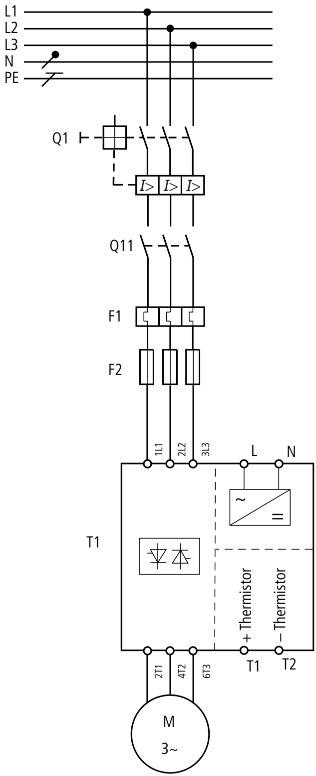
: Emergency-Stop
S1: Off
S2: On
T1: Enable (E2 = 1 → enabled)

1. The signalling contacts of the overload relay are linked into the On/Off circuit. In the event of a fault, the soft starter decelerates for the set ramp time and stops.
2. The signalling contacts of the overload relay are linked into the enabling circuit. In the event of a fault, the soft starter’s output is immediately de-energized. Although the soft starter shuts off its output, the mains contactor remains energized. To de-energize the mains contactor as well, include a second contact of the overload relay in the On/Off circuit.

Electronic motor starters and drives

Connection examples, DM4

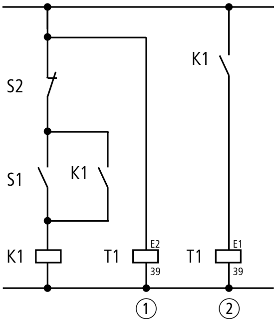
DM4 with overload relay



Standard connection

For isolation from the mains, either a mains contactor upstream of the soft starter or a central switching device (contactor or main switch) is necessary.

Control section

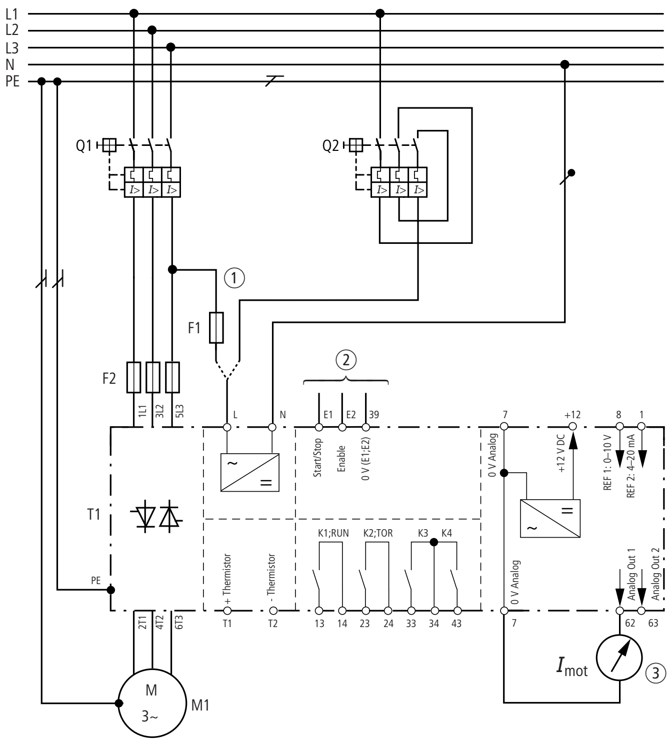


S1: Soft start
S2: Soft stop
① Enable
② Soft start/Soft stop

Electronic motor starters and drives

Connection examples, DM4

DM4 without separate mains contactor



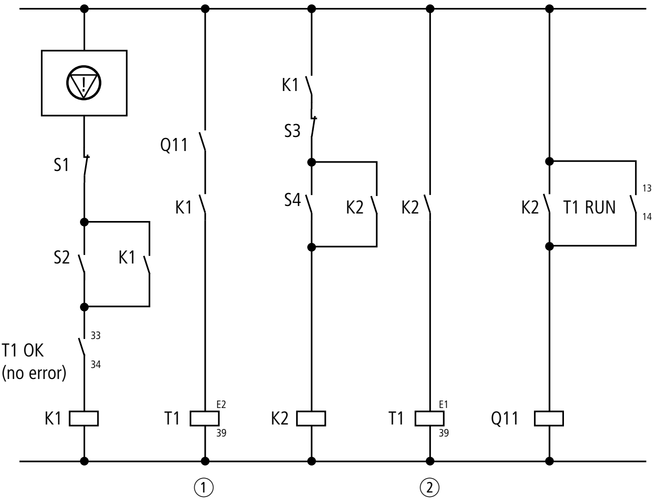
① Control voltage through Q1 or F1 or through Q2
② See control section
③ Motor current indication

Electronic motor starters and drives
Connection examples, DM4

2

DM 4-340 with separate mains contactor

Control section

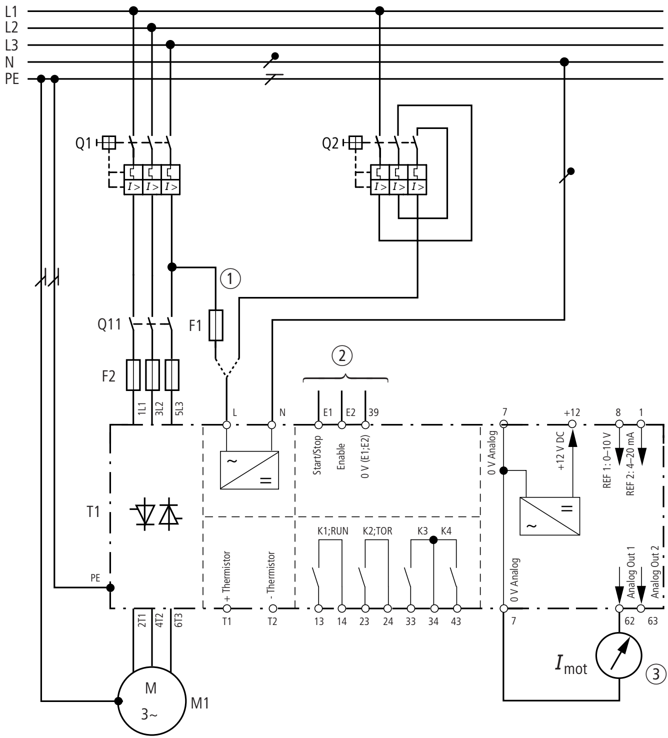


Emergency-Stop
S1: Off
S2: On
① Enable
② Soft start/Soft stop

Electronic motor starters and drives

Connection examples, DM4

DM4-340 with separate mains contactor



① Control voltage through Q1 or F1 or through Q2
② See Control section
③ Motor current indication

Electronic motor starters and drives

Connection examples, DM4

Bypass connection

After the run-up (full mains voltage reached) the DM4 soft starter actuates the bypass contactor. Thus, the motor is directly connected with the mains.

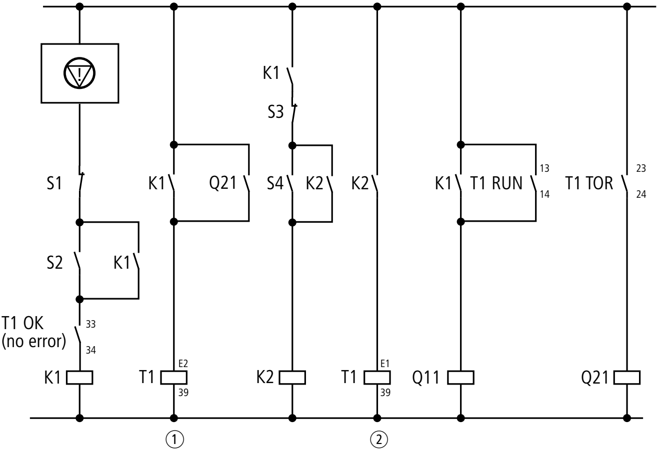
Advantage:

- The soft starter's heat dissipation is reduced to the no-load dissipation.
- The limit values of radio interference class "B" are adhered to.

The bypass contactor is now switched to a no-load state and can therefore be AC-1 rated.

If an immediate de-energization is required in the event of an Emergency-Stop, then the bypass contactor must also switch the motor load. In this case it must be AC-3 rated.

Control section

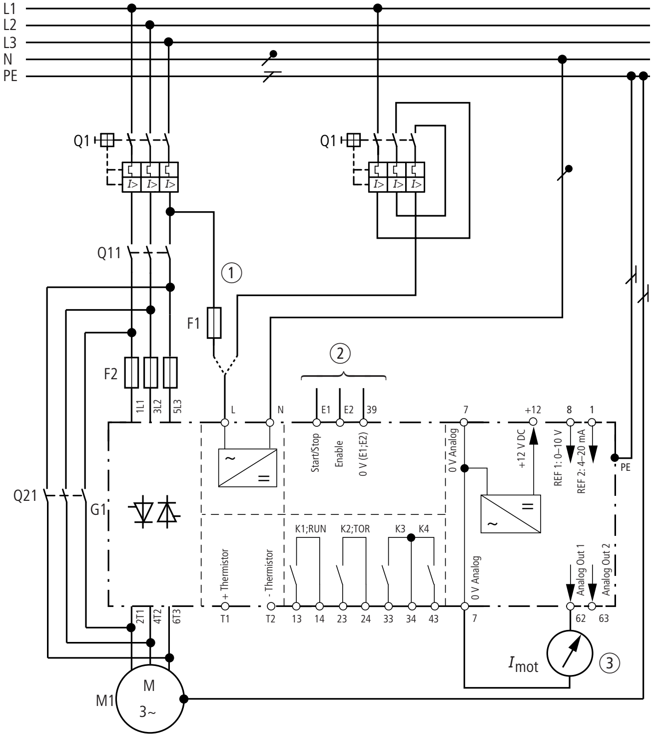


Emergency-Stop
S1: Off
S2: On
① Enable
② Soft start/Soft stop

Electronic motor starters and drives

Connection examples, DM4

DM4-340 with bypass



① Control voltage through Q1 or F1 or through Q2

② See Control section

③ Motor current indication

Electronic motor starters and drives

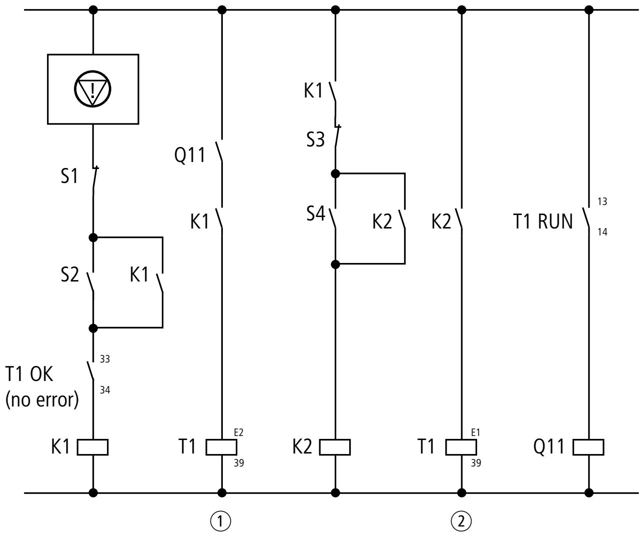
Connection examples, DM4

Delta connection

A delta connection allows the use of a soft starter with a lower rating than the motor it is used to control. Connected in series with each motor winding, the current the soft starter needs to supply is reduced by a factor of √3. This layout has the drawback that six motor supply cables are needed. Apart from that there are no restrictions. All soft starter functions remain available.

For this you have to connect the motor in delta and the voltage in this connection method must agree with the mains voltage. For 400 V mains voltage the motor must therefore be marked with 400 V/690 V.

Control section

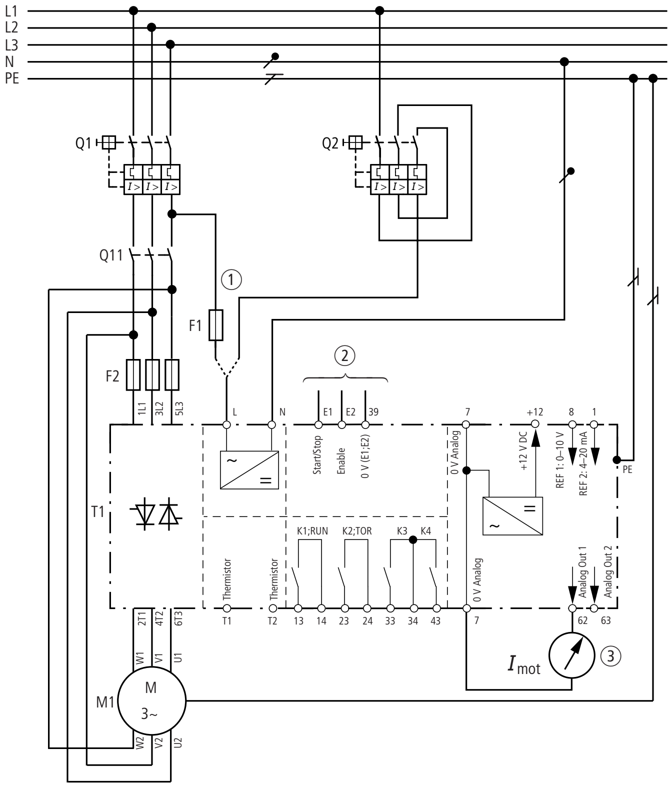


Emergency-Stop
S1: Off
S2: On
① Enable
② Soft start/Soft stop
E2: Enable
T1: +thermistor
T2: –thermistor

Electronic motor starters and drives

Connection examples, DM4

DM4-340 Delta



① Control voltage through Q1 or F1 or through Q2
② See Control section
③ Motor current indication

Electronic motor starters and drives

Connection examples, DM4

Starting several motors sequentially with a soft starter

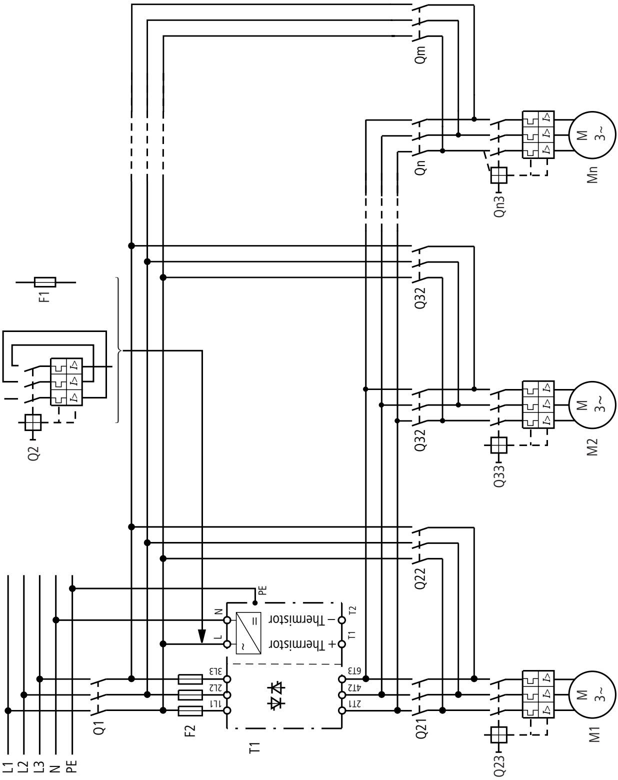
When starting several motors one after the other using a soft starter, keep to the following sequence when changing over:

- Start using soft starter
- Switch on bypass contactor
- Block soft starter
- Switch soft starter output to the next motor
- Restart

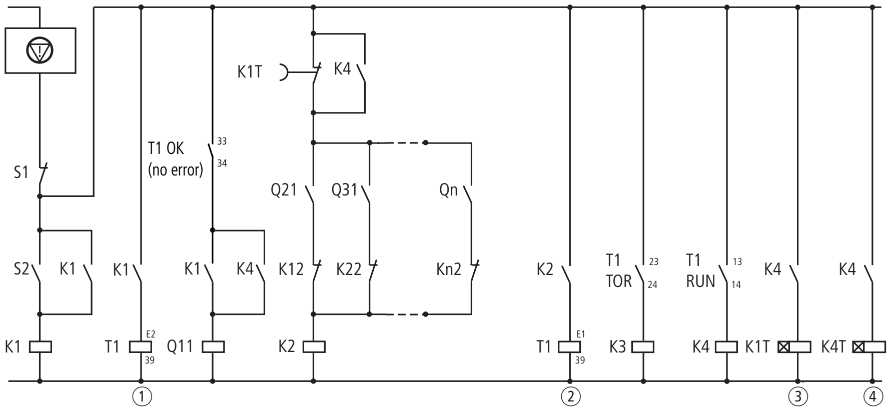
Electronic motor starters and drives

Connection examples, DM4

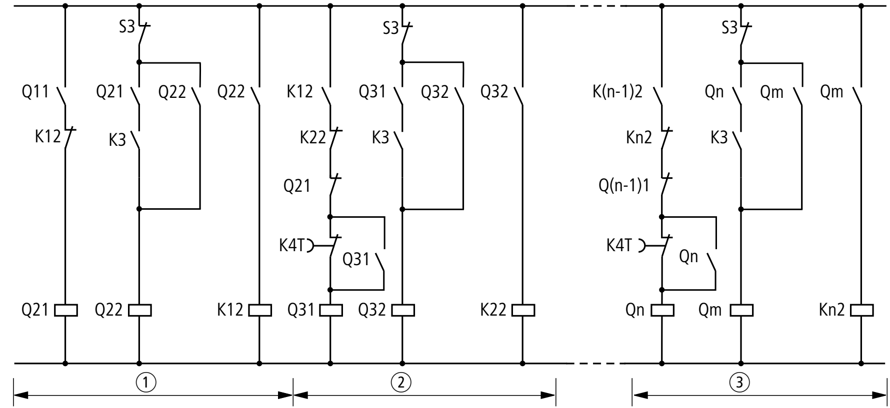
DM4-340 cascade



Control section part 1



DM4-340 cascade, control section part 2



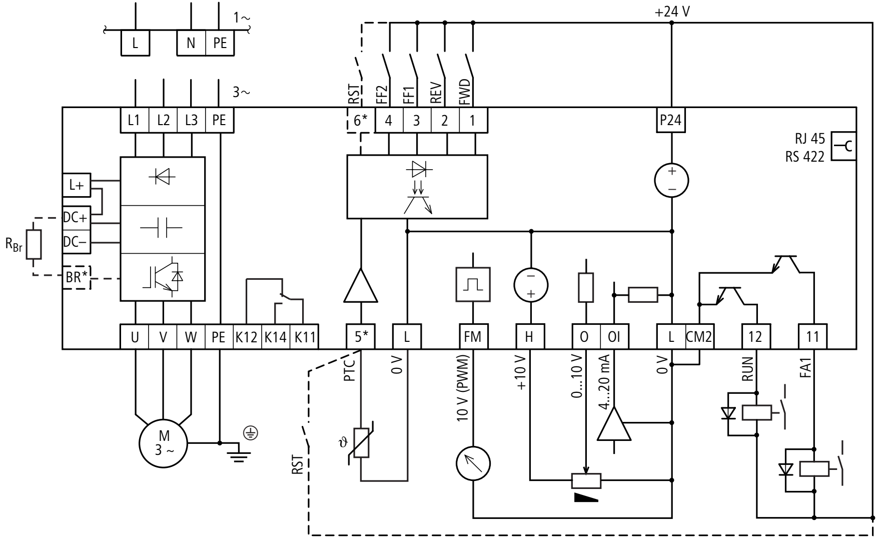
Emergency-Stop
S1: Off
S2: On
① Enable
② Soft start/Soft stop

③ Set the timing relay so that the soft starter is not thermally overloaded. The appropriate time relates to the admissible operating frequency of the selected soft starter. Alternatively, select the soft starter so that the required times can be attained.

④ Set the timing relay to a return time of about 2 s. 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. To switch off motors individually, you need to make use of N/C contact S3.

Notes

Block diagram, DF5 and DV5

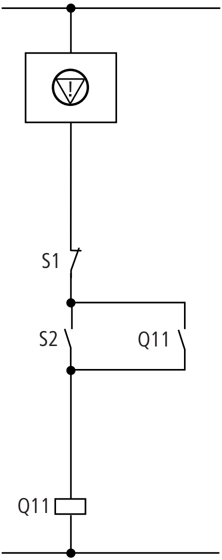


BR* DV5 only
6* DV5 only
5* Input RST for DF5

Electronic motor starters and drives

Connection examples, DF5 and DV5

Basic control

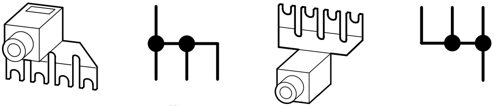


Example 1
Reference input through potentiometer R1
Enable (START/STOP) and direction control through terminals 1 and 2 with internal control voltage

: Emergency-Stop circuit
S1: Off
S2: On
Q11: Mains contactor
F1: Line protection
PES: Cable screen PE connection
M1: Motor, 3-phase 230 V

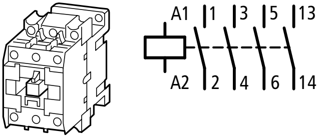
Note:
For EMC-conformant mains connection, suitable radio interference suppression measures must be implemented according to product standard IEC/EN 61800-3.

DILM12-XP1



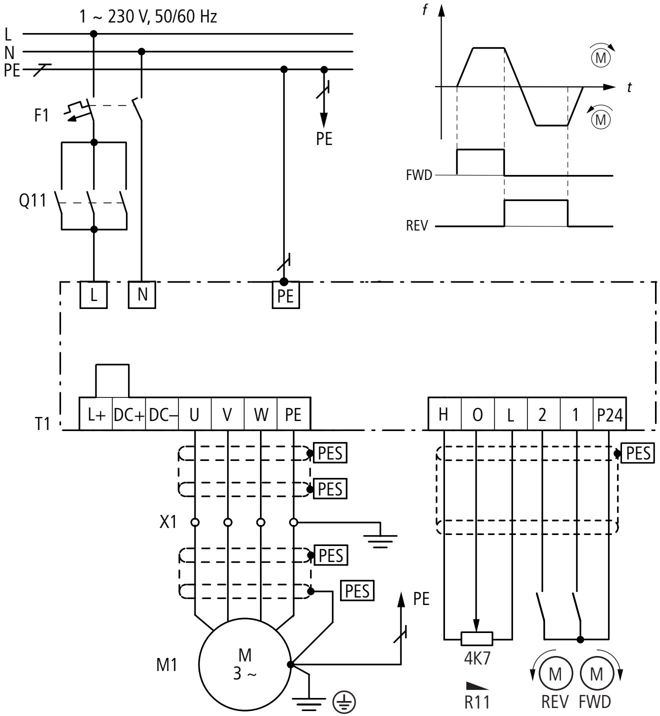
(4th pole can be broken off)

DILM



Electronic motor starters and drives
Connection examples, DF5 and DV5

Wiring



– Single-phase frequency inverter DF5-322-...
– Directional control through terminals 1 and 2
– External reference input from potentiometer R1

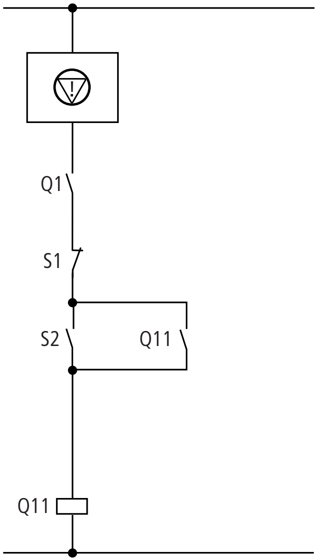
FWD: Clockwise rotating field enable
REV: Anticlockwise rotating field enable

Electronic motor starters and drives

Connection examples, DF5 and DV5

DF5-340-... frequency inverters with EMC-conformant connection

Control section



Example 2
Reference input through potentiometer R11 (f_s) and fixed frequency (f_1, f_2, f_3) through terminal 3 and 4 with internal control voltage
Enable (START/STOP) and rotating field selection through terminal 1

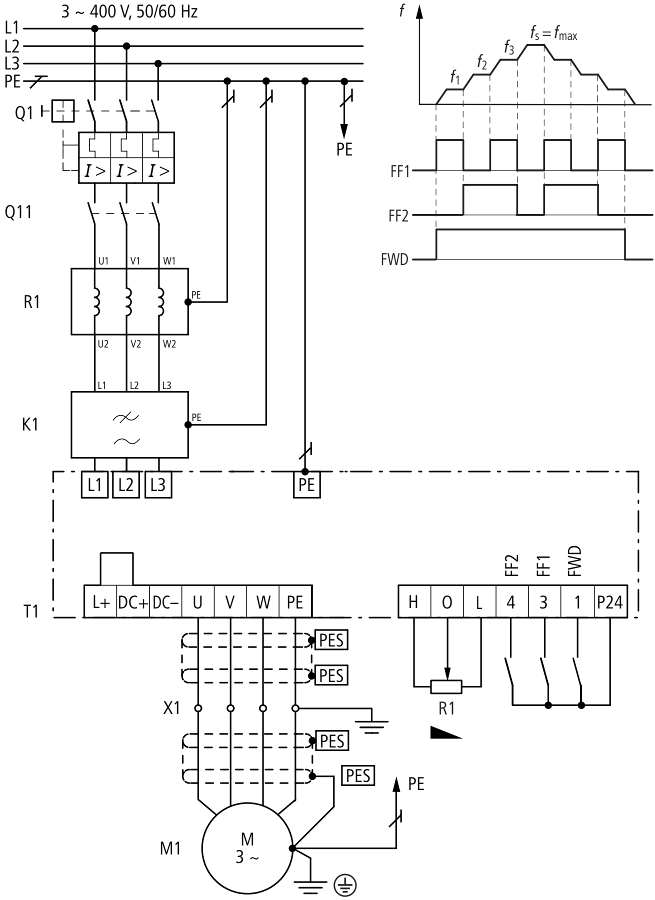
: Emergency-Stop circuit
S1: Off
S2: On
Q11: Mains contactor
R1: Line reactor
K1: RFI filter
Q1: Line protection
PES: Cable screen PE connection
M1:Motor, 3-phase 400 V

FWD: Clockwise rotating field enable, reference frequency f_S
FF1: Fixed frequency f_1
FF2: Fixed frequency f_2
FF1+FF2: Fixed frequency f_3

Electronic motor starters and drives

Connection examples, DF5 and DV5

Wiring



Electronic motor starters and drives

Connection examples, DF5 and DV5

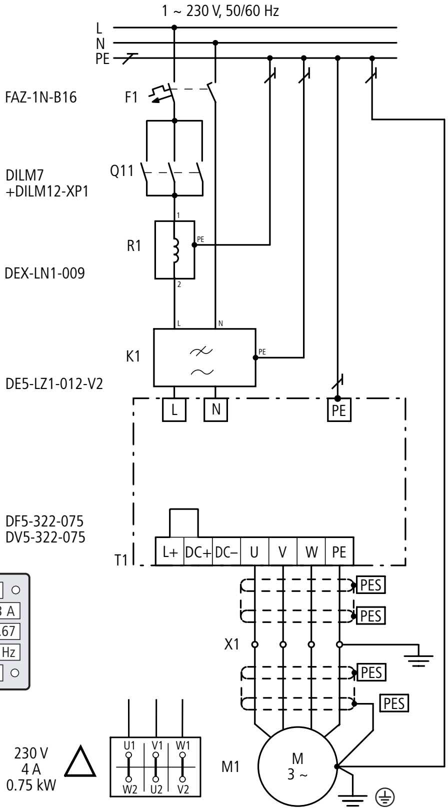
Version A: Motor in delta circuit

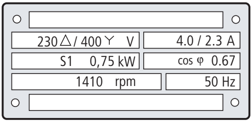
Motor: P = 0.75 kW
Mains: 3/N/PE 400 V 50/60 Hz

The 0.75 kW motor described below can be delta-connected to a single-phase 230 V mains (version A) or star-connected to a 3-phase 400 V mains.

Select the appropriate frequency inverter for your mains voltage:

- DF5-322 for 1 AC 230 V
- DF5-340 for 3 AC 400 V
- Model-specific accessories for EMC-complaint connection.

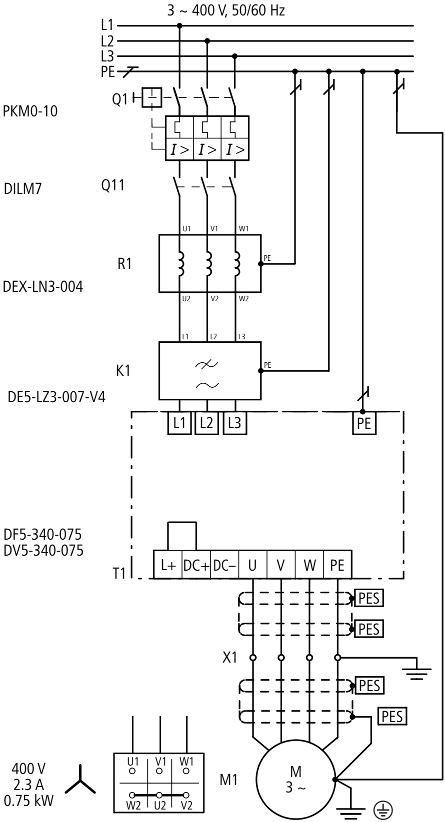




Electronic motor starters and drives

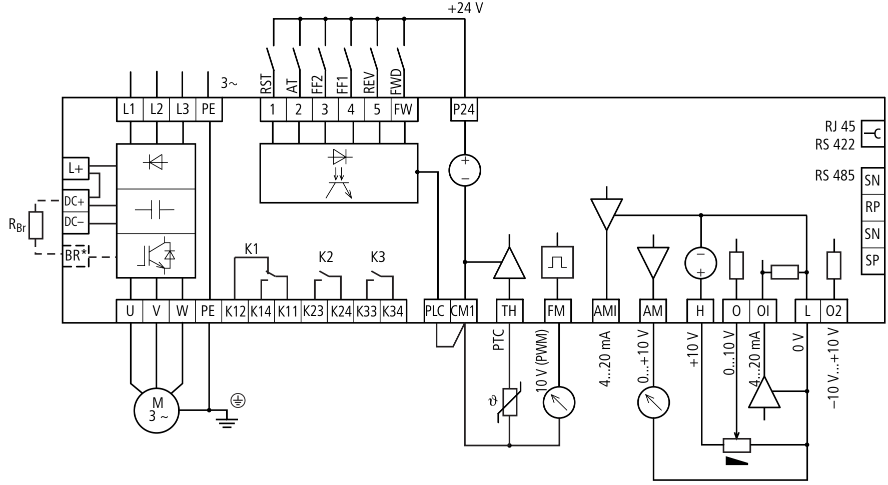
Connection examples, DF5 and DV5

Version B: Motor in star circuit



Notes

Block diagram, DF6



BR* DF6-320-11K, DF6-340-11K and DF6-340-15K only

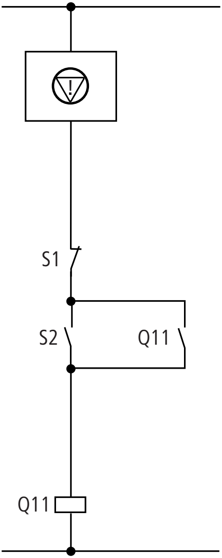
Electronic motor starters and drives

Connection examples, DF6

Frequency inverter DF6-340-...

Control section

Example: Temperature regulation for ventillation system. When the room temperature rises, the fan speed must increase. The target temperature can be set with potentiometer R11 (e.g. 20 °C)

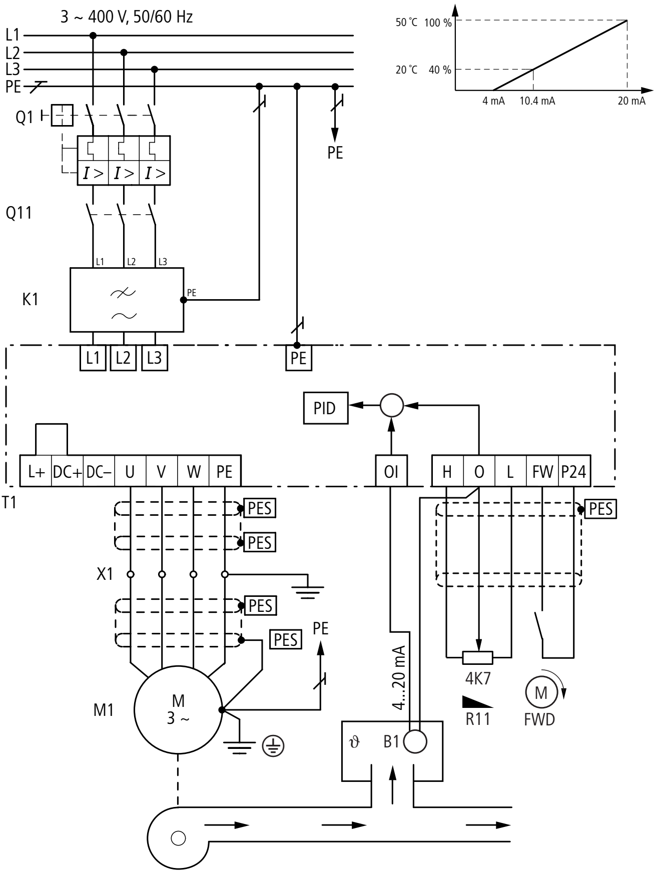


: Emergency-Stop circuit
S1: Off
S2: On
Q11: Mains contactor
Q1: Line protection
PES: Cable screen PE connection
K1: RFI filter

Electronic motor starters and drives

Connection examples, DF6

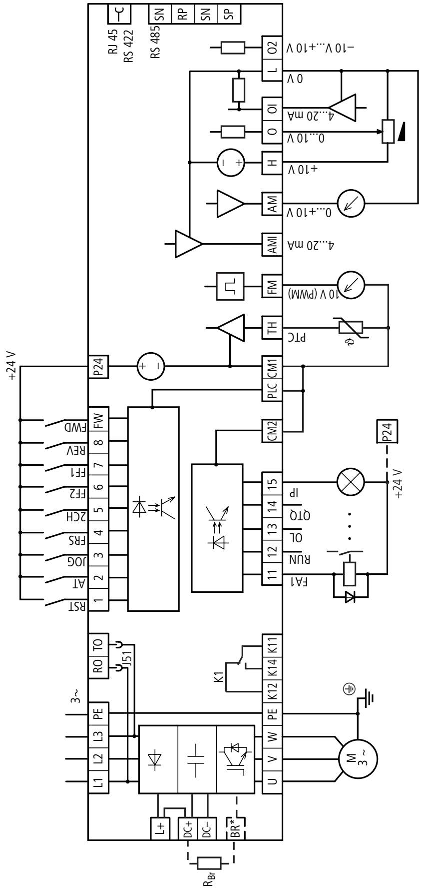
Wiring



Electronic motor starters and drives

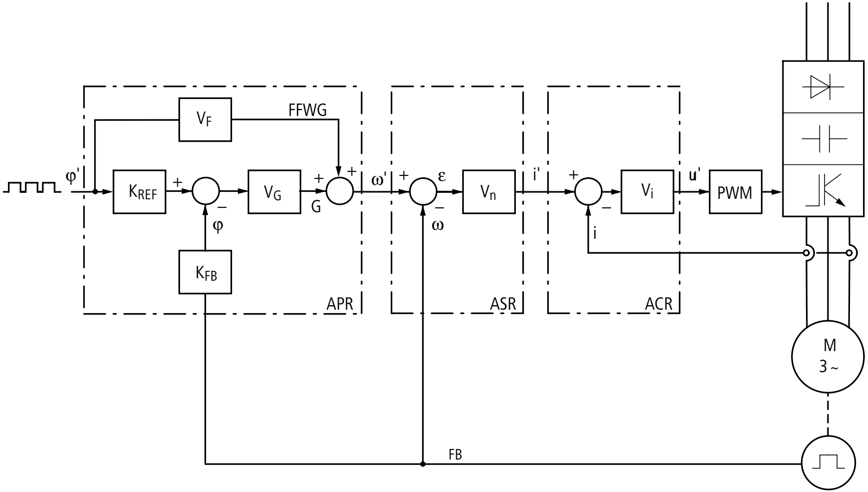
Connection examples, DV6

Block diagram, DV6



BR* DV6-340-075, DV6-340-11K and DV6-320-11K only

Block diagram: speed control circuit, vector frequency inverter DV6 with encoder interface module DE6-IOM-ENC



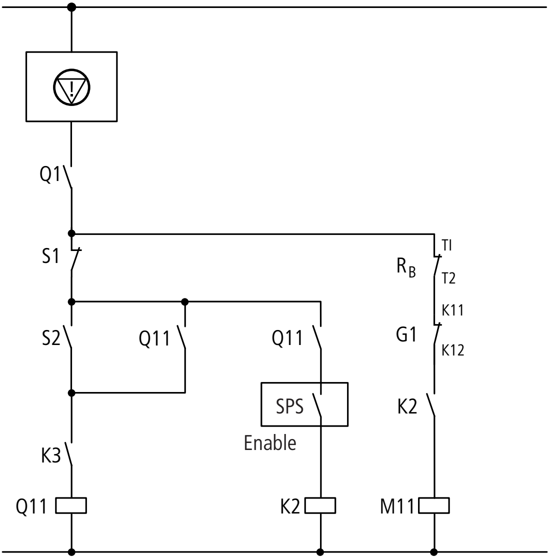
Electronic motor starters and drives

Connection examples, DV6

2

DV6-340-... vector frequency inverters with built-in encoder module (DE6-IOM-ENC) and external DE4-BR1-... braking resistor

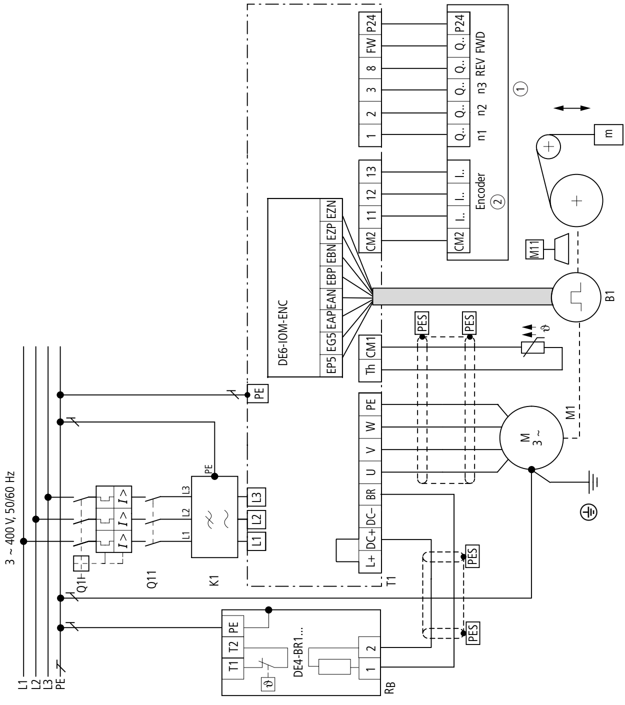
Control section



Example:
Hoisting gear with speed regulation, control and monitoring through PLC
Motor with thermistor (PTC resistor)

: Emergency-Stop circuit
S1: Off
S2: On
Q1: Line protection
Q11:Mains contactor
K2: Control contactor enable
R_B: Braking resistor
B1: Encoder, 3 channels
PES:Cable screen PE connection
M11:Holding brake

Electronic motor starters and drives
Connection examples, DV6

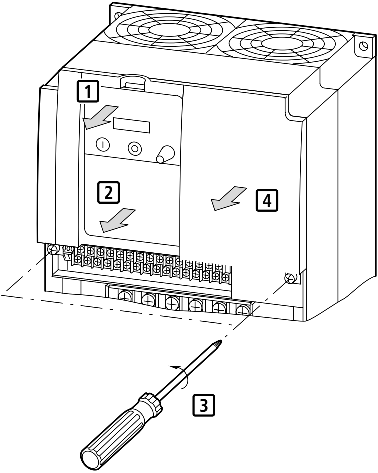


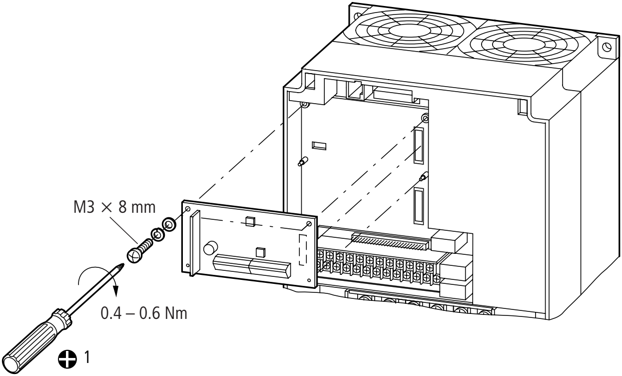
Electronic motor starters and drives

Connection examples, DV6

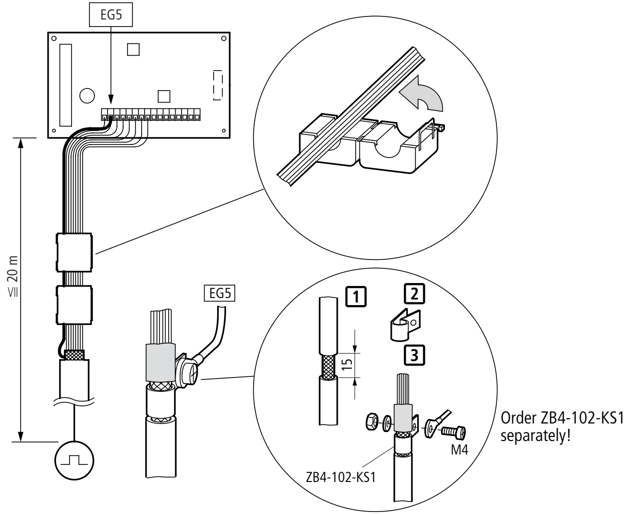
2

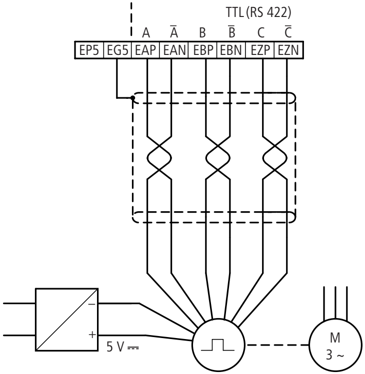
Installing encoder interface module DE6-IOM-ENC





Electronic motor starters and drives
Connection examples, DV6





Electronic motor starters and drives

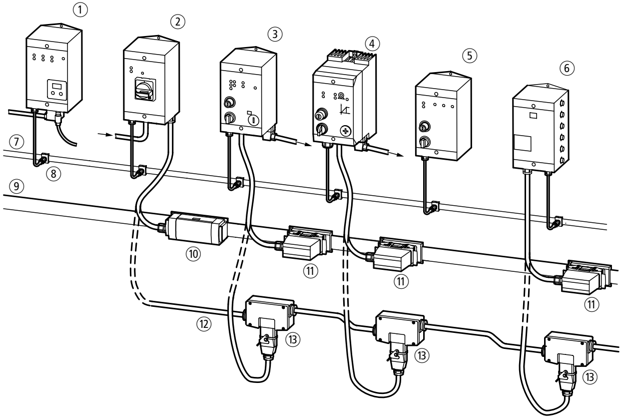
Rapid Link system

2

Rapid Link system

Rapid Link is a modern automation system for material handling systems. Because the Rapid Link modules can be simply fitted into a power and data bus, it allows electrical drives to be installed and taken into operation much more quickly than with conventional methods.

Note:
Before you take the Rapid Link system into operation, you must obtain and read manual AWB2190-1430. This publication is available for download as PDF file from the Moeller Support Portal.



Function modules:

① Interface control unit → the interface to the open field bus

② Disconnect control unit → power infeed with lockable rotary handle;
→ circuit-breaker to protect from overload and short-circuits

③ Motor control unit → 3-phase electronic overload protection with DOL starter, expandable DOL starter or reversing starter function

④ Speed control unit→ controls three-phase asynchronous motors with four fixed speeds, bidirectional operation and soft starting

⑤ Operator control unit → local manual control for conveying equipment

⑥ Logic control unit → Intelligent unit for autonomous processing of I/O signals

Electronic motor starters and drives
Rapid Link system

Power and data bus:
⑦ AS-Interface® flat cable
⑧ Link for M12 connector cables
⑨ Flexible busbar for 400 V ~ and 24 V
⑩ Power feed for flexible busbar
⑪ Plug-in power link for flexible busbar
⑫ Round cable for 400 V ~ and 24 V
⑬ Plug-in power link for round cable

Engineering

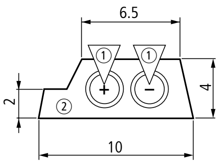
The Rapid Link function modules are installed immediately adjacent to the drives. They can be connected to the power and data bus at any point without having to interrupt the bus.

The AS-Interface® **data bus** is a system solution for networking different modules. AS-Interface® networks are quick and easy to implement.

AS-Interface® uses a geometrically coded, unscreened flat cable with a cross-section of 2 × 1.5 mm². It is used to transmit both power as well as all data traffic between PLC and I/O and – to some extent – supplies the connected devices with energy.

The installation meets the usual requirements. Engineering is simplified by full flexibility in system layout and mounting.

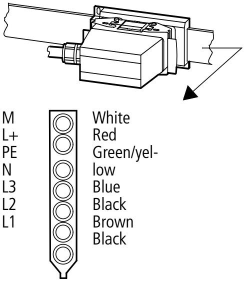
When a link is connected to the flat cable, two metal pins pierce through the cable's jacket and into the two cores to establish a contact with the AS-Interface® cable. There is no need to cut and strip cables, apply ferrules or connect individual cores.



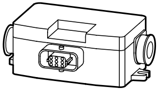
① Piercing pins
② Flat cable, protected against polarity reversal

The **power bus** supplies the Rapid Link function modules with main and auxiliary power. Plug-in tap-off points can be quickly and safely connected at any point along the bus. The power bus can consist either of a flexible busbar (flat cable) or standard round cables:

- The flexible busbar RA-C1 is a 7-core flat cable (cross-section 2.5 mm² or 4 mm²) and has the following structure:



- For the power bus you can also use conventional round cables (cross-section 7 × 2.5 mm² or 7 × 4 mm², outer core diameter < 5 mm, flexible copper conductor to IEC/EN 60228) with round cable feeders RA-C2. The cable can have an external diameter of 10 to 16 mm.



Electronic motor starters and drives

Rapid Link system

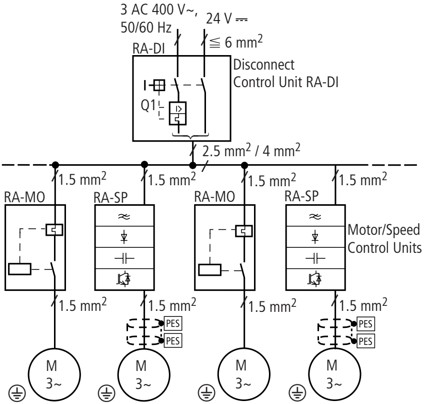
Warning!

- Rapid Link must be operated only on three-phase systems with earthed star point and separate N and PE conductors (TN-S network). It must not be operated unearthed.
- All devices am connected to the power and data bus must also meet the requirements for safe isolation according to IEC/EN 60947-1 Annex N or IEC/EN 60950. The 24 V DC power supply unit must be earthed on the secondary side. The 30 V DC PSU for the AS-Interface®-/RA-IN-power supply must meet the safe isolation requirements according to SELV.

The power sections are supplied through disconnect control unit RA-DI (see illustration below) with:

- I_e = 20 A/400 V at 2.5 mm²
- I_e = 20 to 25 A/400 V at 4 mm².

Round cables up to 6 mm² can be used to feed power to disconnect control unit RA-DI.



Disconnect control unit RA-DI protects the cable from overload and provides short-circuit protection for the cable as well as all connected RA-MO motor control units.

The combination of RA-DI and RA-MO fulfills the requirements of IEC/EN 60947-4-1 as starter with type “1” coordination. That means that the contactor’s contacts in the RA-MO are allowed to weld in the event of a short-circuit in the motor terminal strip or the motor supply cable. This arrangement also conforms to IEE wiring regulations.

Electronic motor starters and drives

Rapid Link system

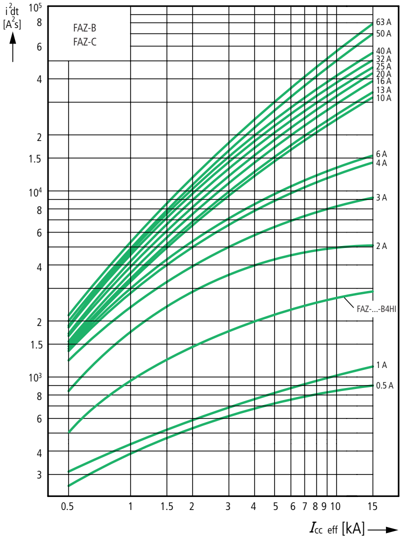
The affected RA-MO motor control unit must be replaced after a short-circuit!

When you configure a power bus with a disconnect control unit, observe the following:

- Even in the event of a 1-pole short-circuit at the line end, the short-circuit current must exceed 150 A.
- The total current of all running and simultaneously starting motors must not exceed 110 A.
- The total load current (about 6 × mains current) of all connected speed control units must not exceed 110 A.
- Observe the voltage drop in your specific application.

Instead of the disconnect control unit, you can use a 3-pole miniature circuit-breaker $I_n \leqq 20$ A and B or C characteristic. Here, you must observe the following:

- The let-through energy I^2t in the event of a short-circuit must not exceed 29800 A²s.
- Therefore the short-circuit current I_{cc} at the mounting location must not exceed 10 kA → characteristic curve.



Electronic motor starters and drives
Rapid Link system

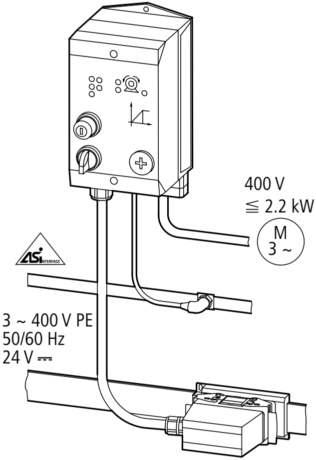
Motor control unit

Motor control unit RA-MO allows the direct bidirectional operation of three-phase motors. The rated current is adjustable from 0.3 to 6.6 A (0.09 to 3 kW).

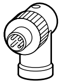
2

Connections

Motor control unit RA-MO is supplied ready for installation. The connection to the AS-Interface® data bus and the motor is described below. The connection to the power bus is described in the earlier general section “Rapid Link system”.



The unit is connected to AS-Interface® through an M12 plug with the following PIN assignment:

M12 plug	PIN	Function
	1	ASi+
	2	–
	3	ASi–
	4	–

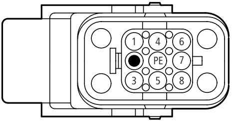
External sensors are connected through an M12 socket.

PIN	Function
1	L+
2	I
3	L–
4	I

On the RA-MO the motor feeder features a plastic-encapsulated socket. The length of the motor cable is limited to 10 m.

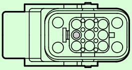
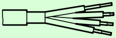
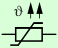
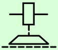
The **motor** is connected through a halogen-free, 8 × 1.5 mm², unscreened, DESINA-conformant motor supply cable with a length of 2 m (SET-M3/2-HF) or 5 m (SET-M3/5-HF).

Alternatively you can assemble your own motor supply cable with plug SET-M3-A with 8 × 1.5 mm² contacts

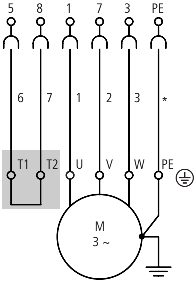


Electronic motor starters and drives

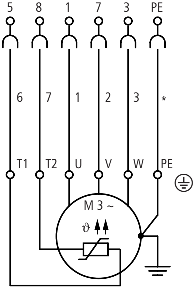
Rapid Link system

	 SET-M3/...			
1	1	U	–	–
•	–	–	–	–
3	3	W	–	–
4	5	–	–	B1 (~/–)
5	6	–	T1	–
6	4	–	–	B2 (~/+)
7	2	V	–	–
8	7	–	T2	–
PE	PE	PE	–	–

Motor connection without thermistor



Motor connection with thermistor



If motors are connected without PTC thermistor (thermoclick), cables 6 and 7 must be linked at the motor; otherwise the RA-MO issues a fault message.

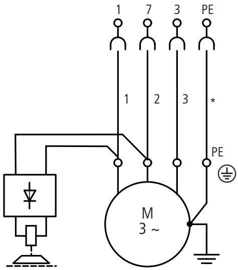
Electronic motor starters and drives

Rapid Link system

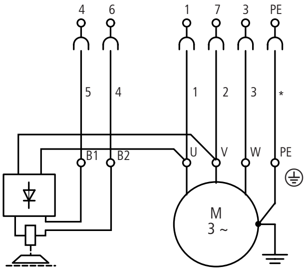
Note:

The two connections illustrated below apply only for motor control unit RA-MO.

Connecting a 400 V AC brake:



Connecting a 400 V AC brake with rapid braking:



For controlling braking motors, their manufacturers provide braking rectifiers, which are fitted in the motor terminal strip. If the DC circuit is opened at the same time, the voltage at the braking coil drops off much quicker, causing the motor to also brake more quickly.

Electronic motor starters and drives

Rapid Link system

Speed Control Unit RA-SP

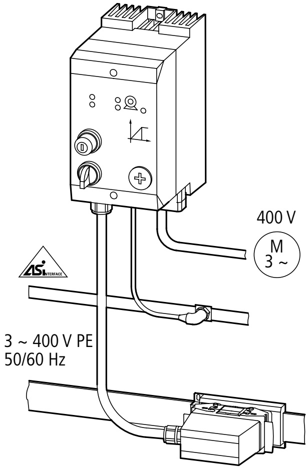
Speed control unit RA-SP is used for electronic variable speed control of three-phase motors.

Note:

Unlike the other Rapid Link system devices, the RA-SP speed control unit's enclosure is fitted with a heat sink and requires an EMC-conformant mounting and connection.

Connections

Speed control unit RA-SP is supplied ready for connection. The connection to the AS-Interface® data bus and the motor is described below. The connection to the power bus is described in the earlier general section "Rapid Link system".



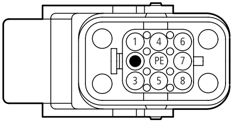
The unit is connected to AS-Interface® through an M12 plug with the following PIN assignment:

M12 plug	PIN	Function
	1	ASi+
	2	–
	3	ASi–
	4	–

On the RA-SP the motor feeder features a metal-encapsulated socket. To meet EMC requirements, this is connected with PE and heat sink over a large area. The matching plug is also metal-encapsulated and the motor cable is screened. The length of the motor cable is limited to 10 m. The motor cable's screen must have a large-area connection with PE at both ends, and the **motor connection** terminals must also, therefore, meet EMC requirements.

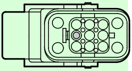
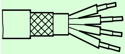
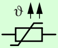
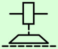
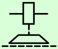
The motor is connected through a halogen-free 4 × 1.5 mm² + 2 × (2 × 0.75 mm²), screened, DESINA-conformant motor supply cable with a length of 2 m, (SET-M4/2-HF) or 5 m, (SET-M4/5-HF).

Alternatively you can assemble your own motor supply cable with plug SET-M4-A, with 4 × 1.5 mm² + 4 × 0.75 mm² contact.



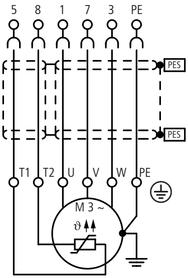
Electronic motor starters and drives

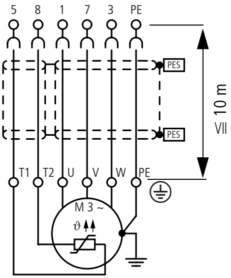
Rapid Link system

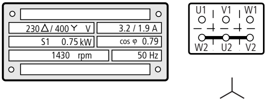
	 Servo cable SET-M4/...	M 3~		RA-SP2-...	
				341-...  400 V AC	341(230)-...  230 V AC
1	1	U	–	–	–
•	–	–	–	–	–
3	3	W	–	–	–
4	5	–	–	B1 (~)	B1 (~)
5	7	–	T1	–	–
6	6	–	–	B2 (~)	B2 (~)
7	2	V	–	–	–
8	8	–	T2	–	–
PE	PE	PE	–	–	–

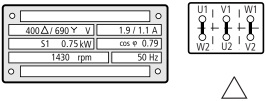
Electronic motor starters and drives

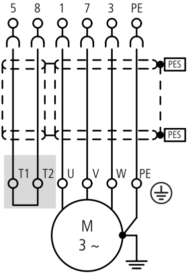
Rapid Link system

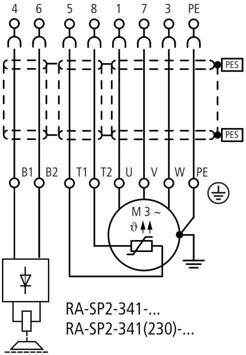












RA-SP2-341-...
RA-SP2-341(230)-...

For controlling braking motors, their manufacturers provide braking rectifiers, which are fitted in the motor terminal strip.

Note:

When using speed control unit RA-SP, do not connect the braking rectifier directly to the motor terminals (U/V/W)!

Notes

Command and signalling devices

Command and signalling devices
RMQ

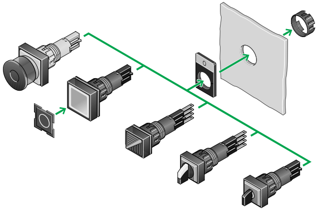
Commands and signals are the fundamental functions for controlling machines and processes. The required control signals are produced either manually by control circuit devices or mechanically by position switches. The respective application governs the degree of protection, the shape and colour.

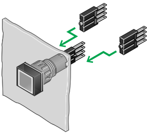
Advanced technology has been used consistently in the development of the new control circuit devices RMQ-Titan®. The use of LED elements and laser inscription throughout offer maximum reliability, efficiency and flexibility. In detail, this means:

- 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,
- 100.000 h, i.e.machine lifespan,
- Impact and vibration resistant,
- LED operating voltage from 12 to 500 V,
- Low power consumption – only 1/6 of filament lamps,
- Expanded operating temperature range -25 to +70 °C,
- Light testing circuit,
- Built-in safety circuits for highest operational reliability and accessibility,
- Abrasion-proof and clearly contrasting laser inscription,
- Customer-specific symbols and inscriptions from 1 off,
- Text and symbols can be freely combined,
- Terminations using screws and Cage Clamp[1)] throughout,
- Spring-loaded Cage Clamp terminals for reliable and maintenance free contact,
- Switching contacts suitable for use with electronic devices to EN 61131-2: 5 V/1 mA,
- Freely programmable switching behaviour on all selector switch actuators: spring-return/stay-put,
- All actuators in illuminated and non-illuminated version,
- Emergency-Stop buttons with pull- and turn-to-release function,
- Emergency-Stop buttons with lighting option for active safety,
- Contacts switch differing potentials,
- For use also in safety-related circuits using positive operation and positively opening contacts,
- Complying with industry Standard IEC/EN60947.

1) Cage Clamp is a registered trade mark of Messrs. WAGO Kontakttechnik GmbH, Minden.

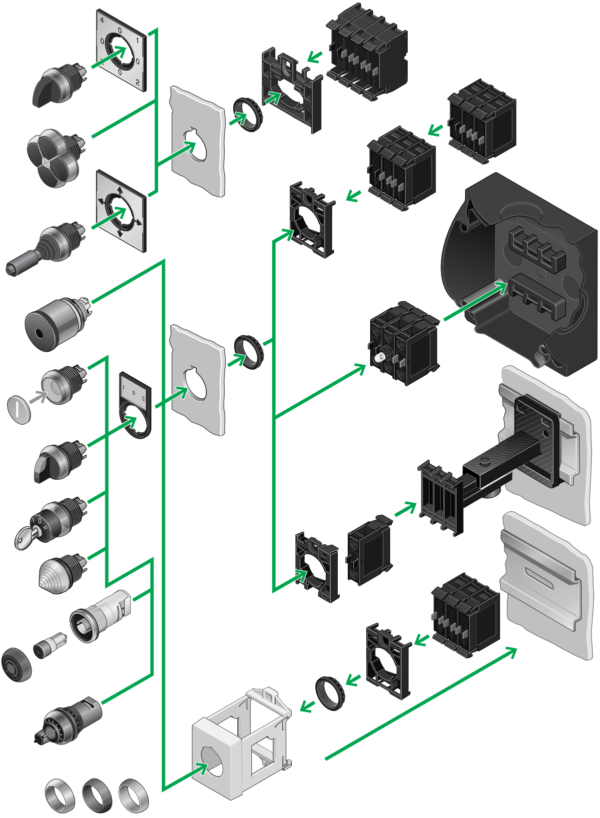
RMQ16





Command and signalling devices
RMQ

RMQ-Titan® System Overview



Command and signalling devices
RMQ

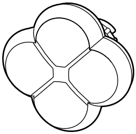
RMQ-Titan®

Four-way pushbutton

Moeller has added more operator elements to its highly successful range of control circuit devices RMQ-Titan. They are modular in construction. Contact elements from the RMQ-Titan range are used. The front rings and front frames are of the familiar RMQ-Titan format and colour.

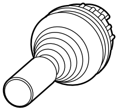
Four-way pushbutton

The four-way pushbuttons enable users to control machines and systems in four directions of movement, with each direction of movement being assigned one contact element. The actuator has four individual button plates. They can be specifically selected for various applications and can be laser-inscribed to suit the customer's requirements.



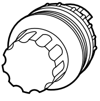
Joystick

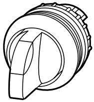
The joystick has four precisely assigned positions. Each direction of movement is assigned one contact element. The joystick enables users to control machines and systems in four directions of movement.



Selector switch actuators

The selector switch actuators have four positions. The actuator is available as rotary head or thumb-grip as required. One contact element is assigned to each On and each Off position.



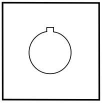


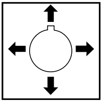
Labels

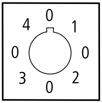
Moeller offers labels in various versions for all the operator elements. Versions available are:

- Blank,
- With direction arrows,
- With inscription 0–1–0–2–0–3–0–4.

In addition, customized inscriptions are possible. The software Labeleditor enables customized inscriptions to be designed and these can be subsequently applied to the labels by laser, permanently and proof against wiping off.

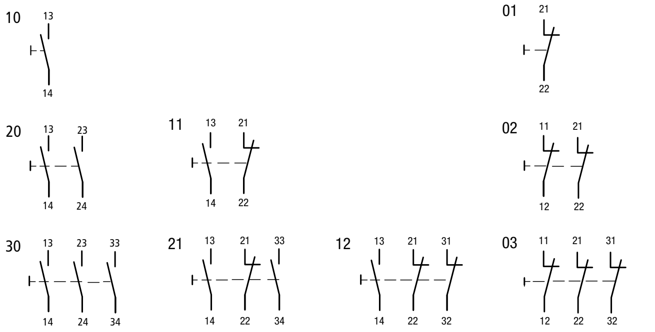




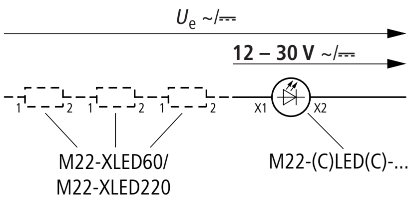


Command and signalling devices
RMQ

Terminal markings and function numbers (conventional number/circuit symbol), EN 50013

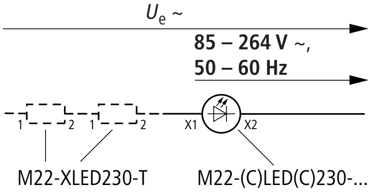


Voltage versions with series elements



M22-XLED60 1)	U_e ≦AC/DC
1×	60 V
2×	90 V
3×	120 V
...	...
7×	240 V
M22-XLED220	U_e ≦
1 ×	220 VDC

1) For increasing the voltage AC/DC.



M22-XLED230-T 1)	U_e ≦
1×	400 V~
2×	500 V~

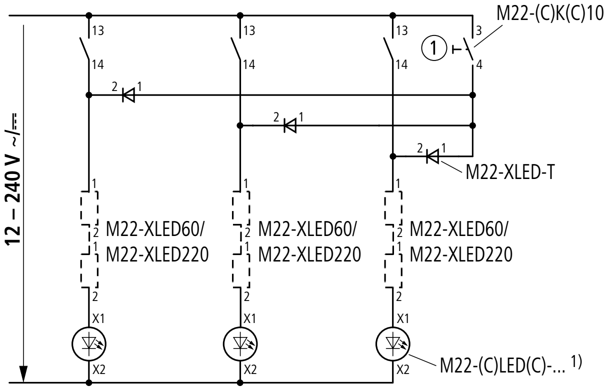
1) AC– for increasing the voltage 50/60 Hz.

Command and signalling devices
RMQ

Circuit 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.

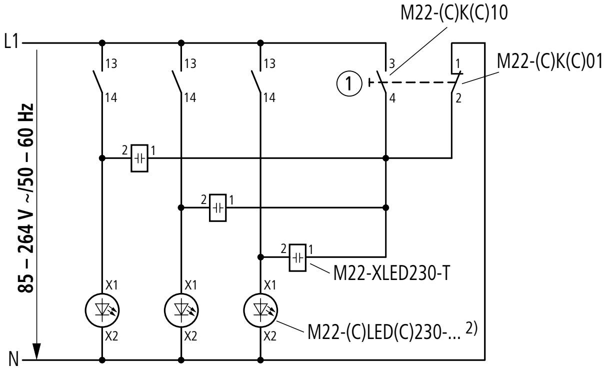
M22-XLED-T for U_e = 12 to 240 V AC/DC (also for light test with signal towers SL)



① Test button
1) Only for elements 12 to 30 V.

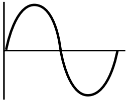
Command and signalling devices
RMQ

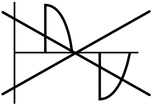
M22-XLED230-T for U_e = 85 to 264 V AC/50 – 60 Hz



① Test button

1) For elements 85 to 264 V.



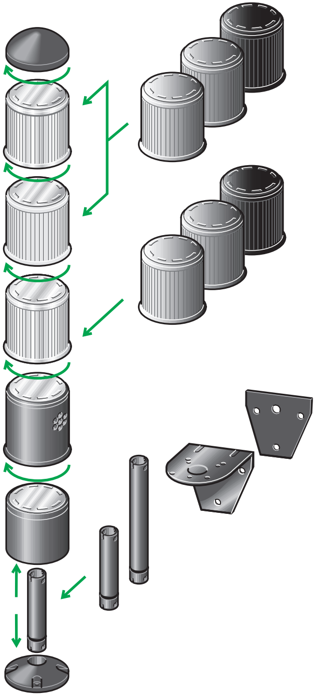


Command and signalling devices

Signal Towers SL

Signal Towers SL – everything under visual control at all times

Signal towers SL 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 indicator even from a distance, and dealt with as necessary.



Product features

- Continuous light, flashing light, strobe light and acoustic indicator can be combined as required.
- 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.
- Use of filament bulbs or LEDs as required.
- A large number of complete units simplifies selection, ordering and stock holding for standard applications.

The various colours of the light elements indicate the operating status 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

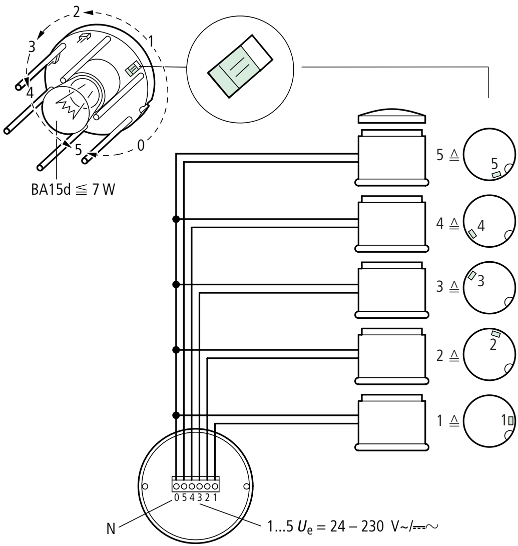
BLUE:
Discontinuity – action mandatory

WHITE:
Other status – can be used as required.

Command and signalling devices

Signal Towers SL

Programmability



Five signal lines from a terminal strip in the basic module run through each module. The module is addressed via a wire link (jumper) on each printed circuit board. Five different addresses can also be allocated several times.

Thus, for example, a red strobe light and in parallel with it an acoustic indicator can indicate and announce the dangerous status of a machine. Insert both jumpers into the same position on the pcb – and it's done!

(→ section “Circuit for light test”, page 3-6.)

Command and signalling devices

Position switches LS-Titan®, AT

	LS, LSM, AT0, ATR	AT4	AT4/.../ZB
Standards	• IEC 60947, EN 60947, VDE 0660 → EN 50047 • Dimensions • Fixing dimensions • Switching points • Minimum IP65	• IEC 60947, EN 60947, VDE 0660 → EN 50041 • Dimensions • Fixing dimensions • Switching points • IP65	• IEC 60947, EN 60947, VDE 0660 → EN 50041 • Dimensions • Fixing dimensions • Switching points • IP65
Suitable applications	• Also for use in safety circuits, by positive operation and positively opening contacts	• Also for use in safety circuits, by positive operation and positively opening contacts	• Safety position switches for protection of personnel • With separate actuating element for protective guards • Positive operation and positively opening contacts • Approval by German Trade Association and SUVA (Swiss accident prevention authority)
Actuator	• Plunger • Roller plunger • Roller lever • Angled roller lever • Adjustable roller lever • Actuating rod • Spring rod actuator • Operating heads adjustable in 90° steps	• Plunger • Roller head (adjustable in 90° steps, can be operated vertically or horizontally) • Roller plunger • Roller lever • Adjustable roller lever • Actuating rod • Spring rod actuator • Operating heads adjustable in 90° steps	• Coded actuating element • Operating head: – Adjustable in 90° steps – Can be actuated from both sides • Actuating element – Convertible for vertical and horizontal fixing • With triple coding

Command and signalling devices

Position switches LS-Titan®, AT

	AT0-...-ZB	ATO-...ZBZ
Standards	• IEC 60947, EN 60947, VDE 0660 • IP65	• IEC 60947, EN 60947, VDE 0660 • IP65
Suitable applications	• Safety position switches for protection of personnel • With separate actuating element for protective guards • Positive operation and positively opening contacts • Approved by German Trade Association and SUVA (Swiss Accident Insurance Institue)	• Safety position switches for protection of personnel • With separate actuating element for protective guards • Positive operation and positively opening contacts • Electromagnetic interlocking • Approved by German Trade Association and SUVA (Swiss Accident Insurance Institue)
Actuator	• Coded actuating element • Operating head: – Adjustable in 90° steps – Can be actuated from four sides and from above	• Coded actuating element • Operating head: – Adjustable in 90° steps – Can be actuated from four sides

Command and signalling devices
Position switches LS-Titan®, AT

AT4/ZB, AT0-ZB safety position switches

Moeller safety position switches have been specially designed for monitoring the position of protective guards such as doors, flaps, hoods and grilles. They meet the requirements of the German Trade Association for the testing of positively opening position switches for safety functions (GS-ET-15). These reqquirements include:

"Position switches for safety functions must be designed such that the function used for protection cannot be changed or defeated by hand or by using simple tools." Simple tools include: pliers, screwdrivers, pins, nails, wire, scissors, pocket knives, etc.

In addition to these requirements, AT0-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 positively opening contacts (see EN 60947-5-1/10.91). 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 actuating element 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 actuating element assumes the Off position. Moeller position switches all meet these requirements.

Certification

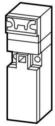
All Moeller safety position switches are certified by the German employers liability insurance association or by the Technical Monitoring Service (TÜV), Rheinland, and the Swiss accident prevention authority (SUVA).

Command and signalling devices

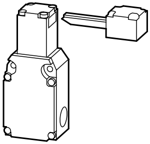
Position switches LS-Titan®, AT

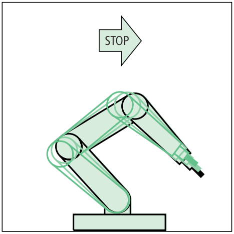
“Personnel protection” by monitoring the protective device

AT0-ZB



AT4/ZB



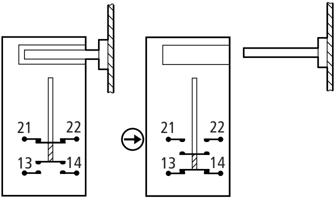


- Door open
- AT...-ZB switches off the power
- No danger

AT...ZB

Closed

Open



→ Personnel protection

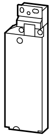
Door opening	→ Enabling contact (21–22) opening positively
Door open	→ Enabling contact safely open, even where attempts are made to tamper using basic tools
Closing door	→ Triple-coded actuator closes the enable contact

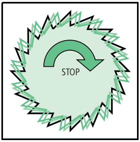
Command and signalling devices

Position switches LS-Titan®, AT

"Enhanced personnel protection" by monitoring and interlocking the protective device

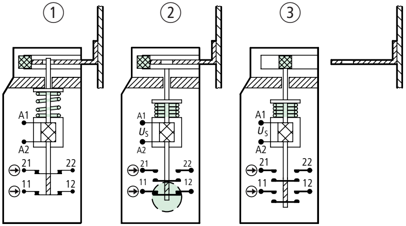
AT0-ZBZ





- Stop command
- Waiting time
- Machine stops
- Protective device on
- No danger

AT0-...FT-ZBZ, spring-powered interlock (closed-circuit principle)



1. Interlocked
2. Released
3. Open

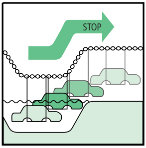
→ Enhanced personnel protection with separate indication of the door position

1. Door closed + interlocked	→ De-energized: even with mains failure or wire breakage: door interlocked = safe condition enable contact(21-22) closed	**4.** Door open	→ Both contacts blocked in the open position, even where attempts are made to tamper using basic tools
2. Releasing of door	→ Applies voltage to coil (A1, A2) e.g. via zero-speed monitor, enabling contact (21-22) opens	**5.** Closing of door	→ Triple-coded actuator cancels blocking of the enabling contact. Door position contact (11-12) closes
3. Opening of door	→ Only possible once it is released. Door position contact (11-12) opens	**6.** Interlocking of door	→ Disconnects coil voltage: 1. Actuator, interlocked 2. Enabling contact closed → Enable only, when door interlocked

Command and signalling devices

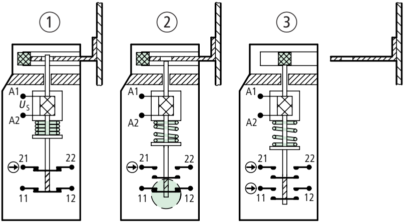
Position switches LS-Titan®, AT

"Process protection"



- Stop command
- Waiting time
- Process sequence ended
- Protective device on
- Product satisfactory

AT0-...MT-ZBZ, magnet-powered interlock (open-circuit principle)



① Interlocked
② Released
③ Open

→ Process protection + personnel protection with separate indication of the door position

1. Door closed + interlocked	→ Energized: enables immediate access in the event of mains failure and wire breakage. Both contacts closed	**4.** Door open	→ Both contacts blocked in the open position, even where attempts are made to tamper using basic tools
2. Releasing of door	→ Disconnects power from coil (A1, A2) e.g. via zero-speed monitor, enabling contact (21-22) opens	**5.** Closing of door	→ Triple-coded actuator cancels blocking of the enabling contact. Door position contact (11-12) closes
3. Opening of door	→ Only possible once it is released. Door position contact (11-12) opens	**6.** Interlocking of door	→ Applies coil voltage: 1. Actuator, interlocked 2. Enabling contact closed → Enabling possible only with the door interlocked

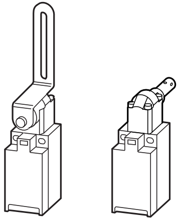
Command and signalling devices

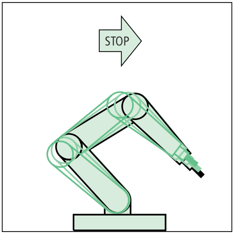
Position switches LS-Titan®, AT

3

"Personnel protection" by monitoring of the protective device

ATR-... /TKG ATR-.../TS

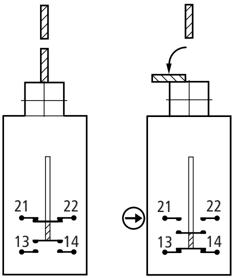




- Hinged protective cover open
- ATR/T... switches off the power
- No danger

ATR-.../TKG, ATR-.../TS

Closed Open



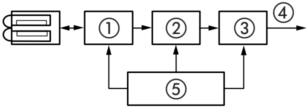
→Personnel protection

Opening of hinged protective cover	→	Enabling contact (21–22) opening positively
Hinged protective cover open	→	Enabling contact safely open, even where attempts are made to tamper using basic tools
Closing of hinged protective cover	→	Closes enabling contact (21–22)

Command and signalling devices
Inductive proximity switches LSI

The inductive proximity switch operates on the principle of the attenuated LC oscillator: when metal enters the response range of the proximity switch, power is withdrawn from the system. The metal part causes an energy loss, which is caused by the formation of eddy currents. The eddy current losses are related to the size and nature of the metal part.

The change in the oscillation amplitude of the oscillator results in a current change, which is evaluated in the downstream electronics and is converted into a defined switching signal. A steady-state signal is available at the output of the unit, for the duration of the attenuation.



① Oscillator
② Rectifier
③ Amplifier
④ Output
⑤ Power supply

Properties of inductive proximity switches

The following details apply to all inductive proximity switches:

- Protective insulation to IEC 346/VDE 0100 or IEC 536,
- Degree of protection IP67,
- High operating frequency or switching frequency,
- Maintenance and wear-free (long service life),
- Resistant to vibration,
- Any required mounting position
- LED display indicates the switching or output status and simplifies adjustment during installation,
- Operational temperature range –25 to +70 °C
- Oscillating load: cycle time 5 minutes, amplitude 1 mm in the frequency range 10 to 55 Hz,
- Comply with IEC 60947-5-2,
- Have a steady-state output which remains activated as long as the unit is being attenuated
- Bounce-free switching behaviour in the microsecondsrange (10^{-6} s).

Switching distance S

The switching distance is the distance at which a metal part approaching the active surface effects a signal change at the output. The switching distance depends on:

- Direction of approach
- Parameter
- Material of the metal part

The following correction factors must be used for different materials:

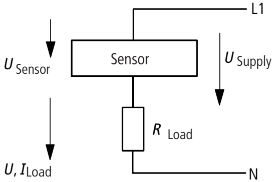
Steel (St 37)	$1.00 \times S_n$
Brass	$0.35 - 0.50 \times S_n$
Copper	$0.25 - 0.45 \times S_n$
Aluminium	$0.35 - 0.50 \times S_n$
High-grade steel	$0.60 - 1.00 \times S_n$

S_n = Rated switching distance

Command and signalling devices
Inductive proximity switches LSI

AC operating mode

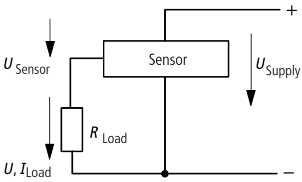
AC inductive proximity switches have two terminals. The load is connected in series with the sensor.



DC operating mode

DC inductive proximity switches have three terminals and are operated with a protective low voltage.

The switching behaviour can be determined more precisely, because the load is actuated via a separate output, and is independent of the load.



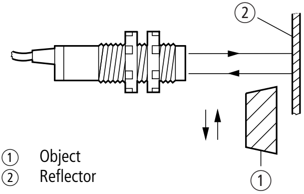
Command and signalling devices

Optical proximity switches LSO

Principle of operation

The optoelectronic sensors in the switch operate using modulated infrared light. Visible light therefore cannot affect their operation. Infrared light can penetrate even severe dirt on the optics, and thus ensures reliable operation. Proximity switch transmitters and receivers are matched to one another. The sensor receiver has an integral bandpass filter to amplify primarily the transmitted frequency. All other frequencies are attenuated. This gives the units good resistance to extraneous light. Precision plastic optics ensure long range and long sensing distances. There are two types of optical proximity switch, distinguished by their function.

Reflected-light beam



① Object
② Reflector

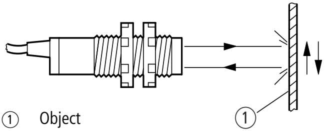
The reflected-light beam transmits infrared light to the object being scanned, which reflects this light in all directions. The portion of this light which strikes the receiver ensures a switching signal is produced, assuming adequate intensity. Evaluation takes place of "Reflection" and "No reflection". These states mean the same as presence or absence of an object in the sensing range. The degree of reflection of the object surface to be monitored affects the operating range S_d.

The following correction factors apply to different reflecting material characteristics.

Material	Factor app.
Paper, white, matt, 200 g/m^2	$1 \times S_d$
Metal, gloss	$1.2 – 1.6 \times S_d$
Aluminium, black, anodized	$1.1 – 1.8 \times S_d$
Polystyrene, white	$1 \times S_d$
Cotton, white	$0.6 \times S_d$
PVC, grey	$0.5 \times S_d$
Wood, untreated	$0.4 \times S_d$
Card, black, gloss	$0.3 \times S_d$
Card, black, matt	$0.1 \times S_d$

S_d = Switching range

Reflected-light barrier



① Object

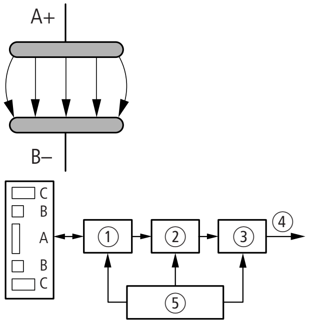
The unit transmits a pulsed infrared light beam, which is reflected by a triple reflector or mirror. The interruption in the light beam causes the unit to switch. Light barriers identify objects irrespective of their surface, as long as they do not have a gloss finish. The reflector size must be chosen such that the object to be detected virtually completely interrupts the light beam. Reliable detection is always achieved if the object is the same size as the reflector. The unit can also be set to detect transparent objects.

Command and signalling devices

Capacitive proximity switches LSC

Principle of operation

The active area of a capacitive proximity switch LSC is formed by two concentrically arranged metal electrodes. You can imagine these as the electrodes of a capacitor that are opened up. The electrode surfaces of this capacitor are arranged in the feed-back branch of a high-frequency oscillator circuit. This is adjusted such that it will not oscillate when the surface is clear. When an object approaches the active surface of the proximity switch, it enters the electric field in front of the electrode surfaces. This effects a rise in the coupling capacitance between the plates and the oscillator begins to respond. The oscillation amplitude is monitored via an evaluation circuit and converted into a switching command.



① Oscillator
② Evaluation circuit
③ Amplifier
④ Output
⑤ Power supply
A, B Main electrodes
C Auxiliary electrode

Effects

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

Metals achieve the greatest switching distances due to their high conductivity. Reduction factors for various metals, such as are necessary with inductive proximity switches, need not 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 ε 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.

Note

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

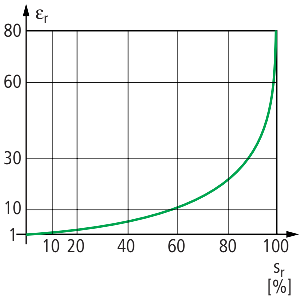
Influence of environmental conditions

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.

Command and signalling devices
Capacitive proximity switches LSC



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 proximity switches than dry wood.

Material	ε_r
Air, vacuum	1
Teflon	2
Wood	2 to 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

Command and signalling devices

Electronic position switches LSE-Titan®

Switching point adjustable and variable

The switching 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 behaviour. This ensures a defined and reproduceable switching point. The switching point lies in the range from 0.5 to 5.5 mm (supplied as = 3 mm).

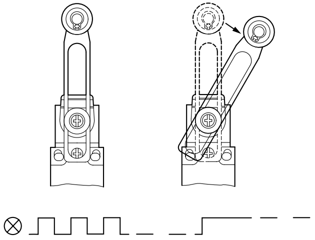
Adjustment to a new switching point is carried out as follows:

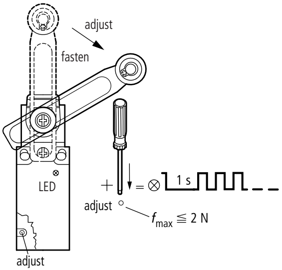
Move the plunger from the original to the new switch position. For this purpose, press the setting button for 1 s. The LED now flashes with a high pulse frequency and the new switching point is retentively set.

In redundant structures, position switches LSE-Titan just like electromechanical position switches, achieve safety category 3 or 4 to EN 954-1, Safety of machinery.

Note

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



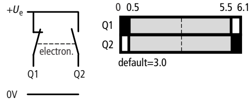


TÜV Rheinland

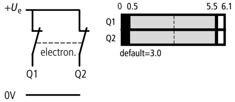
Bauart geprüft
Functional Safety
Type approved

Contact travel diagram

LSE-11



LSE-02



Command and signalling devices
Analog electronic position switches

Two types are available:
- LSE-AI with current output,
- LSE-AU with voltage output.

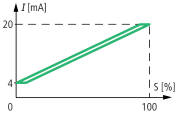
Analog, mechanically actuated position switches directly linked with the world of automation

Analog position switches LSE-AI (4 to 20 mA) and LSE-AU (0 to 10 V) represent another innovation in electronic position switches. Using them, it is now possible for the first time to monitor the actual position of a flue gas valve or an actuator continuously. The actual position is converted in analog fashion into voltage (0 to 10 V) or current (4 to 20 mA) and then continuously signalled to the electronics. Even objects of varying sizes or thicknesses, such as brake shoes, can be scanned and the results processed further.

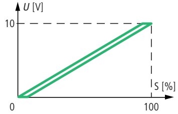
Simple rotational-speed dependent control systems of fan motors or smoke-venting blowers signal the opening angle of the air damper (e.g. 25, 50 or 75 %) and thus save power and material wear. The analog position switches also have a diagnosis output for further processing of data. This means that the safe status can be monitored and analysed at all times. The position switch also has a self-test function. The outputs Q1 and Q2 are constantly scanned for overload, short circuit against 0 V and short circuit against $+U_e$.

Contact travel diagram

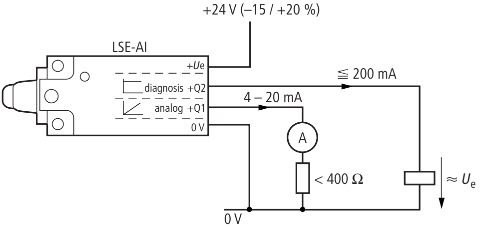
LSE-AI



LSE-AU

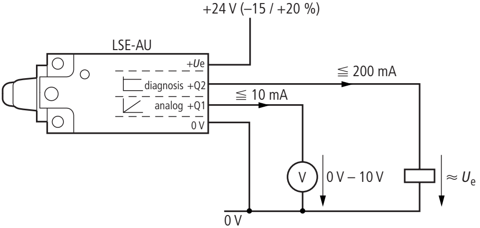


Connection diagram



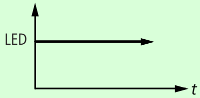
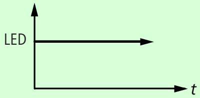
Command and signalling devices

Analog electronic position switches

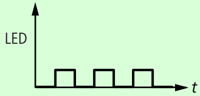
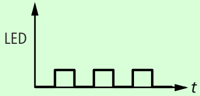
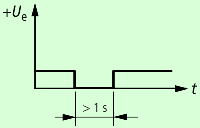
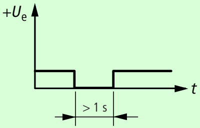


Circuit diagram

Normal scenario

	LSE-AI	LSE-AU
Q1	4 – 20 mA	0 – 10 V
Q2	≈ U_e	≈ U_e
LED		

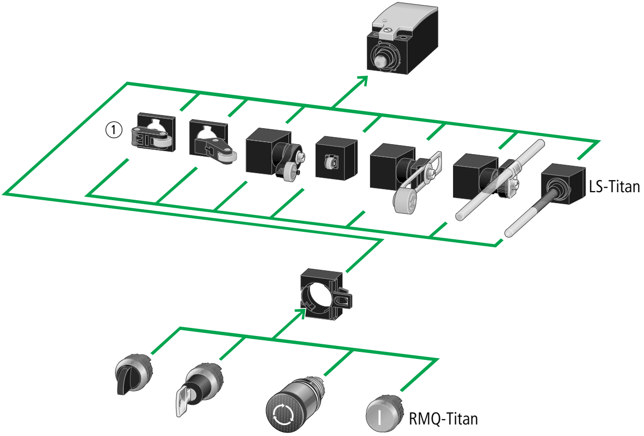
Fault scenario

	LSE-AI	LSE-AU
Q1	0 mA	0 V
Q2	0 V	0 V
LED		
Reset		

Command and signalling devices

New combinations for your solutions

RMQ-Titan® and LS-Titan®



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

Actuating devices RMQ-Titan® simply snap fitted

Another unique feature is the possibility to combine control circuit devices from the RMQ-Titan range with the position switches LS-Titan. Pushbuttons, selector switches or Emergency-Stop buttons can all be directly snapped on to any position switch as operating head. The complete unit then has at least the high degree of protection IP66 at front and rear.

In addition, all the operating heads and the adapter for accepting the RMQ-Titan actuators have a bayonet fitting that enables quick and secure fitting. Using the bayonet fitting, the heads can be attached in any of the four directions (4 × 90°).

Notes

Rotary Switches

Rotary Switches
Overview

Use and mounting forms

Moeller rotary 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 mounting forms 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 Main Catalogue for "Industrial Switchgear".

Other contact arrangements are listed in the K115 specialist catalog in addition to the switches listed in the Main Catalogue.

Basic type	P	I_u	Use as						Mounting type				
	[KW]	[A]	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
TM	3.0	10	–	×	–	×	–	×	○	○	–	○	–
T0	6.5	20	×	×	–	×	×	×	+	○	○	○	+
T3	13	32	×	×	–	×	×	–	+	○	○	○	+
T5b	22	63	×	×	×	×	×	–	+	–	○	–	+
T5	30	100	×	–	×	×	–	–	+	–	○	–	+
T6	55	160	×	–	–	×	–	–	–	–	+	–	+
T8	132	315 1)	×	–	–	×	–	–	–	–	+	–	+
P1-25	13	25	×	×	×	–	–	–	+	○	+	○	+
P1-32	15	32	×	×	×	–	–	–	+	○	+	○	+
P3-63	37	63	×	×	×	–	–	–	+	–	+	○	+
P3-100	50	100	×	×	×	–	–	–	+	–	+	○	+
P5-125	45	125	×	×	–	–	–	–	+	–	–	–	+
P5-160	55	160	×	×	–	–	–	–	+	–	–	–	+
P5-250	90	250	×	×	–	–	–	–	+	–	–	–	+
P5-315	110	315	×	×	–	–	–	–	+	–	–	–	+

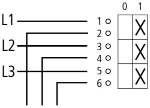
P = Max. motor rating; 400/415 V; AC-23 A
I_u = Max. rated uninterrupted current
1) In enclosed version (surface mounting), max. 275 A.
○ Depending on the number of contact units, function and contact sequence.
\+ Irrespective of the number of contact units, function and contact sequence.

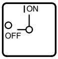
Rotary Switches

ON-OFF Switches, Main Switches, Maintenance Switches

ON-OFF switches, main switches

T0-2-1
P1-25
P1-32
P3-63
P3-100
P5-125
P5-160
P5-250
P5-315

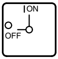




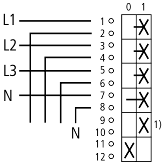
FS 908

Maintenance switches (safety switches) with auxiliary contacts

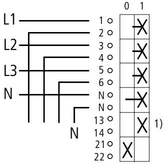
T0-3-15680

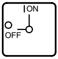


FS 908



P1-25/.../
P1-32/.../
P3-63/.../
P3-100/.../
...N/NHI11





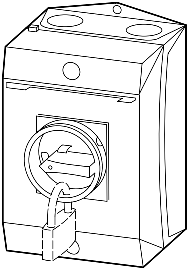
FS 908

1) Load shedding contact

These switches can also be used as switch-disconnectors for lighting, heating or combined loads.

Main switches to IEC/EN 60 204 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.



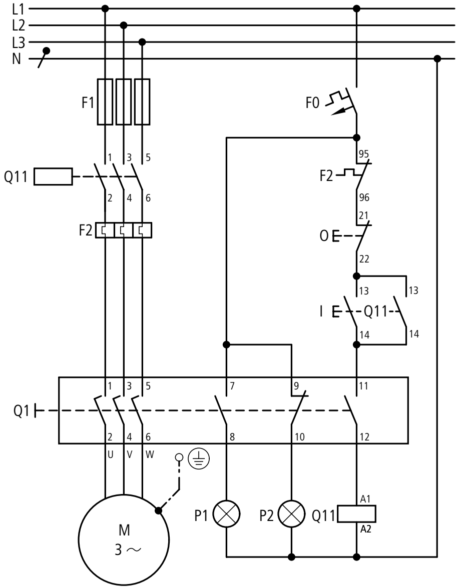
Maintenance switches are fitted to electrical machines or installations to provide safe working conditions in accordance with the safety regulations.

By attaching his own padlock to the SVB padlocking feature, the electrician can protect himself against anyone switching on without authorization (→ section “Circuit diagram example for maintenance switches with a load shedding contact and (or) switch position indicator”, page 4-4).

Rotary Switches

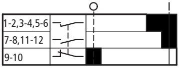
ON-OFF Switches, Main Switches, Maintenance Switches

Circuit diagram example for maintenance switches with a load shedding contact and (or) switch position indicator



P1: On
P2: Off
Q11: Load shedding

T0(3)-3-15683 circuit diagram



T0(3)-3-15683 maintenance switch

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 of the early-break contact, then the main contacts isolate the motor supply.

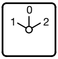
Switch position indication: The position of the switch can be signalled to the control panel or mimic diagram panel via additional NO and NC contacts.

Rotary Switches

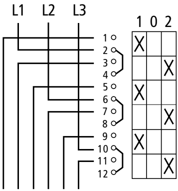
Changeover Switches, Reversing Switches

Changeover switches

T0-3-8212
T3-3-8212
T5B-3-8212
T5-3-8212
T6-3-8212
T8-3-8212

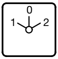


FS 684

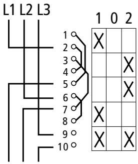


Reversing switches

T0-3-8401
T3-3-8401
T5B-3-8401
T5-3-8401



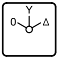
FS 684



Rotary Switches
(Reversing) Star-Delta Switches

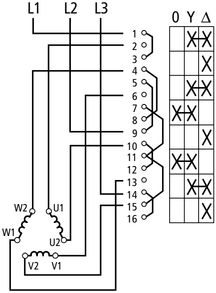
Star-delta switches

T0-4-8410
T3-4-8410



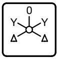
FS 635

T5B-4-8410
T5-4-8410

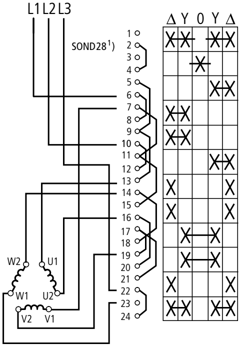


Reversing star-delta switches

T0-6-15877
T3-6-15877



FS 638



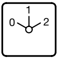
1) Standard contactor interlock

→ section "Interlock Circuits", page 4-11

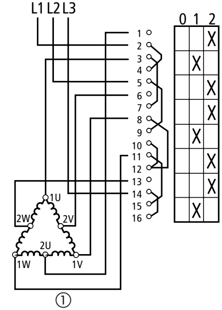
Rotary Switches
Multi-Speed Switches

2 speeds, non-reversing

Tapped winding arrangement
T0-4-8440
T3-4-8440
T5B-4-8440
T5-4-8440

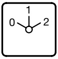


FS 644

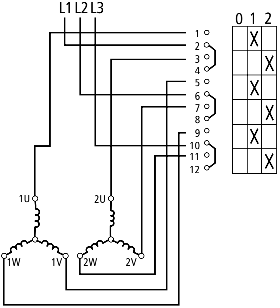


① without links

2 separate windings
T0-3-8451
T3-3-8451
T5B-3-8451
T5-3-8451



FS 644

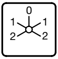


Rotary Switches
Multi-Speed Switches

2 speeds, reversing

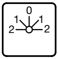
Tapped winding arrangement

T0-6-15866
T3-6-15866

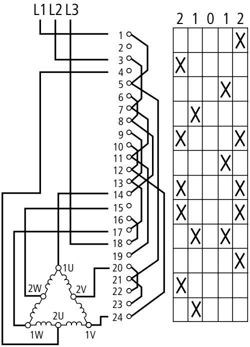


FS 629

T5B-7-15866
T5-7-15866

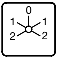


FS 441



2 separate windings, reversing

T0-5-8453
T3-5-8453



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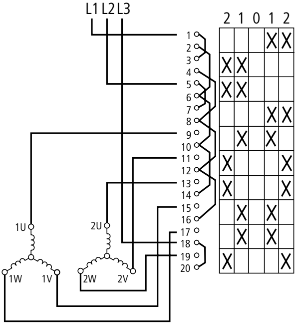
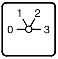


Rotary Switches
Multi-Speed Switches

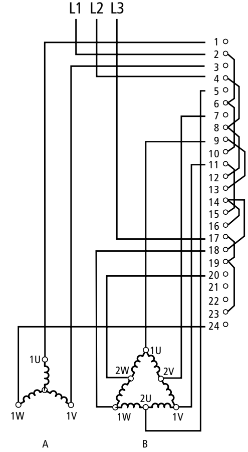
3 speeds, non-reversing

Tapped winding arrangement, single winding for low speed

T0-6-8455
T3-6-8455
T5B-6-8455
T5-6-8455



FS 616



0	1	2	3
	X		
	X		
			X
			X
		X	
		X	
			X
			X
		X	
			X
	X		

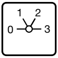
0-(A)Y - (B)△ = (B)YY

Rotary Switches
Multi-Speed Switches

3 speeds, non-reversing

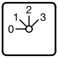
Tapped winding arrangement, single winding for high speed

T0-6-8459
T3-6-8459

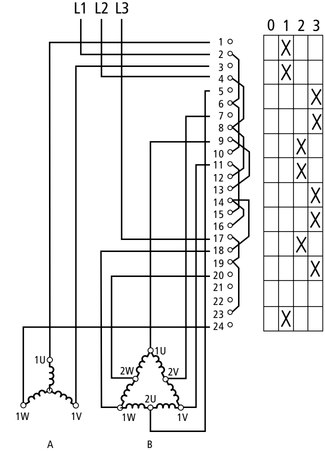


FS 616

T5B-6-8459
T5-6-8459



FS 420



0-(B)△- (B)YY -(A)Y

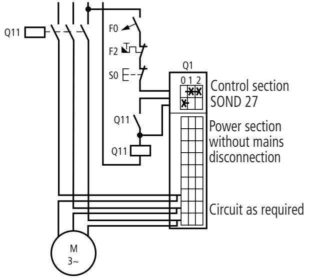
Rotary Switches
Interlock Circuits

Interlock circuits between rotary 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 power failure
- The facility for remote disconnection (e.g. emergency-stop) can be provided by one or more Off pushbuttons.

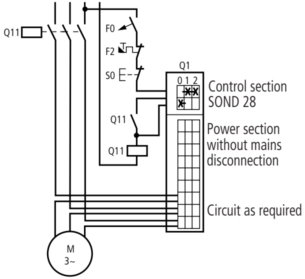
Without mains disconnection (SOND 27)

Mains disconnection only by contactorprimarily for star-delta circuit



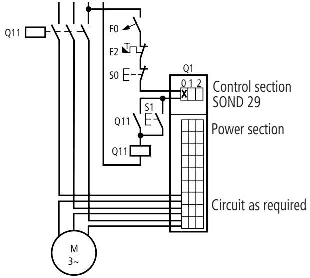
With mains disconnection (SOND 28)

Mains disconnection by contactor and switch



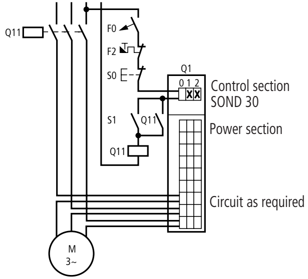
Interlock with contactor (SOND 29)

Contactor can be energized only when switch is in the Off position



Interlock with contactor (SOND 30)

Contactor can be energized only when switch is in an operating position



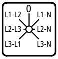
Rotary Switches
Single-Phase Starting Switches

Meter selector switches enable you to measure currents, voltages and power in three-phase systems with only one measuring device.

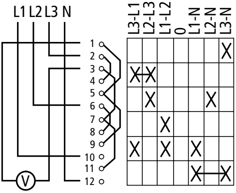
Numerous circuits are possible for the different measurements, some of the most common ones being shown below.

Voltmeter selector switches

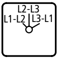
T0-3-8007
3 × phase to phase
3 × phase to neutral with "0" position



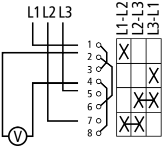
FS 1410759



T0-2-15922
3 × phase to neutral without "0" position

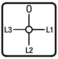


FS 164854

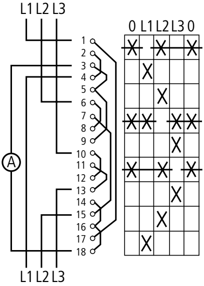


Ammeter selector switches

T0-5-15925
T3-5-15925
For direct measurement



FS 9440

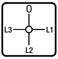


Rotary Switches

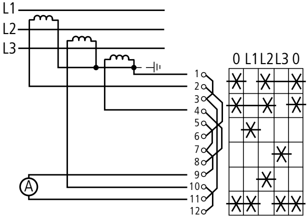
Meter Selector Switches

Ammeter selector switches

T0-3-8048
T3-3-8048
For measurement via transformers, complete rotation possible



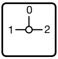
FS 9440



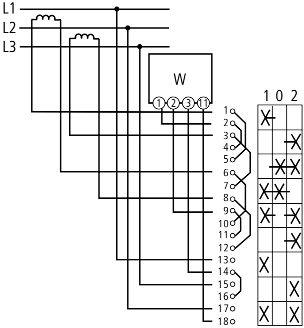
Wattmeter selector switches

T0-5-8043
T3-5-8043
Two-phase method (Aron circuit) for three-cable installations loaded as required. The sum of the two readings gives the total output.

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.



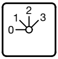
FS 953



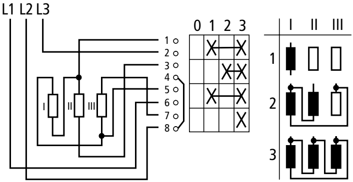
Rotary Switches
Heater Switches

1-pole disconnection, 3 steps

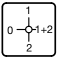
T0-2-8316
T3-2-8316
T5B-2-8316



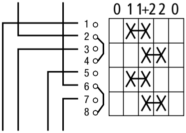
FS 420



T0-2-15114, complete rotation possible



FS 193840



□ switched
■ not switched

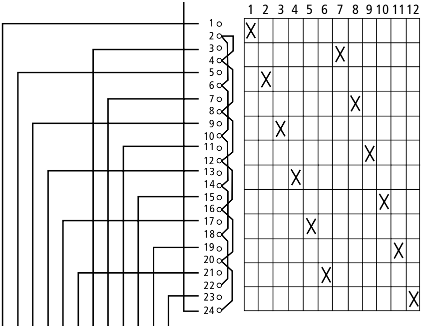
Further heater switches, 2- and 3-pole, with alternative circuitry, output stages, and number of steps are described in the Moeller Main Catalogue, Industrial Switchgear and in the catalogue K 115.

Rotary Switches
Step Switches

One step closed in each position, complete rotation possible

T0-6-8239
T3-6-8239

FS 301



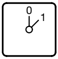
4

Rotary Switches
Step Switches

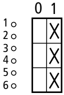
Stay-put switches

On-Off stay-put switches

1-pole: T0-1-15401
2-pole: T0-1-15402
3-pole: T0-2-15403

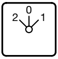


FS 415

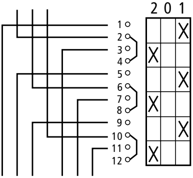


Changeover switches

1-pole: T0-1-15421
2-pole: T0-2-15422
3-pole: T0-3-15423

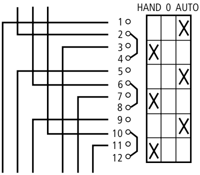


FS 429



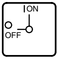
1-pole: T0-1-15431
2-pole: T0-2-15432
3-pole: T0-3-15433

FS 1401

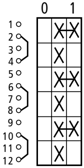


On-Off stay-put switches (also usable as main switches, mains isolating device)

1-pole: T0-1-15521
2-pole: T0-2-15522
3-pole: T0-3-15523
With pulsed contact in the intermediate position



FS 908



Rotary Switches

Rotary Switches and Switch-Disconnectors with ATEX Approval

What does ATEX stand for?

ATmosphéres **EX**plosibles = **ATEX**

Explosive atmospheres

Gas

Dust

Two standards

For operators: 1999/92/EC
(binding from 06/2006)

Explosion risk assessment

Gas, steam, mist	**Dust**	**Ex risk**
Zone 0	Zone 20	continuous, frequent, long,
Zone 1	Zone 21	occasional
Zone 2	**Zone 22**	**normally not, but otherwise for a short period**

Selection of devices and protective systems by categories

Gas, steam,	**Dust**	**Category**
mist Zone 0,		
1, 2 Zone 1, 2	Zone 20, 21, 22	1
Zone 2	Zone 21, 22	1, 2
	Zone 22	1, 2, **3**

For manufacturers: 94/9/EC
(binding from 06/2003)

Device groups

Group	**Application field**
I	Mining
II	**everything apart from mining**

Selection of devices by device groups

Group	**Category**	**Safety**
I	M1	very high
I	M2	high
II	1	very high
II	2	high
II	**3**	**normal**

Rotary Switches

Rotary Switches and Switch-Disconnectors with ATEX Approval

ATEX approval for Moeller

Moeller offers T rotary switches (from 32 to 100 A) and P switch-disconnectors (from 25 to 100 A) in accordance with the binding ATEX Directive 94/6 EC (binding from 06/2006). The switches are provided with the equipment marking Ex II3D IP5X T90°C and are approved for the Ex zone 22 in explosive dust atmospheres.

Explosive dust atmospheres are present in:

- Mills,
- Metal polishing workshops,
- Woodworking facilities,
- Cement industry,
- Aluminium industry,
- Animal feed industry,
- Grain storage and preparation,
- Agriculture,
- Pharmacy etc.

The ATEX switches are used as:

- Main switches
- Maintenance switches
- Repair switches,
- ON-OFF switches or,
- Changeover switches.

The following ATEX switches are available:

Current range	T rotary switches	P switch-disconnectors
25 A	–	P1-25/I2
32 A	T3-.../I2	P1-32/I2
63 A	T5B-.../I4	P3-63/I4
100 A	T5-.../I5	P3-100/I5

Note

Moeller ATEX switches have passed the EC prototype test for main, maintenance and repair switches for the current ranges from 25 to 100 A. They are approved for explosive dust atmospheres in accordance with category II 3D, with the test number: BVS 04E 106X.

For further information see installation instructions AWA1150-2141.

General installation and application notes

- Only suitable cable glands may be used for category 3D!
- Use only temperature resistant cables (> 90°C)!
- The maximum surface temperature is 90°C!
- Operation only permissible at an ambient temperature between –20 and +40°C!
- Observe the technical data of the switch used!
- Never open the device in dust explosive atmospheres!
- Observe the requirements of EN 50281-1-2!
- It should be checked that the device is free of dust prior to assembly!
- Do **not** open the device when energized!

4

Contactors and Relays

Contactors and Relays
Contactor relays

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 favour.

Safety

The contactor relay contacts themselves constitute a considerable safety feature. By design and construction they ensure electrical isolation between the actuating circuit and the operating circuit, in the de-energized state, between the contact input and output. All Moeller contactor relays have double-break contacts.

The German Trade Associations demand that, for control systems of power-driven metalwork presses, the contacts of contactors must be interlocked. Interlocking means that the contacts are mechanically connected to one another such that break contacts and make 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 entire life, even when defective (e.g. when a contact is welded). The contactor relays DILER and DILA fulfil this requirement.

Moeller contactor relays

Moeller offers two ranges of contactor relays as a modular system:

- Contactor relays DILER,
- Contactor relays DILA.

and the modules are described on the following pages.

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 normally open and normally closed 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 unit and 21/22 on the add-on auxiliary contact module.

Contactors and Relays
Contactor relays

The system and the Standard

European Standard EN 50011 “Terminal markings, reference 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 make and break contacts in the device, and their terminal markings.

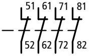
Ideally devices with the reference letter E should be used. The basic devices DILA-40, DILA-31, DILA-22 as well as DILER-40, DILER-31 and DILER-22 comply with the E version. .

For 6 and 8 pole contactor relays, the “E” version means that four make 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-3131, they result in contact combinations with reference letters X and Y.

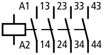
Below are 3 examples of contactors with 4 normally open and 4 normally closed contacts with different reference letters. Version E is to be preferred.

Example 1

DILA-XHI04



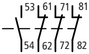
+
DILA-40



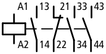
≙ 44 E
DILA40/04

Example 2

DILA-XHI13



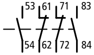
+
DILA-31



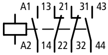
≙ 44 X
DILA31/13

Example 3

DILA-XHI22



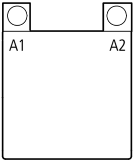
+
DILA-22



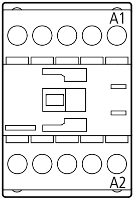
≙ 44 Y
DILA22/22

Contactors and Relays
Contactor relays

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 voltage peaks :

- RC suppressors
- 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.

Suppressor circuits

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.

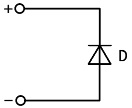
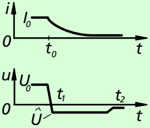
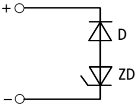
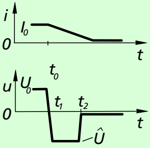
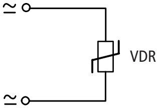
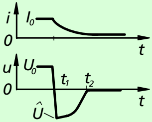
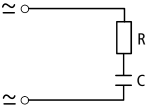
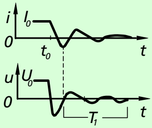
One of the disturbance factors occurs when inductive loads, such as coils of electromagnetic switching devices, are switched off. High cut-off induction voltages can be produced when such devices are switched off and, under some circumstances, can destroy adjacent electronic devices or, via capacitive coupling mechanisms, can generate interference voltage pulses and thus cause disruptions in operation.

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

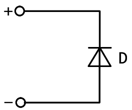
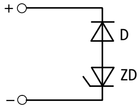
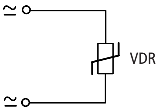
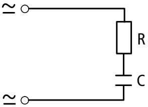
Contactors and Relays

Contactor relays

Circuit diagram	Load current and voltage responses	Proof against incorrect connection also for AC	Additional dropout delay	Induction voltage limiting defined
		–	Very long	1 V
		–	Medium	U_{ZD}
		Yes	Short	U_{VDR}
		Yes	Short	–

Contactors and Relays

Contactor relays

Circuit diagram	Damping also below U_{LIMIT}	Increased rating with circuitry.	Remarks	
	–	–	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-energisation. Highly suitable for AC.
			Disadvantage:	Precise dimensioning required

Contactors and Relays
Timing and special purpose relays

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

The switching capacity of electronic timing relays corresponds to the utilisation categories AC 15 and DC 13.

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

- **Version A** (DILET… and ETR4) Universal devices:
  DC 24 to 240 V
  AC 24 to 240 V, 50/60 Hz
- **Version W** (DILET… and ETR4)
  AC devices:
  AC 346 to 440 V, 50/60 Hz
- **ETR2…** (as row mounting device to DIN 43880)
  Universal device:
  DC 24 to 48 V
  AC 24 to 240 V, 50/60 Hz

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

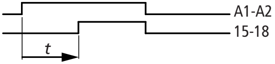
- DILET11, ETR4-11,ETR2-11
  Function 11 (on-delayed)
- ETR2-12
  Function 12 (off-delayed)
- ETR2-21
  Function 21 (fleeting contact on energisation)
- ETR2-42
  Function 42 (flashing, pulse initiating)
- ETR2-44
  Function 44 (flashing, two speeds; can be set to either pulse initiating or pause initiating)
- Multifunction relay DILET70, ETR 4-69/70
  Function 11 (on-delayed)
  Function 12 (off-delayed)
  Function 16 (on and off delayed)
  Function 21(fleeting contact on energisation)
  Function 22 (fleeting contact on de-energisation)
  Function 42 (flashing, pulse initiating)
- **Function 81** (pulse generating)
  Function 82 (pulse shaping)
  ON, OFF
- Multifunction relay ETR2-69
  Function 11 (on-delayed)
  Function 12 (off-delayed)
  Function 21 (fleeting contact on energisation)
  Function 22 (fleeting contact on de-energisation)
  Function 42 (flashing, pulse initiating)
  Function 43 (flashing, pause initiating)
  Function 82 (pulse forming)
- Star/delta timing relay ETR4-51
  Function 51 (on delayed)

With both DILET70 and 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. Equiped with two change-over contacts which can be converted to two timing contacts 15-18 and 25-28 (A2-X1 bridged) or one timing contact 15-18 and a non-delayed contact 21-24 (A2-X1 not bridged). If the link A2-X1 is removed, only the timed contact 15-18 carries out the functions described below.

Contactors and Relays
Timing and special purpose relays

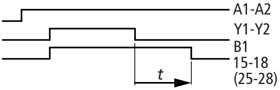
Function 11
On-delayed



The control voltage *U*s is applied via an actuating contact to the terminals A1 and A2.

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

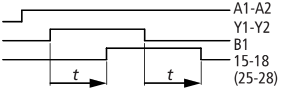
Function 12
Off-delayed



After the control 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 the terminals Y1 and Y2 in the DILET70 are linked by a potential-free make contact or, in the case of the ETR4-69/70 or ETR2-69, a potential is applied to B1, the changeover contact changes without delay to the position 15-18 (25-28).

If the connection between the terminals Y1–Y2 is now interrupted, or 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).

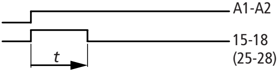
Function 16
On- and Off-delayed



The control voltage *U*s is applied directly to the terminals A1 and A2. If the terminals Y1 and Y2 in the DILET70 are linked by a potential-free contact, or in the case of of the ETR4-69/70 a potential is applied to B1, after a set time ***t*** the changeover contact goes to the position 15-18 (25-28).

If the connection Y1-Y2 is now interrupted, or 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.

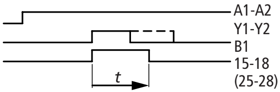
A fleeting pulse (terminals 15-18, 25-28) of defined duration is therefore produced from a two-wire control process (voltage on A1/A2) by this function.

5

Contactors and Relays
Timing and special purpose relays

Function 82

Pulse forming

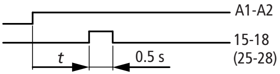


After the control voltage has been applied to A1 and A2, the changeover contact of the output relay remains in the rest position 15-16 (25-26). If the terminals Y1 and Y2 in the DILET70 are linked by a potential-free contact, or in the case of the ETR4-69/70 or ETR2-69, a potential is applied to B1, the changeover contact changes without delay to the position 15-18 (25-28).

If Y1-Y2 is now opened again, or B1 is separated from the potential, the changeover contact remains actuated until the set time has elapsed. If, instead, Y1-Y2 remain closed or 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-forming function, irrespective of whether the input pulse via Y1-Y2 or B1 is shorter or longer than the set time.

Function 81

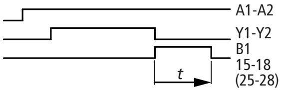
Pulse generating with fixed pulse



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 s. This function is therefore a fleeting pulse with a time delay.

Function 22

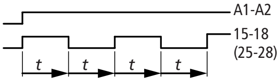
Fleeting contact on de-energization



The control voltage U_s is applied directly to A1 and A2. If the terminals Y1 and Y2 of the DILET70, that have been shorted (DILET-70 potential-free) before at a convienient time, are opened again (or for ETR4-69/70 or ETR2-69 the contact B1 again potential-free) the contact 15-18 (25-28) closes for the duration of the set time.

Function 42

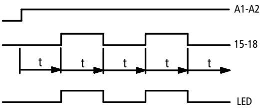
Flashing, pulse initiated



After the voltage *U*s 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.

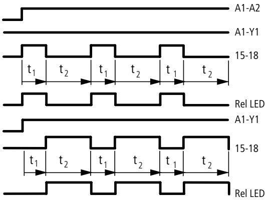
Contactors and Relays
Timing and special purpose relays

Function 43
Flashing, pause initiated



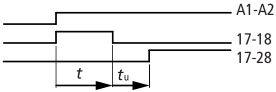
After the voltage U_s has been applied to A1 and A2 the change-over contact of the output relay stays in position 15-16 for the set flashing time and after the duration of this time goes to position 15-18 (the cycle begins with a pause phase).

Function 44
Flashing, two speeds



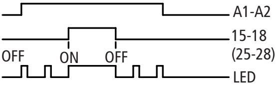
After the voltage U_s has been applied to A1 and A2 the changeover contact of the output relay goes to position 15-18 (pulse begin). By bridging the contacts A1 and Y1 the relay can be switched to pause begin. The times t_1 and t_2 can be set to different times.

Function 51 Star-delta
On-delayed



When the control voltage U_s is connected to A1 and A2 the instantaneous contact goes to position 17-18. After the set time duration the instantaneous contact opens and the timing contact 17-28 closes after a changeover time t_u of 50 ms.

On-Off Function

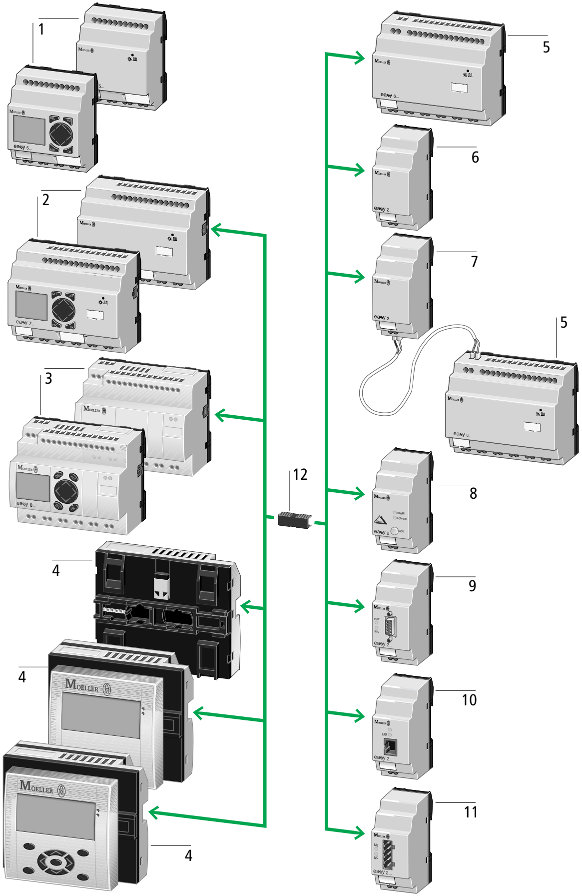


The On-Off function allows the operation of a control system to be tested and is an aid, for example, for commissioning. The Off function allows the output relay to be de-energized and it no longer reacts to the functional sequence. The On function energizes the output relay. This function is dependent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

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Control relay easy



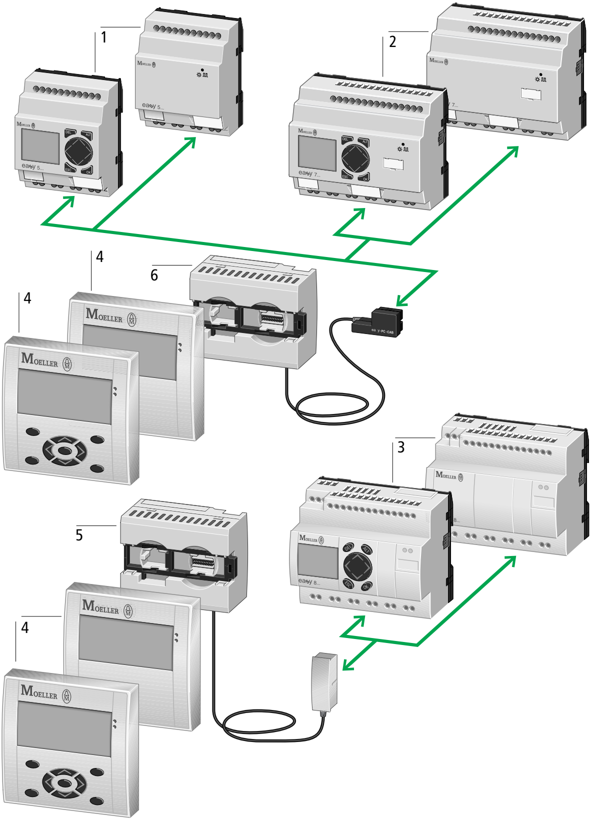
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

1 Basic unit easy512
2 Basic unit, expandable easy719, easy721
3 Basic unit, expandable easy819, easy820, easy821, easy822
4 Multi Function Display MFD-Titan, expandable
5 Expansion unit easy618, easy620
6 Expansion unit easy202
7 Coupling unit easy200 for remote expansion of easy700, easy800 and MFD-Titan
8 Network module PROFIBUDS-DP; EASY204-DP
9 Network module AS-Interface; EASY205-ASI
10 Network module CANopen; EASY221-CO
11 Network module DeviceNet; EASY222-DN
12 Data plug EASY-LINK-DS

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®



Contactors and Relays
Control relay easy, Multi Function Display MFD-Titan®

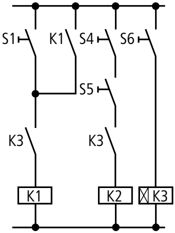
1 Basic unit easy512
2 Basic unit, expandable easy719, easy721
3 Basic unit, expandable easy819, easy820, easy821, easy822
4 Multi Function Display MFD-Titan
5 Power supply/communication module MFD-CP4-800
6 Power supply/communication module MFD-CP4-500

Contactors and Relays

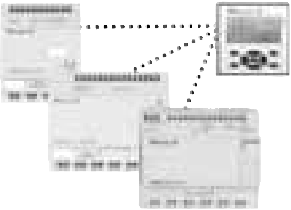
Control relay easy, Multi Function Display MFD-Titan®

Programming instead of wiring

Circuit diagramms are the basis of all electrotechnical applications. In practice electrical devices are wired to each other. With the control relay easy it is simply by pushbutton or with easy to use easy-soft... by computer. Simple menu operation in many languages simplify the input. That saves time and therefore costs. easy and MFD-Titan are the professionals for the world market.



"Remote" Display – Text display for easy500, easy700, easy800 in IP65

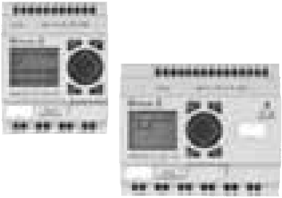


Using Plug & Work the display MFD-80.. is connected via the supply and communication module MFD-CP4.. to the easy. The MFD-CP4.. has an integrated, 5 m long connection cable. Advantage: No software or driver is necessary for connection. The MFD-CP4.. offers real Plug & Work. The input and output wiring is connected to the easy. The MFD-80.. is mounted into two 22.5 mm mounting holes. The IP65 display is backgound illuminated and easily readable. Individual labeling of the displays is possible.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Control relay easy500 and easy700

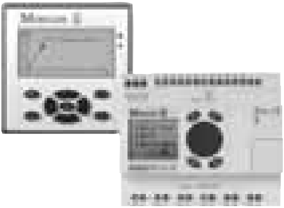


easy500 and easy700 have the same functions. easy700 offers more inputs and outputs, is expandable and can be connected to a standard bus system. The series and parallel linking of contacts and coils takes place in up to 128 current paths. Three contacts and and a coil in series. The display of 16 operating and report texts is via an internal or external display.

The main functions are:

- Multi-function timing relay
- Current impulse relay,
- Counter
  - forwards and backwards,
  - Fast counter,
  - Frequency counter,
  - Operational time counter,
- Analog value comparator,
- Week and year time switch,
- Automatic summertime changeover,
- Remanent actual values of markers, numbers and timing relays.

MFD-Titan and easy800



MFD…CP8… und easy800 have the same functions. MFD-80.. with IP65 they can be used in harsher environments. In addition for expansion and connection to standard bus systems 8 easy800 or MFD-Titan can be networked via easyNet. The series and parallel linking of contacts and coils takes place in up to 256 current paths. Four contacts and a coil in series. The display of 32 operating and report texts is via an internal or external display.

Extra to the functions offered by easy700 the easy800 and the MFD-Titan offers:

- PID controller,
- Arithmetic modules,
- Value scaling,
- and much more.

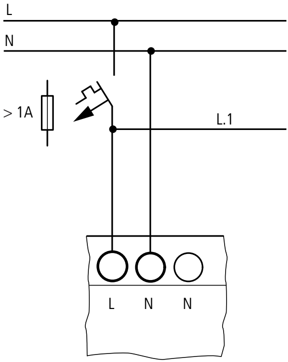
Individual labeling of the MFD-80 is possible.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Power supply connection

for AC devices



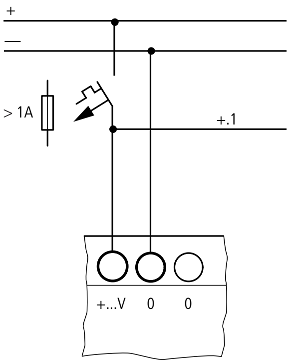
Basic unit

EASY512-AB-…	24 V AC
EASY719-AB-	24 V AC
EASY512-AC-…	115/230 V AC
EASY719-AC-…	115/230 V AC
EASY811-AC-…	115/230 V AC
MFD-AC-CP8-…	115/230 V AC

Expansion devices

EASY618-AC…	115/230 V AC

for DC devices



Basic units

EASY512-DA-…	12 V DC
EASY719-DA-…	12 V DC
EASY512-DC-…	24 V DC
EASY719-DC-…	24 V DC
ASY819-DC-…	24 V DC
EASY82.-DC-…	24 V DC
MFD-CP8-…	24 V DC

Expansion devices

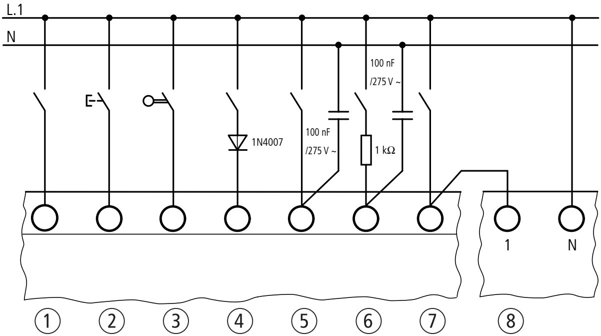
EASY618-DC…	24 V DC
EASY620-DC…	24 V DC

5

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Digital input connection of the AC devices



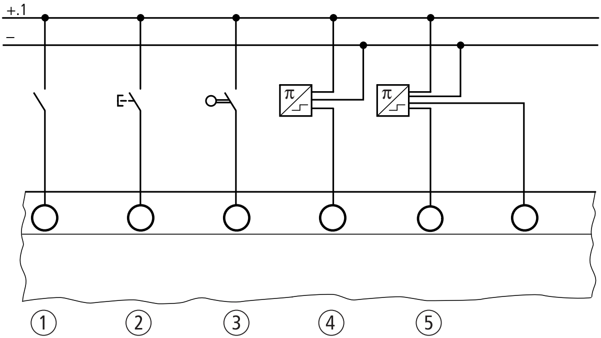
1. Input signal via relay contact e.g. DILER
2. Input signal via pushbutton RMQ Titan
3. Input signal via position switch e.g. LS Titan
4. Conductor length 40 to 100 m for input without additional switching (e.g. easy700 I7, I8 already has addition switching, possible conductor length 100 m)
5. Increasing the input current
6. Limiting the input current
7. Increasing the input current with EASY256-HCI
8. EASY256-HCI

Note

- Due to the input circuitry the drop-out time of the input is increased.
- Length of input conductor without addtional switching ≦40 m, with additional switching ≦100 m.

Contactors and Relays
Control relay easy, Multi Function Display MFD-Titan®

Digital input connection of the DC devices



1. Input signal via relay contact e.g. DILER
2. Input signal via pushbutton RMQ Titan
3. Input signal via position switch e.g. LS Titan
4. Proximity switch, three wire
5. Proximity switch, four wire

Note

- With conductor length consider also the volt-drop.
- Due to the high residual currents don´t use two wire proximity switches.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Analogue inputs

Depending upon the device two or three 0 to 10 V inputs are available.

The resolution is 10 Bit = 0 to 1 023.

Valid:

I7 = IA01 I8 = IA02	EASY512-AB/DA/DC…
I7 = IA01 I8 = IA02 I11 = IA03 I12 = IA04	EASY719/721-AB/DA/DC… EASY819/820/821/822-DC… MFD-R16, MFD-R17, MFD-T16, MFD-TA17

Caution!

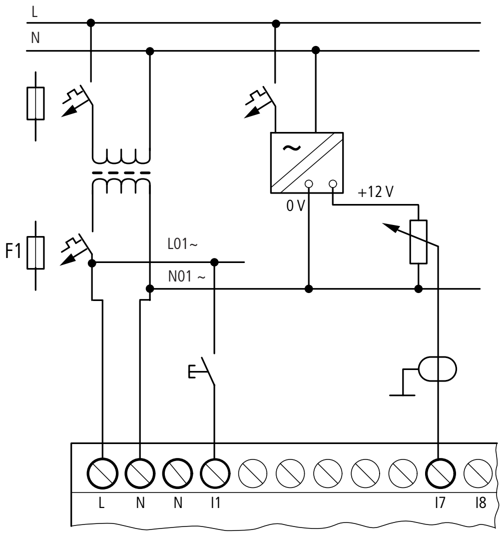
Analogue signals are more sensitive to interferance than digital signals, therefore the signal cables should be carefully routed and connected. Inappropriate connections can lead to unwanted switching conditions.

- Use screened, twisted pair conductors, to stop interference of the analogue signals.
- With short conductor lengths earth the screen on both sides and fully. With a conductor length of approx. 30 m the earthing on both sides can lead to circulating currents between the earthing points and interference of the analogue signals. In this case only earth the conductor on one side.
- Don´t lay the signal conductor parallel to the power conductor.
- Inductive loads that must be switched by easy should be connected to a seperate power supply or a suppressor circuit should be used for motors and valves. Supplying loads such as motors, magnetic valves or contactors and easy from the same power supply can by switching lead to interference of the anologue input signal.

Contacts and Relays

Control relay easy, Multi Function Display MFD-Titan®

Connection of power supply and analogue inputs for easy..AB device



Note

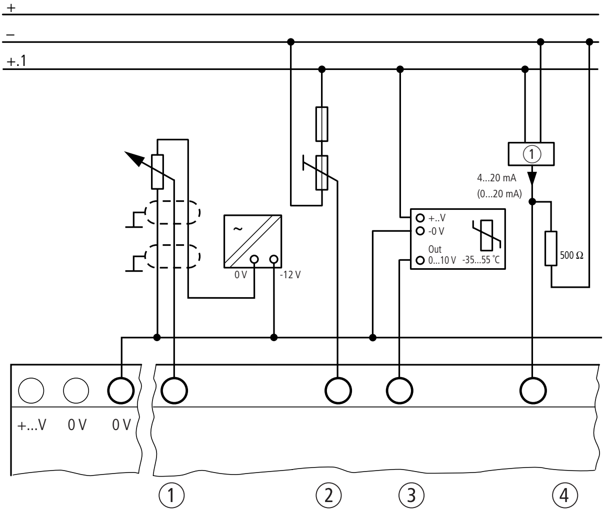
easy..AB devices that process analogue signals must be supplied via a transformer so that there is a galvanic seperation from the mains supply. The neutral conductor and the reference potential of DC supplied analogue sensors must be galvanically connected.

Be sure the common reference potential is earthed or monitored by an earth-fault monitoring device. Pay attention to the applicable reglations.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Analogue input connections to easy…DA/DC-… or MFD-R…/T…



1. Setpoint device via separate power supply and potentiometer ≦1 kΩ, e.g. 1 kΩ, 0.25 W
2. Setpoint device with upstream resistance 1.3 kΩ, 0.25 W, potentiometer 1 kΩ, 0.25 W (value for 24 V DC)
3. Temperature monitoring via temperature sensor and transducer
4. Sensor 4 to 20 mA mit resistor 500 Ω

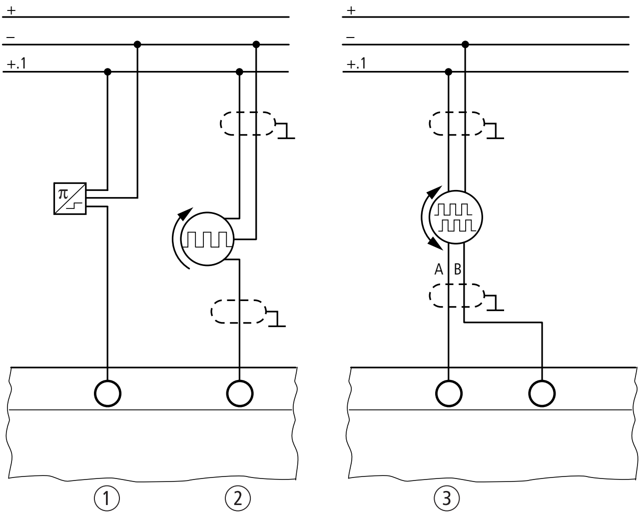
Note

- Pay attention to the differing number and designation of the analogue inputs of each device type.
- Connect the 0 V of the or the MFD-Titan with the 0 V of the power supply of the analogue encoder.
- sensor of 4(0) to 20 mA and a resistance of 500 Ω give the following approx. values:
  - 4 mA ≈ 1.9 V,
  - 10 mA ≈ 4.8 V,
  - 20 mA ≈ 9.5 V.
- Analogue input 0 to 10 V, Resolution 10 Bit, 0 to 1 023.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Connection "fast counter", "frequency generator"and "incremental encoder" for easy…DA/DC devices or MFD-R…/-T…



① Fast counter, square wave signal via proximity switch, pulse pause relationship should be 1:1
easy500/700 max. 1 kHz
easy800 max. 5 kHz
MFD-R/T… max. 3 kHz

② Square wave signal via frequency generator, pulse pause relationship should be 1:1
easy500/700 max. 1 kHz
easy800 max. 5 kHz
MFD-R/T… max. 3 kHz

③ Square wave signal via incremental encoder 24 V DC
easy800DC… and MFD-R/T… max. 3 kHz

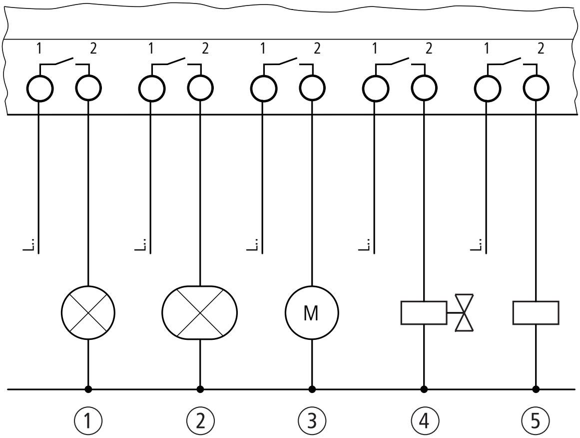
Note

Pay attention to the different number and designation of the inputs of the "fast counter", "frequency generator" and "incremental encoder" for each device type.

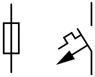
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Connection of relay outputs for easy and MFD-Titan



Protection operating potential L..



≦ 8 A/B16

Possible AC voltage range:
24 to 250 V, 50/60 Hz
z. B. L1, L2, L3 phase against neutral

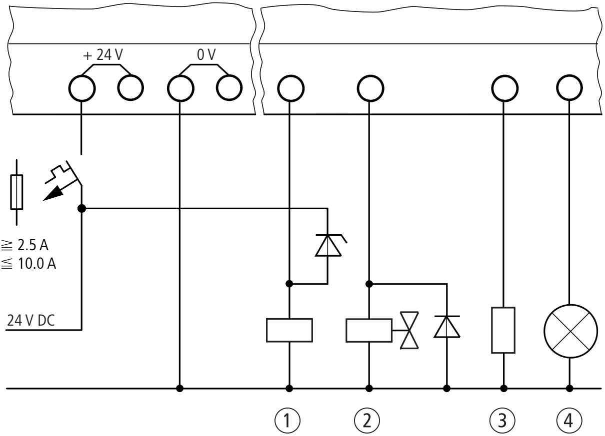
Possible DC voltage range:
12 to 300 V DC

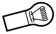
① Lamp, max. 1 000 W at 230/240 V AC
② Fluorescent tube, max. 10 × 28 W with electronic starter, 1 × 58 W with conventional starter at 230/240 V AC
③ AC motor
④ Valve
⑤ Coil

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Connection from transistor outputs for easy and MFD-Titan



1. Contactor coil with zener diode as suppressor, 0.5 A bei 24 V DC
2. Valve with diode as suppressor, 0.5 A at 24 V DC
3. Resistor, 0.5 A at 24 V DC
4.  Indicator lamp 3 or 5 W at 24 V DC, Output dependant upon device types and outputs

Note

When switching off inductive loads the following should be considered:

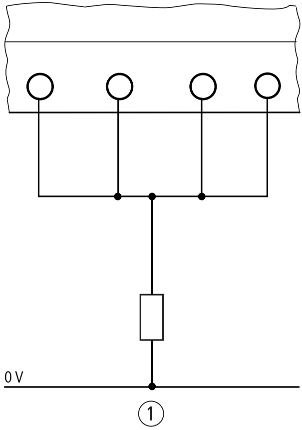
Suppressed inductances cause less interference in the total electrical system. It is generally recommended to connect the suppressor as close as possible to the inductance.

When the inductances are not suppressed, then : several inductances must not be switched off at the same time, so that in the worst case the driver block does not overheat. Should, in an emergency stop situation the +24 V DC supply be switched off by another contact and thereby more than one controlled output be switched off, the inductances must have a suppressor.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

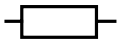
Parallel switching



(1) Resistor

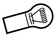
Note

The outputs may only be switched parallel within a group (Q1 to Q4 or Q5 to Q8, S1 to S4 or S5 to S8) ; e.g. Q1 and Q3 or Q5, Q7 and Q8. Parallel switched outputs must be simiItaneously energised.



when 4 outputs in parallel,
max. 2 A at 24 V DC

when 4 outputs in parallel,
max. 2 A at 24 V DC
Inductance without suppression
max. 16 mH

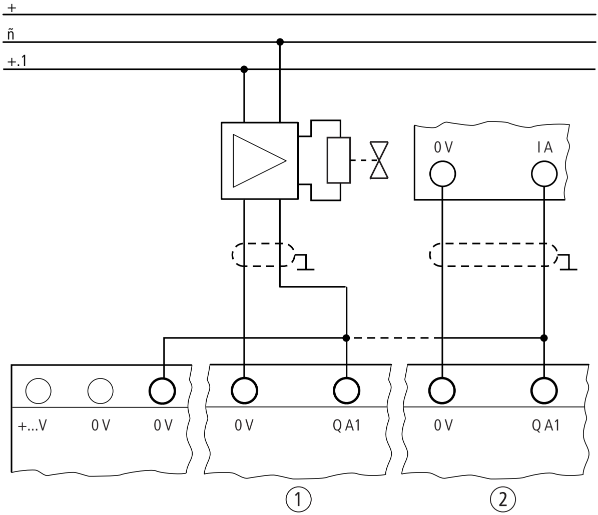


12 or 20 W at 24 V DC
Output dependant upon device types
and outputs

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Connection of analogue outputs for EASY820-DC-RC…, EASY822-DC-TC…, MFD-RA… and MFD-TA…



① Servo valve control
② Set value sekection for drive control

Note

- Analogue signals are more sensitive to interferance than digital signals, therefore the signal conductors should be carefully routed. Inappropriate connections can lead to unwanted switching conditions.
- Analogue output 0 to 10 V, Resolution 10 Bit, 0-1023.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Expansion of the input and output points for easy and MFD-Titan

To expand the input and output points there are various solutions :

Central expansion, to 40 I/O
easy700, easy800 and MFD-Titan can be expanded via easy202, easy618 or easy620. Here there are a maximum of 24 inputs and 16 outputs available. An expansion of the basic device is possible.

Decentral expansion, to 40 I/O
easy700, easy800 and MFD-Titan can be expanded via the coupling module easy200-EASY with easy618 or easy620. The expansion device can be operated up to 30 m from the basic device. There are a maximum of 24 inputs and 16 outputs available. An expansion of the basic device is possible.

Networking via EASY-Net, up to 320 I/O
When expanding the inputs and outputs via EASY-Net eight easy800 or MFD-Titan can be connected to each other. Every easy800 or MFD-Titan can be extended with an expansion device. 1 000 m Network length is possible. There are two types of operation:

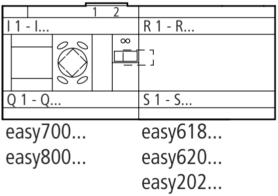
- One master (position 1, device address 1) plus up to 7 further devices. The programme is in the master.
- One master (position 1, device address 1) plus up to 7 further “intelligent” or “non-intellegent” devices. Every “intelligent” device has a programme.

Contactors and Relays

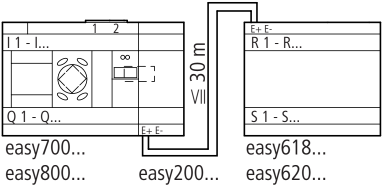
Control relay easy, Multi Function Display MFD-Titan®

Central and decentral expansion for the basic devices easy700, easy800 and MFD-Titan

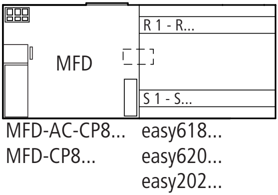
central expansion



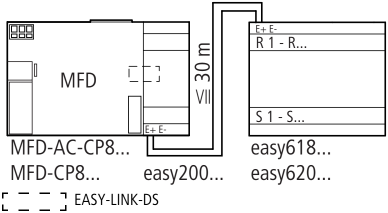
decentral expansion



central expansion



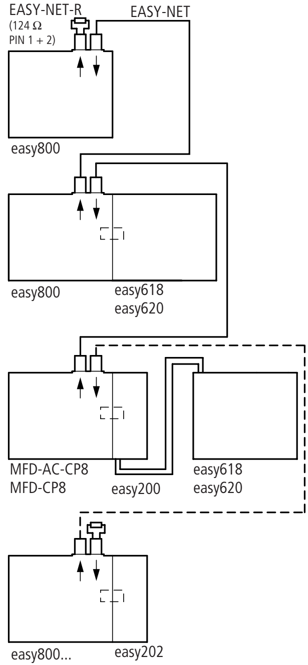
decentral expansion



Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

EASY-NET, Network connection "through the device"



Geographic location, position[1]	Device Example 1	Example 2
1	1	1
2	2	3
3	3	8
8	8	2

EASY-LINK-DS

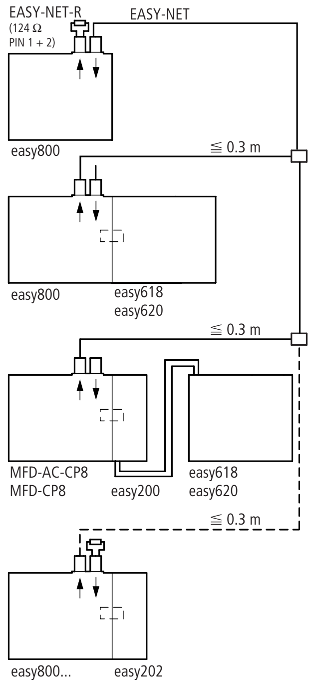
1) The geographic location/place 1 **always** has the device address 1.

- Addressing the devices:
  - Automatic addressing of device 1 or via EASY-SOFT… by PC, **geographic location = device**,
  - Single addressing on the corresponding device or via EASY-SOFT… on each device, **geographic location and device can be different**.
- The max. total length with EASY-NET is 1 000 m.
- Should EASY-NET be interrupted or a device is not operational, the network isn´t active past the interrupted point.
- 4 core cable unscreened, each two cores twisted. Characteristic impedance of the cable must be 120 Ω.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

EASY-NET, Network connection “T piece with spur cable”



EASY-LINK-DS

Geographic location, position1)	Device Example 1	Example 2
1	1	1
2	2	3
3	3	8
8	8	2

1) The geographic location/place 1 **always** has the device address 1.

- Addressing the devices:
  – Single addressing on corresponding device or via EASY-SOFT… on every device.
- The max. total length, including spur cables, with EASY-NET is 1000 m.
- The max. length of T pieces to easy800 or to MFD-Titan is 0,30 m.
- Should EASY-NET be interrupted between the T piece and the device, or a device is not operational, the network is still active to any further device.
- 4 core cable unscreened, each two cores twisted. Three cores are required.
  Characteristic impedance of the cable must be 120 Ω.

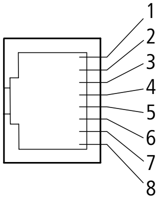
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

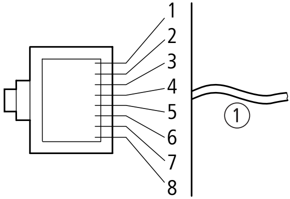
Network connection

Sockets RJ 45 and plug

Connection layout of socket RJ 45 on easy and MFD-Titan.



Connection layout of plug RJ45 on easy and MFD-Titan.



(1) Cable entry side
8 pole RJ 45, EASY-NT-RJ 45

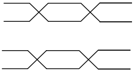
Layout with EASY-NET

PIN 1; ECAN_H; Data conductor; conductor pair A
PIN 2; ECAN_L; Data conductor; conductor pair A
PIN 3; GND; ground conductor; conductor pair B
PIN 4; SEL_IN; Select conductor; conductor pair B

Configuration of the network cable for EASY-NET

The network cable does not need to be screened.

The characteristic impedance of the cable must be 120 Ω.



A	1	ECAN_H
A	2	ECAN_L
B	3	GND (Ground)
B	4	SEL_IN

Note

The minimal operation with easy-NET functions with the conductors ECAN_H, ECAN_L, GND. The SEL_IN conductor is solely for automatic addressing.

Bus terminal resistor

A bus terminal resistor must be connected to the geographical first and last device in the network:

- Value of the bus terminal resistor 124 Ω,
- Connect to PIN 1 and PIN 2 of the RJ-45 plug,
- Connection plug : EASY-NT-R.

Pre-finished conductors, RJ45 plug on both ends

Conductor length [cm]	Part reference
30	EASY-NT-30
80	EASY-NT-80
150	EASY-NT-150

Contactors and Relays
Control relay easy, Multi Function Display MFD-Titan®

Freely useable conductors

100 m 4 × 0.14 mm²; twisted in pairs:
EASY-NT-CAB

RJ-45 plug:
EASY-NT-RJ 45

Crimping tool for RJ-45 plug: EASY-RJ45-TOOL.

Calculation of cross section when conductor length is known

The minimum cross section is calculated for the know maximum use of the network.

l = Length of conductor in m

S_{min} = minimum cross section in mm²

ρ_{cu} = specific resistance of copper, when nothing else given 0,018 Ωmm²/m

$$S_{min} = \frac{l \times \rho_{cu}}{12.4}$$

Note

When the result of the calculation doesn´t give a normal cross section use the next highest normal cross section.

Calculation of conductor length when the cross section is known

For a known conductor cross section the maximum conductor length is calculated.

l_{max} = Length of conductor in m

S = Conductor cross section in mm²

ρ_{cu} = specific resistance of copper, when nothing else given 0,018 Ωmm²/m

$$l_{max} = \frac{S \times 12.4}{\rho_{cu}}$$

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Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Permissible network length for EASY-NET

Conductor length EASY-NET total	Transmission speed	Conductor cross section, standardised		Bus conductor, minimum conductor cross section
		EN	AWG	
m	kBaud	mm²		mm²
≦ 6	≦1000	0.14	26	0.10
≦ 25	≦ 500	0.14	26	0.10
≦ 40	≦ 250	0.14	26	0.10
≦ 125	≦ 125 1)	0.25	24	0.18
≦ 175	≦ 50	0.25	23	0.25
≦ 250	≦ 50	0.38	21	0.36
≦ 300	≦ 50	0.50	20	0.44
≦ 400	≦ 20	0.75	19	0.58
≦ 600	≦ 20	1.0	17	0.87
≦ 700	≦ 20	1.5	17	1.02
≦ 1 000	= 10	1.5	15	1.45

1) Default setting

Note

The chacteristic impedance of the conductor must be 120 Ω!

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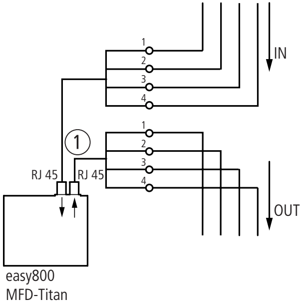
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Network connection with conductor cross section > 0.14 mm², AWG26

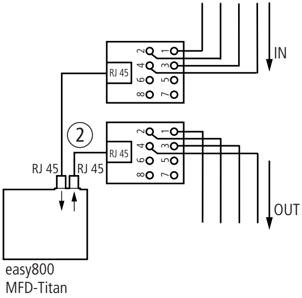
Network connect "through the device".

Example A, with terminals



① Recommendation ≦ 0.3 m

Example B, with interface element

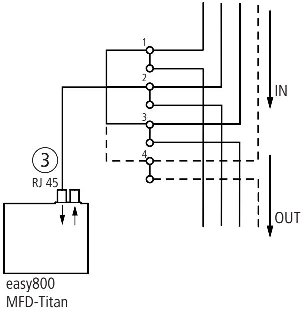


② Recommendation ≦ 0.3 m (EASY-NT-30)

Network connection with T piece and spur cable

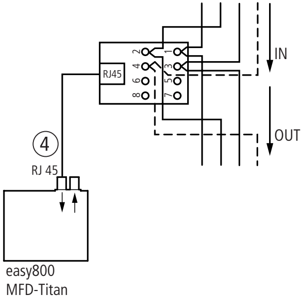
Network connection "T piece with spur cable"

Example A, with terminals



③ ≦ 0.3 m (3 core)

Example B, with interface element

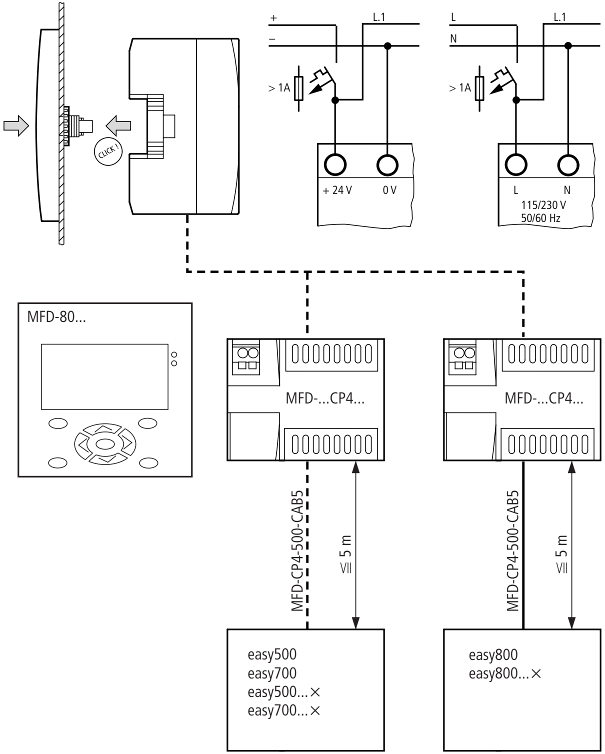


④ ≦ 0.3 m (EASY-NT-30)

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Remote display in IP65



On the "remote display" MFD-80… the easy indication display is shown.

The easy can also be operated with the MFD-80-B.

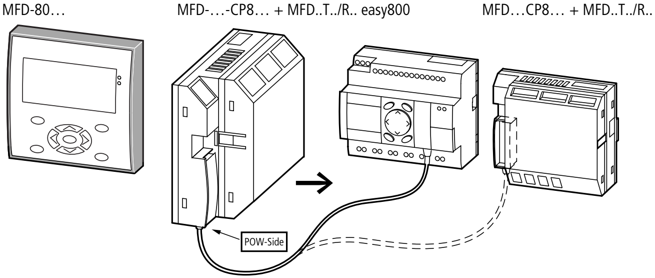
No extra software or programming is necessary to operate the "remote display".

The connection cable MFD-CP4-…-CAB5 can be shortened.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

COM-LINK connection



The COM-LINK is a point to point connection serial interface. Via this interface the status of the inputs and outputs are read as well as marker areas read and written. Twenty marker double words read or written are possible. Read and written are freely selectable. This data can be used for the set values or display functions.

The devices of the COM-LINK have different functions. The active device is always a MFD…CP8… and controls the complete interface.

The remote device can be a easy800 or a MFD…CP8… and answers to the requests of the active devices. The remote device dosen´t recognise the difference if the COM-LINK is active or a PC with EASY-SOFT-PRO uses the interface.

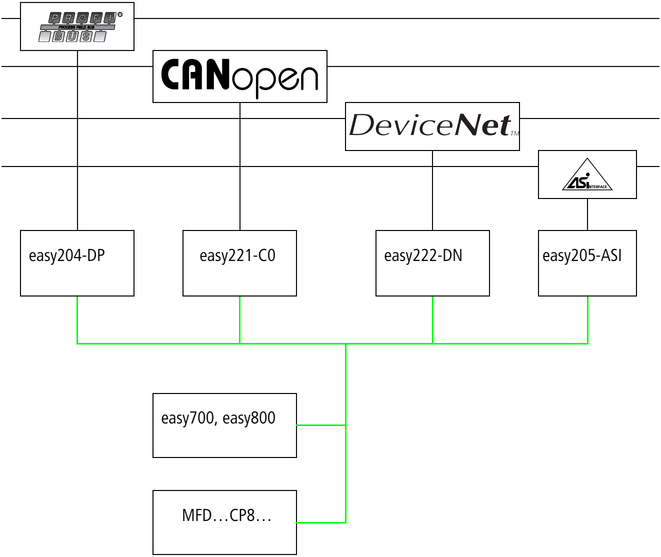
The devices of the COM-LINK can be centralised or decentralised extended with easy expansion devices.

The remote device can also be a device in the EASY-NET.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Field bus connection to the production process



network module can be connected with easy700, easy800 or MFD-Titan. The network module is intergrated as slave in the configuration.

Expansion of the input and output points via EASY-NET is possible (→ section "EASY-NET, Network connection "through the device"", page 5-31 and → section "EASY-NET, Network connection "T piece with spur cable"", page 5-32).

Further information can be found in the associated manuals:

- AWB2528-1508
  easy500, easy700, control relay,
- AWB 2528-1423
  easy800, control relay,
- AWB2528-1480D
  MFD-Titan, Multi Function Display.

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Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Contacts, coils, function modules, operand

Operand	Description	easy500, easy700	easy800, MFD…CP8…
I	Input basic device	×	×
R	Input expansion device [1)]	×	×
Q	Output basic device	×	×
S	Output expansion device	×	×
ID	Diagnosis annuciator easy-NET	–	×
M	Marker	×	×
N	Marker	×	–
P	P button	×	×
:	:	×	×
RN	Bit input easy-NET	–	×
SN	Bit output easy-NET	–	×
A	Analogue value comparitor	×	×
AR	Arithmetic	–	×
BC	Block comparison	–	×
BT	Block transfer	–	×
BV	Boolean function	–	×
C	Counting relay	×	×
CF	Frequency counters	× [2)]	×
CH	High speed counter	× [2)]	×
CI	Incremental value counter	–	×
CP	Comparitor	–	×
DB	Data module	–	×
D	Text output	×	×
DC	PID controller,	–	×
FT	PT1 Signal smoothing filter	–	×
GT	Draw value out of the easy-NET	–	×
Ö H/HW	(clock)/Week time clock	×	×
Y/HY	Summer/winter changeover clock	×	×
LS	Value scaling	–	×
Z/MR	Master reset	×	×

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

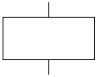
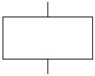
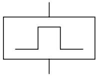
Operand	Description	easy500, easy700	easy800, MFD…CP8…
NC	Number transducer	–	×
O/OT	Hours run counter	×	×
PT	Place value in the easy-NET	–	×
PW	Pulse width modulation	–	×
SC	Sychronise clock via network	–	×
ST	Reference cycle time	–	×
T	Time-delay relay	×	×
VC	Value limiting	–	×
MB	Marker byte	–	×
MD	Marker double word	–	×
MW	Marker word	–	×
I, IA	Analogue input	×	×
QA	Analogue output	–	×

1) With easy700, easy800 and MFD…CP8…
2) With easy500 and easy700 programmable as operation type.

Coil functions

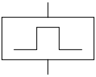
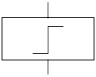
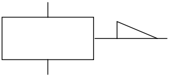
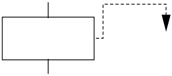
The switching behaviour of the relay coil is determined by the selected coil function. The specified function should for each relay coil only be used once in the wiring diagram.

Not used outputs Q and S can also be used as markers like M and N.

Circuit diagram symbol	easy display	Coil function	Example
	[	Contactor function	[Q1, [D2, [S4, [:1, [M7
	]	Contactor function with inverse result	]Q1,]D2,]S4
	Ŀ	Cyclical impulse at negative edge	ĿQ3, ĿM4, ĿD8, ĿS7

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Circuit diagram symbol	easy display	Coil function	Example
	⎍	Cyclical impulse at positive edge	⎍Q4, ⎍M5, ⎍D7, ⎍S3
	⎾	Surge function	⎾Q3, ⎾M4, ⎾D8, ⎾S1
	S	Latch (set)	SQ8, SM2, SD3, SS4
	R	Reset (reset)	RQ4, RM5, RD7, RS3

Parameter sets for times

Example based on EASY-512…

Depending up on the programme the following parameters can be set:

- Switching function,
- Time range,
- Parameter display,
- Time 1 and
- Time 2.

```
T1   ⎍   S   +
I1     30.000
I2   I7
□  T:00.000
```

T1 Relay No.
I1 Time 1
I2 Time 2
□ Switch state output:
  □ Normally open contact open,
  ■ Normally open contact closed
⎍ Switching function
S Time range
+ Parameter display
30.000 constant as value, e. g. 30 s
I7 Variable, e. g. Analoge value I7
T:00.000 clock time

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Possible coil functions:

- Trigger = TT..
- Reset = RT..
- Halt = HT..

Parameter	Switching function
X	Switching with On-delay
?X	Switching with On-delay and random time range
■	Switching with Off-delay
?■	Switching with Off-delay and random time range
X■	Switching with On-delay and Off-delay
?X■	Switching with On-delay and Off-delay with random time
⎍	Switching with single pulse
⎍⎍	Switching with flashing

Parameter	Time range and set time	Resolution
S 00.000	Seconds: 0.000 to 99,999 s	easy500, easy700 10 ms easy800, MFD…CP8… 5 ms
M:S 00:00	Minutes: Seconds 00:00 to 99:59	1 s
H:M 00:00	Hours: Minutes, 00:00 to 99:59	1 min.

Parameter set	Displaying the parameter set via menu item “Parameter”
+	Can be accessed
-	Cannot be accessed

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Basic circuits

The easy circuit configuration is input in ladder diagram. This section includes a few circuit examples which are intended to demonstrate the possibilities for your own circuit diagrams.

The values in the logic table have the following meanings for switching contacts:

0 = Normally open contact open, normally closed contact closed

1 = Normally open contact closed, normally closed contact open

For relay coils Qx”

0 = Coil not energized

1 = Coil energized

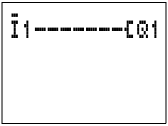
Note

The examples are shown as for easy500 and easy700. For easy800 and MFD…CP8… four contacts and one coils can be used in each path.

Negation

Negation means that the contact opens, rather than closes when actuated (NOT circuit).

In easy circuit example contact I1 changes with the **ALT** button normally closed and normally open contacts.

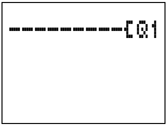


Logic table

I1	Q1
1	0
0	1

Permanent contact

To keep a relay coil permanently energised wire the connection completely across all contact areas from the coil to the left hand side.



Logic table

---	Q1
1	1

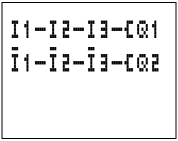
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Series circuit

Q1" is actuated via three normally open contacts connected in series (AND circuit).

Q2" is actuated via three normally closed contacts connected in series (NAND circuit).



In the easy circuit configuration, up to three normally open or normally closed contacts can be connected in series in one line. Where more than three normally open contacts have to be wired in series, use an auxiliary relay M.

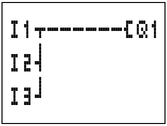
Logic table

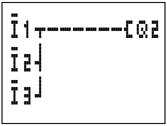
I1	I2	I3	Q1	Q2
0	0	0	0	1
1	0	0	0	0
0	1	0	0	0
1	1	0	0	0
0	0	1	0	0
1	0	1	0	0
0	1	1	0	0
1	1	1	1	0

Parallel switching

Q1 is controlled via a parallel circuit of several normally open contacts (OR circuit).

A parallel circuit of normally closed contacts controls Q2 (NOR circuit).





Logic table

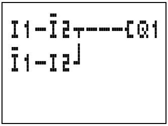
I1	I2	I3	Q1	Q2
0	0	0	0	1
1	0	0	1	1
0	1	0	1	1
1	1	0	1	1
0	0	1	1	1
1	0	1	1	1
0	1	1	1	1
1	1	1	1	0

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Changeover circuit

A changeover circuit is realised in easy with two series circuits that are then combined in parallel (XOR).



XOR means e**X**clusive **OR** circuit. Only when a contact is closed, is the coil energized.

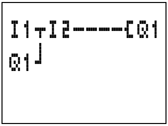
Logic table

I1	I2	Q1
0	0	0
1	0	1
0	1	1
1	1	0

Hold-on circuit

A combination of series and parallel contacts are wired to a hold-on circuit.

S1 normally open contact on I1
S2 normally closed contact on I2



The hold-on (self-maintaining) function is achieved by the Q1 contact being connected in parallel to I1. When I1 is actuated and reopened, the current flows via contact Q1 until I2 is actuated.

Logic table

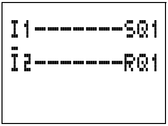
I1	I2	Contact Q1	Coil Q1
0	0	0	0
1	0	0	0
0	1	0	0
1	1	0	1
1	0	1	0
0	1	1	1
1	1	1	1

The hold-on (self-maintaining) circuit is used to switch machines on and off. The machine is switched on at the input terminals via normally open contact S1 and is switched off via normally closed contact S2.

S2 opens the connection to the control voltage in order to switch off the machine. This ensures that the machine can be switched off even in the event of a wire breaking. I2 is always closed when not actuated.

Alternatively a hold-on circuit with wire break monitoring can used with the set and reset coil functions.

S1 normally open contact on I1
S2 normally closed contact on I2



Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

When I1 is switched, coil Q1 latches. I2 inverts the normally closed signal from S2 and switches when S2 is actuated and the machine must be switched off or when there is a broken wire.

Keep to the order that each coil is wired in the easy circuit diagram: first wire the “S”-coil, and then the“R”-coil. When I2 is actuated, the machine will then be switched off even if I1 is switched on again.

Impulse changeover relay

An impulse changeover relay is often used for lighting control e.g. stairway lighting.

S1 normally open contact on I1

```
I1--------ʃQ1
```

Logic table

I1	Status of Q1	Q1
0	0	0
1	0	1
0	1	1
1	1	0

On-delayed timing relay

The on-delay can be used to override a short impulse or with a machine, to start a further operation after a time delay.

S1 normally open contact on I1

```
I1--------TT1
T1--------[M1
```

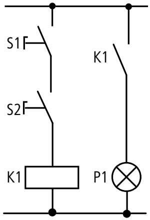
5

Contactors and Relays

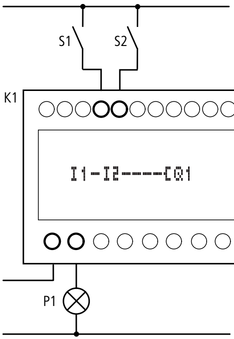
Control relay easy, Multi Function Display MFD-Titan®

Wiring of contacts and relays

Fixed wiring

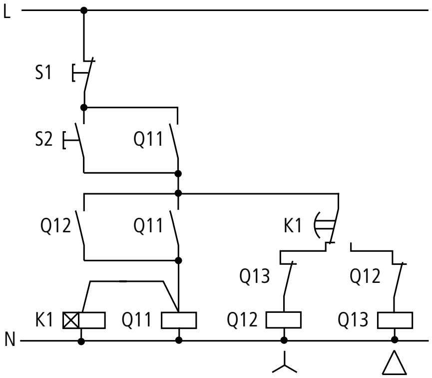


Wired with easy



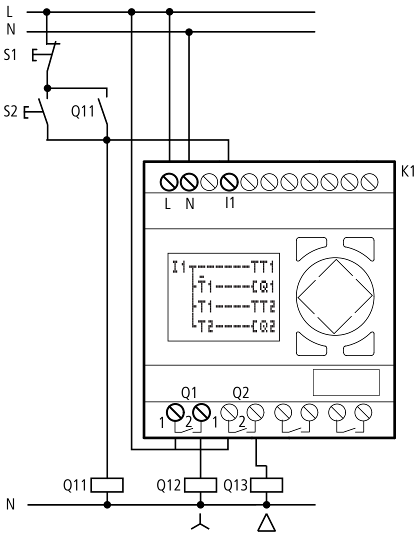
Star-delta starting

With easy it is possible to implement two star/delta circuits. The advantage of easy is that it is possible to select the changeover time between star and delta contactors, and also the time delay between switching off the star contactor and switching on the delta contactor.



Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®



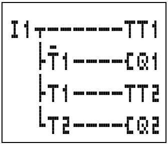
Operation of the easy circuit configuration

Start/stop the circuit with the external pushbuttons S1and S2. The mains protection starts the time relay in easy.

I1: Mains protection switched on

Q1: Star contactor ON

Q2: Delta contactor ON



T1: Changeover time star/delta (10 to 30 s)

T2: Waiting time between starcontactor off and delta contactor on (30, 40, 50, 60 ms)

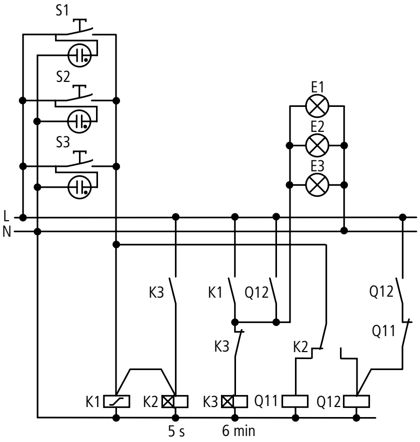
If your easy has an integral time switch, star/delta starting can be combined with the time switch. In this case, use easy to also switch the mains contactor.

Contactors and Relays
Control relay easy, Multi Function Display MFD-Titan®

Stairway lighting

For a conventional circuit a minimum of five elements are required. An impulse relay, two timing relays, two auxiliary relays.

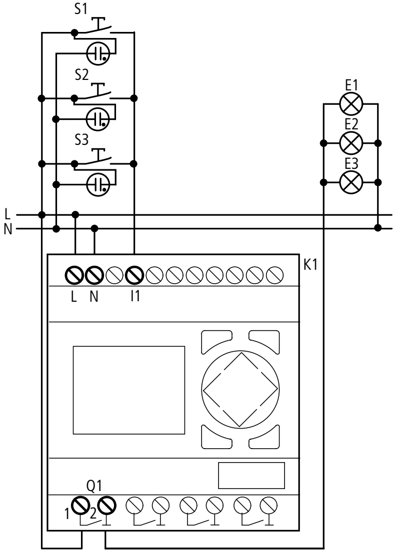
easy needs only four elements. With five connections and the easy circuit the stairway lighting is operational.



Important note
Four such stairway circuits can be implemented with one easy device.

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®



Button pressed briefly	Light On or Off, the impulse changeover relay function is able to switch off continuous lighting where required.
Light Off after 6 min.	Switched off automatically. With continuous lighting this function is not active.
Button pressed for longer than 5 s	Continuous lighting

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

The easy circuit configuration for the function below looks like this:

```
I1--------TT2
T2--------SM1
I1┬-------ʃQ1
T3┘
Q1-M̄1-----TT3
Q̄1--------RM1
```

Expanded easy circuit configuration: after four hours, the continuous lighting is switched off.

```
I1-------┬TT1
         └TT2
T2--------SM1
T1┬-------ʃQ1
T3┤
T4┘
Q1┬M̄1-----TT3
  └-------TT4
Q̄1--------RM1
```

Meaning of the contacts and relays used:

I1: Pushbutton ON/OFF
Q1: Output relay for lighting ON/OFF
M1: Auxiliary relay used to block the "switch off automatically after 6 minutes" when using continuous lighting.
T1: Cyclical impulse for switching Q1 ON/OFF, (⎍, impulse with value 00.00 s)
T2: Scan to determine how long the pushbutton was pressed. When pressed for longer than 5 s, it changes to continuous lighting. (X, On-delayed, value 5 s)
T3: Switch off after the light has been on for von 6 min. (X, on-delayed, value 6:00 min.)
T4: Switch off after 4 hours continuously on. (X, On-delayed, value 4:00 h)

Contactors and Relays
Control relay easy, Multi Function Display MFD-Titan®

4 way shift register

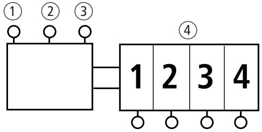
A shift register can be used for storing an item of information – e.g. sorting of items into "good" or "bad" – two, three or four transport steps further on.

A shift pulse and the value (0" or 1") to be shifted are required for the shift register.

Values which are no longer required are deleted via the reset input of the shift register. The values in the shift register pass through the register in the following order:

1st, 2nd, 3rd, 4th storage position.

Block diagram of the 4-way shift register



1. Pulse
2. Value
3. Reset
4. Storage position

Function:

Pulse	Value	Storage position			
		1	**2**	**3**	**4**
1	1	1	0	0	0
2	0	0	1	0	0
3	0	0	0	1	0
4	1	1	0	0	1
5	0	0	1	0	0
Reset = 1		0	0	0	0

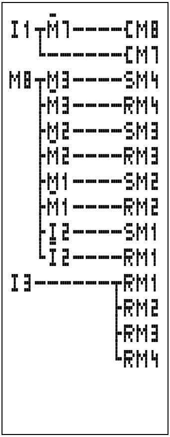
Allocate the value 0 with the information content bad. Should the shift register be accidently deleted, no bad parts will be reused.

I1: Shift clock pulse (PULSE)
I2: Information (good/bad) for shifting (VALUE)
I3: Delete contents of shift register (RESET)
M1:1. memory position
M1:2. memory position
M1:3. memory position
M1:4. memory position
M7:Auxiliary relay one shot cycle pulse
M8:One shot cycle pulse clock pulse

5

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®



Generate shift tact

4th memory position, set
4th memory position, delete
3rd memory position, set
3rd memory position, delete
2nd memory position, set
2nd memory position, delete
1st memory position, set
1st memory position, delete
Delete all memory positions

Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Display text and actual values , display and edit set values

easy500 and easy700 can display 16, easy800 can display 32 freely editable texts. In these texts actual values of function relays such as, timer relays, counters, hours run counters, anolog value comparitors, dates, times or analog values can be displayed. Set values of timer relays, counters, hours run counters and analog value comparitors can be altered during the display of the texts.

```
SWITCHING,
CONTROL,
DISPLAY,
ALL EASY!
```

Example of a text display:

The text display has the following display characteristics:

Display	
`RUN TIME M:S`	Line 1, 12 characters
`T1  :012:46`	Line 2, 12 characters, one actual value or set value
`C1  :0355  ST`	Line 3, 12 characters, one actual value or set value
`PRODUCED`	Line 4, 12 characters

The text output unit D (D = Display,) functions in the circuit diagram like a normal marker M. Should a text be attached to a marker this would be shown at condition 1 of the coil in the easy display. A precondition is that the easy is in RUN mode and before the texts are displayed the status display is shown.

D1 is defined as alarm text and has therefore priority over other displays.

D2 to D16/D32 are displayed when activated. When several displays are activated they are shown one after the other every 4 secs. When a set value is edited the corresponding display remains shown until the value transfer.

In one text several values, actual and set values, from for example, function relays, analog input values or times and dates can be combined. The set values can be edited:

- easy500 and easy700, two values,
- easy800, four values.

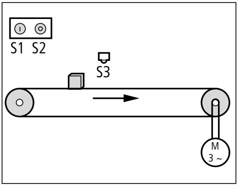
Contactors and Relays

Control relay easy, Multi Function Display MFD-Titan®

Visualisation with MFD Titan

The visualisation with MFD-Titan is by "screens", on which the display is shown.

Example of a "screen":



The following screen elements can be combined.

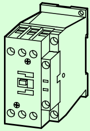
- Graphic elements
  - Bit display
  - Bitmap
  - Bargraph
- Pushbutton elements
  - Latching pushbuttons
  - Pushbutton area
- Text elements
  - Static text
  - Message text
  - Screen menu
  - Ticker text
  - Rolling text
- Value display elements
  - Date and time displays
  - Number values
  - Timer relay value display
- Value input elements
  - Value inputs
  - Timer relay value inputs
  - Date and time inputs
  - Weekly timer inputs
  - Yearly timer inputs

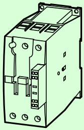
Notes

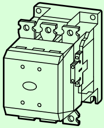
Contactors and Relays

Contactors DIL, Motor overload relays Z

Rated operational current I_e at 400 V	Max. AC-3 motor rating 220 V, 230 V	380 V ,400 V	660 V, 690 V	1000 V	Conv. therm. current $I_{th} = I_e$ AC-1	Part no.
A	kW	KW	kW	kW	A	
6.6	1.5	3	3	–	22	**DILEEM**
8.8	2.2	4	4	–	22	**DILEM**
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**
17	5	7.5	11	–	40	**DILM17**
25	7.5	11	14	–	45	**DILM25**
32	10	15	17	–	45	**DILM32**
40	12.5	18.5	23	–	60	**DILM40**
50	15.5	22	30	–	70	**DILM50**
65	20	30	35	–	85	**DILM65**
80	25	37	63	–	130	**DILM80**
95	30	45	75	–	130	**DILM95**
115	37	55	105	–	190	**DILM115**
150	48	75	125	–	190	**DILM150**
185	55	90	175	108	275	**DILM185**
225	70	110	215	108	315	**DILM225**
250	75	132	240	108	350	**DILM250**
300	90	160	286	132	400	**DILM300**
400	125	200	344	132	500	**DILM400**
500	155	250	344	132	700	**DILM500**
580	185	315	560	600	800	**DILM580**
650	205	355	630	600	850	**DILM650**
750	240	400	720	800	900	**DILM750**
820	260	450	750	800	1000	**DILM820**
1000	315	560	1000	1000	1000	**DILM1000**







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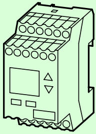
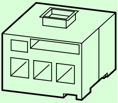
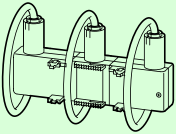
Contactors and Relays

Contactors DIL, Motor overload relays Z

Part no.	Auxiliary contact blocks For top mounting	 For side mounting	Motor overload relay	Electronic motor protection system ZEV
DILEEM	02DILEM 11DILEM 22DILEM	–	ZE-0,16 to ZE-9	
DILEM				
DILM7	DILA-XHI(V) … DILM32-XHI …	–	ZB12-0,16 to ZB12-12	
DILM9				
DILM12			ZB32-0,16 to ZB32-32	
DILM17				
DILM25				
DILM32				
DILM40	DILM150XHI(V)…	DILM1000-XHI(V) …	ZB65-10 to ZB65-65	ZEV + ZEV-XSW-25 ZEV-XSW-65 ZEV-XSW-145 ZEV-XSW-820 
DILM50				
DILM65				
DILM80			ZB150-35 to ZB150-150	
DILM95				
DILM115				
DILM150				
DILM185	–	DILM1000-XHI…	Z5-70/FF250 to Z5-250/FF250	
DILM225				
DILM250				
DILM300			ZW7-63 to ZW7-630	
DILM400				
DILM500				
DILM580				
DILM650				
DILM750			–	
DILM820				
DILM1000				

5

Contactors and Relays

Contactors DIL

Accessories

Unit	DILE(E)M	DIL7 to DILM150		DILM185 to DILM500	DILM580 to DILM1000
		AC	DC		
Suppressor circuits	–	–	integrated	integrated	integrated
RC suppressors	X	X			
Varistor suppressors	X	X			
Star-point bridge	X	X	X	X	–
Parallel connector	X	X	X	to DILM185	–
Mechanical inter-lock	X	X	X	X	X
Sealable shroud	X	–	–	–	–
Cable terminals	–	–	–	X	to DILM820
Individual coils	–	X[1)]	X[1)]	X	X
Electronic modules	–	–	–	X	X
Electronic modules including coils	–	–	–	X	X
Terminal cover	–	–	–	X	X

1) from DILM17

Contactors and Relays
Contactors DIL

Contactors DILM

These are designed and tested to IEC/EN 60 947. For every motor rating between 3 kW and 560 kW there is a suitable contactor available.

Equipment features

- Magnet system
  Due to the new electronic operation the DC contactors from 17 to 65 A have a sealing power of only 0.5 W. Even for 150 A is only 1.5 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 32 A can be controlled directly from the PLC.
- Intergrated suppressor DC
  With all DC contactors DILM a suppressor is integrated in the electronics.
- Plug-in suppressors AC
  With all AC contactors DILM up to 150 A a suppressor can be simply plugged in on the front when required.
- Control of the contactors DILM185 to DILM1000 by three different methods:
  – Conventionally via coil terminals A1-A2
  – Directly from a PLC via terminals A3-A4
  – by a low power contact via terminals A10-A11.
- Conventional control of contactors DILM185-S to DILM500-S via coil terminals A1-A2.
  There are two coil versions (110 to 120 V 50/60 Hz and 220 to 240 V 50/60 Hz) available.
- All contactors up to DIL150 are finger and back-of-hand proof to IEC 536. Additional terminal covers are available from DILM185 onwards.
- Double-frame terminal for contactors DILM7 to DILM150
  With the new double frame-clamp the 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 normally open or normally closed contact.
- Screw or spring terminals
  The contactors DILE(E)M and DILA/DILM12, including the corresponding auxiliary contacts, up to 1 000 A, are available with screw or spring terminals.
- Contactors with screwless terminals
  They have spring terminals in the mains current circuit as well as for the coil terminals and auxiliary contacts. The shake proof and maintenance free spring terminals can terminate two conductors each of 0.75 to 2.5 mm² with or without ferrules.
- Connection terminals
  Up to DILM65 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 DILM150 Allen screws are used.
- Mounting
  All contactors can be fitted on to a mounting plate with fixing screws. DILE(E)M and DILM up to 65 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 150 A can be achieved without extra space requirement. The mechanical interlock ensures that both connected contactors cannot be similtaneously be operated. Even with a mechanical shock the contacts of both contactors cannot close similtaneously.

Contactors and Relays
Contactors DIL

In addition to individual contactors, complete contactor combinations are also available from Moeller:

- DIUL reversing contactors from 3 to 75 kW/400 V
- SDAINL star-delta starters from 5.5 to 132 kW/400 V

Application

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 locked-rotor 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 switching 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 switching 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 DILNM 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 a normally closed contact that cannot be similtaneously closed with the normally open main contacts.

Contactors and Relays
Contactors DIL

Contactor DILP

DILP contactors are used for problem-free switching of supply systems including the neutral pole or for economical switching of resistive loads.

In three-phase distribution systems, mainly 3 pole switchgear and protective devices are used. 4 pole switchgear and protective devices are used in order to switch the neutral pole as well in special applications.

In the area of 4 pole applications, there are national differences concerning the Standards situation, the customary distribution system and conventions that go beyond the Standards.

Rating data
max. rated operational current I_e

AC-1 open			**conv. therm. current**	
40 °C	**50 °C**	**70 °C**	$I_{th} = I_e$ **AC-1 open**	**Part no.**
160 A	160 A	155 A	160 A	DILP160/22
250 A	230 A	200 A	250 A	DILP250/22
315 A	270 A	215 A	315 A	DILP315/22
500 A	470 A	400 A	500 A	DILP500/22
630 A	470 A	400 A	630 A	DILP630/22
800 A	650 A	575 A	800 A	DILP800/22

Contactors and Relays
Overload relays Z

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:

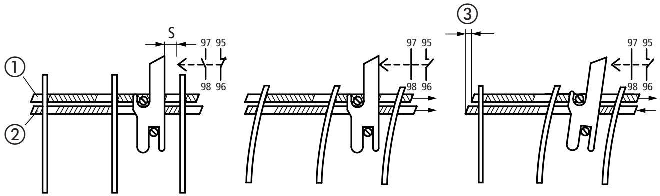
- Non starting,
- Overload,
- Phase-failure.

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 contact. 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 reference temperature is reached. The tripping delay 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 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 947-4-1 and therefore can also provide protection for EEx e motors (→ following diagramms).



Normal operation (no fault)

Three phase overload

One phase drops out

① Trip bridge
② Differential bar
③ Differential travel

Contactors and Relays

Overload relays Z

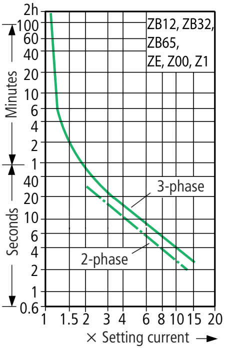
When the bimetallic strips in the main current section of the relay deflect as a result of three-phase motor overloading, all three act on a trip bar and a differential bar. A shared trip lever switches over the auxiliary contact when the limits are reached. The trip and differential bars lie against 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.

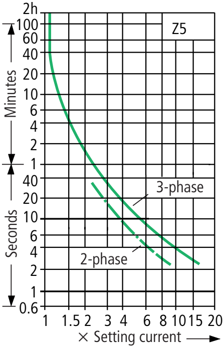
Design note → section "Motor protection in special applications", page 8-7;
Further information to motor protection → section "All about Motors", page 8-1.

Tripping characteristics

The overload relays ZE, ZB12, ZB32 and the Z5 up to 150 A are, due to the German Physical/Technical Bureau (PTB), suitable for protection of EEx e-motors to the ATEX-Guidelines 94/9 EG. In the relevant manual all tripping characteristics are printed for all currents.

These tripping characteristics are mean values of the scatter bands at an ambient 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.





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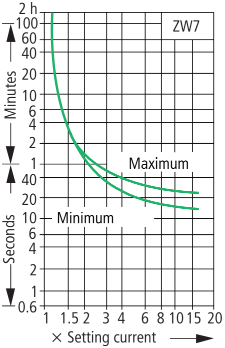
Contactors and Relays

Overload relays Z



Contactors and Relays

ZEV electronic motor-protective system

Method of operation and control

Like overload relays operating on the bimetallic strip principle, electronic motor-protective relays are current-dependent protective devices.

The acquisition of the actual flowing motor current in the three external conductors of the motor connections is with motor protection system ZEV with seperate push-through sensors or a sensor belt. These are combined with an evaluation unit so that seperate arrangement of the current sensor and the evaluation unit is possible.

The current sensor is based on the Rogowski principle from the measurement technology. . The sensor belt has no iron core, unlike a current transformer, therefore it doesn´t become saturated and can measure a very wide current range.

Due to this inductive current detection, the conductor cross-sections used in the load circuit have no influence on the tripping accuracy. With electronic motor-protective relays, it is possible to set higher current ranges than is possible with electromechanical thermal overload relays. In the ZEV System, the entire protected range from 1 to 820 A is covered using only an evaluator .

The ZEV electronic motor-protective system carries out motor protection both by means of indirect temperature measurement via the current and also by means of direct temperature measurement in motors with thermistors.

Indirectly, the motor is monitored for overload, phase failure and unbalanced current consumption.

With direct measurement, the temperature in the motor winding is detected by means of one or more PTC thermistors. In the event of excessive temperature rise, the signal is passed to the tripping unit and the auxiliary contacts are actuated. A reset is not possible until the thermistors cool to less than the response temperature. The built-in thermistor connection allows the relay to be used as complete motor protection.

In addition, the relay protects the motor against earth faults. Small currents flow out even in the event of minor damage to the motor winding insulation. These earth faults currents are registered on an external summation current transformer which adds together the currents in the phases, evaluats them and reports earth-fault currents to the microprocessor in the relay.

By selecting one of the eight tripping classes (CLASS) allows the motor to be protected to be adapted from normal to extended starting conditions. This allows the thermal reserves of the motor to be used safely.

The motor-protective relay is supplied with an auxiliary voltage. The evaluator has a multi-voltage version, which enables all voltages between 24 V and 240 V AC or DC to be applied as supply voltage. The devices have monostable behaviour; they trip out as soon as the supply voltage fails.

Contactors and Relays
ZEV electronic motor-protective system

In addition to the usual normally closed contact (95-96) and the normally open contact (97-98) for overload relays the motor protection relay ZEV is equipped with a programmable normally open contact (07-08) and a programmable normally closed contact (05-06). The above mentioned, usual contacts react directly via thermistors or indirectly via the current, to the detected temperature rise of the motor, including phase-failure sensitivity.

The programmable contacts can be assigned to various signals, such as

- Earth-fault,
- Pre-warning at 105 % thermal overload,
- separate indication of thermistor tripping
- internal device fault

The function assignment is menu-guided using a display. The motor current is entered without tools using the keypad, and can be clearly verified on the display.

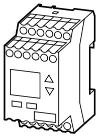
In addition the display allows a differential diagnosis of tripping causes, and therefore a faster error handling is possible.

Tripping in the event of a three-pole balanced overload at x-times the set current takes place within the time specified by the tripping class. The tripping delay in comparison with the cold state is reduced as a function of the preloading of the motor. Very good tripping accuracy is achieved and the tripping delays are constant over the entire setting range.

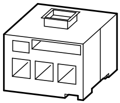
If the motor current imbalance exceeds 50 %, the relay trips after 2.5 s.

The accredition exists for overload protection of explosion proof motors of the explosion protection "increased safety" EEx e to guideline 94/9/EG as well as the report of the German Physical/Technical Bureaux (PTB report) (EG-Prototype test certificate number PTB 01 ATEX 3233). Further information can be found in the manual AWB2300-1433D "Motor protection system ZEV, overload monitoring of motors in EEx e areas".

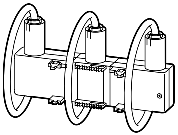
Electronic motor protection system ZEV



Evaluation device
1 to 820 A



Push-through sensor
1 to 25 A
3 to 65 A
10 to 145 A



Sensor belt
40 to 820 A

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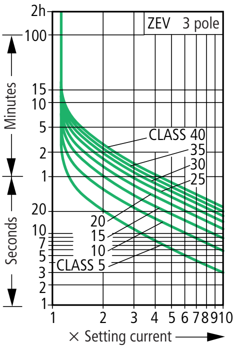
Contactors and Relays

ZEV electronic motor-protective system

Tripping characteristics



Tripping characteristics for 3 phase loads

These tripping characteristics show the relationship between the tripping time from cold to the current (multiples of set current I_E). After preloading with 100 % of the set current and the temperature rise to the operational warm state associated with it, the stated tripping delays are reduced to approx. 15 %.

Tripping limits for 3 pole balanced load

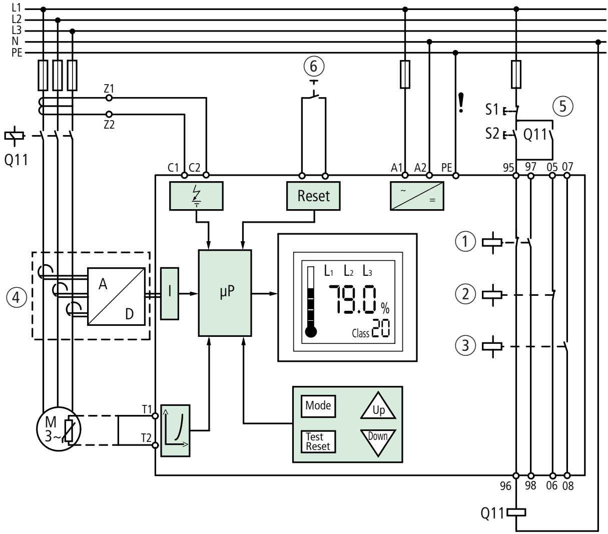
Response time

- < 30 min. at up to 115 % of the set current
- > 2 h at up to 105 % of the set current from cold

Contactors and Relays

ZEV electronic motor-protective system

Electronic motor protection sytem ZEV with earth-fault monitoring and thermistor monitored motor



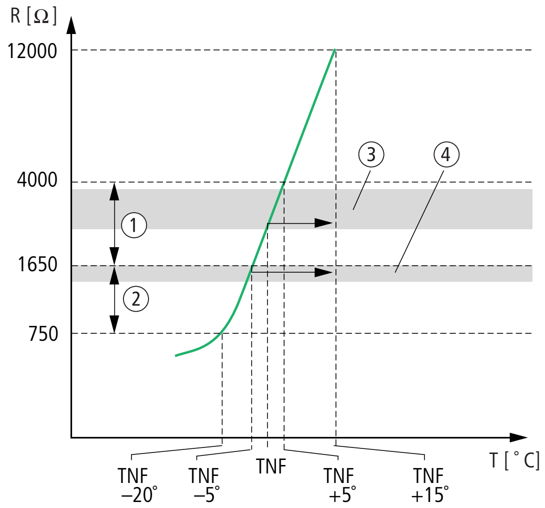
① Fault
② Programmable contact 1
③ Programmable contact 2
④ Current sensor with A/D transducer
⑤ Self hold-in of the contactor prevents an automatic re-start after the control voltage has failed and then returned (important for EEx e applications, → AWB2300-1433D)
⑥ Remote reset

Contactors and Relays

ZEV electronic motor-protective system

Thermistor protection

With thermistor motor protection, to DIN 44081 and DIN 44082, up to six PTC thermistor temperature sensors with a thermistor resistance of $R_K \leqq 250\ \Omega$ or nine with a $R_K \leqq 100\ \Omega$ can be connected to terminals T1-T2.



TNF= Nominal response temperature

1. Tripping range IEC 60947-8
2. Re-switch on range IEC 60947-8
3. Tripping at 3200 Ω ±15 %
4. Re-switch on at 1500 Ω +10 %

The ZEV switches off at R = 3200 Ω ±15 % and switches on again at R = 1500 Ω +10 %. With switch off due to thermistor input the contacts 95-96 and 97-98 switch over. Additionally, the thermistor trip can be programmed to different trip messages on contacts 05-06 or 07-08.

With temperature monitoring with thermistors, no dangerous condition can occur should a sensor fail as the device would directly switch off.

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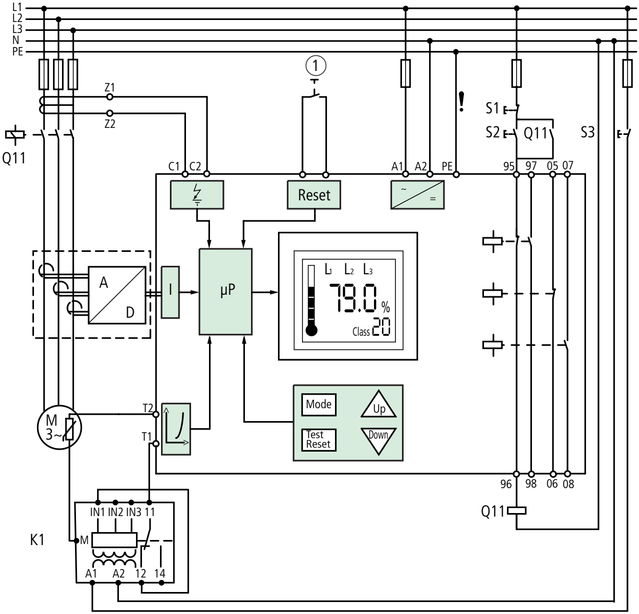
Contactors and Relays

ZEV electronic motor-protective system

Electronic motor protection system ZEV with short-circuit monitoring at the thermistor input



Short-circuit in the thermistor circuit can, when required, be detected by the additional use of a current monitor K1 (e. g. type EIL 230 V AC from the company Cronzet or the similar type 3U6352-1-1AL20 from the company Siemens).

Basic data

- Short-circuit current in the sensor circuit ≦ 2.5 mA,
- max. cable length to sensor 250 m (unscreened),
- Total PTC thermistor sensor resistance ≦ 1500 Ω
- Programming ZEV: “Auto reset”,
- Setting current monitor:
  - Device to lowest current level,
  - Overload tripping,
  - Store the tripping,
- Confirmation of the short-circuit after clearing with pushbutton S3.

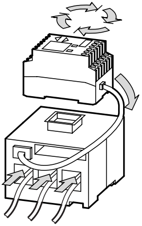
Contactors and Relays
ZEV electronic motor-protective system

Device mounting

The mounting of the device is very simple due to the clip-on and the push-through mounting.

Mounting details of every device can be found in the mounting instructions AWA2300-1694 or the manual AWB2300-1433D.

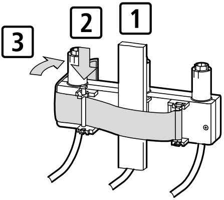
Mounting ZEV and current sensor



- Place the ZEV in the desired mounting position.
- Click the ZEV on the current sensor.
- Position motor conductors through the current sensor.

Mounting on the current conductors

Due to the fixing band the Rogowski sensor ZEV-XSW-820 is particularly easy to mount. And this saves the user time and money.

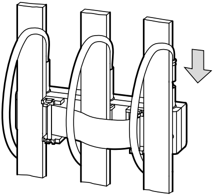


1 Wrap the band around the current conductors.

2 Engage the fixing pin.

3 Pull the fixing band tight and close with the velcro fastener.

Attaching the sensor coils → following diagram.



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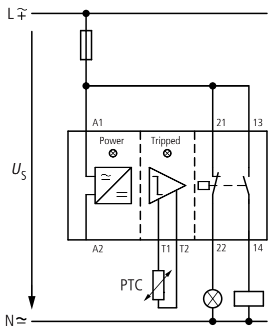
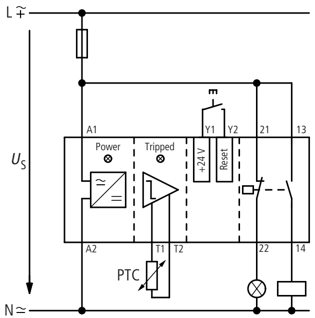
Contactors and Relays

Thermistor machine protection device 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 actuation 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-cicuit in sensor circuit monitor. Should the resistance in the sensor circuit fall below 20 Ohm it trips. The EMT6-DBK also has a zero voltage safe, re-switch on lock-out and stores the fault by a loss of voltage. Switching on again is possible only after the fault has been rectified and the control voltage is present again.

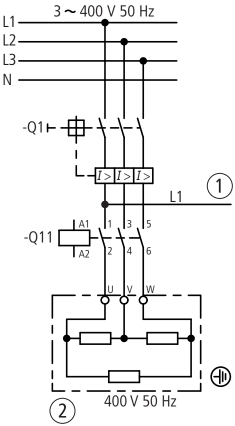
Since all the units use the closed-circuit principle, they also respond to a broken wire in the sensor circuit.

The thermistor machine protection relays EMT6… are accredited for protection of EEx e motors to ATEX-Guideline 94/9 EG by the German Physical/Technical Bureaux. For protection of EEx e motors the ATEX Guidelines require short-circuit monitoring in the sensor circuit. Because of their integrated short-circuit monitoring the EMT6-K(DB) and EMT6-DBK are especially suitable for this application.

Contactors and Relays

Thermistor machine protection device EMT6

EMT6 as contact protection relay



Application example

Control of a storage tank heater

① Control circuit
② Heater

Q11: Heater protection

Description of operation

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 make 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 normally open 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 $T = T_{max}$.

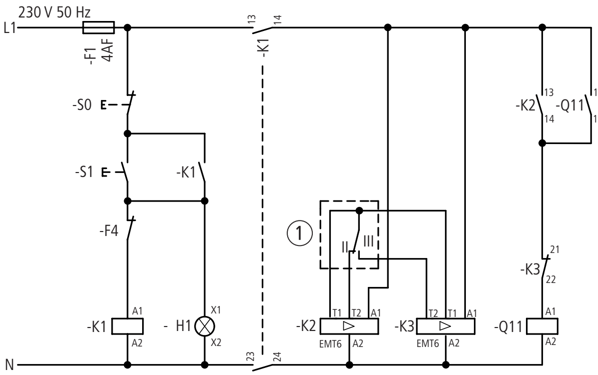
When $T = T_{max}$ the changeover contact of the contact thermometer has the position I-III. The sensor circuit of the EMT6 (K3) is low resistance, the normally closed contact K3/21-22 open. The main protection Q11 drops out.

Contactors and Relays

Thermistor machine protection device EMT6

Safety against broken wires

Security against wire break 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 deenergisation” is carried out.



① Contact thermometer change over contact
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}

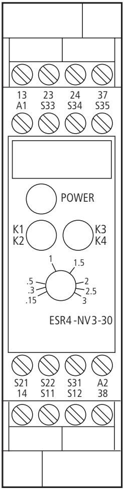
Contactors and Relays
Electronic safety relay ESR

Application

The electronic safety relay is used for monitoring safety relevant controls. The requirements for the electrical equiping of machines is defined in IEC/EN 60204. The machine operater must assess the risk on his machine to EN 954-1 and install the controls to the necessary safety category 1, 2, 3 or 4.

Surface mounting

The electronic safety relay consists of a mains unit, the electronics and two redundant relays with forced contacts for the switching and indication circuits.



Function

After switch on, in failure free operation the safety relevant circuit is controlled via the electronics and using a relay the switching circuit is switched on.

After switch off and in the case of a failure (earth-fault, short-circuit, wire break) the switching circuit is immediately (stop category 0) or delayed (Stop category 1) switched off and the motor isolated from the mains supply.

In redundant safety circuits a short-circuit is not dangerous, so that only by renewed switch on is the failure recognised and re-switch on is blocked.

Further information sources

Mounting instructions

- Evaluation device for two handed switching ESR4-NZ-21, AWA2131-1743
- Basic device for emergency and safety barrier apllications
  - ESR4-NV3-30, ESR4-NV30-30, AWA2131-1838
  - ESR3-NO-31 (230V), AWA2131-1740
  - ESR4-NO-21, ESR4-NM-21, AWA2131-1741
  - ESR4-NO-30, AWA2131-2150
  - ESR4-NT30-30, AWA2131-1884
- Basis device for emergency applications ESR4-NO-31, AWA2131-1742
- Emergency relay ESR4-NE-42, ESR4-VE3-42, AWA2131-1744

Safety manual , TB0-009D

Main catalogue Industrial Switchgear, Section 4 “monitoring relays”.

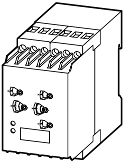
Contactors and Relays
Measurement and monitoring relay EMR4

General

For the various applications measurement amd monitoring relays are necessary. With the new EMR4 range Moeller covers a large number of requirements :

- general use, current monitor EMR4-I
- space saving monitoring of the rotary field, phase sequence relay EMR4-F
- protection against destruction or damage of single system parts, phase monitoring relay EMR4-W
- safe recognition of phase failure, phase imbalance monitoring relay EMR4-A
- increased safety by motor current principle , level relay EMR4-N
- increase of the operational safety, insulation monitoring relay EMR4-R

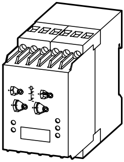
Current monitoring relay EMR4-I



The current monitoring relay EMR4-I is suitable for the monitoring of AC as well as DC current. Pumps and drill machines can be monitored for low load or overload. That is due to the selectable under or over limit.
There are two versions each with three measuring ranges (30/100/1000 mA, 1.5/5/15 A). The multi-voltage coil allows universal use of the relay. The two auxiliary changeover contacts allow for a direct feedback.

Selected bridging of short current peaks
By using the selected time delay of between 0.05 and 30 s short current peaks can be bridged.

Phase monitoring relay EMR4-W



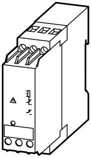
The phase monitoring relay EMR4-W monitors as well as the field rotation also the voltage height. That means protection against destruction or damage of single system parts. Here the minimum low voltage and also the maximum over voltage can be easily set, within a defined range, to the required voltage.
Also a delayed on or a delayed off can be set. In the delayed on position short voltage breaks can be bridged. The delayed off position allows for a failure storage for the set time. The delay time can be set between 0.1 und 10 s.

The relay activates with the correct rotation and voltage. After drop-out the device reactivates when a the voltage exceeds a 5 % hysteresis.

Contactors and Relays

Measurement and monitoring relay EMR4

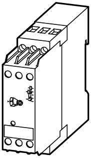
Phase sequence relay EMR4-F500-2



With the only 22.5 mm wide phase sequence relay, portable motors, by which the direction of rotation is important (e. g. pumps, saws, drills), can be monitored for correct rotation. That means space in the switchboard due to the narrow width and protection against damage due to the monitoring of the rotating field.

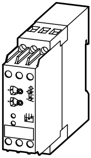
With correctly rotating field the changeover contact switches the control voltage of the motor switching device. The EMR4-F500-2 covers the total voltage range from 200 to 500 V AC.

Phase imbalance relay EMR4-A



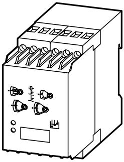
The 22.5 mm wide phase imbalance relay is the correct protection device against phase failure. The motor is then protected against destruction. That the phase failure is monitored on the basis of phase displacement can be recognised with a higher motor feedback and an overload of the motor can be prevented. The relay is able to protect motors with a rated voltage of
U_n = 380 V, 50 Hz.

Level monitoring relay EMR4-N



The level monitoring relay EMR4-N is used mostly as dry running protection for pumps or for level regulation of liquids. It operates with sensors that measure conductivity. A sensor is required for the maximum and also a sensor for the minimum level. A third sensor is used for earth potential.

The 22.5 mm wide device EMR4-N100 is suitable for conductive liquids. It can be switched from level regulation to dry running protection. The safety is increased as in both cases the motor current principle is used.



The level monitoring relay EMR4-N500 has an increased sensitivity and is suitable for less conductive liquids. Due to an integrated rise and fall delay of between 0.1 and 10 s moving liquids can also be monitored.

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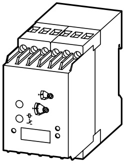
Contactors and Relays
Measurement and monitoring relay EMR4

Insulation monitoring relay EMR4-R



EN 60204 "Safety of machines" provides increased operational safety by the monitoring of the control voltage circuit for earth-fault using an insulation monitor. This is the main application for the EMR4-R. There are similar requirements in medically used areas. An earth-fault is signalled via a changeover contact so that a fault can be cleared without expensive down time.

The device has a selectable fault memory so that the fault must be acknowledged after it´s removal. By the use of a Test button the device can be checked for correct operation at any time.

AC or DC control voltage

There is a device for AC and also DC. Therefore the total control voltage range is covered. The DC device has a multi-voltage source. Therefore AC as well as DC is possible.

Further information sources

Mounting instructions

- Phase imbalance monitoring relay EMR4-A400-1 AWA2431-1867
- Insulation monitoring relay EMR4-RAC-1-A AWA2431-1866
- Insulation monitoring relay EMR4-RDC-1-A AWA2431-1865
- Level monitoring relay EMR4-N100-1-B AWA2431-1864
- Phase sequence relay EMR4-F500-2 AWA2431-1863
- Phase monitoring relay EMR4-W… AWA2431-1863
- Current monitoring relay EMR4-I… AWA2431-1862

Main catalogue Industrial Switchgear, Section 4 "monitoring relays".

5

Motor-protective circuit-breaker

Motor-protective circuit-breaker
Overview

Definition

Motor-protective circuit-breakers are circuit-breakers used for 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 release for protection of the motor winding (overload protection) and an electromagnetic release (short-circuit protection).

The following accessories can be fitted to motor-protective circuit-breakers:

- Undervoltage release,
- Shunt release,
- Auxiliary contact,
- Trip-indicating auxiliary contact.

Moeller motor-protective circuit-breakers

PKZM01
The motor-protective circuit-breaker PKZM01 reintroduces the pushbutton actuation up to 16 A which was very popular with customers. The mushroom actuator for Emergency-Stop operation on simple machines is also being reintroduced. The PKZM01 is preferably installed in surface-mount or flush-mount enclosures. Many accessory parts from the PKZM0 can be used.

Major system module: motor-protective circuit-breaker

PKZM4
The PKZM4 system is a modular and efficient system for switching and protecting motor loads up to 63 A. It is the “big brother” of the PKZM0 and can be used with almost all PKZM0 accessory parts.

Major system modules: motor-protective circuit-breakers

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.

The major system modules are:

- Motor-protective circuit-breakers
- Transformer-protective circuit-breakers
- (High-capacity) contact modules

Description → section “The motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4”, page 6-4.

PKZ2
PKZ2 for motor and distribution circuit protection

The PKZ2 is a modular and efficient system for protecting, switching, signalling and remote operation of motors and systems in low-voltage switchgear systems up to 40 A.

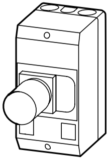
The major system modules are:

- Motor-protective circuit-breakers
- System-protective circuit-breakers
- (High-capacity) contact modules

Description → section “Motor and system protection”, page 6-16.

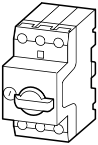
Motor-protective circuit-breaker
Overview

PKZM01
circuit-breaker

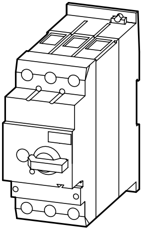


In surface mounting enclosure

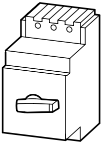
PKZM0
circuit-breaker



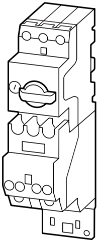
PKZM4
circuit-breaker



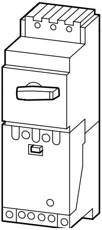
PKZ2
circuit-breaker



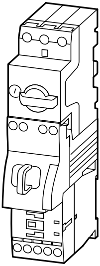
PKZM0
compact starter



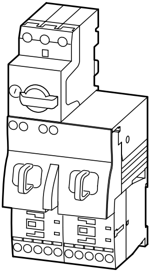
PKZ2
compact starter



MSC-D
direct-on-line starter



MSC-R
reversing starter



Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4

The motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4

The PKZM01, PKZM0 and PKZM4 use bimetallic releases which are delayed depending on the magnitude of the current to offer a proven, technical solution for motor protection. The releases are sensitive to phase failure and are temperature-compensated. The rated current with the PKZM0 up to 32 A is split into 15 ranges, for the PKZM01 it is split into 12 ranges and for the PKZM4 up to 63 A into 7 ranges. The installation (motor) and the supply cable are reliably protected by short-circuit releases, permanently set to 14 × I_u. The motor start is also guaranteed in every operational situation. The single-phasing sensitivity of PKZM0 and PKZM4 allows for the use in the protection of EEx 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.

The compact starter

It consists of the motor-protective circuit-breaker PKZM0 and the contact module SE00-...-PKZ0 which can be attached and features identical contours. It has been developed for standard applications such as switching and protection of a cooling water pump or a similar application, and complies to the latest motor starter standards:

- IEC/EN 60 947-4-1
- &$§
- &$§

Whereas the motor-protective circuit-breaker PKZM0 guarantees the disconnection, short-circuit and overload protection tasks, the contact module (contactor) S(E)00-...-PKZ0 assumes the operational switching of the motor current. The compact starter can master a short-circuit current of 100 kA at 4 kW and 400 V.

While the compact starter represents an economic solution for standard tasks, the high-capacity compact starter was developed specifically for switching and protection of motors in critical processes. This refers to motors whose failure would involve severe consequential costs. In order to guarantee the highest possible level of system availability, the high-capacity compact starter is comprised of the motor-protective circuit-breaker PKZM0 and the weld-free high-capacity contact module (contactor) S00-...-PKZ0. It is guaranteed to be capable of immediate switch on even after a short-circuit of up to 100 kA/400 V.

The compact starters and high-capacity compact starters from the PKZ2 are available for motor ratings of more than 4 kW/400 V (up to 18.5 kW/400 V, or the combination of PKZM4 with the proven contactor DIL.

Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4

Motor starter combinations

The motor-starter combinations MSC are available up to 32 A. Motor starters up to 12 A consist of a motor-protective circuit-breaker PKZM0 and a contactor DILM. 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 motor-protective circuit-breaker PKZM0 and the contactor DILM up to 12 A feature the respective interfaces for this purpose.

The motor-starter combination MSC from 16 A consists of a motor-protective circuit-breaker PKZM0 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 direct-on-line starter MSC-D and as a reversing starter MSC-R.

Motor-protective circuit-breakers for starter combinations

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 unit 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 automatic reset, where an overload relay or a thermistor overload relay is used as well.

Transformer-protective circuit-breaker and current limiter

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 × 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. With the exception of the S00-...-PKZ0 high-capacity contact module, all the PKZM0 system accessories can be combined with the PKZM0-T.

PKZM0-...-C

The PKZM0 features a version with springloaded terminals. A version with springloaded terminals on both sides, and a combined version which features springloaded terminals on the outgoer side only can be chosen. The conductors can be connected here without ferrules. The connections are maintenance-free.

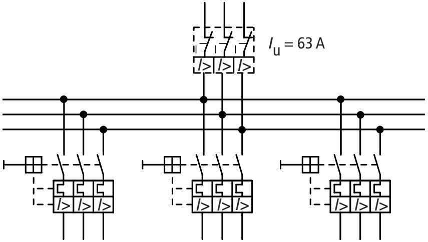
CL-PKZ0

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 termination's as the PKZM0. When they are mounted on a top-hat rail alongside one another, it is possible to connect them by means of B3...-PKZ0 three-phase commoning links. The switching capacity of the series connected PKZM0 or PKZM4 + CL is 100 kA at 400 V. In a short-circuit the contacts of the motor-protective circuit-breaker and CL will open. While the current limiter returns to 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 feed direction may be used.

Motor-protective circuit-breaker

PKZM01, PKZM0 and PKZM4

Individual and group protection using CL-PKZ0



Use the BK25/3-PKZ0 for terminals > 6/4 mm²

For grouped connection use B3...PKZ0 three-phase commoning links B3...PKZ0. Note utilization factors to IEC/EN 60 947.

Examples:

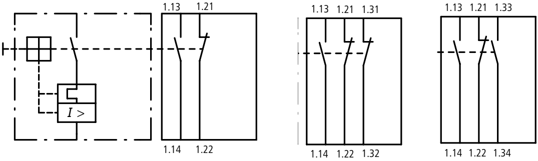
PKZM0-16, PKZM4-16 or	PKZM0-16/20, PKZM4-16/20 or	PKZM0-20, PKZM4-20 or	PKZM0-25, PKZM4-25
4 × 16 A × 0.8 = 51.2 A	2 × (16 A + 20 A) × 0.8 = 57.6 A	3 × 20 A × 0.8 = 50 A	3 × 25 A × 0.8 = 60 A

Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4 – auxiliary contacts

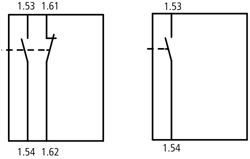
Auxiliary contacts and standard auxiliary contacts NHI for PKZM01, PKZM0 and PKZM4

They switch at the same time as the main contacts. They are used for remote indication of the operating state, and interlocking of switches against one another. They are available with screw terminals or springloaded terminals.

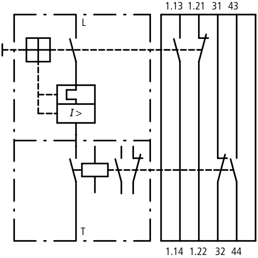
Side mounted:



Integrated:



Only for (high-performance) compact circuit-breakers PKZM0-.../S...

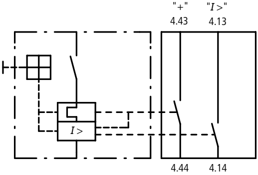


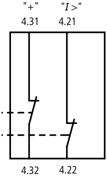
Motor-protective circuit-breaker

PKZM01, PKZM0 and PKZM4 – auxiliary contacts

Trip-indicating auxiliary contact AGM for PKZM01, PKZM0 and PKZM4

These provide information about the reason for the PKZM0 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.





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Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4 – releases

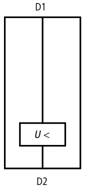
Voltage releases

These operate according to the electromagnetic principle and act on the switch mechanism of the circuit-breaker.

Undervoltage release

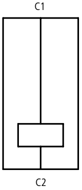
These switch the circuit-breaker off when no voltage is present. They are used for safety tasks. The undervoltage release U-PKZ0, which is connected to voltage via the early-make auxiliary contacts VHI20-PKZ0, allows the circuit-breaker to be switched on. In the event of power failure, the undervoltage 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 VHI-PKZ0 can 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.

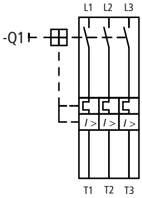


Motor-protective circuit-breaker

PKZM01, PKZM0 and PKZM4 – operating principle schematics

Motor-protective circuit-breakers PKZM01, PKZM0 and PKZM4

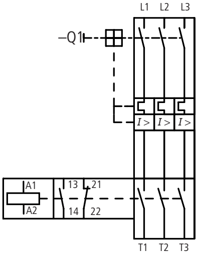
Manually operated motor-starter



Compact starter and high-capacity compact starter with maximum number of auxiliary contacts fitted

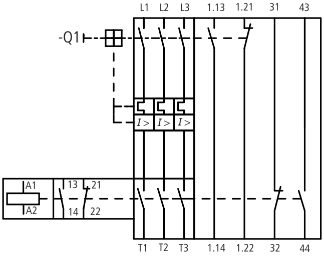
Compact starters consist of:

- PKZM0 motor-protective circuit-breaker and
- Contact module (contactor) SE00-...-PKZ0



Compact starter

PKZM0-.../SE00-... + NHI2-11S-PKZ0

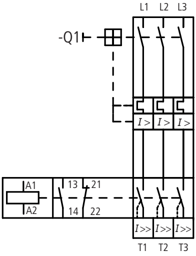


Motor-protective circuit-breaker

PKZM01, PKZM0 and PKZM4 – operating principle schematics

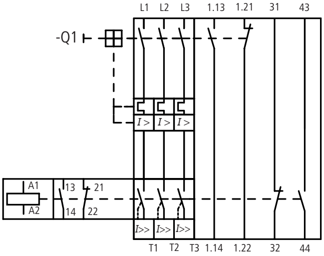
High-capacity compact starter consisting of:

- PKZM0 motor-protective circuit-breaker and
- High-capacity contact module (contactor) SE00-...-PKZ0



High-capacity compact starters

PKZM0-.../S00-... + NHI2-11S-PKZ0



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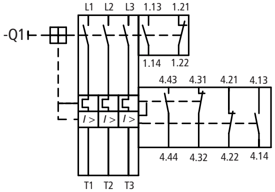
Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4 – operating principle schematics

Motor-protective circuit-breaker with auxiliary contact and trip-indicating auxiliary contact

PKZM01(PKZM0-...)(PKZM4...) + NHI11-PKZ0 + AGM2-10-PKZ0



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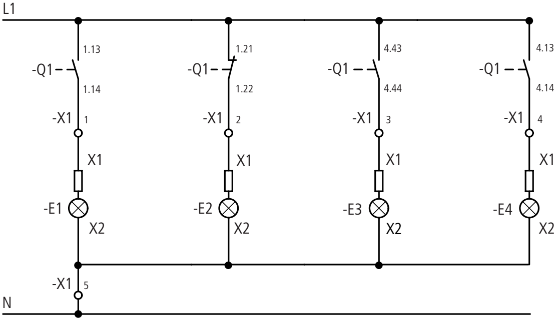
For differential fault indication
(Overload or short-circuit)



E1: circuit-breaker ON
E2: circuit-breaker OFF

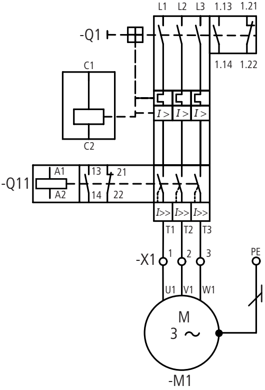
E3: general fault, overload release
E4: short-circuit release

Motor-protective circuit-breaker

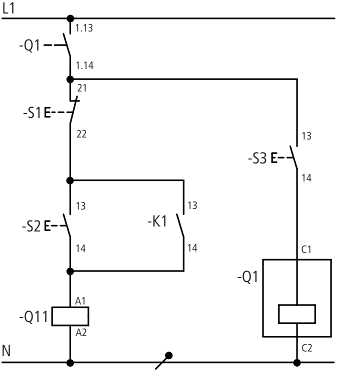
PKZM01, PKZM0 and PKZM4 – operating principle schematics

Remote switch off via shunt release

High-capacity compact starter with auxiliary contact and shunt release
PKZM0-.../S00-.. + A-PKZ0



Q11: Contact module

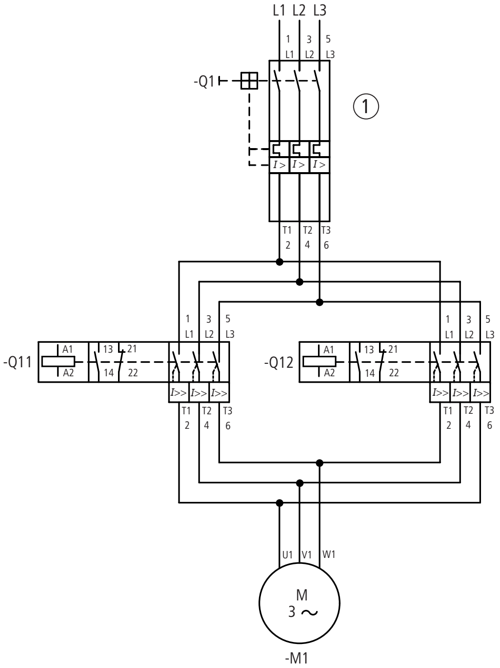


S1: Off
S2: On
S3: Circuit-breaker On

Motor-protective circuit-breaker
PKZM01, PKZM0 and PKZM4 – operating principle schematics

Direct switch-on, reversible

(High-capacity) compact reversing starter PKZM0-.., 2 x (S)00-.../EZ-PKZ0
(with mechanical interlock MV-PKZ0 if required)

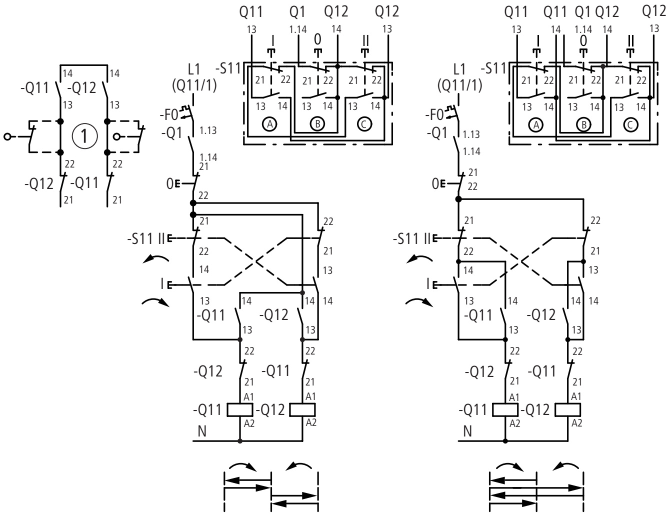


① Fuseless

Motor-protective circuit-breaker

PKZM01, PKZM0 and PKZM4 – operating principle schematics

For standard applications contact modules SE00-...-.PKZ0
may be used instead of high-capacity contact modules S00-...-PKZ0.



① With position switches
remove the links

Motor-protective circuit-breaker

PKZ2 – overview

Motor and system protection

The PKZ2 achieves its modularity by combining the motor or system-protective circuit-breaker with various accessories. This results in numerous application options and adaptation to widely differing requirements.

The circuit-breaker

The circuit-breakers PKZ2/ZM... consists of:

- Basic unit and
- Plug-in trip block.

There is a choice of trip blocks:

- Motor-protective trip blocks (11 versions for the range from 0.6 to 40 A)
- System-protective trip blocks (5 versions for the range from 10 to 40 A)

All trip blocks are equipped with adjustable overload and short-circuit releases.

Overload from ... to:

- Motor-protective trip-blocks: 8.5 to 14 × I_e
- Trip block for distribution circuit protection: 5 to 8.5 × I_e

Standards

The motor-protective circuit-breaker PKZ2 complies with the IEC 947 and EN 60947 standards. The circuit-breaker has a switching capacity of 30 kA/400 V outside the inherently-safe range. It is auto-protected up to a rated operational current of 16 A. In addition, the PKZ2 complies with the requirements stipulated in IEC/EN 60 204 for disconnectors and main switches.

Special motor-protective trip block ZMR-...-PKZ2

This trip block features an overload relay function which allows the following interesting application:

In the event of an overload, the circuit-breaker does not trip. Instead, a normally closed contact (95-96) is actuated which switches off the contactor in the control circuit (contactors up to 18.5 kW, AC-3). At the same time, a normally open contact (97-98) is actuated, which ensures remote indication. The normally closed contact and normally open contact are suitable for carrying two different potentials.

The trip block has a manual and an automatic position:

- Automatic position: The normally closed contact and normally open contact automatically return to the original position after the bimetallic strips have cooled down. The contact can be actuated again by actuation, for example, of a pushbutton.
- Manual position: An acknowledgement locally, at the unit, moves the contacts back to the original position after tripping.

Important note!

For an EEx e application, the normally closed contact 95-96 must be used to shed the contact module or contactor, to achieve disconnection.

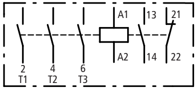
6

Motor-protective circuit-breaker
PKZ2 – overview

(High-capacity) contact module S-...-PKZ2

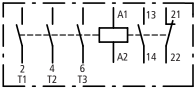
A compact starter combination is produced by combining a contact module S-...-PKZ2 (contactor) featuring the same contours with the PKZ2:

- Switch + standard contact module SE1A-...-PKZ2. The contact module features the same functions and properties of a standard contactor and can be used for operational switching of 1 × 10^6 AC-3 operations.



- Switch + S-PKZ2... high-capacity contact module. A high-capacity compact starter is obtained by using a motor-protective circuit-breaker (PKZ2/ZM...) as the switch, and a combination circuit-breaker is produced by using a circuit-breaker (PKZ2/ZM-...-8) as the switch.

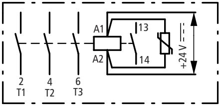
The high-capacity contact module increases the switching capacity of the combination to 100 kA/400 V, and is suitable for 1 × 10^6 AC-3 operations.



(High-capacity) contact module for 24 V DC control voltage

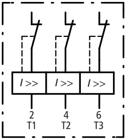
An actuating voltage of 24 V DC can be used with the contact module SE1A-G-PKZ2 (24 V DC) and the high-capacity contact module S-G-PKZ2 (24 V DC). It is necessary to take account of:

- Pull-in capacity: 150 VA,
- Pull-in current: 6.3 A (16 to 22 ms),
- Holding power: 2.7 W,
- Holding current: 113 mA.



Current limiter CL-PKZ2

A specially developed current-limiter module which can be attached and featuring the same contours is available to increase the switching capacity of the circuit-breaker to 100 kA/400 V. In the event of a short-circuit the contacts of the PKZ2 and CL-PKZ2 will open. The PKZ2 trips via the magnetic release and remains in this position. The CL-PKZ2 returns to the rest position after the short circuit. Both units are ready for operation again after the fault.



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Motor-protective circuit-breaker

PKZ2 – remote operator

The remote operator allows the PKZ2 to be switched on and off remotely during operation. After tripping, it can be reset to 0 by the remote operator.

The PKZ2 system has two remote operators:

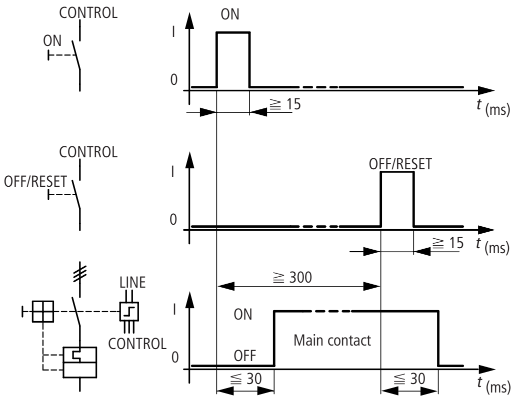
- In the RE-PKZ2 – the electronic remote operator for standard applications – both CONTROL and LINE are separate inputs, but with the same reference potential. This allows actuation using low current units, e.g. control circuit devices.
- The electronic remote operator RS-PKZ2 can be actuated directly, without any coupling elements, from the semiconductor outputs of a PLC (24 V DC).
  Electrical isolation between the CONTROL and LINE allows it to take power for the switching process from a separate power supply (e.g. 230 V 50 Hz).

Both remote operators must be supplied with the mains supply of 700 W/VA for 30 ms at the terminals 72–74 during the switching operation (On/Off/Reset). Twelve voltage versions are available per remote operator. These cover a wide application range. The remote operators can optionally be set for manual or automatic operation.

- Manual position: remote switching on is reliably electrically interlocked.
- Automatic position: remote switching on is possible.

An integrated normally open contact (33–34) when closed indicates the automatic position of the remote operator.

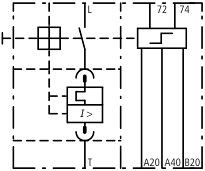
Minimum command time for the remote operators RE-PKZ2 and RS-PKZ2



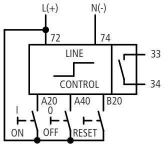
Motor-protective circuit-breaker

PKZ2 – remote operator

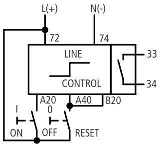
Remote operator RE-PKZ2



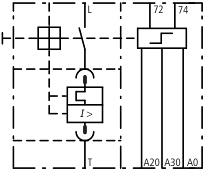
Off and Reset separate



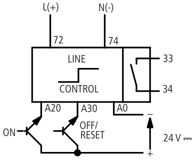
Off equals Reset

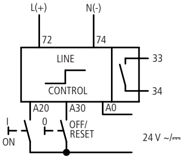


Remote operator RS-PKZ2



Off equals Reset





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Motor-protective circuit-breaker

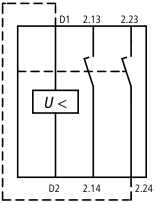
PKZ2 – release

Voltage releases

Undervoltage release U

Undervoltage releases trip the circuit-breaker in the event of a power failure and prevent restarting when the power returns. Three versions are available:

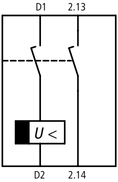
- Non-delayed,
- With/without early-make auxiliary contact,
- With 200 ms dropout delay.



Undervoltage releases which switch off without delay are suitable for Emergency-Stop circuits.

The undervoltage release can be energized early by an additional link (see circuit diagram).

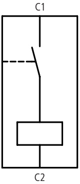
Undervoltage release with a 200 ms dropout delay.



Shunt release A

Shunt releases trip the circuit-breaker when a voltage is applied. These are an economic option for switching off remotely.

Shunt releases are suitable for AC and DC, and one version covers a wide voltage range.



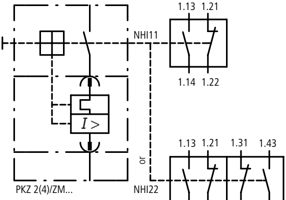
Motor-protective circuit-breaker

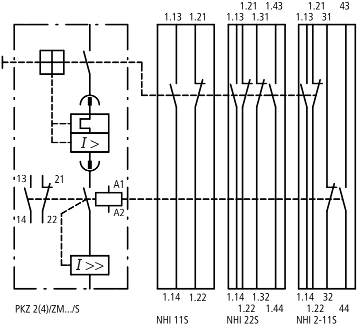
PKZ2 – auxiliary contact, trip-indicating auxiliary contact

Standard auxiliary contact NHI

The NHI is available in 2 versions.
NHI for circuit-breakers, fitted and featuring the same contours, for indicating the position of the main contacts of the switch.

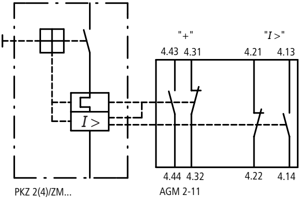
NHI ... S for the starter combination, featuring the same contours, for indication of the position of the main contacts of the contactor and/or those of the circuit-breaker.





Trip-indicating auxiliary contact AGM

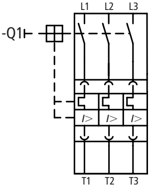
The trip-indicating auxiliary contact is of particular importance. Two separate contact pairs signal that the circuit-breaker is in the tripped position. One contact pair (normally open & normally closed) signals general tripping and one pair signals tripping in the event of a short circuit. If the normally open contact 4.43/4.44 and the normally closed contact 4.21/4.22 are connected in series, then it is also possible to indicate overload tripping differentially.



Motor-protective circuit-breaker
PKZ2 – operating principle schematics

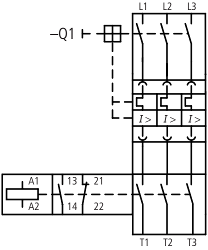
Motor-protective circuit-breaker consisting of:

- PKZ2 basic unit
- Plug-in trip block Z



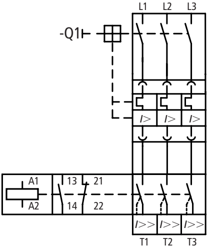
Compact starter, consisting of:

- Basic unit
- Trip block
- Contact module SE1A...-PKZ2, which can be attached and has the same contours, for operational switching

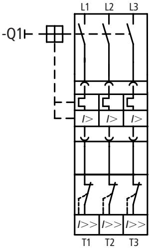


High-capacity compact starter, consisting of:

- Basic unit
- Trip block
- High-capacity contact module fitted with same contour profile



Circuit-breaker with current limiter fitted



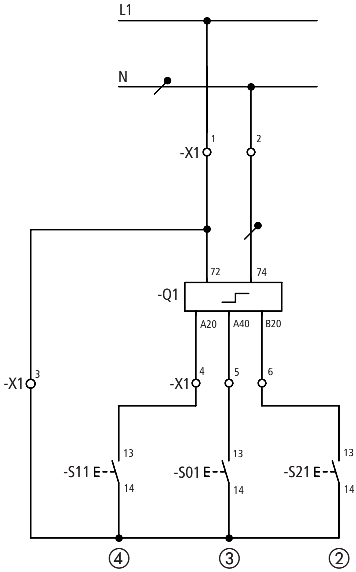
6

Motor-protective circuit-breaker

PKZ2 – operating principle schematics

On-off switching with remote operator

Separate actuation of Off and Reset

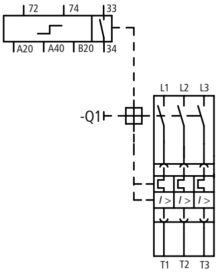


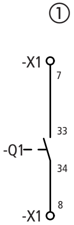
① Separate actuation of OFF and Reset
② Reset
③ OFF
④ ON

Actuation by control circuit devices (e.g. pushbuttons NHI, AGM, VS3, EK...SPS with potential-free contacts).

Circuit-breaker with remote operator, standard version.

Example 1: PKZ2/ZM-.../RE(...)



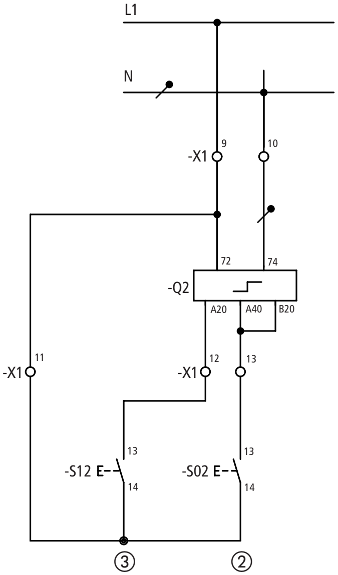


Auxiliary contact for signalling the manual/automatic position of the remote operator. Indicates the automatic position when closed.

6

Motor-protective circuit-breaker
PKZ2 – operating principle schematics

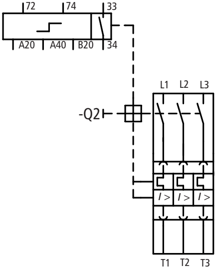
Joint actuation of Off and Reset
Circuit-breaker with remote operator, standard version.



① Off = Reset
② Off/Reset
③ ON

Actuation by control circuit devices (e.g. pushbuttons NHI, AGM, VS3, EK...SPS with potential-free contacts).

Example 2: PKZ2/ZM-.../RS(...)



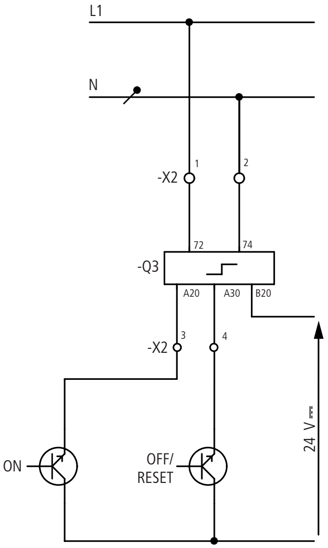
Auxiliary contact for signalling the manual/automatic position of the remote operator. Indicates the automatic position when closed.

Motor-protective circuit-breaker

PKZ2 – operating principle schematics

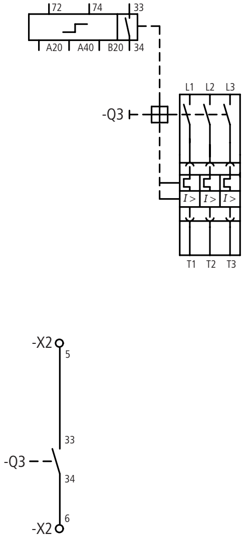
Circuit-breaker with remote operator, 24 V DC version with electronic outputs

For direct actuation by a programmable logic controller (PLC).



Actuation by PLC with 24 V DC electronic outputs.
Auxiliary contact for signalling the manual/automatic position of the remote operator.

Example 3: PKZ2/ZM-.../RS(...)



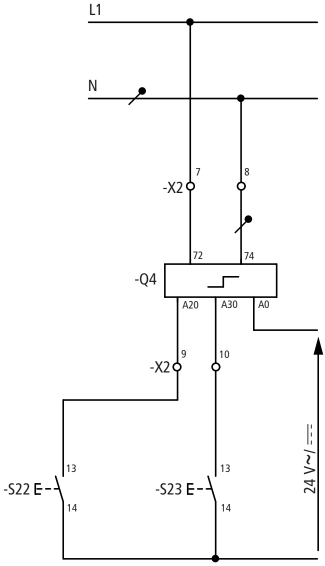
Indicates the automatic position when closed.

Motor-protective circuit-breaker

PKZ2 – operating principle schematics

Circuit-breaker with remote operator

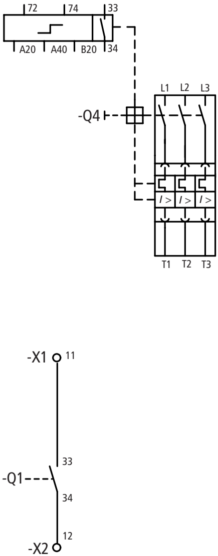
Actuation by control circuit devices.



S22: On
S23: Off/Reset

Actuation by control circuit devices via 24 V AC/DC.
Auxiliary contact for signalling the manual/automatic position of the remote operator. Indicates the automatic position when closed.

Example 4: PKZ2/ZM-.../RS(...)



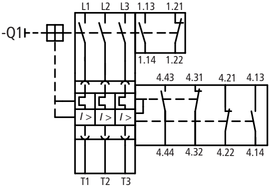
Motor-protective circuit-breaker

PKZ2 – operating principle schematics

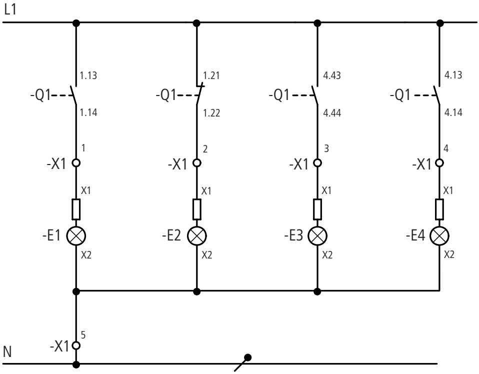
Indication by auxiliary contacts

Circuit-breaker with auxiliary contact and trip-indicating auxiliary contact.

Example: PKZ2/ZM-... + NHI11-PKZ2 + AGM2-11-PKZ2



For differential fault indication.



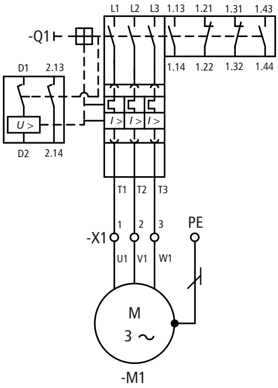
E1: Circuit-breaker On
E2: Circuit-breaker Off
E3: General fault, Overload tripping
E4: Short-circuit tripping

Motor-protective circuit-breaker

PKZ2 – operating principle schematics

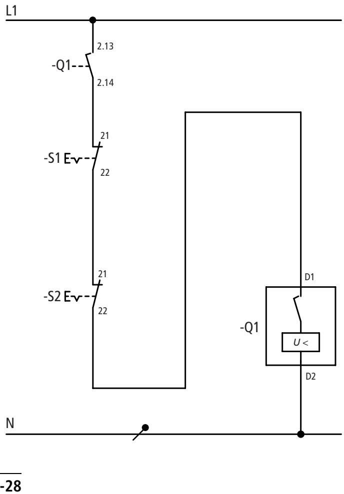
Use of the undervoltage release in the Emergency-Stop circuit

Motor-protective circuit-breaker with auxiliary contact and undervoltage release.



Example: PKZ2/ZM... + NHI22-PKZ2 + UHI-PKZ2

All poles of the Emergency-Stop circuit are isolated from the mains supply in the event of a power failure.



S1: Emergency-Stop
S2: Emergency-Stop

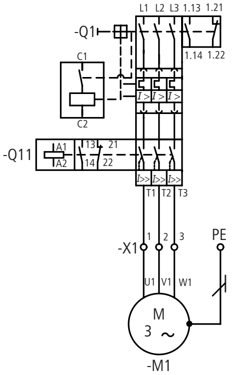
Motor-protective circuit-breaker

PKZ2 – operating principle schematics

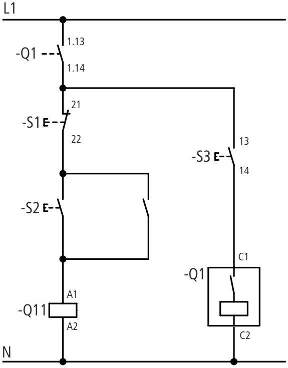
Remote switch off via shunt release

High-capacity compact starter with auxiliary contact and shunt release

Example: PKZ2/ZM-.../S-PKZ2 + A-PKZ2



Q11: High-capacity contact module



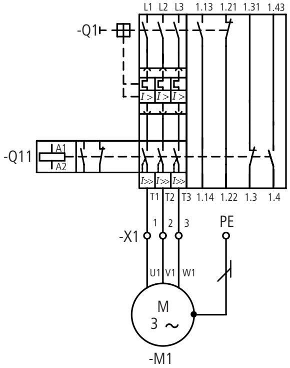
S1: Off
S2: On
S3: Circuit-breaker Off

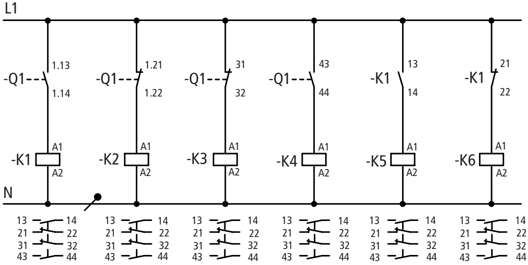
Motor-protective circuit-breaker

PKZ2 – operating principle schematics

High-capacity compact starter with maximum number of auxiliary contacts fitted

**Example: PKZ2/ZM.../S-PKZ2 +
NHI2-11S-PKZ2**





K1: Circuit-breaker On
K2: Circuit-breaker Off
K3: Contact module Off
K4: Contact module On
K5: Contact module On
K6: Contact module Off

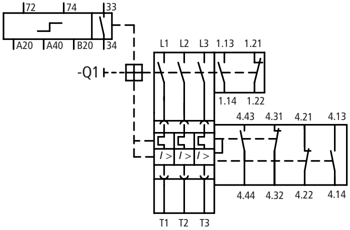
Motor-protective circuit-breaker

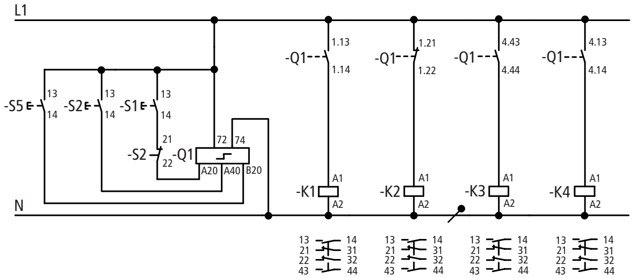
PKZ2 – operating principle schematics

Remotely actuated circuit-breaker with switch status indication

Motor-protective circuit-breaker with remote operator + auxiliary contact (1 NO, 1 NC) + trip indicating auxiliary contact

Example: PKZ2/ZM.../RE + NHI11-PKZ2 + AGM2-11-PKZ2





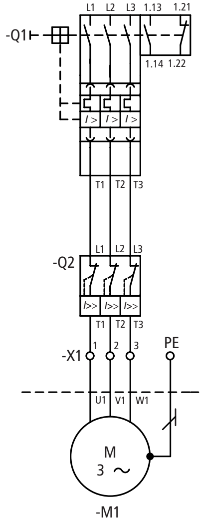
S1: On
S2: Off
S5: Reset
Q1: Auxiliary contact, indication: manual-auto
K1: Circuit-breaker On
K2: Circuit-breaker Off
K3: Overload indication
K4: Short-circuit indication

6

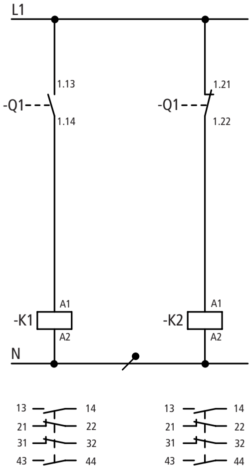
Motor-protective circuit-breaker
PKZ2 – operating principle schematics

Circuit-breaker with current limiter in separate mounting

Example: PKZ2/ZM... + NHI11-PKZ2 with CL/EZ-PKZ2



Q2: Current limiter, separate mounting

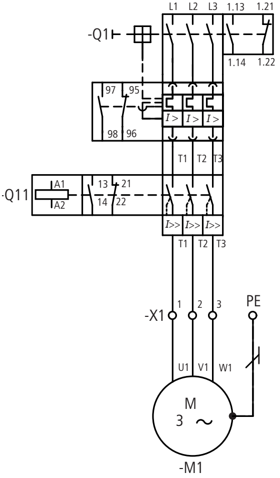


K1: Circuit-breaker On
K2: Circuit-breaker Off

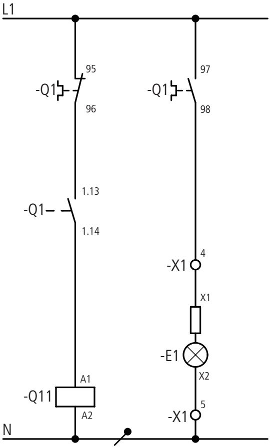
Motor-protective circuit-breaker
PKZ2 – operating principle schematics

Special trip block ZMR-...-PKZ2 with overload relay function

For switching off a contactor in the control circuit in the event of an overload by means of a trip block ZMR-...PKZ2 with an overload relay function and with simultaneous indication. The circuit-breaker thumb-grip remains in the "On" position. Circuit-breaker with trip block ZMR, high-capacity contact module S and NHI11-PKZ2.



Q11: High-capacity contact module



Q11: Shutdown
E1: Overload indication

6

Notes

Circuit-breakers

Circuit-breakers
Overview

NZM circuit-breakers

These circuit-breakers protect electrical equipment against thermal overloading and in the event of a short circuit. They cover the rated current range from 20 to 1600 A.

Depending on the version, they have additional protective functions such as fault-current protection, earth-fault protection or the capability for energy management by recognition of load peaks, and deliberate load shedding.

Circuit-breakers NZM are distinguished by their compact shape and their current-limiting characteristics.

Switch-disconnectors without tripping units are available in the same sizes as the circuit-breakers and can be fitted with additional shunt or undervoltage releases to suit on the versions concerned.

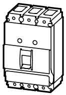
Circuit-breakers NZM and switch-disconnectors are built and tested to the specifications in IEC/EN 60947.

They feature isolating characteristics. In conjunction with a locking device, they are suitable for use as main switches to IEC/EN 60204.

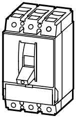
The electronic releases of frame sizes NZM2, NZM3 and NZM4 feature communication capabilities.

The current states of the circuit-breaker onsite can be visualized via a **D**ata **M**anagement **I**nterface (DMI) or via digital output signals. Additionally, the circuit-breakers can be connected to a network, e.g. PROFIBUS-DP.

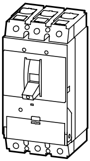
NZM1



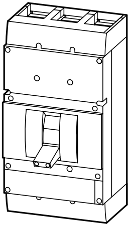
NZM2



NZM3



NZM4



Circuit-breakers
Overview, shunt releases

IZM circuit-breakers

These circuit-breakers protect electrical equipment in the rated current range from 630 to 6300 A. They have digital tripping electronics, which are available in four different versions.

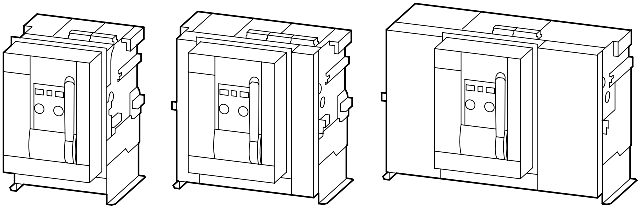
The tripping units offer extensive protection and signalling functions, extending from standard short-circuit and overload protection to energy management with data transmission.

Circuit-breakers IZM are built and tested to the specifications in IEC/EN 60947.

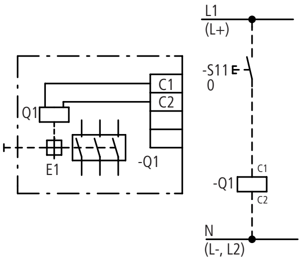
They feature isolating characteristics. In conjunction with a locking device, they are suitable for use as main switches to IEC/EN 60204.

The circuit-breakers in the IZM range are also available as IN switch-disconnectors without tripping units.

IZM1 **IZM2** **IZM3**



Shunt releases A (Q1)

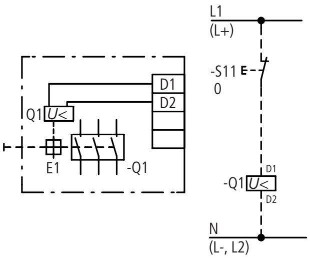


An electromagnet which, when a voltage is applied, actuates a tripping mechanism. When de-energized, the system is in the rest position. A normally open contact actuates the system. If the shunt release is rated for intermittent duty, the intermittent operation must be ensured by positioning appropriate auxiliary contacts (usually HIN/S1) upstream of the circuit-breaker.

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

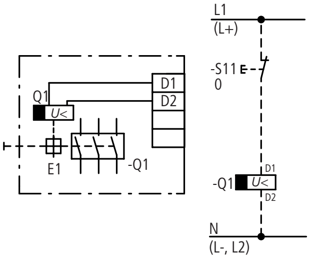
Undervoltage release U (Q1)



An electromagnet which actuates a tripping mechanism upon interruption of the voltage. 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-Stop).

Undervoltage releases trip the circuit-breaker when the power fails in order, for example, to prevent motors from restarting automatically. They are also suitable for very reliable interlocking and remote switching off since disconnection always occurs in the event of a fault (e.g. wire breakage in the control circuit). The circuit-breakers cannot be closed when the undervoltage releases are de-energized.

Off-delayed undervoltage release UV (Q1)

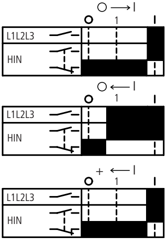


The off-delayed undervoltage release is a combination of a separate delay unit (UVU) and the respective release. This release is used to prevent brief interruptions in power leading to disconnection of the circuit-breaker. The delay time is adjustable between 0.06 and 16 s.

Circuit-breakers

Contact sequence of the auxiliary contacts

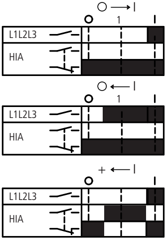
Standard auxiliary contact HIN



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.

- Standard auxiliary contacts behave like main switch contacts
- Switch position indication
- Interlocking
- Disconnection of the shunt release

Trip-indicating auxiliary contact RHI, new designation: trip-indicating auxiliary contact HIA



0 → I

Switch on

0 ← I

Switch off

+ ← I

Trip

■ contacts closed

☐ contacts opened

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 switches. No pulse is produced when the switch is opened or closed manually, or by a motor operator.

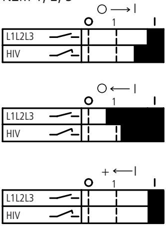
- Indication that the switch is in the tripped position
- Switch position indication only if tripping is caused by, for example, overcurrent, short-circuit, test or voltage release. No fleeting contact when switched on or off manually or switched off with the motor (exception: manual switch off with motor operator NZM2, 3, 4).

Circuit-breakers

Contact sequence of the auxiliary contacts

Early-make auxiliary contact HIV

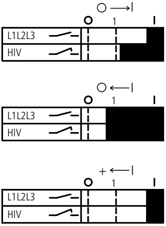
NZM 1, 2, 3



Used to provide command or signal outputs from 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.

The HIV has the same position in the tripped position of the circuit-breaker and the off position of the circuit-breaker. Because of their early-make feature, they can be used for energizing the undervoltage release (→ section "Undervoltage releases", page 7-4).

NZM 4



0 → I

Switched on

0 ← I

Switch off

+ ← I

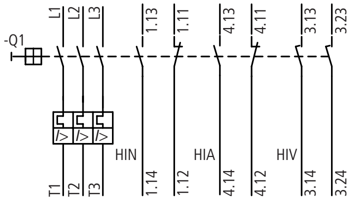
Trip

■ contacts closed

☐ contacts opened

Circuit-breakers
Internal circuit diagrams

NZM1

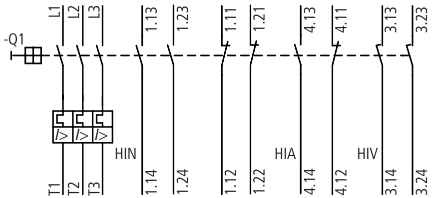


Contact elements M22-K10 (K01) from the RMQ-Titan range from Moeller are used for the auxiliary contacts. Two early-make auxiliary contacts (2 NO) are also available.

Maximum component fitting:

	NZM			
	1	2	3	4
HIN, 1 NO or 1 NC	1	2	3	3
HIA, 1 NO or 1 NC	1	1	1	2
HIV, 2 NO	1	1	1	1

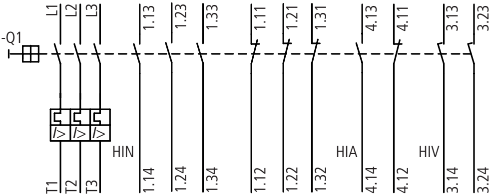
NZM2



Details about the auxiliary contacts: → section "Maximum component fitting:", page 7-7

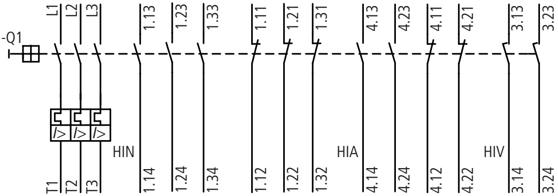
Circuit-breakers
Internal circuit diagrams

NZM3



Details about the auxiliary contacts: → section "Maximum component fitting:", page 7-7

NZM4

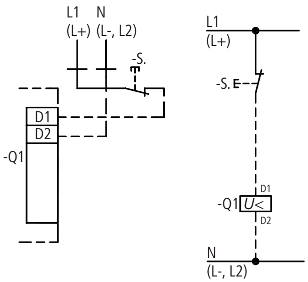


Details about the auxiliary contacts: → section "Maximum component fitting:", page 7-7

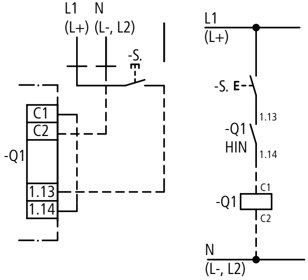
Circuit-breakers

Remote switch-off with voltage releases

Remote switch-off with undervoltage releases



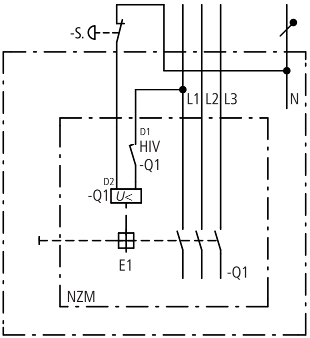
Remote switch-off with shunt release

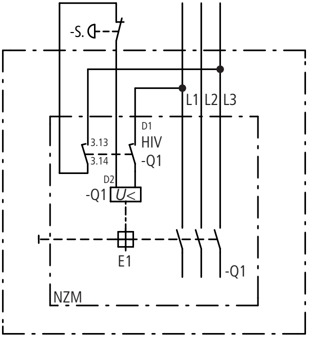


Circuit-breakers
Remote switch-off with voltage releases

Main switch application in processing machines with Emergency-Stop function conform to the IEC/EN 60204-1 standard

In the OFF position of the main switch all control elements and control cables which exit the control panel are voltage free. The only live components are the control-voltage tap-offs with the control lines to the early-make auxiliary contact.



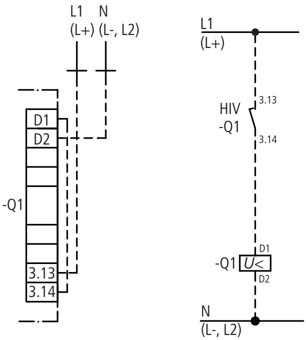


7

Circuit-breakers

Application of the undervoltage release

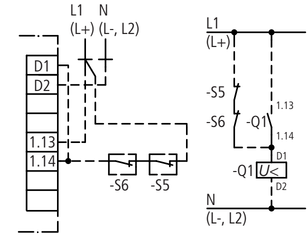
Shut off of the undervoltage release



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



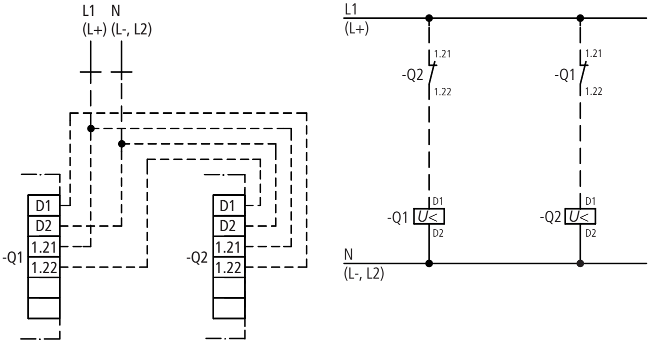
Circuit-breakers with undervoltage release produce a positive Off position in conjunction with interlocking auxiliary contacts on the starter (S5), ancillary devices on the motor (e.g. brush lifting, S6) or on all switches in multi-motor drives.

The circuit-breaker cannot be closed unless the starter or switch is in the zero or Off position.

Circuit-breakers

Shutdown of the undervoltage release

Interlocking of several circuit-breakers using an undervoltage release

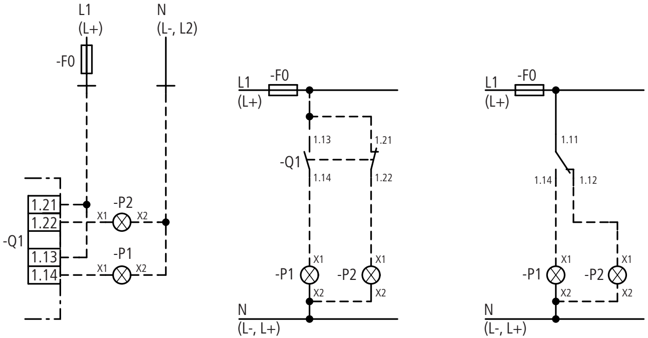


When interlocking 3 or more circuit-breakers, each circuit-breaker must be interlocked with the series-connected normally closed contacts of the auxiliary contacts on the other circuit-breakers using one contactor relay – for contact duplication – per auxiliary contact. If one of the circuit-breakers is closed, the others cannot be closed.

Circuit-breakers

Indication of the switch position

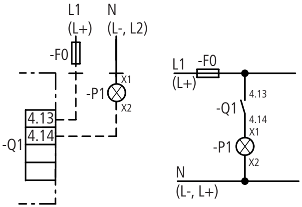
On and Off indication using standard auxiliary contacts HIN (Q1)



P1: On
P2: Off

Tripped indication using trip-indicating auxiliary contact HIA (Q1)

Trip-indicating auxiliary contacts for mesh network switches



P1: Tripped

Circuit-breakers

Short-time delayed circuit-breaker – internal circuit diagrams

Time-discriminating network topology

Short-time delayed circuit-breakers NZM2(3)(4)/VE enable a time-discriminating network design with variable stagger times.

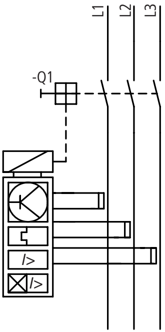
Where the prospective short-circuit currents are extremely high, additional installation protection is achieved by instantaneous releases, which respond without any delay.

NZM2(3)(4)...-VE...

Trip block VE

Adjustable short-time delay:

0, 20, 60, 100, 200, 300, 500, 750, 1000 ms



Circuit-breakers

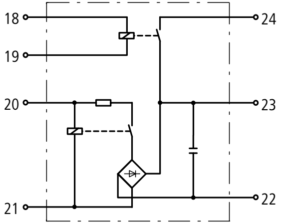
Mesh network circuit-breaker

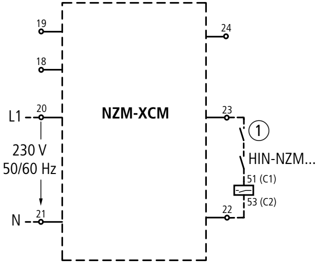
NZM1, NZM2, NZM3, NZM4

Circuit with capacitor unit and shunt release 230 V, 50 Hz.

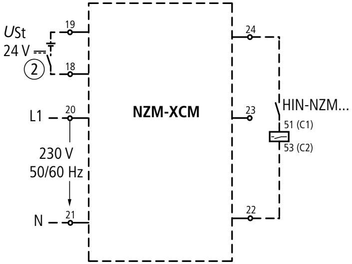
The configuration of the capacitor unit which provides the energy for the shunt release of the mesh network circuit-breaker can be undertaken independently of the circuit-breaker.

Connect the NZM-XCM to the power feed side!





① Mesh network relay



② Mesh network relay with low-capacity contacts

Circuit-breakers

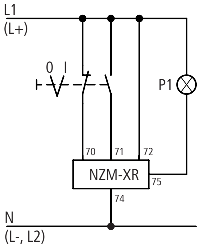
Remote operation with motor operator

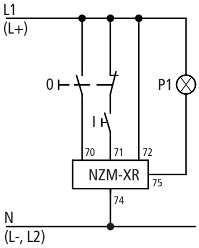
Two-wire control

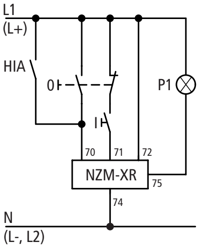
Three-wire control

Three-wire control with automatic return to the Off position after tripping

NZM2, 3, 4







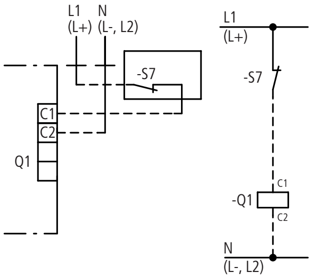
7

Circuit-breakers
as a transformer switch

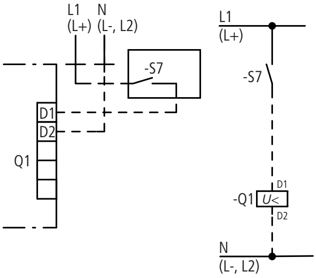
Faults upstream of the low-voltage circuit-breaker, e.g. in the transformer itself, are disconnected by suitable protective devices (e.g. a Buchholz relay) on the high-voltage side. The S7 auxiliary contact of the high-voltage circuit-breaker trips out the NZM transformer switch on the low-voltage side 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-breaker with shunt release Q1



Circuit-breaker with undervoltage release Q1



Circuit-breakers
with residual-current release

NZM2-4-XFI, XFI30

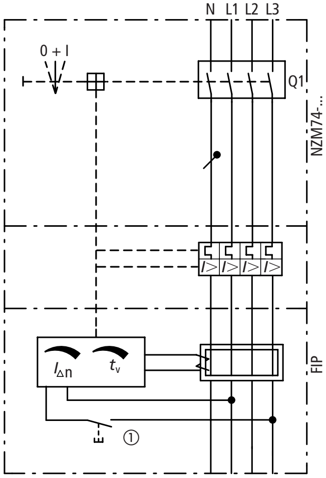
These circuit-breakers with integrated residual current protection offer:

- Overload protection
- Short-circuit protection
- Fault-current protection

In addition to the protective functions, this circuit-breaker can perform the functions of a main switch with isolating characteristics. Like RCCB's built conform to VDE 0664, the residual current release recognises AC and DC fault currents. The residual-current release NZM74-... and NZM2-4-FI(30) are “pulse current sensitive”. The NZM2-4-FIA(30) is sensitive to AC and DC. In the event of a fault the circuit-breaker disconnects the fault circuitry. The residual-current protective switches for the NZM2-4 and NZM74 are built and tested to IEC/EN 60 947 and VDE 0664 Part 3.

The residual-current release requires no external auxiliary voltage for tripping. For the switch rated current range 30–250 A at rated voltages 200–690 V (NZM2-4) and 380 – 690 V (NZM74), rated fault currents $I_{\Delta n}$ = 0.1-0.5*-1-3 A and delay times t_V ~ 60-150-300-450 ms can be set in steps. The XFI30 or FIP30 trips at a rated fault current of 30 mA.

* 0.3 at NZM74



① Test button

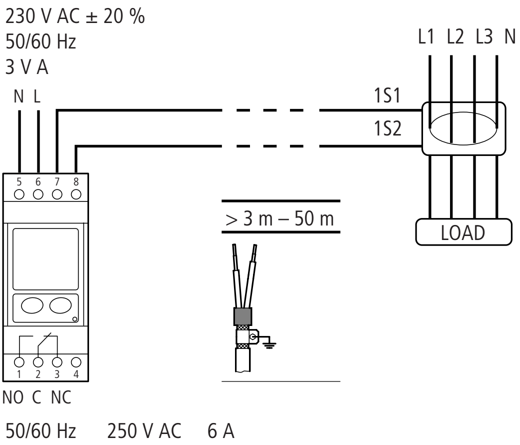
Circuit-breakers
with residual-current release

Residual-current relay PFR with ring-type transformer

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 three different relay types and seven different transformer types available. They cover operating currents ranging from 1 to 1800 A. The three relay types are:

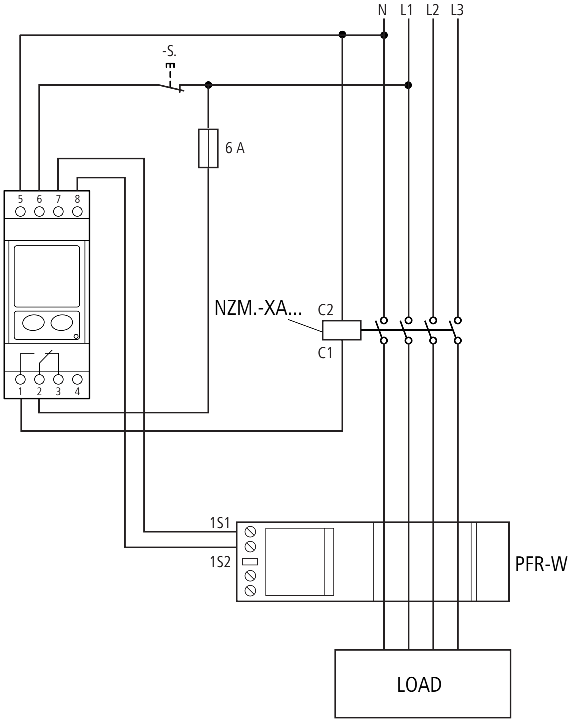
- Rated fault current 30 mA, permanently set
- Rated fault current 300 mA, permanently set
- Rated fault current from 30 mA to 5 A and a delay time from 20 ms to 5 s which is variable in stages.

The fault 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.



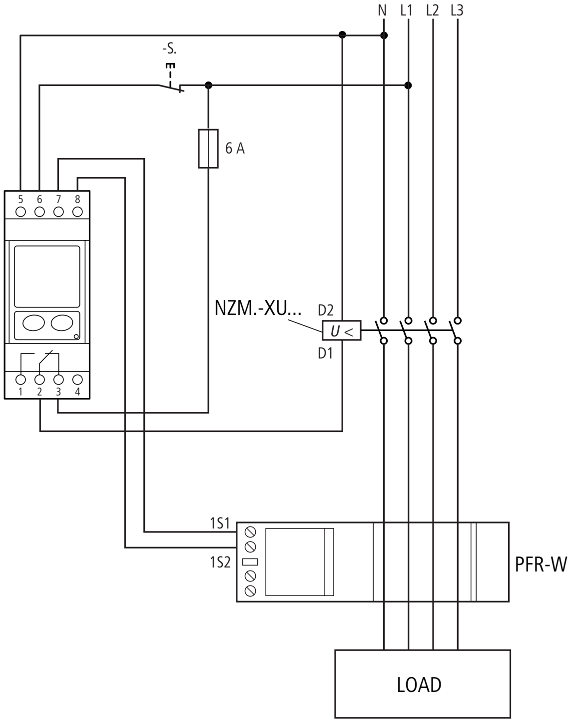
Circuit-breakers
with residual-current release

Trip of circuit-breakers with shunt release and possible external reset of the relay by a pushbutton (NC contact)



Circuit-breakers
with residual-current release

Trip of circuit-breakers with undervoltage release and possible external reset of the relay by a pushbutton (NC contact)



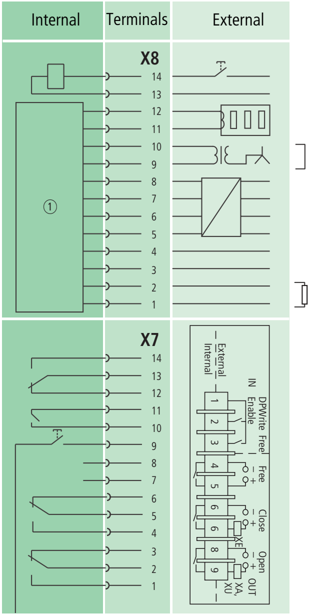
Terminal assignment of the control circuit plug

Control circuit plugs X8, X7, X6, X5 are identical

X8: optional control circuit plug
(Connections X8:1 to X8:8 only with IZM...-U... and IZM...-D...)

① Electronic overload release

XFR remote reset
G-converter S2
G-converter S1
IZM-XW(C) N-converter S2
IZM-XW(C) N-converter S1
External voltage transformer star
External voltage transformer L3
External voltage transformer L2
External voltage transformer L1
0 V DC
24 V DC
Internal system bus +
Internal system bus –



L/L+
N/L- U_s
e.g.[1)]
Jumper with no N-converter
L1
L2
L3
N
24 V DC external power supply

Terminating resistor, if no external system bus module

X7: optional control circuit plug
Not available with communication function IZM-XCOM-DP.
At the position of X7 a communications module is located.

Tripped signalling switch XHIA

Signal state
Spring-operated stored energy
XEE electrically “ON”

XHIS signalling switch on first voltage release

XHIS signalling switch on second voltage release

IZM-XCOM-DP

L/L+ U_s

1) Convertor in transformer star point or summation current convertor 1200 A/1 A

X6: standard control circuit plug

XE/A first shunt release

Standard auxiliary switch XHI: S1 “NO”

Standard auxiliary switch XHI: S1 “NC”

Closing release XE/A

“Ready to close” auxiliary switch XHIB

Standard auxiliary switch XHI: S2 “NO”

Standard auxiliary switch XHI: S2 “NC”

X5: optional control circuit plug

Only XUV “non-delayed trip”

XA1, XU, XUV second voltage release

Standard auxiliary contact XHI11/XHI22/XHI31: S3 “NO”, XHI40: S7

Standard auxiliary contact XHI11/XHI22/XHI31: S3 “NC”, XHI40: S7

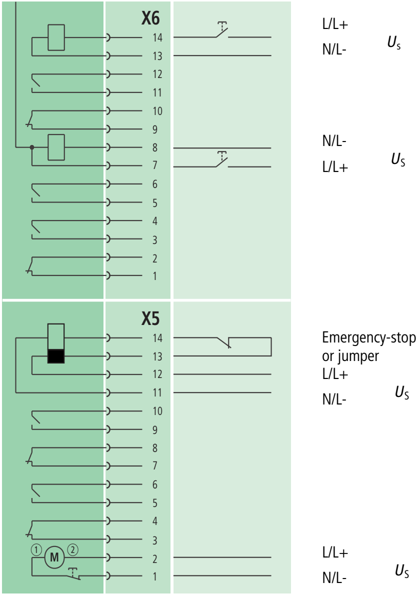
Standard auxiliary contact XHI22: S4 “NO”, XHI31/XHI40: S8 “NO”

Standard auxiliary contact XHI22: S4 “NC”, XHI31/XH40: S8 “NO”

Motor operators

Optional motor cut-off switch XMS

① black-white, ② brown

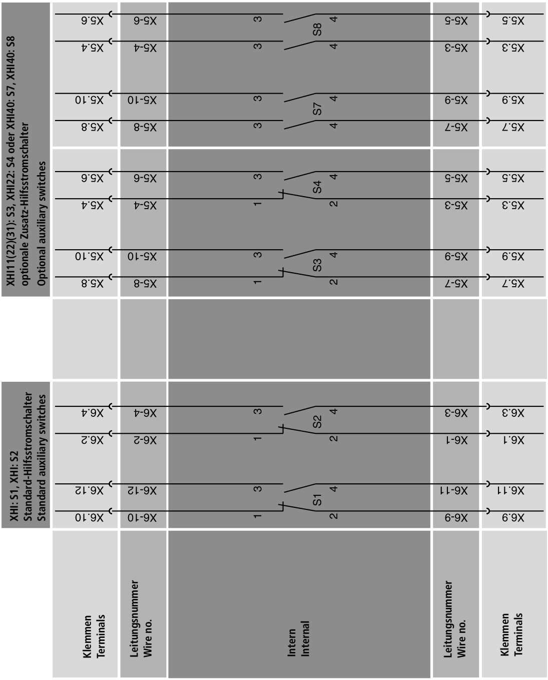


Circuit-breakers

IZM circuit-breakers

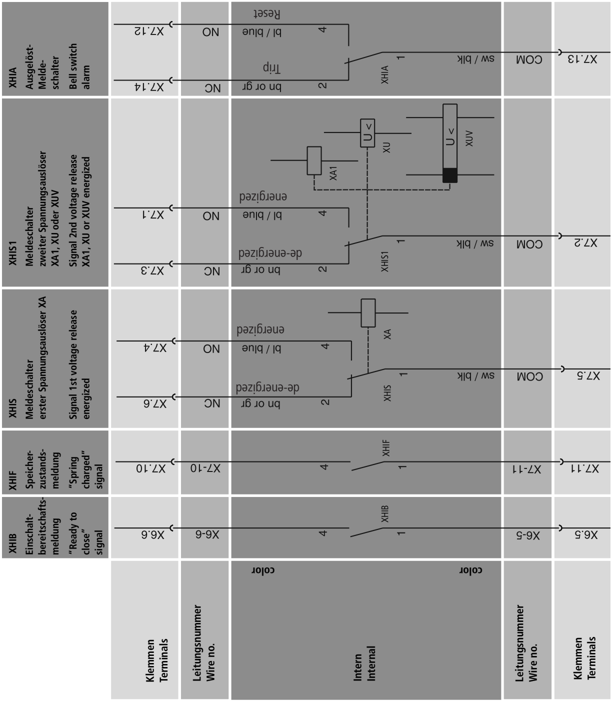
Control circuit isolator

7



Circuit-breakers
IZM circuit-breakers

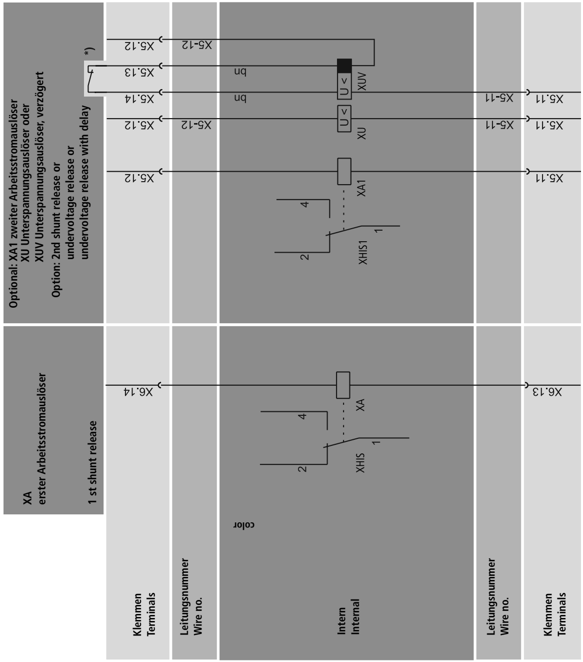
Signalling switch



Circuit-breakers

IZM circuit-breakers

Voltage release/electrical manual reset

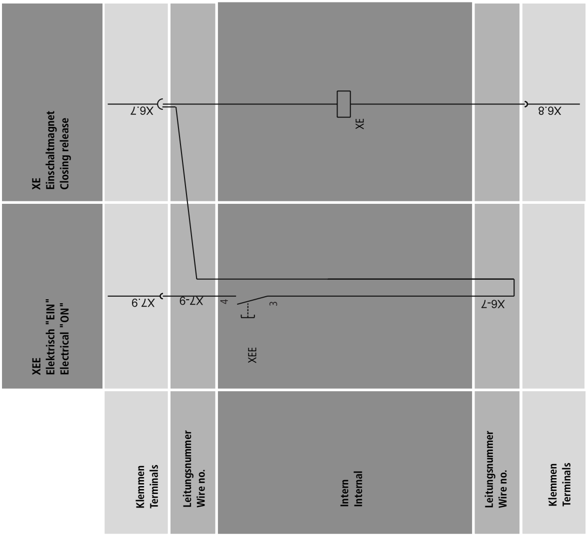


*) Emergency-stop or jumper

Circuit-breakers

IZM circuit-breakers

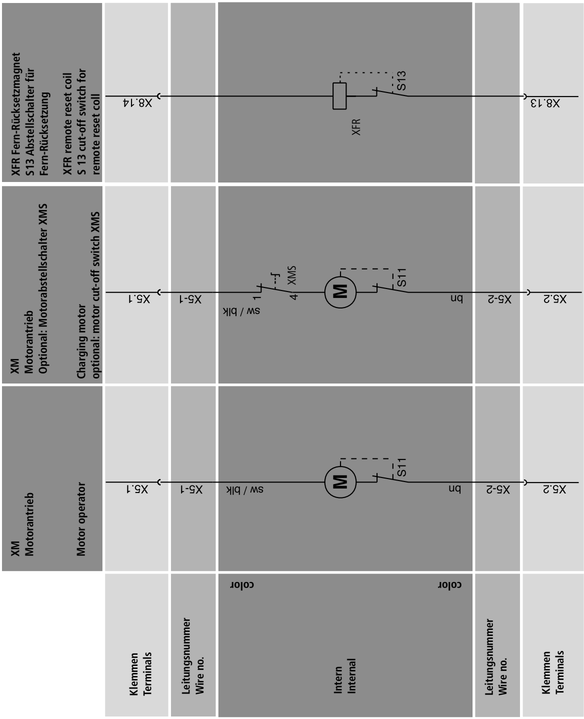
Closing release/electrical ON



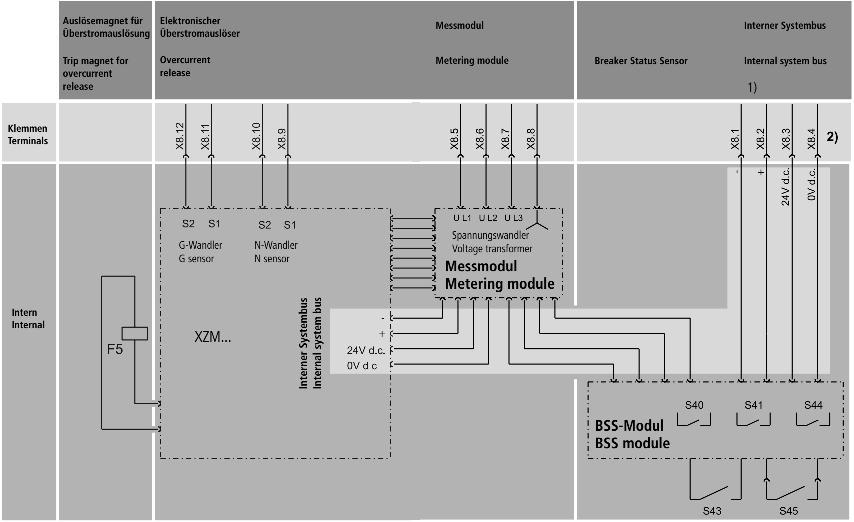
Circuit-breakers

IZM circuit-breakers

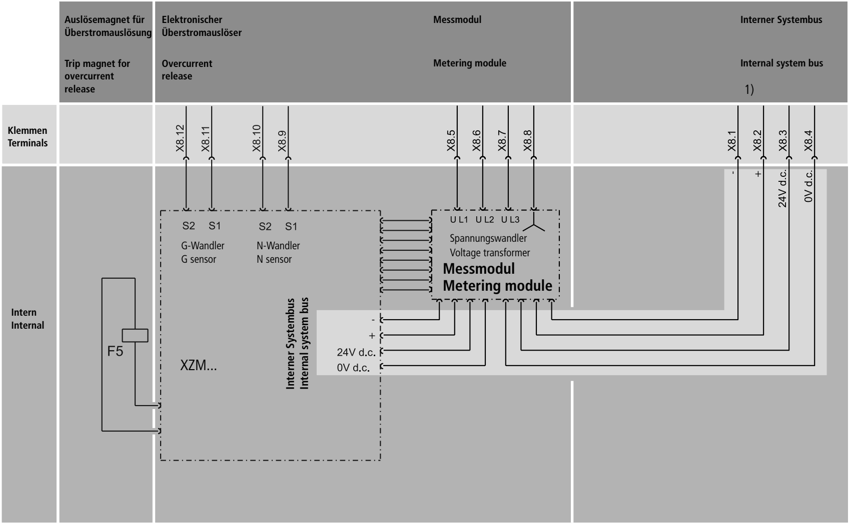
Motor operator, remote reset magnet



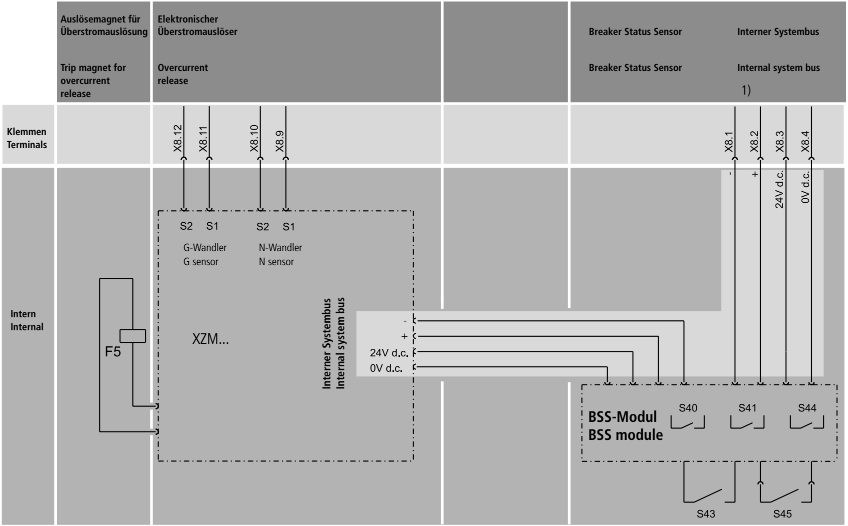
Protective circuits for overcurrent release with breaker status sensor and metering module



Protective circuits for overcurrent release, metering module only



Protective circuits for overcurrent release, breaker status sensor only



Notes

All about Motors

All about Motors

All about Motors
Motor protection

Overload relay with manual reset

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. Moeller overload relays are always supplied with manual reset but can be converted to automatic reset by the user.

Overload relays with automatic reset

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 starters, individually compensated motors, current transformer-operated relays etc. may require that the relay setting deviates from the rated motor 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 frequency of operation 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.

All about Motors
Motor protection

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

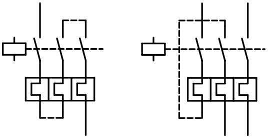
With changes in the motor which do not cause an increase in current consumption: Effects of humidity, reduced cooling due to a reduction in speed or motor dirt, temporary additional external heating of the motor or bearing wear.

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 single-pole or 2-pole circuits.

1-pole **2-pole**



An important characteristic feature of overload relays conforming to IEC/EN 947-4-1 are the tripping classes (10 A, 10, 20, 30). They determine different tripping characteristics for the various starting conditions of motors (normal starting to heavy starting).

8

All about Motors
Motor protection

Response values

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 $t \leqq 2$ h	C Tripping class 10 A 10 20 30	 Tripping time in minutes $\leqq 2$ $\leqq 4$ $\leqq 8$ $\leqq 12$	D Tripping class 10 A 10 20 30	 Tripping time in seconds $2 < T \leqq 10$ $4 < T \leqq 10$ $6 < T \leqq 20$ $9 < T \leqq 30$	
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.

All about 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 $t \leqq 2$ 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 $\times I_e$ (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 and is usually approximately 12 to 20 $\times I_e$.

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

Short-circuit rating of the main circuit

With currents that exceed the breaking capacity of the motor starter in relation to the utilization category (EN 60947-1), it is permissible for the current flowing during the operating 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 co-ordination (1 and 2). It is common practice to state in the details of protective devices which type of co-ordination is ensured by them.

All about Motors

Motor protection

Type "1" co-ordination

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" co-ordination

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 welding for which the manufacturer must give maintenance instructions.

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

Short-circuit withstand 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).

Motor protection in special applications

Heavy starting duty

An adequate tripping delay is essential in order to allow a motor to start up smoothly. In the majority of cases, overload relays ZB, motor-protective circuit-breakers PKZ(M) or circuit-breakers NZM can be used. The tripping delays can be taken from the tripping characteristics in the Moeller Main Catalogue, Industrial Switchgear.

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 normal operation. However, there are other solutions to the problem:

Current transformer-operated relay ZW7

The ZW7 consists of three special saturable core current transformers, supplying an overload relay Z00. It is used principally for medium and large motors.

Up to two times rated 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 current occur, and hence permits longer starting times.

Adjusting the current transformer-operated relay ZW7 for lower motor ratings

The setting ranges quoted in the Moeller Main Catalogue, Industrial Switchgear apply when the incoming cable is looped once through the transformer relay.

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All about Motors

Motor protection

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 motor rating 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 motor-protective relay ZEV or a thermistor overload relay EMT 6 in conjunction with an overload relay Z meets the requirements.

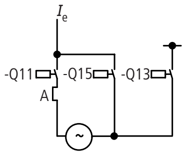
8

Star-delta starter (Y Δ)

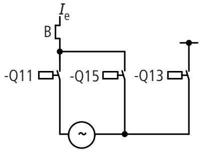
Non-reversing

Changeover time with overload relay in position

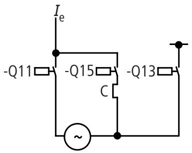
A: < 15 s



B: > 15 < 40 s



C: > 40 s



Setting of the overload relay

$0.58 \times I_e$
Full motor protection in Y (star) position

$1 \times I_e$
Only partial motor protection in Y position

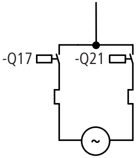
$0.58 \times I_e$
Motor not protected in Y (star) position

All about Motors

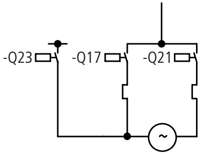
Motor protection

Multi-speed switch

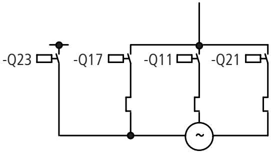
2 speeds
2 separate windings



One tapped winding



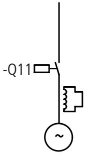
3 speeds
1 × tapped winding
+ 1 winding



Attention must be paid to short-circuit protection of the overload relays.
Separate supply leads should be provided if required.

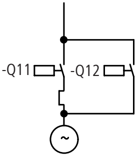
Heavy starting duty

Current transformer-operated relay ZW7



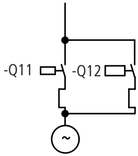
For medium and large motors

Bridging of motor protection during starting



For small motors; no protection during starting

Bridging during starting using bridging relay



Automatic cut out

8

All about Motors
Motor protection

Individually compensated motor

I_e = Rated motor operational current [A]
I_w = Active cur. } Proportion of motor
I_b = Reactive cur. rated operational current [A]
I_c = Rated capacitor current [A]

I_{EM} = Setting current of overload relay [A]
$\cos\varphi$ = Motor power factor
U_e = Rated operational voltage [V]
P_c = Rated capacitor output [kvar]
C = Capacitance of capacitor [µF]

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

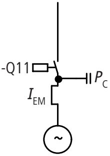
$$I_b = \sqrt{I_e^2 - I_w^2}\,[A]$$

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

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

Capacitor connected

to contactor terminals

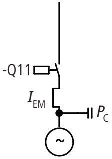


Setting I_{EM} of overload relay

$$I_{EM} = 1 \times I_e$$

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 relay for machine protection relays

Thermistor overload relays are used in conjunction with temperature-dependent semiconductor 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 EMT6 comply with the characteristics for the combination of protective devices and PTC sensors to VDE 0660 Part 303. 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. 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/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 operational current. The overload relay then assumes stalling protection; the thermistor protection monitors the motor winding.

Thermistor overload relays can be used in conjunction with up to six PTC sensors to DIN 44081 for direct monitoring of temperatures in EEx e motors compliant to the ATEX directive (94/9 EC). Copies of PTB certification are available on request.

All about Motors
Motor protection

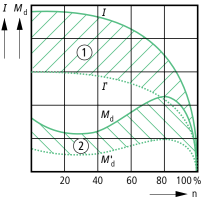
Protection of current and temperature-dependent motor-protective devices

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 frequency of operation	–	+	+
Voltage and frequency fluctuations	+	+	+
Increased coolant temperature	–	+	+
Impaired cooling	–	+	+

+ Full protection
(+) Partial protection
– No protection

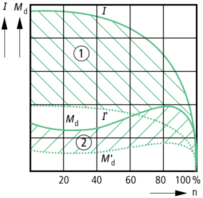
All about Motors
Notes on engineering

Three-phase automatic starters



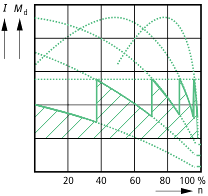
Three-phase automatic stator resistance starters with starting resistors

Single or multi-step resistors are connected upstream of the three-phase squirrel-cage motors to reduce the starting current and torque.
With single-step starters, the starting current is approximately three times the motor full-load current. With multi-step starters, the resistors can be so designed that the starting current is only 1.5 to 2 times the motor full-load current, with a very low level of starting torque.



Three-phase automatic stator resistance starters with starting transformers

This type of starting is preferable where the same starting torque is to be obtained as with the primary resistance starters but the starting current taken from the mains is to be further reduced. A reduced voltage U_a (approximately 70 % of the rated operational voltage) is supplied to the motor when starting via the starting transformer. Thus, the current taken from the mains is reduced to approximately half the direct starting current.



Three-phase automatic rotor starters with starting resistors

Resistors are connected in the rotor circuit of the motor to reduce the starting current of motors with slip-ring rotors. The current taken from the mains is thus reduced. In contrast to stator resistance starters, the torque of the motor is practically proportional to the current taken from the mains. The number of steps of the automatic starter is determined by the maximum permissible starting current and by the type of the motor.

I: line current
M_d: torque
n: speed
① Reduction of the line current
② Reduction of the torque

All about Motors

Notes on engineering

Important data and features of three-phase automatic starters

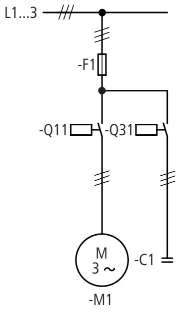
1) Style of starter	Stator resistance starter (for squirrel-cage motors)			Rotor starter (for slipring rotors)
2) Type of starter	Star-delta switches	With starting resistors	With starting trans-formers	Rotor resistance starter
3) Number of starting stages	1 only	Normally 1	Normally 1	Selectable (no longer selectable when current or torque have been determined)
4) Voltage reduction at the motor	0.58 × rated operational voltage	Selectable: a × rated operational voltage (a < 1) e.g. 0.58 as with ⋎△ starter	Selectable: 0.6/0.7/0.75 × U_a (transformer tappings)	None
5) Starting current taken from mains	0.33 × inrush current at rated operational voltage	a × inrush current at rated operational voltage	Selectable (see 4) 0.36/0.49/0.56 × inrush current at rated operational voltage	Selectable: from 0.5 to about 2.5 × rated current
5a) Starting current at the motor	As above	As above	Selectable (see 4) 0.6/0.7/0.75 × I_e	As above
6) Starting torque	0.33 × tightening torque at rated operational voltage	a^2 × tightening torque at rated operational volt-age	Selectable (see 4) 0.36/0.49/0.56 × tightening torque at rated operational voltage	Selectable (see 5) from 0.5 to pull-out torque
7) Current and torque reduction	Proportional	Current reduction less than torque reduction	Proportional	Current reduction much greater than torque reduction. From pull-out torque to rated speed almost proportional
8) Approximate price (for similar data). DOL starting = 100 (with overload relay, enclosed)	150–300	350–500	500–1500	500–1500

All about Motors
Notes on engineering

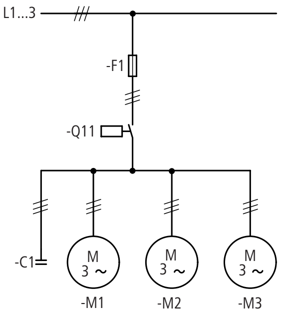
Switching of capacitors

DIL contactors for capacitors – individual switching

Individual compensation



Group 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 current can occur; these can, however, be reliably switched by Moeller DIL contactors.

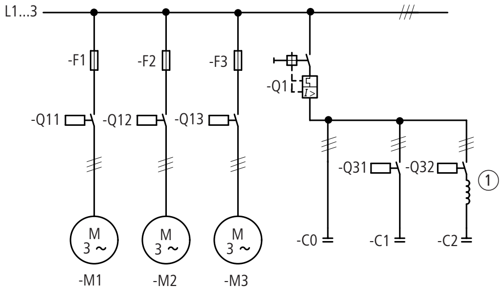
When installing capacitors, the VDE specification 0560 part 4 (Germany) and the standards which apply to each country should be observed. According to these, capacitors not directly connected to an electrical device which forms a discharge circuit, should be equipped with a rigidly connected discharge 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.

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.

All about Motors
Notes on engineering

Contactor for capacitor DIL…K – 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 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 Moeller in the DILMK… 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 incoming leads to the capacitors or by inserting an air-cored coil with a minimum inductance 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.

All about 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, film, diskette, etc. 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 EN 292-2.

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 components. These include:

- 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

- Single-line or multi-line representation
- Connected, semi-connected or separate representation
- Topographical representation

In addition to this, there is the process-orientated representation with the function chart (see previous pages).

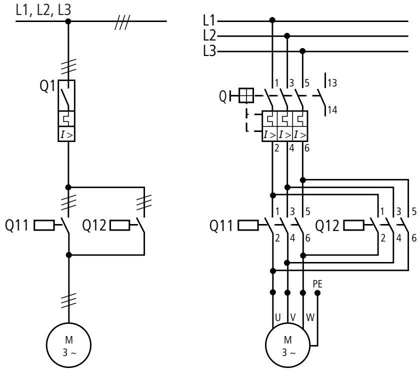
Examples for drawing up circuit documents are given in IEC/EN 61082-1.

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, which 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.

All about Motors
Circuit documents



Circuit diagram: 1-pole and 3-pole representation

Wiring diagrams

Wiring diagrams show the conductive connections between electrical components. 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.

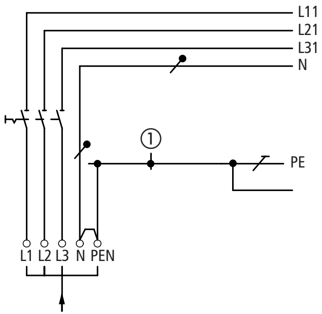
- Unit wiring diagram: representation of all the connections within the device or combination of devices.
- Interconnection diagram: representation of the connections between the device or combination of devices within an installation.
- Terminal diagram: representation of the connection points of an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

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

All about Motors

Power supply

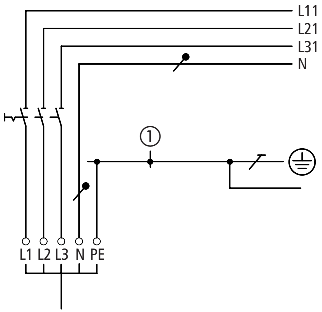
4-conductor system, TN-C-S



① Protective earth conductor
Protective earth terminal in enclosure (not totally insulated)

Overcurrent protective device is required in the supply for compliance to IEC/EN 60204-1

5-conductor system, TN-S supply system



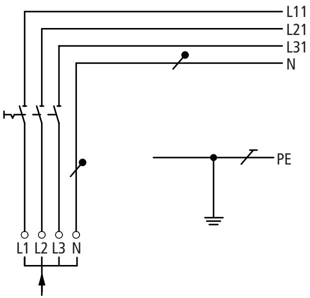
① Protective earth conductor
Protective earth terminal in enclosure (not totally insulated)

Overcurrent protective device is required in the supply for compliance to IEC/EN 60204-1

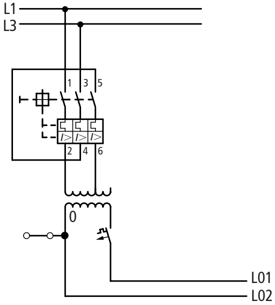
All about Motors

Power supply

3-conductor system, IT supply system



Overcurrent protective device is required in the supply for compliance to IEC/EN 60204-1
For all systems: use the N conductor only with the agreement of the user

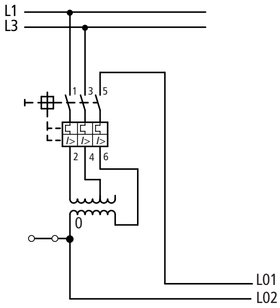


Separate primary and secondary protection

Earthed control circuit. In non-earthed control circuit, remove link and provide insulation monitoring.

All about Motors

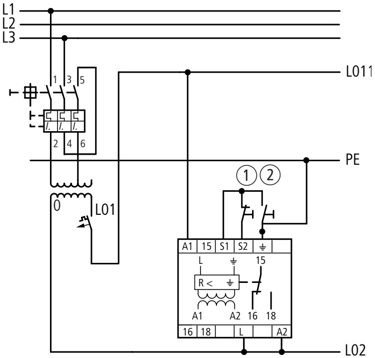
Power supply



Combined primary and secondary protection

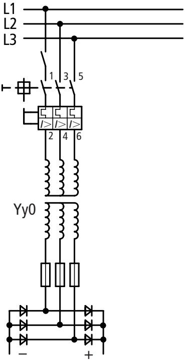
Earthed control circuit. In non-earthed control circuit, remove link and provide insulation monitoring.
Maximum ratio of U1/U2 = 1/1.73
Circuit not to be used with STI/STZ (safety and isolating transformers).

All about Motors
Control circuit supply



Separate primary and secondary protection, with insulation monitoring on the secondary side

① Clear button
② Test button



DC power supply with three-phase bridge rectifier

All about Motors

Contactor markings

The contactors in contactor combinations have, in accordance with EN 61346-2 for equipment and function, the code letter Q, as well as numerical identification, which shows the function of the component (e.g. Q22 = mains contactor with anticlockwise rotation for high speed).

The following table shows the marking used in this Wiring Manual and in Moeller circuit documentation.

Type of component	Mains contactors						Step contactors			
	Standard motor		2 speed/4 speed							
	3 speed									
	One speed		Low speed		High speed					
	Forward Up Hoist	Reverse Down Lower	Forward Up Hoist	Reverse Down Lower	Forward Up Hoist	Reverse Down Lower	Star	Delta	Starting stage	Remarks
DIL (/Z)	Q11									
DIUL (/Z)	Q11	Q12								
SDAINL (/Z)	Q11						Q13	Q15		
SDAIUL (/Z)	Q11	Q12					Q13	Q15		
UPIL (/Z/Z)			Q17		Q21		Q23			
UPIUL (/Z/Z)			Q17	Q18	Q21	Q22	Q23			
UPSDAINL (/Z)			Q17		Q21		Q23	Q19		
U3PIL (/Z/Z/Z)	Q11		Q17		Q21		Q23			
UPDIUL (/Z)			Q17		Q21					
ATAINL (/Z)	Q11						Q13		Q16 to Qn	1-n starting stages
DAINL	Q11									
DDAINL	Q11									
DIL + discharge resistors	Q11								Q14	
DIGL + discharge resistors	Q11									

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.

All about Motors

Direct-on-line start of three-phase motors

Typical circuits with DIL contactors

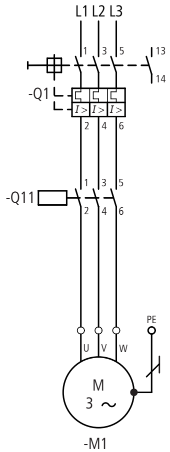
Fuseless without overload relay

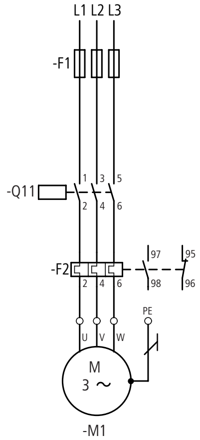
Short-circuit protection[1] and overload protection by means of PKZM motor-protective circuit-breaker or NZM circuit-breaker

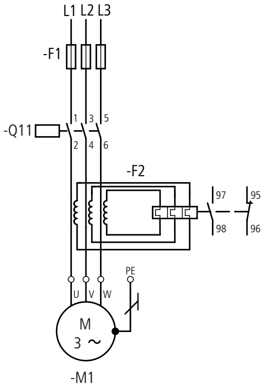
Fuses with overload relay

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.







1) Protective device in the supply line in accordance with Moeller Main Catalogue, Industrial Switchgear or AWA installation instructions

2) Fuse size in accordance with data on the rating plate of the overload relay

3) Fuse size in accordance with Moeller Main Catalogue, Industrial Switchgear (Technical data for contactors)

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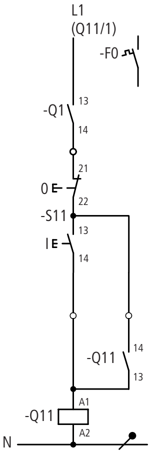
All about Motors

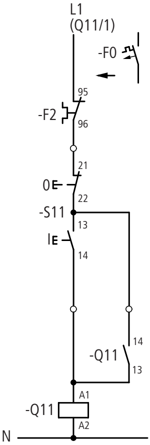
Direct-on-line start of three-phase motors

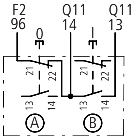
Typical circuit with bridging of overload relay during starting

Without overload relay



With overload relay





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

Control circuit device

I: ON
0: OFF

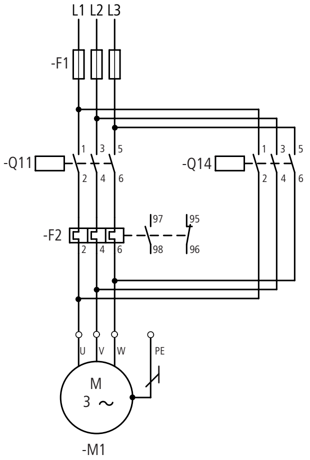
For connection of further control circuit devices → section "Three-wire control", page 8-36

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 enables 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.

All about Motors

Direct-on-line start of three-phase motors

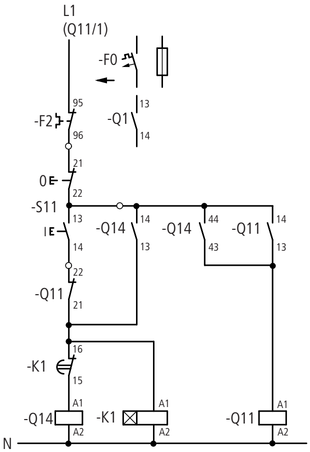
Application on drive motors with severe starting duty



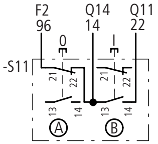
For connection when used with motor-protective circuit-breakers PKZM... and circuit-breakers NZM(H)...
→ section "Fuses with overload relay", page 8-28

All about Motors

Direct-on-line start of three-phase motors



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



Control circuit device

I: ON

0: OFF

For connection of further control circuit devices → section "Three-wire control", page 8-36

Method of operation

Actuation of pushbutton I energizes the 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 starting 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 normally closed contact 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.

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All about Motors

Direct-on-line start of three-phase motors

Two directions of rotation, DIUL reversing contactor

Fuseless without overload relay

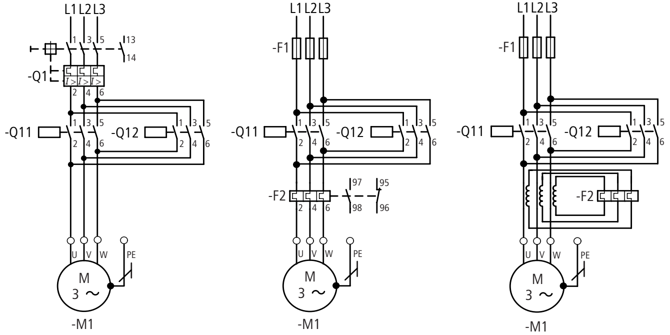
Short-circuit protection and overload protection by means of motor-protective circuit-breaker PKZM or circuit-breaker NZM.

Fuse size in the supply line in accordance with Moeller Main Catalogue, Industrial Switchgear or AWA installation instructions.

Fuses with 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.

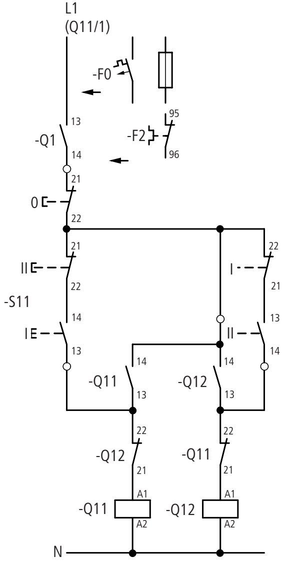


[1] Fuse size in accordance with data on the rating plate of the overload relay F2

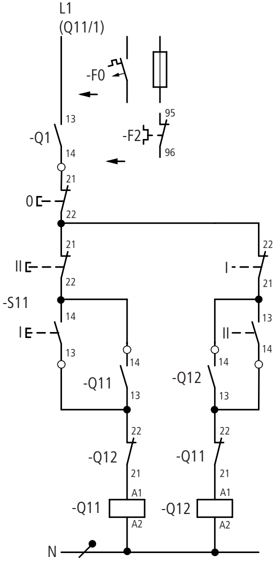
All about Motors

Direct-on-line start of three-phase motors

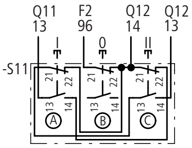
Reversing **after** actuation of pushbutton 0



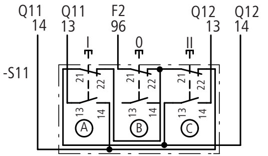
Reversing **without** actuation of pushbutton 0



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



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



All about Motors

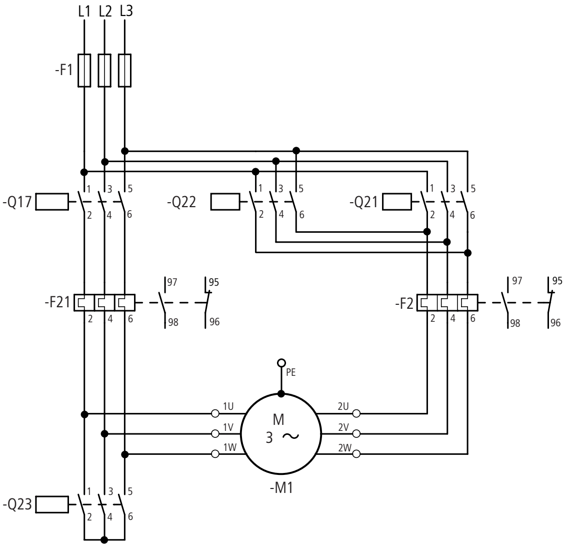
Direct-on-line start of three-phase motors

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 enabled via its own auxiliary contact Q11/14-13 and pushbutton 0 (three-wire control contact). The normally closed contact Q11/22-21 electrically inhibits switch on of contactor Q12. When pushbutton II is pressed, contactor Q12 closes (the motor runs in the anticlockwise direction). 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 normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker will switch.

Reversing and two speeds (reversing contactor)

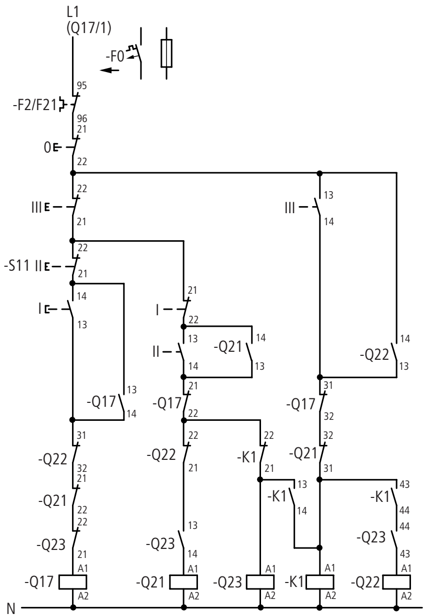
Special circuit (tapped winding) for feed drives, etc.

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



All about 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 – FORWARD (Q22 + Q23)

Q17: Feed forward
Q21: High speed forward
Q23: Star contactor
K1: Contactor relay
Q22: Retract high speed

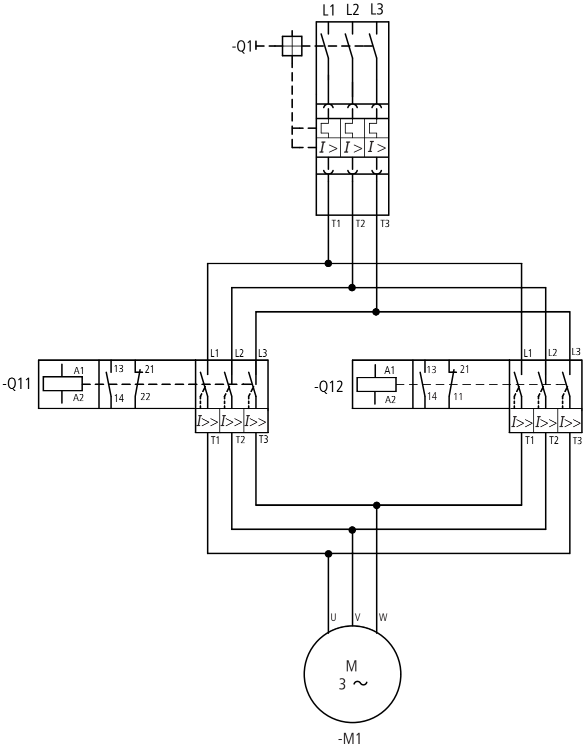
Method of operation: Forward travel is initiated by pressing pushbutton I or II according to the speed required. Pushbutton I switches on the feed motion via Q17. Q17 maintains itself via its normally open contact 13-14. If the feed movement is to occur at high speed star contactor Q23 is energized via pushbutton II which energizes the high speed contactor Q21 via its normally open contact 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 the normally open contacts, K1/43-44 and Q23/44-43, and are maintained via Q22/14-13. The reverse action can only be stopped via pushbutton 0. Direct changeover/reversal is not possible.

All about Motors

Direct-on-line start with motor-protective circuit-breaker PKZ2

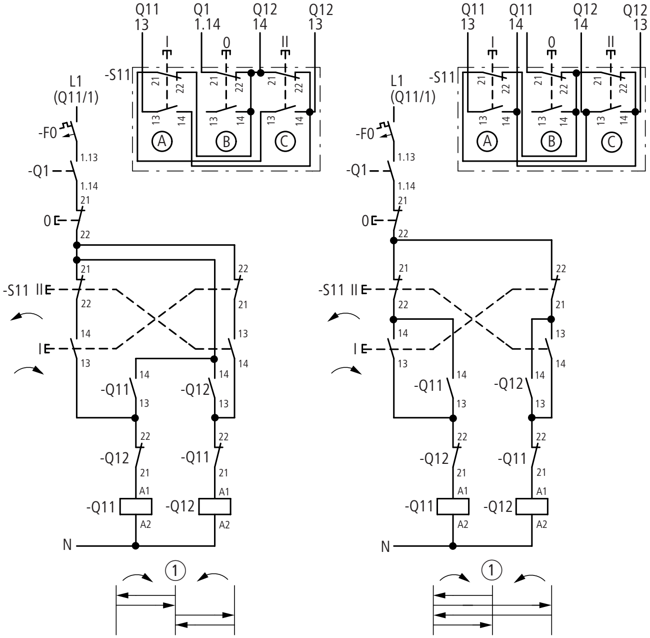
Reversing



Instead of the high-capacity contact modules S-PKZ2, contact module SE1A…-PKZ2 can also be used provided a switching capacity of the circuit-breaker of 30 kA/400 V is sufficient.

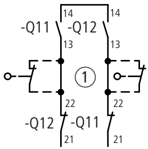
All about Motors

Direct-on-line start with motor-protective circuit-breaker PKZ2



① Stop

S11	RMQ-Titan, M22-…
Q1	PKZ2/ZM-…
Q12	S/EZ-PKZ2
Q11	S/EZ-PKZ2
F0	FAZ

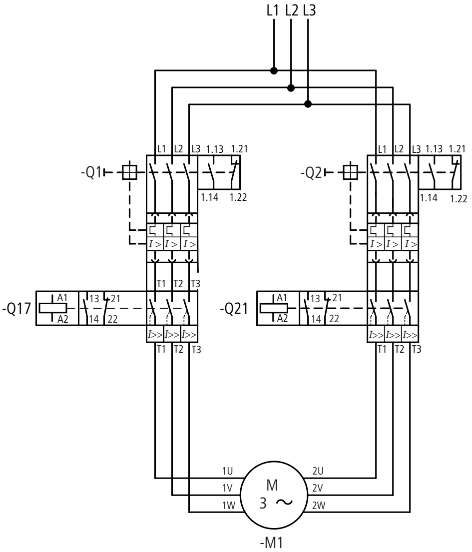


① remove links with position switches

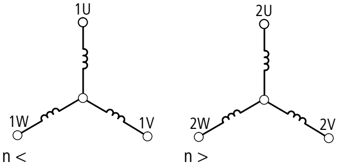
All about Motors

Direct-on-line start with motor-protective circuit-breaker PKZ2

Two speeds



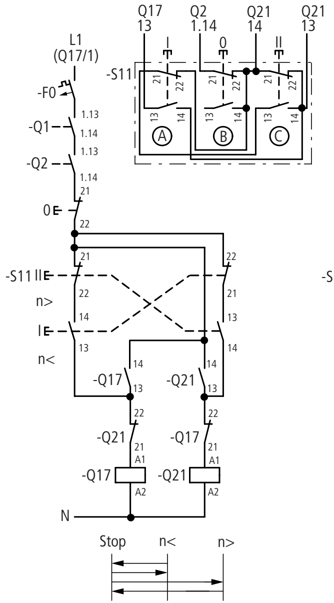
Instead of the high-capacity contact modules S-PKZ2, contact module SE1A…-PKZ2 can also be used provided a switching capacity of the circuit-breaker of 30 kA/400 V is sufficient.



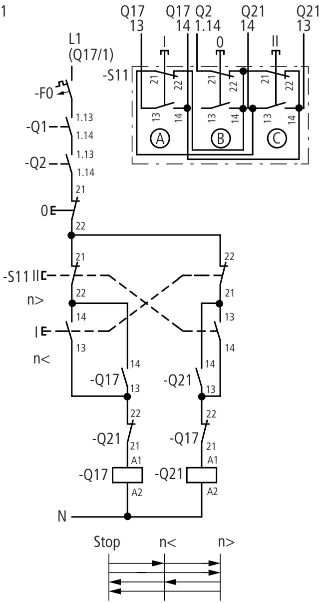
All about Motors

Direct-on-line start with motor-protective circuit-breaker PKZ2

Version 1



Version 2



S11	RMQ-Titan, M22-…	–
Q1, Q2	PKZ2/ZM-…/S	–
Q21	S-PKZ2	n >
Q17	S-PKZ2	n <
S11	RMQ-Titan, M22-…	–

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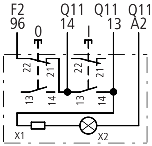
All about Motors

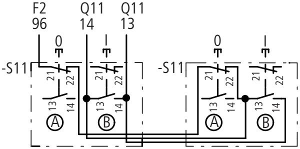
Control circuit device for direct-on-line start

Typical example of circuits with contactor DILM…

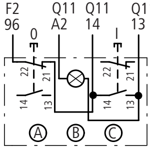
Three-wire control



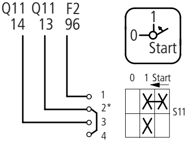
Illuminated pushbutton



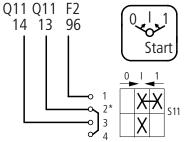
Two two-way pushbuttons



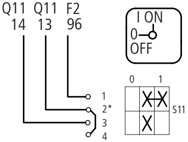
Two-way pushbutton with indicator light



T0-1-15511 spring-return switch with automatic return to position 1

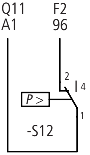


T0-1-15366 spring-return switch with automatic return to position of rest

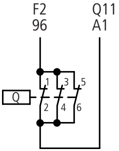


Changeover switch T0-1-15521 with fleeting contact in the intermediate position

Two-wire control



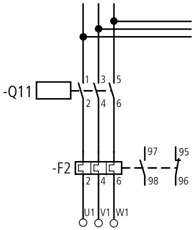
Pressure switch MCS



Float switch SW

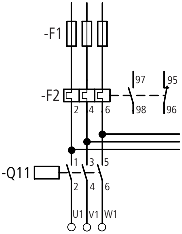
All about Motors
Star-delta switching of three-phase motors

Star-delta starters with overload relay



Arrangement in the motor line

The star-delta starter with overload relay, including a thermally delayed overcurrent relay are situated in a standard circuit configuration in the leads leading to the motor terminals U1, V1, W1 or V2, W2, U2. The overload relay is also operational in the star connection as it is in series with the motor winding and the relay current flowing through it = rated motor current × 0.58.
The complete circuit diagram → section "Automatic star-delta starters SDAINL", page 8-39.

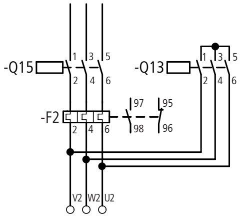


Arrangement in the mains supply line

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 differs from that on → section "Automatic star-delta starters SDAINL", page 8-39. For drives where the F2 relay trips out when the motor is starting in the star circuit, 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 circuit 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.

All about Motors

Star-delta switching of three-phase motors



Configuration in the delta circuit

Instead of the arrangement in the motor line or mains supply line, the overload relay can be placed in the delta circuit. The section shown here indicates the modified circuit diagram from → section "Automatic star-delta starters SDAINL", page 8-39. When heavy, long-starting procedures are involved (e.g. for centrifuges) the F2 relay, rated for relay current = rated motor current × 0.58, can also be connected in the connecting lines between the delta contactor Q15 and the star contactor Q13. In the star circuit no current then flows through the F2 relay. The motor is therefore not protected when starting. This circuit is always used when exceptionally heavy and long starting procedures are involved and when saturable core current transformer-operated relays react too quickly.

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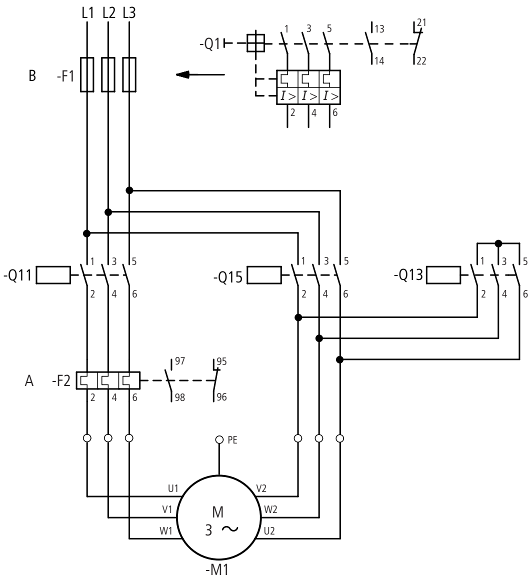
All about Motors

Star-delta switching of three-phase motors

Automatic star-delta starters SDAINL



Arrangement and rating of protective devices

Position A	Position B
F2 = 0.58 × I_e with F1 in position B t_a ≦ 15 s	Q1 = I_e t_a > 15 – 40 s
Motor protection in ⅄ and △ configuration	Only partial motor protection in ⅄ configuration

Rating of switchgear

Q11, Q15 = 0.58 × I_e

Q13 = 0.33 × I_e

All about Motors

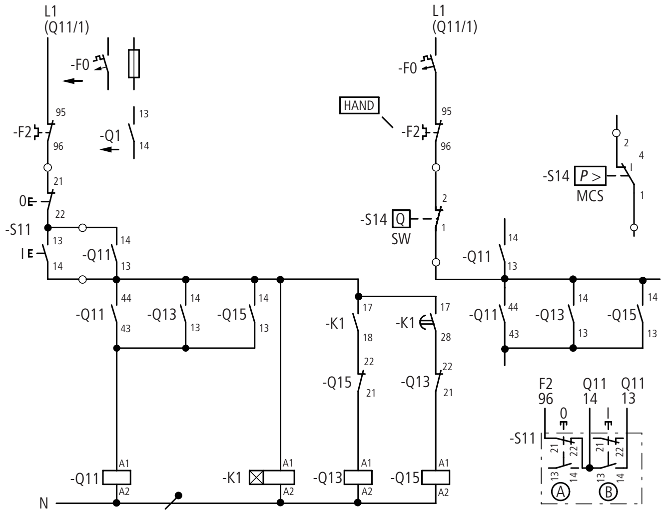
Star-delta switching of three-phase motors

Further notes on the configuration of the overload relay → section “Automatic star-delta starters SDAINL”, page 8-39.

Automatic star-delta starters SDAINL00AM to 4AM250

Pushbutton

Two-wire control



Q11: Mains contactor
K1: Timing relay approx. 10 s
Q13: Star contactor
Q15: Delta contactor

Two-way pushbutton
Control circuit device
I = ON
0 = OFF

For connection of further control circuit devices → section “Control circuit devices for star-delta starting”, page 8-49

Method of operation

Pushbutton I energizes timing relay K1, the normally open contact K1/17–18 (instantaneous contact) which applies voltage to star contactor Q13. Q13 closes and applies voltage to mains contactor Q11 via normally open contact Q13/14–13.

Q11 and Q13 maintain themselves via the normally open contacts Q11/14–13 and Q11/44–43. Q11 applies voltage to motor M1 in star connection.

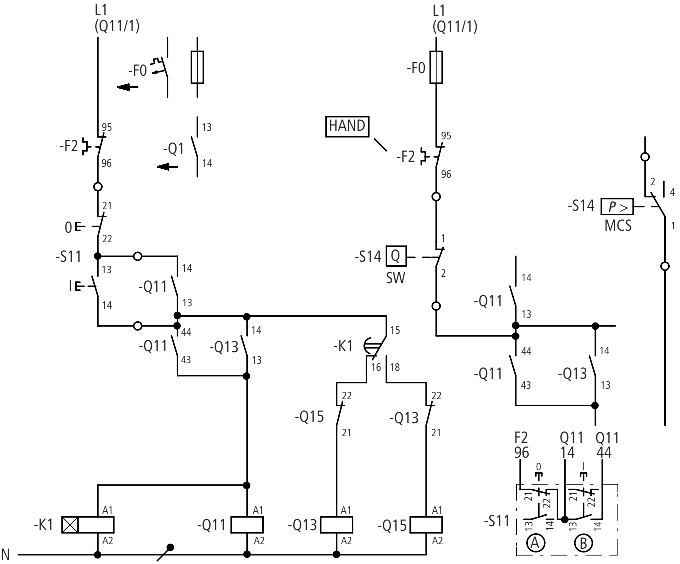
All about Motors
Star-delta switching of three-phase motors

When the set changeover time has elapsed, K1/17–18 opens the circuit of Q13 and after 50 ms closes the circuit via K1/17–28 of Q15 . 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 the overload relay F2, or via the normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

Automatic star-delta starters SDAINL EM

Pushbutton

Two-wire control



K1: Timing relay approx. 10 s
Q11: Mains contactor
Q13: Star contactor
Q15: Delta contactor

Two-way pushbutton
Control circuit device
I = ON
0 = OFF

All about Motors

Star-delta switching of three-phase motors

For connection of further control circuit devices → section "Control circuit devices for star-delta starting", page 8-49

Method of operation

Pushbutton I energizes star contactor Q13, the normally open contact Q13/14–13 applies voltage to mains contactor Q11: Q11 closes and applies mains voltage to motor M1 in star connection. Q11 and Q13 maintain themselves via normally open contact Q11/14–13 and Q11 additionally via Q11/44–43 and pushbutton 0. Timing relay Q11 is energized at the same time as mains contactor K1. When the set changeover time has elapsed, K1 opens the circuit of Q13 via the changeover contact 15–16 and closes the circuit of Q15 via 15–18. Star contactor Q13 drops out.

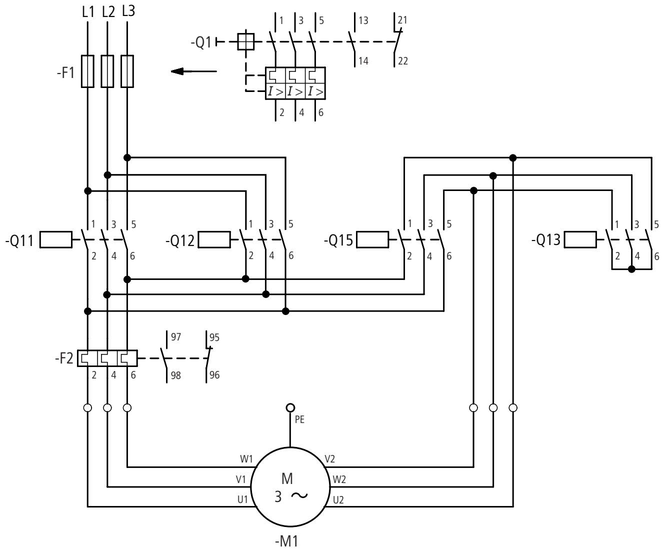
Delta contactor Q15 closes and switches motor M1 to full mains voltage. At the same time, normally closed contact Q15/22–21 interrupts the circuit of Q13, thus interlocking against renewed switching on while the motor is running.

The motor cannot be started 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 the overload relay F2, or via the normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

All about Motors
Star-delta switching of three-phase motors

Automatic reversing star-delta starter SDAIUL

Reversing



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 starters for only one direction of operation

Standard version: relay current = motor rated current × 0.58

For other arrangements of overload relay → section “Star-delta starters with overload relay”, page 8-37

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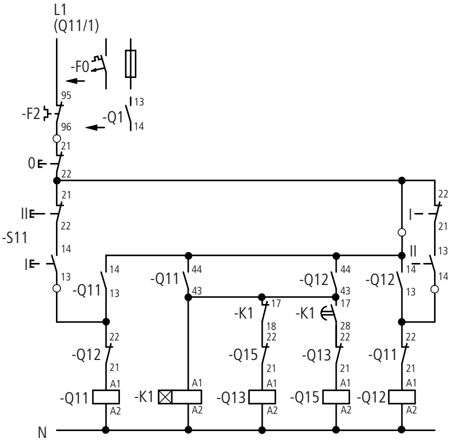
All about Motors

Star-delta switching of three-phase motors

Reversing after actuation of pushbutton 0



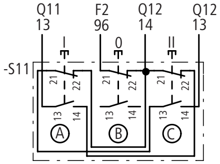
Three-way pushbutton

Control circuit devices

I = Clockwise

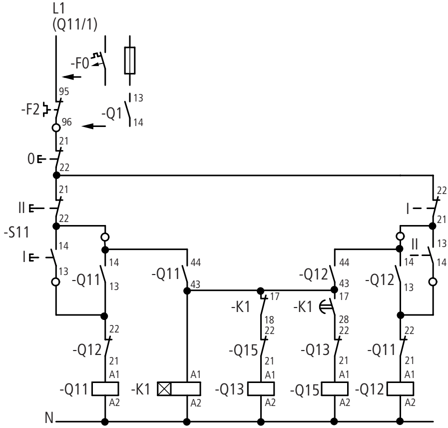
0 = Stop

II = Anticlockwise



All about Motors
Star-delta switching of three-phase motors

Reversing without actuation of pushbutton 0



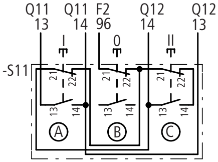
Three-way pushbutton

Control circuit devices

I = Clockwise

0 = Stop

II = Anticlockwise



For connection of further control circuit devices → section “Control circuit devices for star-delta starting”, page 8-49

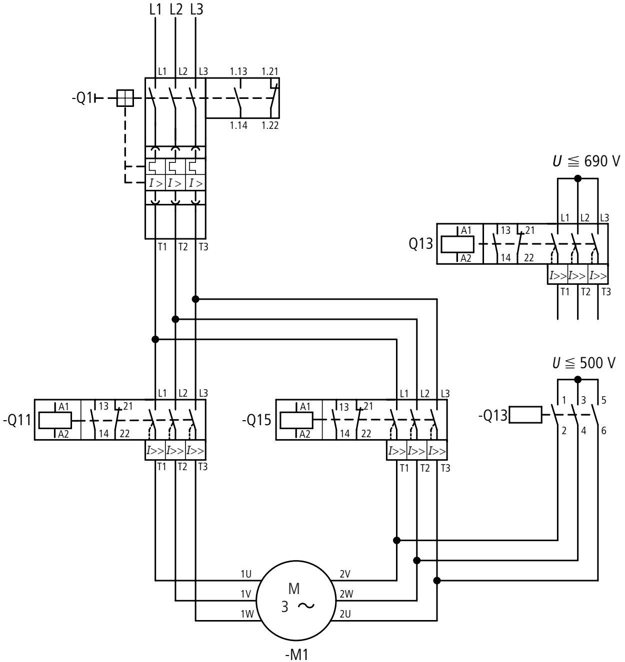
Method of operation

Pushbutton I energizes contactor Q11 (e.g. clockwise), pushbutton II energizes contactor Q12 (e.g. anticlockwise). 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 starts. 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 delta contactor 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.

All about Motors

Star-delta starting with motor-protective circuit-breaker PKZ2



With $I_{cc} > I_{cn}$ short-circuit proof installation required.

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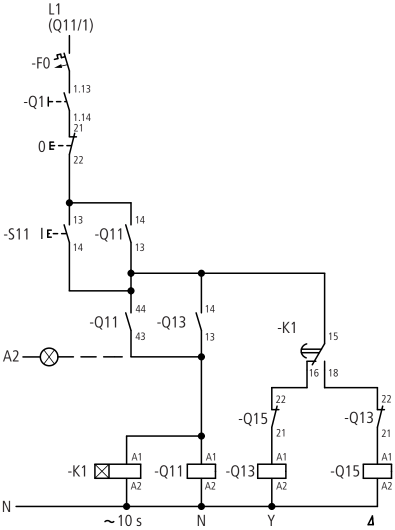
All about Motors

Star-delta starting with motor-protective circuit-breaker PKZ2



2 × RMQ-Titan, M22-… with indicator light M22-L…T0-1-8 rotary switch

All about Motors
Star-delta starting with motor-protective circuit-breaker PKZ2

S11	RMQ-Titan, M22-…			
Q1	PKZ2/ZM-…			
△Q15	S/EZ-PKZ2			
YQ13	DILOM $U_e \leqq$ 500 V AC			
YQ13	S/EZ-PKZ2 $U_e \leqq$ 660 V AC			
K1	ETR4-11-A	*t*	*t* Y (s)	15–40
Q11	S/EZ-PKZ2	N	Motor protection	(Y) + △
F0	FAZ		Setting	*I*

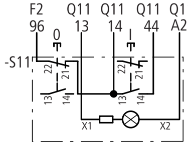
8

All about Motors

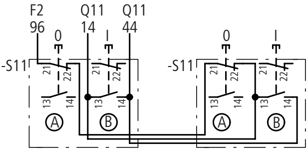
Control circuit devices for star-delta starting

Automatic star-delta starters SDAINL

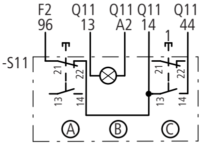
Three-wire control



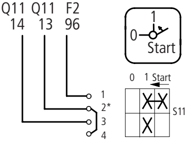
Illuminated pushbutton



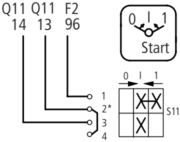
Two two-way pushbuttons



Two-way pushbutton with indicator light

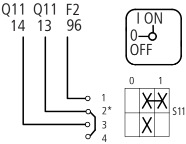


Spring-return switch T0-1-15511 with automatic return to position 1.

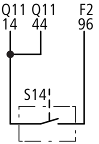


Spring-return switch T0-1-15366 with automatic return to position of rest.

Two-wire control



Changeover switch T0-1-15521 with fleeting contact in the intermediate position

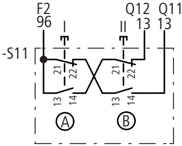


e.g. selector switch
Rotary switch T
Position switch AT
Float switch SW
Pressure switch MCS

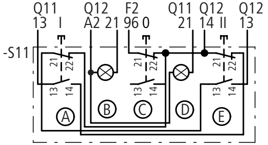
All about Motors

Control circuit devices for star-delta starting

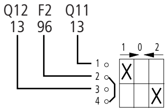
Three-phase reversing contactor DIUL reversing star-delta starter SDAIUL

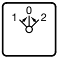


Two-way pushbutton[1] without self-maintaining circuit (inching) for use only with reversing contactors



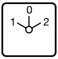
Three-way pushbutton with indicator light. Reversing after actuation of pushbutton 0





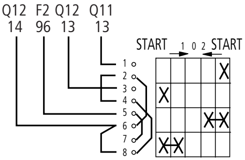
FS 4011

Spring-return switch [1] T0-1-8214, without self-maintaining circuit (inching)
Automatic return to 0 only for reversing contactors



FS 684

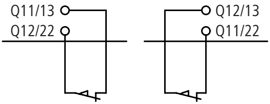
Changeover switch[1] Switch T0-1-8210 remains in position 1 or 2



FS 140660

Spring-return switch T0-2-8177 with automatic return to position 1 or 2

Position switch
Connected by removing the links between the contactor terminals Q11/13 and Q12/22 and between Q12/13 and Q12/22 and interposing the position switches.



[1] Overload relay always with manual reset

All about Motors
Pole-changing motors

The speed is determined by the number of poles on induction motors. Several speeds can be obtained by altering the number of poles. The usual types are:

2 speeds 1:2	1 reversible tapped winding
2 speeds	2 separate windings
3 speeds	1 reversible tapped winding 1:2, 1 separate winding
4 speeds	2 reversible tapped windings 1:2
2 speeds	Tapped winding

The various tapped winding configurations give differential output ratios for the two speeds

Type of connection	△/YY	Y/YY
Output ratio	1/1.5–1.8	0.3/1

The △/YY configuration comes nearest to satisfying the most usual requirement for constant torque. It has the additional advantage that, because nine terminals are available, Y/△ starting can be used to provide smooth starting or to reduce the starting current for the low speed condition (→ section “Motor windings”, page 8-54).

The Y/YY is preferred for better matching of the motor to machines in which the torque increases by a quadratic factor (pumps, fans, rotary compressors). Moeller multi-speed starters can be used for both types of connection.

2 speeds – separate windings

In theory, motors with separate windings allow any combination of speed and any output ratio. Both windings are arranged in Y connection and are completely independent of one another.

Preferred speed combinations are:

Motors with tapped winding	1500/3000	–	750/1500	500/1000
Motors with separate windings	–	1000/1500	–	–
No. of poles	4/2	6/4	8/4	12/6
Code no. low/high	1/2	1/2	1/2	1/2

The code numbers are prefixed to the main notations to denote increasing speed.
Example: 1U, 1V, 1W, 2U, 2V, 2W.
Comparable to EN 60034-8.

All about Motors

Pole-changing motors

Motor circuit

Circuit A

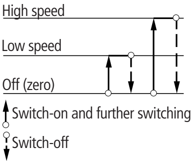
Selection of low and high speed only from zero. No return to low speed, only to zero.

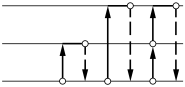
Circuit B

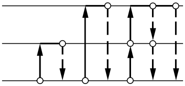
Selection of either speed from zero. Switching from low to high speed possible. Return only to zero.

Circuit C

Selection of either speed from zero. Switching back and forward between low and high speed (high braking torque). Return also to zero.







3 speeds

The 1:2 speeds - tapped windings - are supplemented by the speed of the separate winding. This speed can be below, between or above the two tapped winding speeds. The circuit must consider it (→ page 8-82).

Preferred speed combinations are:

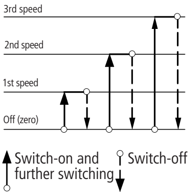
Speeds	1000/1500/3000	750/1000/1500	750/1500/3000	= separate winding (in the circuit diagrams)
No. of poles	6/4/2	8/6/4	8/4/2	
Circuit	X	Y	Z	

All about Motors
Pole-changing motors

Motor circuit

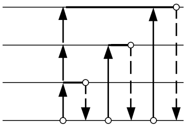
Circuit A

Selection of any speed only from zero. Return only to zero.



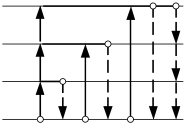
Circuit B

Selection of any speed from zero and from low speed. Return only to zero.



Circuit C

Selection of any speed from zero and from low speed. Return to low speed (high braking torque) or to zero.



4 speeds

The 1:2 speeds - tapped windings - can follow in sequence or overlap, as the following examples show:

1st winding	500/1 000	2nd winding	1 500/3 000 = 500/1 000/1 500/3 000
or 1st winding	500/1 000	2nd winding	750/1 500 = 500/750/1 000/1 500

For motors having 3 or 4 speeds the non-connected winding has to be opened at certain pole ratios to avoid inductive circulating currents. This is achieved via additional motor terminals. A range of rotary switches is equipped with this connection (→ section "Multi-Speed Switches", page 4-7).

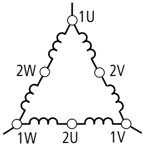
All about Motors

Motor windings

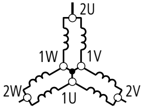
Tapped winding

2 speeds

Low speed △

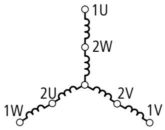


High speed YY

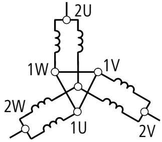


→ page 8-59

Low speed Y



High speed YY

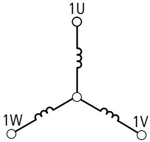


→ page 8-59

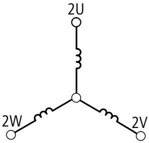
Motor circuit

2 speeds
2 separate windings

Low speed



High speed

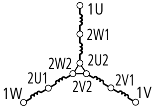


→ page 8-63

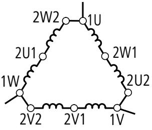
Tapped winding

with Y△ starting at low speed

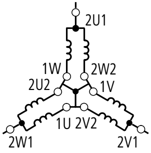
Low speed Y



Low speed △



High speed YY



→ page 8-72

All about Motors
Motor windings

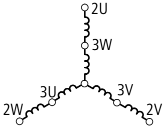
Tapped winding

3 speeds

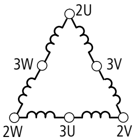
Motor circuit X

2 windings, medium and high speed – tapped winding

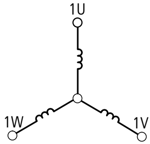
2



or 2



Low speed
Separate winding
1

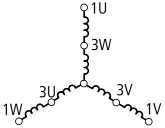


→ page 8-81

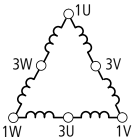
Motor circuit Y

2 windings, low and high speed – tapped winding

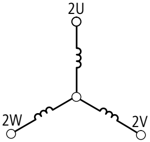
2



or 2



Medium speed
Separate winding
1

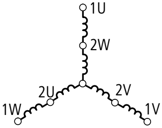


→ page 8-83

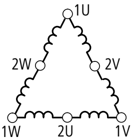
Motor circuit Z

2 windings, low and medium speed – tapped winding

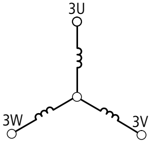
2



or 2



High speed
Separate winding
1



→ page 8-85

Notes

All about Motors

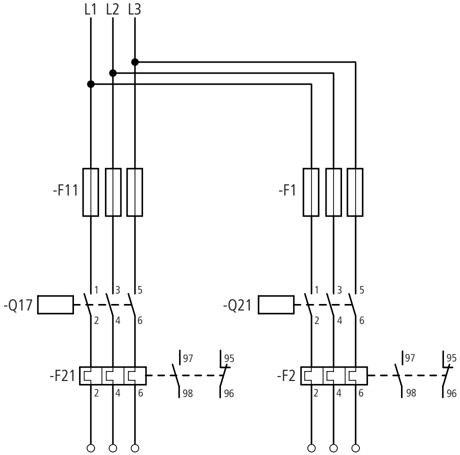
Multi-speed contactor

Certain operating sequences for multi-speed motors may be necessary, or undesirable, depending on the nature of the drive. If, for example, the starting temperature rise is to be reduced or high inertia loads are to be accelerated, it is advisable to switch to low speed first and then to high speed.

It may be necessary to prevent switching from high to low speed in order to avoid oversynchronous braking. In other cases, it should be possible to switch each speed on and off directly. The operating sequence and indexing facilities of rotary switches allow for these possibilities. Multi-speed contactor starters can achieve these circuits by interlocking with suitable control circuit devices.

Fuse protection of the overload relay

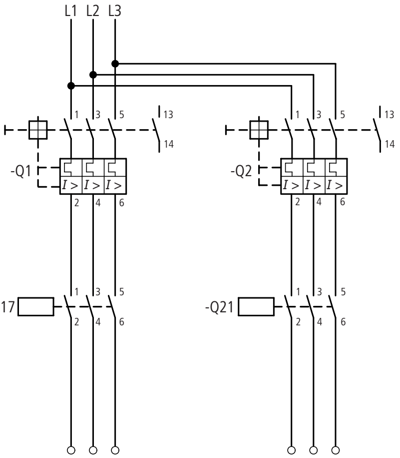
When a common fuse is used in the supply line, it must not be larger than the back-up fuses specified on the rating plate of either overload relay, otherwise each relay must be protected by its own back-up fuse, as shown in the diagram.



All about Motors
Multi-speed contactor

Fuseless arrangement

Multi-speed motors can be protected against short circuits and overloads by motor-protective circuit-breakers PKZ or circuit-breakers NZM, which provide all the advantages of a fuseless circuit. Normally, the fuse in the supply line protects the switches from welding.

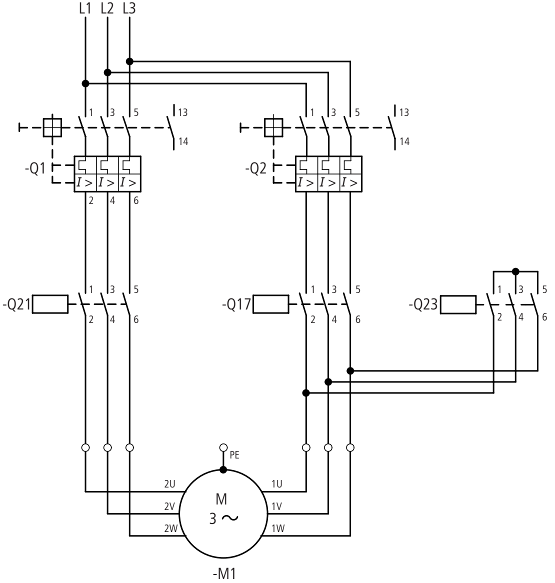


All about Motors

Multi speed switch for three-phase motors

Tapped winding, non-reversing, 2 speeds

Multi-speed contactors UPIL
Fuseless, without overload relay, with motor-protective circuit-breaker or circuit-breaker.



→ section “Motor windings”, page 8-54

Synchronous speeds
One multi-speed winding

All about Motors

Multi speed switch for three-phase motors

Motor terminals	1U, 1V, 1W	2U, 2V, 2W
No. of poles	12	6
rpm	500	1 000
No. of poles	8	4
rpm	750	1 500
No. of poles	4	2
rpm	1 500	3 000
Contactors	Q17	Q21, Q23

Rating of switchgear

Q2, Q17 = I_1 (low speed)

Q1, Q21 = I_2 (high speed)

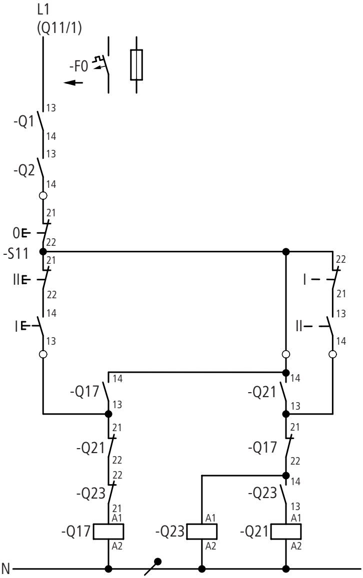
Q23 = 0.5 x I_2

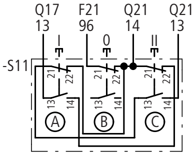
All about Motors

Multi speed switch for three-phase motors

Circuit A (→ page 8-53)

1 three-way pushbutton





Three-way pushbutton

I: Low speed (Q17)

0: Stop

II: High speed (Q21 + Q23)

Q17: Mains contactor, low speed

Q23: Star contactor

Q21: Mains contactor, high speed

For connection of further control circuit devices → page 8-67, **→** page 8-68, **→** page 8-69

Method of operation

Pushbutton I energizes mains contactor Q17 (low speed). Q17 maintains itself via its normally open contact 13 – 14. Pushbutton II energizes star contactor Q23 and via its normally open contact 13–14 mains contactor Q21. Q21 and Q23 maintain themselves via normally open contact 13 – 14 of Q21.

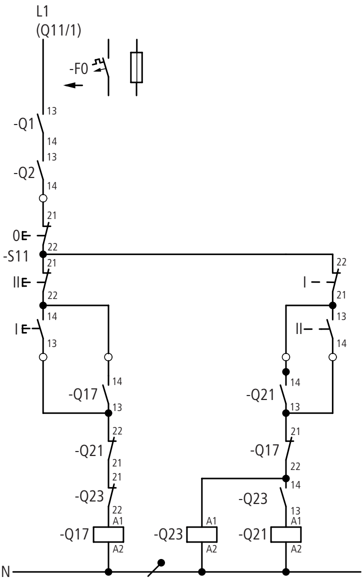
Speed can be changed either after pressing pushbutton 0 (circuit A) or directly by pressing the appropriate pushbutton (circuit C), depending upon the circuit. The motor can be switched off either by pressing pushbutton 0, or in the event of an overload, by normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

All about Motors

Multi speed switch for three-phase motors

Circuit C (→ page 8-53)

1 three-way pushbutton

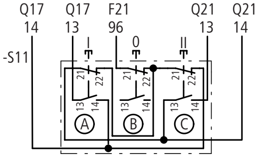


Three-way pushbutton

I: Low speed (Q17)

0: Stop

II: High speed (Q21 + Q23)



Q17: Mains contactor, low speed

Q23: Star contactor

Q21: Mains contactor, high speed

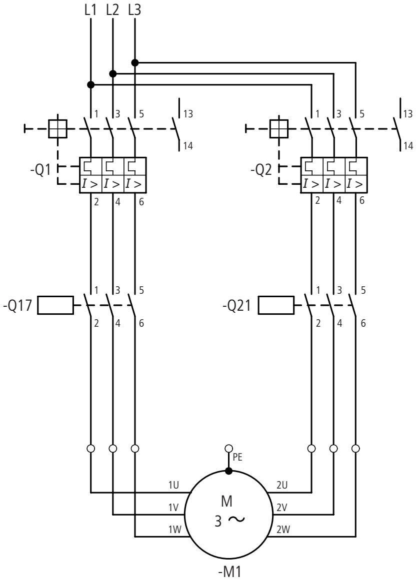
For connection of further control circuit devices → page 8-70

All about Motors

Multi speed switch for three-phase motors

2 separate windings, non-reversing, 2 speeds

Multi-speed contactor UPDIUL, fuseless
without overload relay



Rating of switchgear

Q1, Q17 = I_1 (low speed)

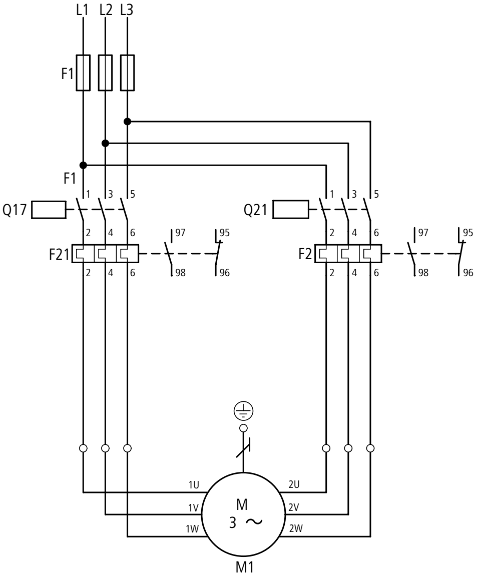
Q2, Q21 = I_2 (high speed)

All about Motors

Multi speed switch for three-phase motors

2 separate windings, non-reversing, 2 speeds

Multi-speed contactor UPDIUL, with fuses and overload relay

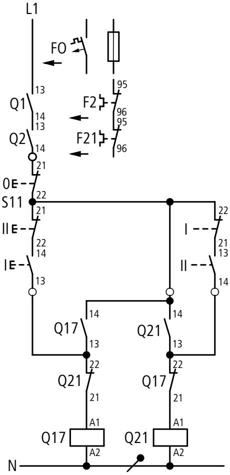


Fuse size in accordance with data on the rating plate of the overload relays F2 and F21. If overload relays F2 and F21 cannot be protected by a common fuse, then use circuit as in → page 8-57. → section "Motor windings", page 8-54.

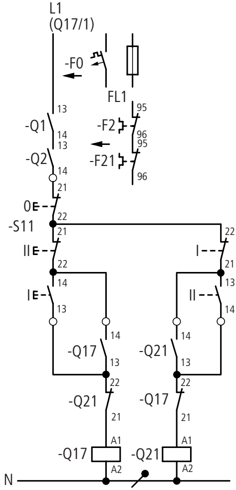
All about Motors

Multi speed switch for three-phase motors

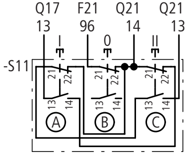
Circuit A (→ page 8-53)
1 three-way pushbutton

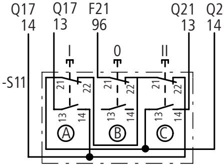


Circuit C (→ page 8-53)
1 three-way pushbutton



Q17: Mains contactor, low speed
Q21: Mains contactor, high speed





Three-way pushbutton

I: Low speed (Q17)
0: Stop
II: High speed (Q21 + Q23)

For connection of further control circuit devices, see → page 8-71.

8

All about Motors
Multi speed switch for three-phase motors

Method of operation
Actuation of pushbutton I energizes the coil of contactor Q17. Q17 brings in the motor at low speed, and after pushbutton I is released, maintains itself via its auxiliary contact 13–14 and pushbutton 0.

Speed can be changed either after pressing pushbutton 0, or directly by pressing the appropriate pushbutton, depending upon the circuit. The motor is switched off either by pressing pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of overload relays F2 and F21.

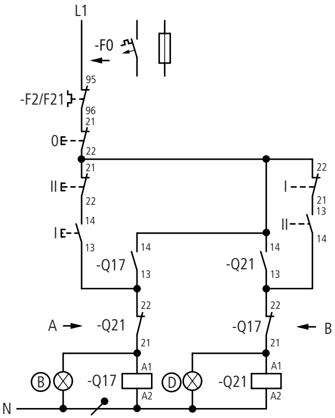
All about Motors

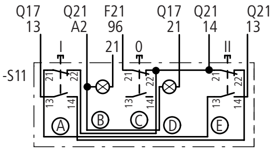
Control circuit devices for multi-speed contactors UPDIUL

2 separate windings, non-reversing, 2 speeds

Circuit A (→ page 8-53)

One three-way pushbutton with indicator lights





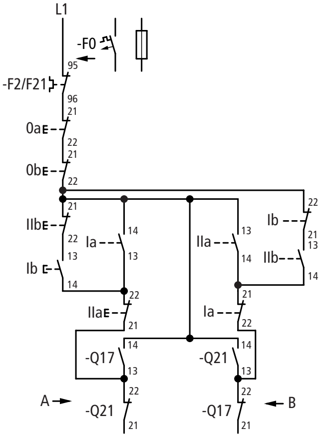
Control circuit devices

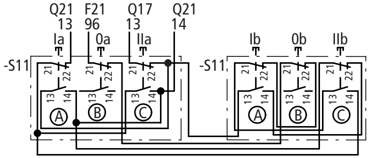
I = Low speed (Q17)
0 = Stop
II = High speed (Q21)

All about Motors

Control circuit devices for multi-speed contactors UPDIUL

Circuit A (→ page 8-53) 2 three-way pushbuttons





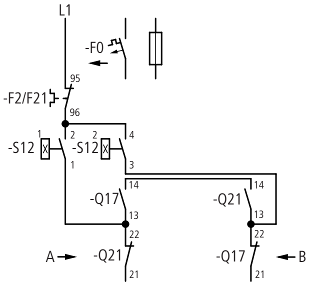
Control circuit devices

I: Low speed (Q17)
0: Stop
II: High speed (Q21)
Remove existing links and rewire

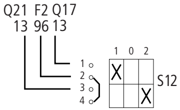
All about Motors

Control circuit devices for multi-speed contactors UPDIUL

Circuit A (→ page 8-53)

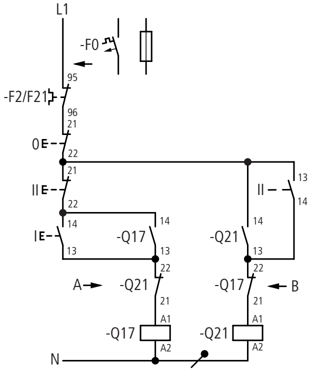


T0-1-8210 changeover switch
Always set overload relay to manual reset



Circuit B (→ page 8-53)

1 three-way pushbutton



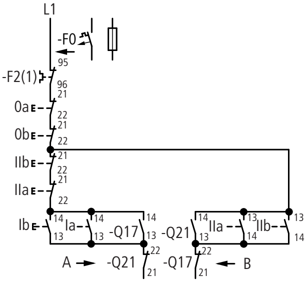
8

All about Motors

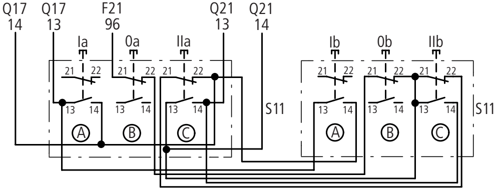
Control circuit devices for multi-speed contactors UPDIUL

Circuit B (→ page 8-53)

2 three-way pushbuttons



Control circuit device for circuit B

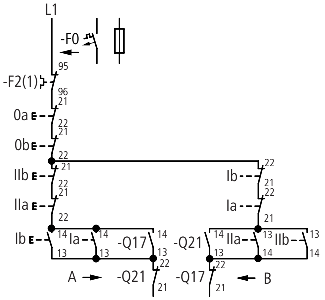


All about Motors

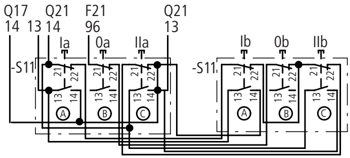
Control circuit devices for multi-speed contactors UPDIUL

Circuit C (→ page 8-53)

2 three-way pushbuttons



Control circuit device for circuit C

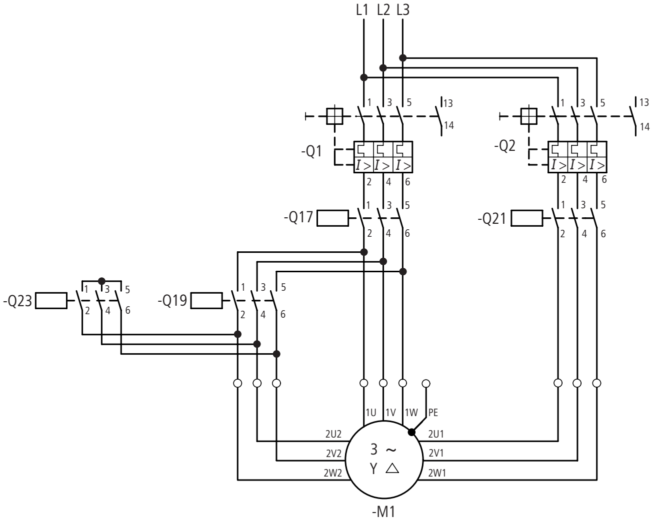


All about Motors
Multi speed switch for three-phase motors

Tapped winding, non-reversing, 2 speeds

Multi-speed contactors UPSDAINL
Star-delta starting at low speed

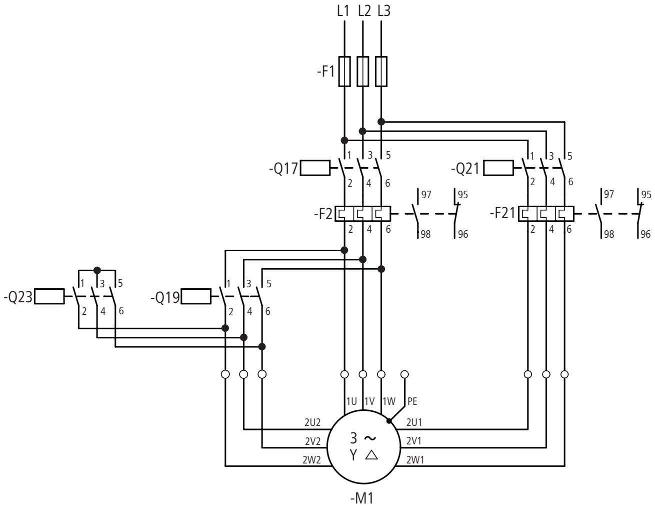
Fuseless
Without overload relay



Rating of switchgear
Q1, Q17 $= I_1$
(low speed)
Q2, Q21 $= I_2$
(high speed)
Q19, Q23 $= 0{,}5 \times I_2$

All about Motors
Multi speed switch for three-phase motors

With **fuses** and overload relay



Rating of switchgear

F2, Q17 $= I_1$

(low speed)

F21, Q21 $= I_2$

(high speed)

Q19, Q23 $= 0{,}5 \times I_2$

F1 $= I_2$

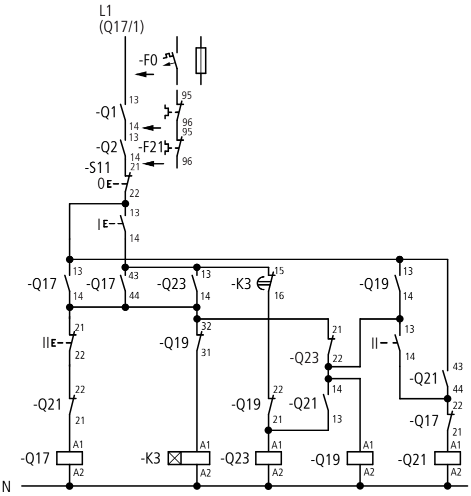
Overload relays F2 and F21 are not used on multi-speed contactors without motor protection. If F2 and F21 cannot be protected by a common fuse, then use circuit on

→ page 8-57.

→ section “Motor windings”, page 8-54.

All about Motors

Multi speed switch for three-phase motors



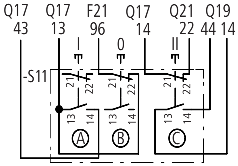
Circuit

Low speed selected only from zero, high speed only via low speed without actuation of the Stop button.

Three-way pushbutton

- I: Low speed (Q17, Q19)
- 0: Stop
- II: High speed (Q21, Q19, Q23)

Q17: Mains contactor, low speed
K3: Timing relay
Q23: Star contactor
Q19: Delta contactor
Q21: Mains contactor, high speed



Method of operation

Actuation of pushbutton I energizes the coil of star contactor Q23, and its normally open contact 13–14 energizes the coil of contactor Q17. The motor runs in star at low speed. The contactors are maintained via auxiliary contact Q17/13–14. At the same time, timing relay K3 cuts in. When the set time has elapsed, K3/15–16 opens the circuit of Q23. Q23 drops out, the coil of delta contactor Q19 is energized and maintains itself via Q19/13–14. The timing relay is de-energized via normally closed contact Q19/32–31.

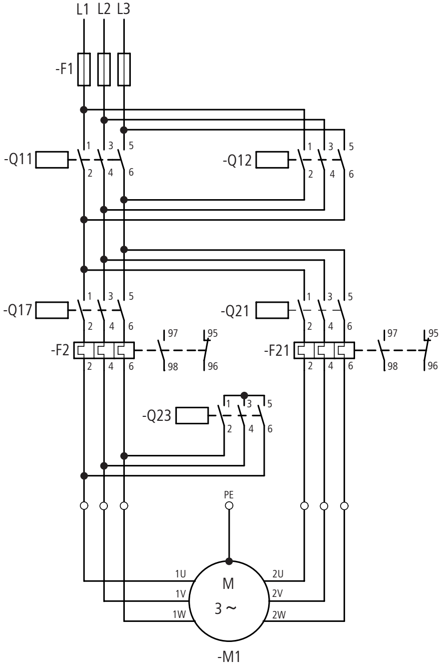
The motor runs in delta at low speed. Actuation of pushbutton II de-energizes the coil of Q17 and via Q17/22–21 energizes the coil of Q21. This state is maintained by Q21/43–44: The coil of star contactor Q23 is re-energized by normally open contact Q21/14–13. The motor runs at high speed. Pushbutton 0 (= Stop) effects disconnection.

All about Motors
Multi speed switch for three-phase motors

Tapped winding, reversing, 2 speeds (direction preselected)

Multi-speed contactors UPIUL

Overload relays F2 and F21 are not used on multi-speed contactors without motor protection.

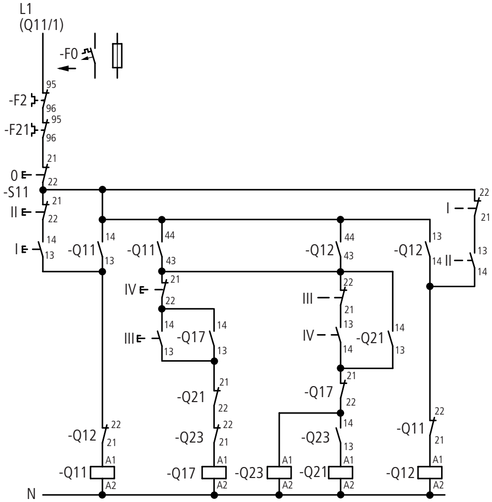


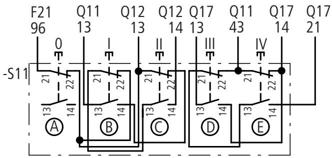
Rating of switchgear
Q11, Q12 = I_2 (low and high speed)
F2, Q17 = I_1 (low speed)
F1, Q21 = I_2
Q23 = 0.5 × I_2 (high speed)

All about Motors
Multi speed switch for three-phase motors

Five-way pushbutton

Circuit
Change of direction FORWARD–REVERSE after actuation of Stop button, optionally followed by SLOW–FAST with no return to low speed.





Control circuit device

0: Stop
I: Forward (Q11)
II: Back (Q12)
III: Slow (Q17)
IV: Fast (Q21 + Q23)

Method of operation

Contactor Q11 is energized by pressing pushbutton I. Contactor Q11 selects the direction, and maintains itself after release of pushbutton I via its auxiliary contact 14–13 and pushbutton 0. Speed-selection buttons III and IV are made operative by Q11/44–43.

Pushbutton III energizes Q17, which maintains itself via its contact 14–13. Pushbutton IV energizes high-speed contactors Q23 and Q21. Auxiliary contact Q21/21–22 makes low-speed pushbutton III inoperative. Pushbutton 0 must be pressed before any change in speed or direction.

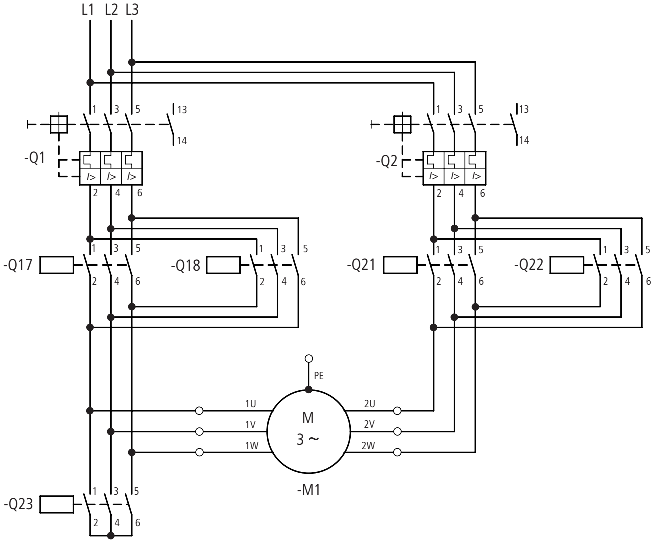
All about Motors

Multi speed switch for three-phase motors

Tapped winding, reversing, 2 speeds (Direction and speed selected simultaneously)

Multi-speed contactor UPIUL

Fuseless without overload relay



Rating of switchgear

Q1, Q17, Q18 = I_1
(low speed)

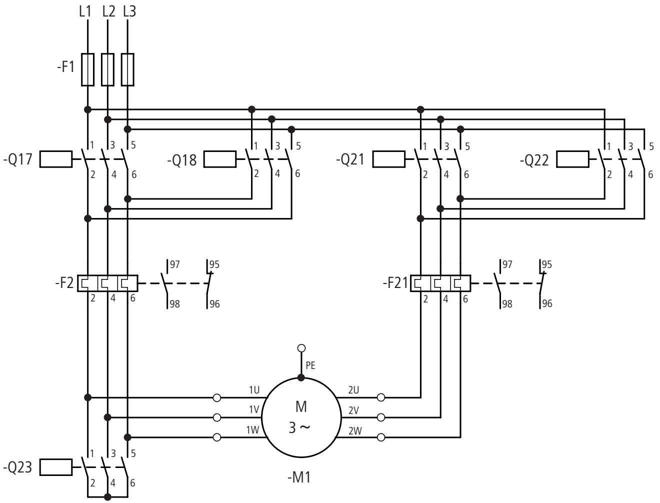
Q2, Q21, Q22 = I_2

Q23 = 0.5 × I_2
(high speed)

All about Motors
Multi speed switch for three-phase motors

Multi-speed contactor UPIUL

With **fuses** and overload relay



Rating of switchgear

F2, Q17, Q18 = I_1
(low speed)

F21, Q21, Q22 = I_2

Q23 = 0.5 × I_2
(high speed)

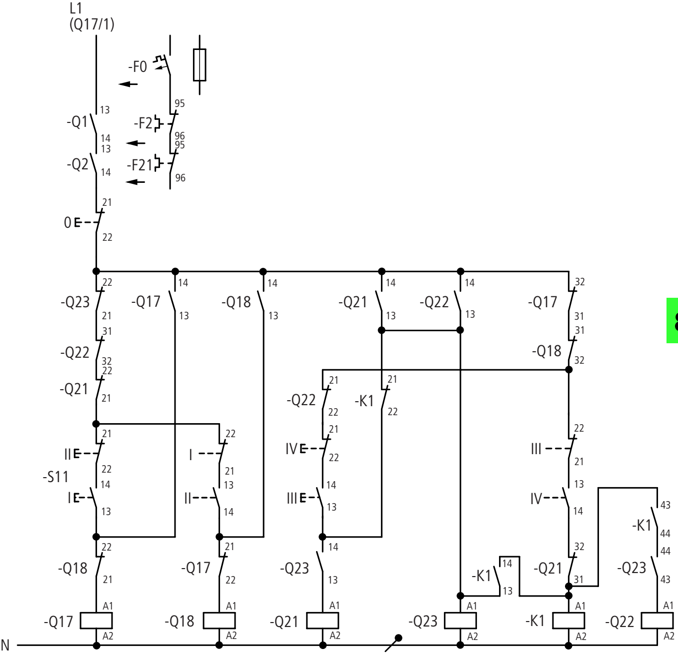
Overload relays F2 and F21 are not used on multi-speed contactors without motor protection

All about Motors

Multi speed switch for three-phase motors

Circuit

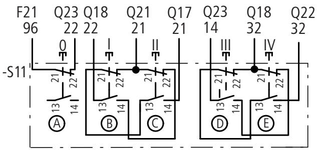
Simultaneous selection of direction and speed via one pushbutton. Always operate Stop button before changeover.



Q17: Slow forward
Q18: Slow back
Q21: Fast forward
Q23: Star contactor
K1: Contactor relay
Q22: Fast back

All about Motors

Multi speed switch for three-phase motors



Five-way pushbutton

Control circuit device

0: Stop
I: Slow forward (Q17)
II: Slow back (Q18)
III: Fast forward (Q21 + Q23)
IV: Fast back (Q22 + Q23)

Method of operation

Desired speed and direction can be selected by actuation of the appropriate pushbutton. Contactors Q17, Q18, Q21 and Q23 maintain themselves by their contact 14–13 and can be de-energized only by actuation of pushbutton 0. Contactors Q21 and Q22 can maintain themselves only when Q23 has picked up and contact Q23/13/13–14 or 44–43 is closed.

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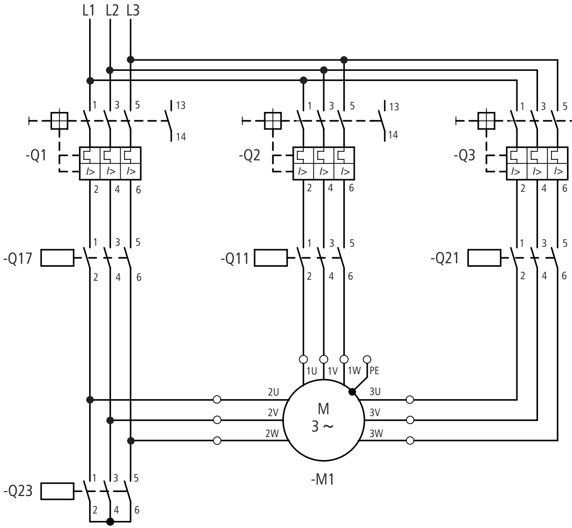
All about Motors
Multi speed switch for three-phase motors

Tapped winding, medium and high speed, non reversing, 3 speeds, 2 windings

Multi-speed contactor U3PIL

Multi-speed contactor U3PIL **with** overload relay → page 8-83



→ section “Motor circuit X”, page 8-55

Synchronous speed

Winding	**1**	**2**	**2**
Motor terminals	1U, 1V, 1W	2U, 2V, 2W	3U, 3V, 3W
No. of poles	12	8	4
Rpm	500	750	1 500
No. of poles	8	4	2
Rpm	750	1500	3 000

No. of poles	6	4	2
Rpm	1 000	1 500	3 000
Contactors	Q11	Q17	Q21, Q23

Rating of switchgear

Q2, Q11 $= I_1$ (low speed)

Q1, Q17 $= I_2$ (medium speed)

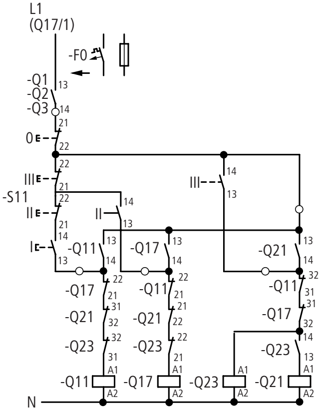
Q3, Q21 $= I_3$ (high speed)

Q23 $= 0.5 \times I_3$

All about Motors

Multi speed switch for three-phase motors

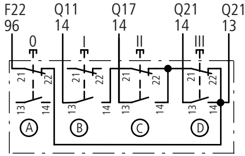
Circuit of motor winding: X
Circuit A



Q11: Low speed winding 1
Q17: Medium speed winding 2
Q23: High speed winding 2
Q21: High speed winding 2

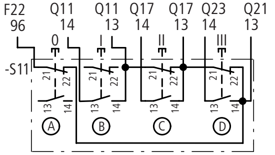
Circuit A

Selection of any speed only from zero. No return to low speed, only to zero.



Circuit B

Selection of any speed from zero or from low speed. Return only to zero.



Four-way pushbutton
0: Stop
I: Low speed (Q11)
II: Medium speed (Q17)
III: High speed (Q21 + Q23)

Method of operation

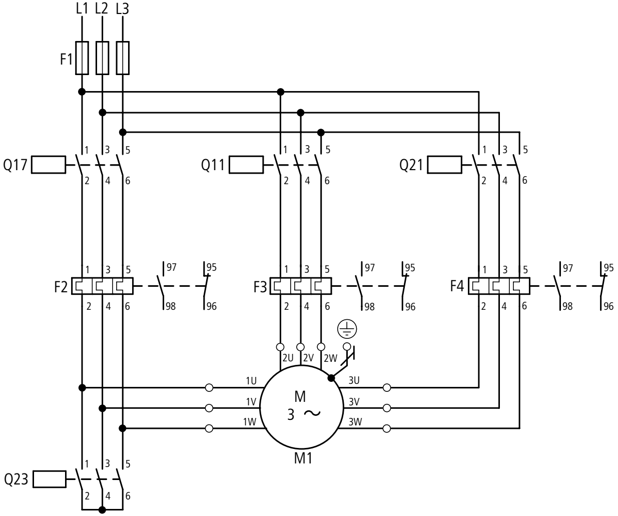
Pushbutton I energizes mains contactor Q11 (low speed), pushbutton II mains contactor Q17 (medium speed), pushbutton III star contactor Q23 and via its normally open contact Q23/14–13 mains contactor Q21 (high speed). All contactors maintain themselves by their auxiliary contact 13–14. Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker can also switch off.

All about Motors
Multi speed switch for three-phase motors

Tapped winding, low and high speed, non-reversing, 3 speeds, 2 windings

Multi-speed contactor U3PIL

Multi-speed contactor U3PIL **without** overload relay → page 8-81



→ section "Motor circuit Y", page 8-55

Synchronous speed

Winding	**2**	**1**	**2**
Motor terminals	1U, 1V, 1W	2U, 2V, 2W	3U, 3V, 3W
No. of poles	12	8	6
Rpm	500	750	1000
No. of poles	8	6	4

Rpm	750	1000	1500
Contactors	Q17	Q11	Q21, Q23

Rating of switchgear

F2, Q17 $= I_1$ (low speed)

F3, Q11 $= I_2$ (medium speed)

F4, Q21 $= I_3$ (high speed)

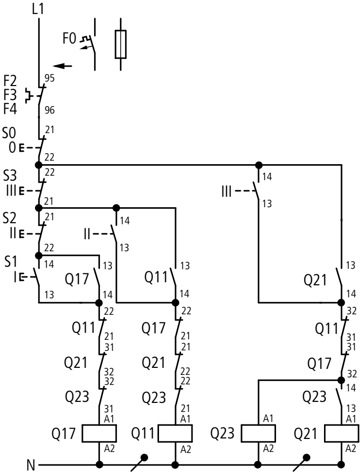
Q23 $= 0.5 \times I_3$

8

All about Motors

Multi speed switch for three-phase motors

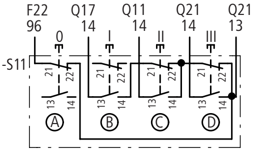
Circuit of motor winding: Y
Circuit A



Q17: Low speed winding 1
Q11: Medium speed winding 1
Q23: High speed winding 2
Q21: High speed winding 2

Circuit A

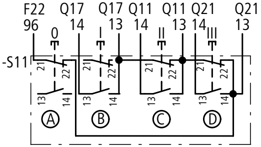
Selection of any speed only from zero. No return to low speed, only to zero.



Circuit B

Selection of any speed from zero or from low speed. Return only to zero.
Four-way pushbutton

0: Stop
I: Low speed (Q17)
II: Medium speed (Q11)
III: High speed (Q21 + Q22)



Method of operation

Pushbutton I energizes mains contactor Q17 (low speed), pushbutton II mains contactor Q11 (medium speed), pushbutton III star contactor Q23 and via its normally open contact Q23/14–13 mains contactor Q21 (high speed). All contactors maintain themselves by their auxiliary contact 13–14.

Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally closed contact 95–96 of overload relays F2, F21 and F22 can also switch off.

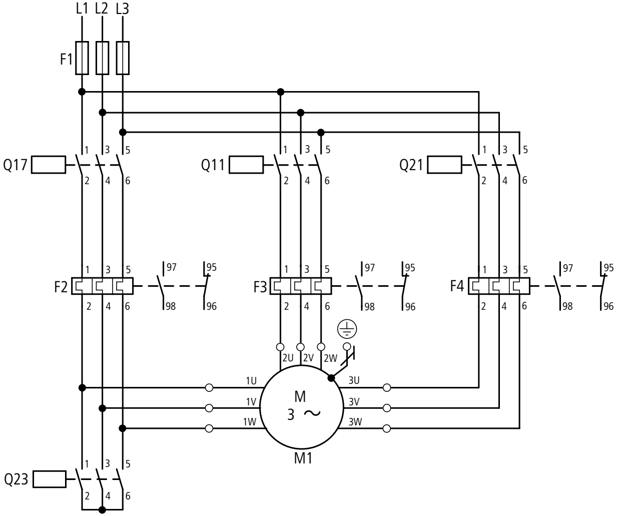
All about Motors

Multi speed switch for three-phase motors

Tapped winding, low and medium speed, non-reversing, 3 speeds, 2 windings

Multi-speed contactor U3PIL

Multi-speed contactor U3PIL **without** overload relay → page 8-57



→ section "Motor circuit Z", page 8-55

Synchronous speed

Winding	**2**	**2**	**1**
Motor terminals	1U, 1V, 1W	2U, 2V, 2W	3U, 3V, 3W
No. of poles	12	6	4
Rpm	500	1000	1500
No. of poles	12	6	2
Rpm	500	1000	3000
No. of poles	8	4	2

Rpm	750	1500	3000
Contactors	Q17	Q21, Q23	Q11

Rating of switchgear

F2, Q17 = I_1 (low speed)

F4, Q21 = I_2 (medium speed)

F3, Q11 = I_3 (high speed)

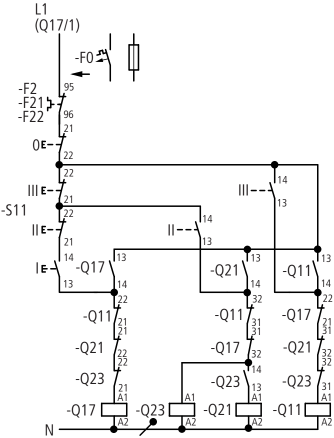
Q23 = $0.5 \times I_3$

8

All about Motors

Multi speed switch for three-phase motors

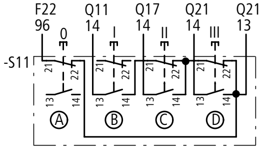
Circuit of motor winding: Z
Circuit A



Q17: Low speed winding 1
Q23: Medium speed winding 2
Q21: Medium speed winding 2
Q11: High speed winding 1

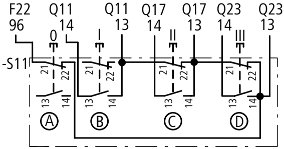
Circuit A

Selection of any speed from zero. No return to low speed, only to zero.



Circuit B

Selection of any speed from zero or from low speed. Return only to zero.



Four-way pushbutton
0: Stop
I: Low speed (Q17)
II: Medium speed (Q21 + Q23)
III: High speed (Q11)

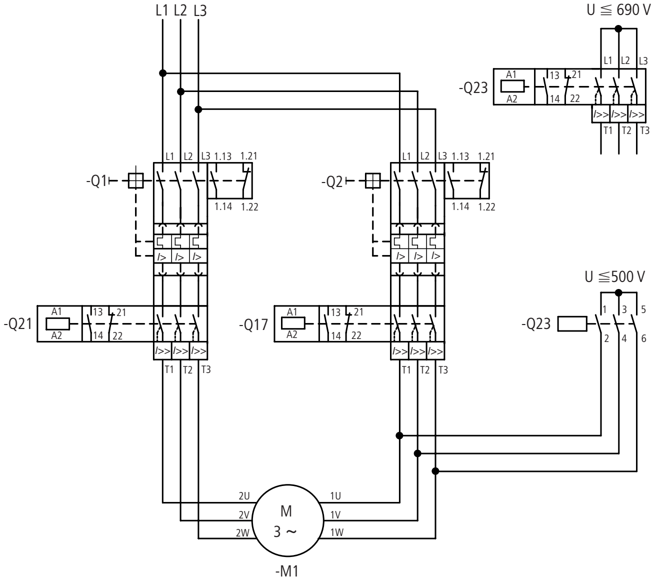
Method of operation

Pushbutton I energizes mains contactor Q17 (low speed), pushbutton II mains contactor Q23 and via its normally open contact Q23/14–13 mains contactor Q21 (high speed / medium speed), pushbutton III mains contactor Q11. All contactors maintain themselves by their auxiliary contact 13–14.

Speed sequence from low to high is optional. Switching in steps from high to medium or low speed is not possible. The motor is always switched off by pressing pushbutton 0. In the event of an overload, normally closed contact 95–96 of overload relays F2, F21 and F22 can also switch off.

All about Motors

Multi speed switch with motor-protective circuit-breaker PKZ2

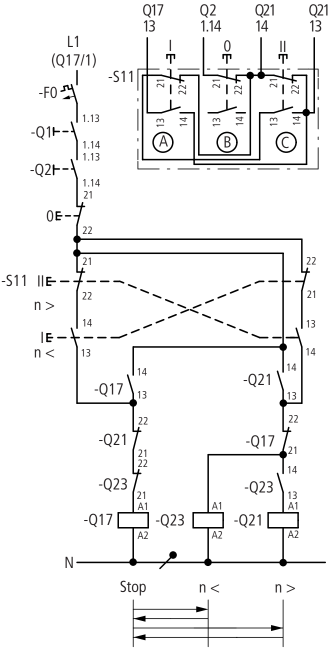


No. of poles	12	6
Rpm	500	1000
No. of poles	8	4
Rpm	750	1500
No. of poles	4	2
Rpm	1500	3000

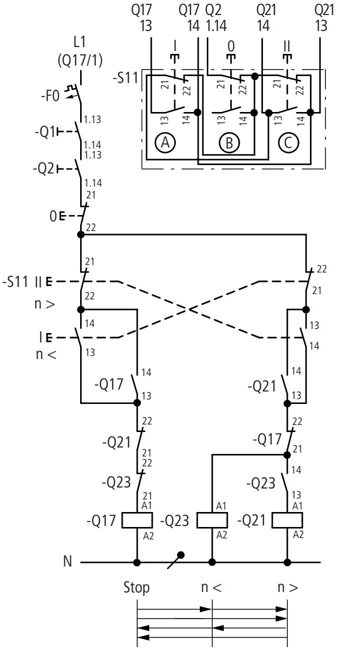
8

All about Motors

Multi speed switch with motor-protective circuit-breaker PKZ2



Circuit A → page 8-53



Circuit C → page 8-53

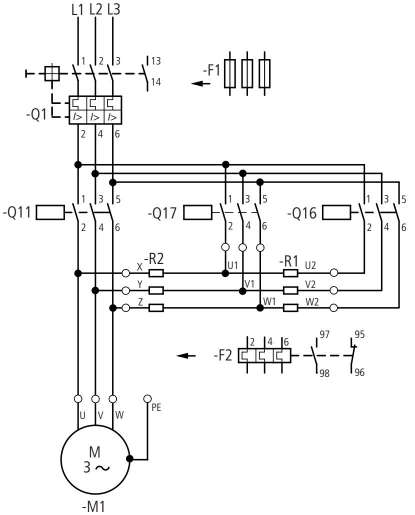
8

S11	RMQ-Titan, M22-…	–	–	–
Q1, Q21	PKZ2/ZM-…/S	*n*>	–	–
Q2, Q17	PKZ2/ZM-…/S	*n* <	–	–
Q23	DILOM	⋎n > U_e ≦ 500 V	–	–
Q23	S/EZ-PKZ	⋎n > U_e ≦ 660 V	F0	FAZ

All about Motors

Three-phase automatic stator starters

Three-phase automatic stator resistance starter DDAINL with mains contactor and resistors, 2-stage, 3-phase version



Use F2 when using F1 instead of Q1.

Rating of switchgear:

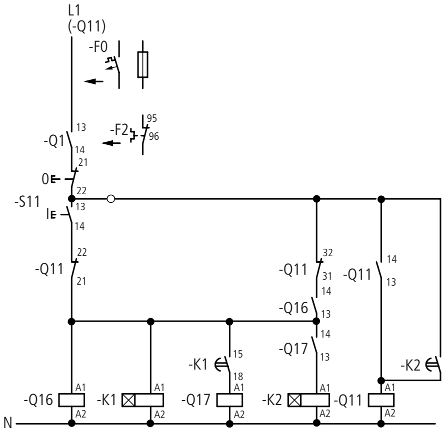
Starting voltage	$= 0.6 \times U_e$
Starting current	$= 0.6 \times$ motor full-load current
Starting torque	$= 0.36 \times$ motor full-load current
Q1, Q11	$= I_e$
Q16, Q17	$= 0.6 \times I_e$
Starting voltage	$= 0.6 \times U_e$

8

All about Motors

Three-phase automatic stator starters

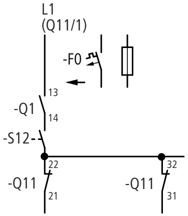
DDAINL three-phase automatic stator resistance starter with mains contactor and resistors, 2-stage, 3-phase version



Q16: Step contactor
K1: Timing relay
Q17: Step contactor
K2: Timing relay
Q11: Mains contactor

Two-wire control

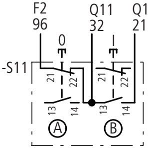
Always set overload relay to manual reset



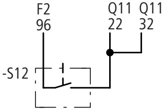
All about Motors

Three-phase automatic stator starters

Three-wire control
Two-way pushbutton
I = ON
0 = OFF



Two-wire control



Method of operation

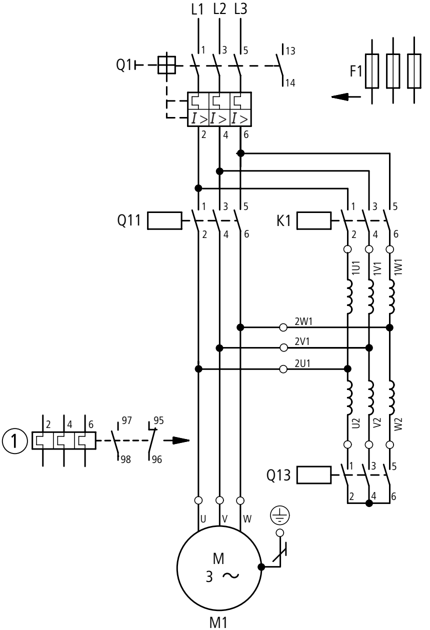
Pushbutton I energizes step contactor Q16 and timing relay K1. Q16/14–13 – maintain themselves via Q11, Q11/32–31 and pushbutton 0. The motor is connected to the supply with rotor resistors R1 + R2. When the set starting time has elapsed, normally open contact K1/15–18 energizes Q17. Step contactor Q17 bypasses starting stage R1. At the same time, normally open contact Q17/14–13 energizes K2. When the set starting time has elapsed, K2/15–18 energizes mains contactor Q11, which bypasses the second starting stage R2, and the motor runs at rated speed. Q11 maintains itself via Q11/14–13. Q16, Q17, K1 and K2 are de-energized by normally closed contacts Q11/22–21 and Q11/32–31. The motor is switched off either after actuation of pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of the overload relay F2 or normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

Step contactor Q17, resistor R2 and timing relay K1 are omitted in single-stage starting circuits. Timing relay K2 is connected directly to Q16/13 and resistor R2 is connected by means of its terminals U1, V1 and W1 to Q11/2, 4, 6.

All about Motors

Three-phase automatic stator starters

Three-phase automatic stator resistance starter ATAINL with mains contactor and starting transformer, 1-stage, 3-phase



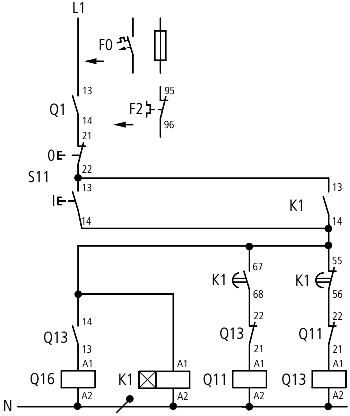
Use F2 when using F1 instead of Q1.

Rating of switchgear

Starting voltage	= 0.7 × U_e (typical value)	Tightening torque	= 0.49 × motor full-load current
Starting current	= 0.49 × motor full-load current	Q1, Q11	= I_e
I_A/I_e	= 6	Q16	= 0.6 × I_e
t_A	= 10 s	Q13	= 0.25 × I_e
S/h	= 30		

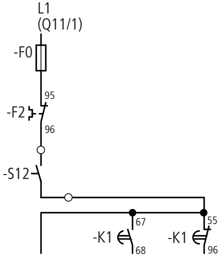
All about Motors

Three-phase automatic stator starters



Two-wire control

Always set overload relay to manual reset (automatic reset)

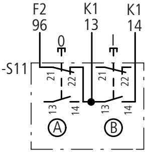


Q16: Step contactor
K1: Timing relay
Q11: Mains contactor
Q13: Star contactor

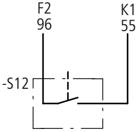
8

Three-wire control

I: ON
0: OFF



Two-wire control



Method of operation

Actuation of pushbutton I simultaneously energizes star contactor Q13, timing relay K1 and, via normally open contact Q13/13–14, step contactor K16, and are maintained via K1/13–14. When K1 has elapsed, normally closed contact K1/55–56 de-energizes star contactor Q13 and – via normally open contact Q13/13–14 – Q16 de-energizes: The starting transformer is disconnected, and the motor runs at rated speed.

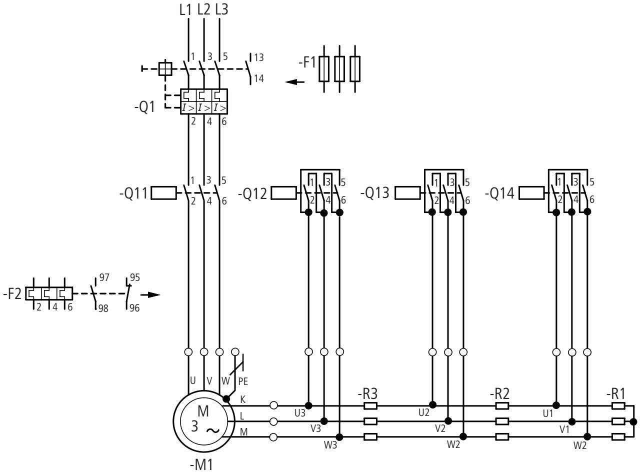
The motor cannot start up again unless previously switched off by actuation of pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of the overload relay F2. With two-wire control, overload relay F2 must always be set to manual reset. If the motor has been switched off by F2, the motor cannot start up again unless the manual reset is released.

All about Motors

Three-phase automatic rotor starters

Three-phase automatic rotor resistance starters DAINL

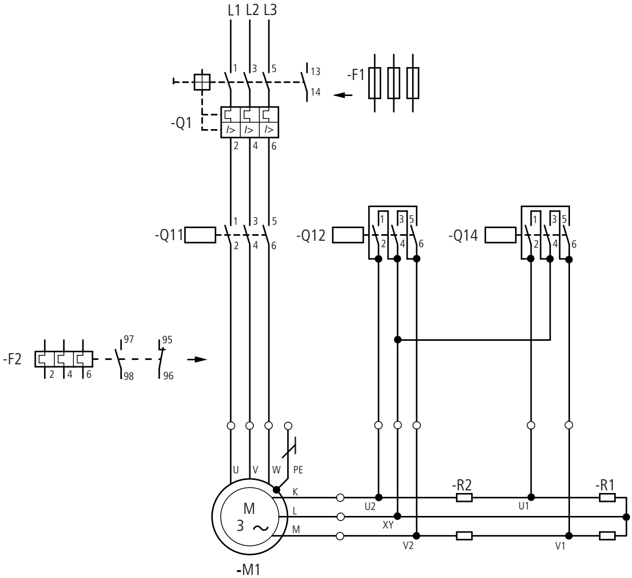
3-stage, rotor 3-phase



Use F2 when using F1 instead of Q1.

All about Motors
Three-phase automatic rotor starters

2-stage, rotor 2-phase



Use F2 when using F1 instead of Q1.
Rating of switchgear

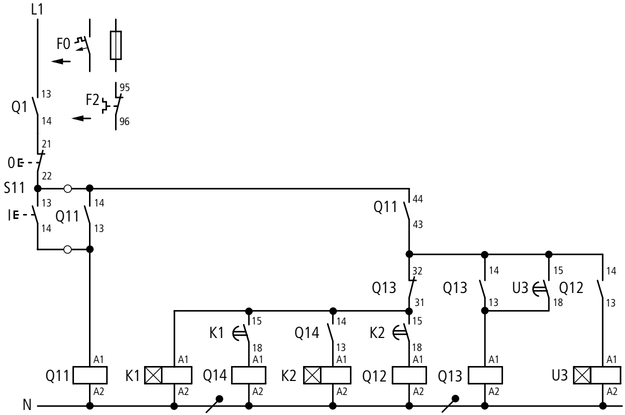
Starting current	$= 0.5–2.5 \times I_e$
Starting torque	= 0.5 to pull-out torque
Q1, Q11	$= I_e$
Step contactors	$= 0.35 \times I_{rotor}$
Final step contactors	$= 0.58 \times I_{rotor}$

8

All about Motors

Three-phase automatic rotor starters

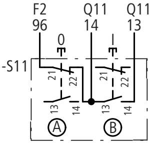
With mains contactor, style 3-stage, rotor 3-phase



Q11: Mains contactor
K1: Timing relay
Q14: Step contactor
K2: Timing relay

Q12: Step contactor
Q13: Final step contactor
K3: Timing relay

Two-way push-button
I: ON
0: OFF



For connection of further control circuit devices: → section "Control circuit devices for star-delta starting", page 8-49

All about Motors
Three-phase automatic rotor starters

Method of operation

Pushbutton I energizes mains contactor Q11: normally open contact Q11/14–13 transfers the voltage, Q11/44–43 energizes timing relay K1. The motor is connected to the supply with rotor resistors R1 + R2 + R3 in series. When the set starting time has elapsed, normally open contact K1/15–18 energizes Q14. Step contactor Q14 short-circuits starting stage R1 and via Q14/14–13 energizes timing relay K2. When the set starting time has elapsed, K2/15–18 energizes step contactor Q12, which short-circuits starting stage R2 and via Q12/14–13 energizes timing relay K3. When the set starting time has elapsed, K3/15–18 energizes final step contactor Q13, which is maintained via Q13/14–13. Step contactors Q14 and Q13 as well as timing relays K1, K2 and K3 are de-energized via Q13. Final step contactor Q13 short-circuits the rotor slip rings: the motor operates with rated speed.

The motor is switched off either by pushbutton 0, or in the event of an overload, by normally closed contact 95–96 of the overload relay F2 or normally open contact 13–14 of the motor-protective circuit-breaker or circuit-breaker.

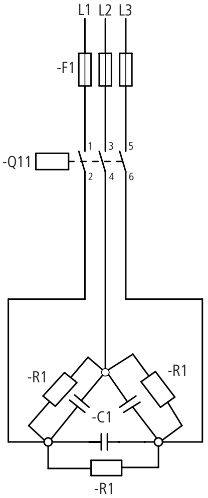
Step contactors Q13 and/or Q12 with their resistors R3, R2 and timing relays K3, K2 are omitted in single-stage or two-stage starting circuits. The rotor is then connected to the resistance terminals U, V, W2 or U, V, W1. The references for step contactors and timing relays in the wiring diagrams are then changed from Q13, Q12, to Q12, Q11 or to Q13, Q11 as appropriate.

When there are more than three stages, the additional step contactors, timing relays and resistors have appropriate increasing designations.

All about Motors
Switching of capacitors

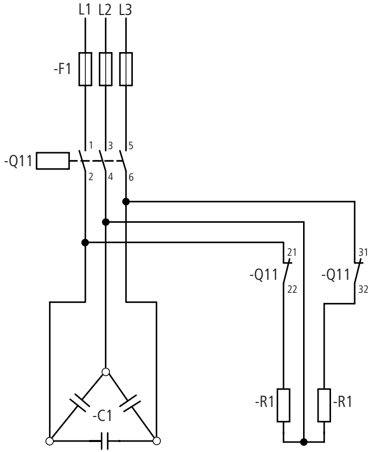
Contactors for capacitors DIL

Individual circuit without quick-discharge resistors



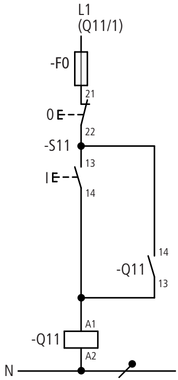
R1 discharge resistors fitted in capacitor

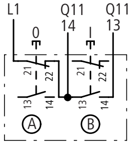
Individual circuit with quick-discharge resistors



R1 discharge resistors fitted to contactor

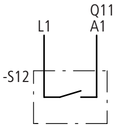
All about Motors
Switching of capacitors





Two-way pushbutton
For connection of further control circuit devices: → section "Control circuit devices for star-delta starting", page 8-49

Two-wire control
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.



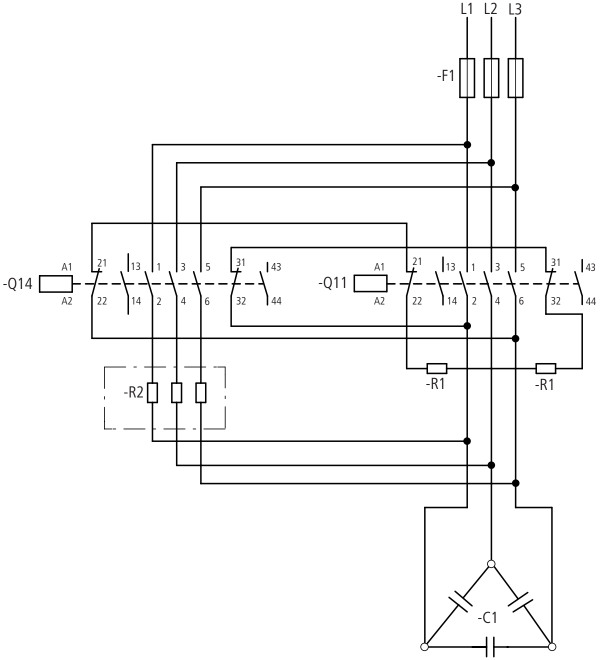
Method of operation
Pushbutton I energizes contactor Q11. Q11 energizes and maintains itself via its own auxiliary contact 14–13 and pushbutton 0. Capacitor C1 is now energized. Discharge resistors R1 are not operative when contactor Q11 is energized. Actuation of pushbutton 0 effects de-energization. Normally closed contacts Q11/21–22 then switch discharge resistors R1 to capacitor C1.

8

All about Motors
Switching of capacitors

Capacitor contactor combination

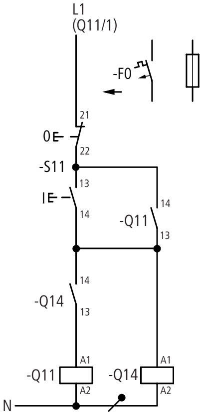
Capacitor contactor with pilot contactor and series resistors. Individual and parallel circuit with and without discharge resistors and with series resistors.

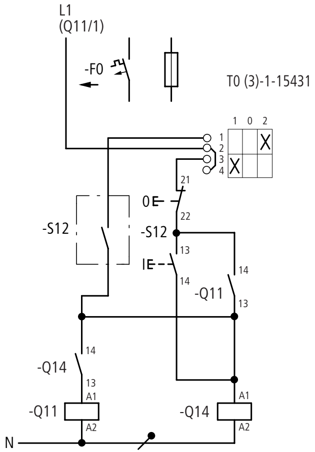


On the version without discharge resistors, resistors R1 and the connections to the auxiliary contacts 21–22 and 31–32 are omitted.

All about Motors

Switching of capacitors





Q11: Mains contactor
Q14: Pilot contactor

Actuation by two-way pushbutton S11

Actuation by selector switch S13, two-wire control S12 (power factor correction relay) and two-way pushbutton S11

Method of operation

Actuation by two-way pushbutton S11: Pushbutton I energizes pilot contactor Q14. Q14 switches capacitor C1 in with bridged series resistors R2. Normally open contact 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. Normally closed contacts Q11/21–22 and 31–32 then switch discharge resistors R1 to capacitor C1.

All about Motors

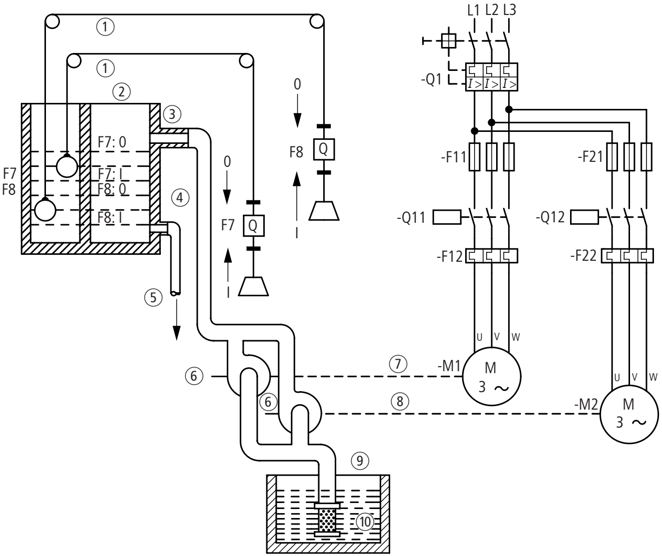
Duplex pump control

Fully automatic control for two pumps

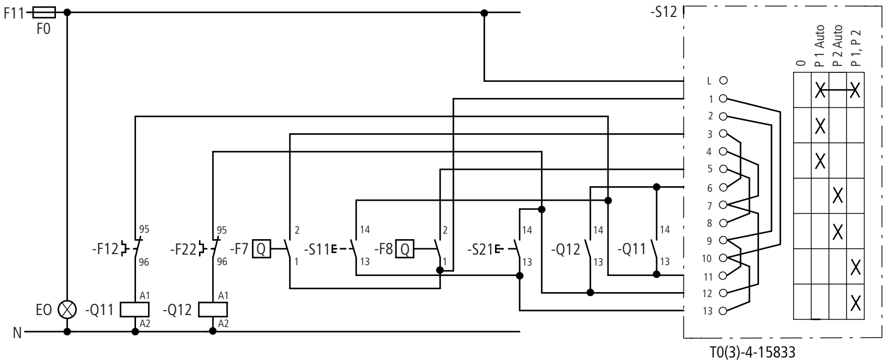
Starting sequence of pumps 1 and 2 can be selected by control switch S12

Control circuit wiring with two float switches for basic and peak loads (operation is also possible with two pressure switches)

P1 Auto	=	Pump 1 constant load, Pump 2 peak load
P2 Auto	=	Pump 2 constant load, Pump 1 peak load
P1 + P2	=	Direct operation independent of float switches (or pressure switches)



1. Cable with float, counterweight, pulleys and clamps
2. Storage tank
3. Inlet
4. Pressure pipe
5. Outlet
6. Centrifugal or reciprocating pump
7. Pump 1
8. Pump 2
9. Suction pipe with filter
10. Well



Float switch F7 closes before F8

Q11: Pump 1 mains contactor

Q12: Pump 2 mains contactor

Method of operation

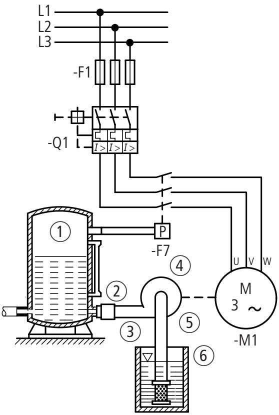
The duplex pump control is designed for operation of two pump motors M1 and M2. Control is via float switches F7 and F8.
Operating mode selector switch S12 in position P1 auto: The system operates as follows:
When the water level in the storage tank falls or rises, F7 switches pump 1 on or off (basic load). If the water level drops below the range of F7 (discharge is greater than intake), F8 starts pump 2 (peak load). When the water level rises again, F8 is deactivated. Pump 2 continues running until F7 stops both pumps.
The operating sequence of pumps 1 and 2 can be determined using operating mode selector switch S12: Position P1 auto or P2 auto.

In position P1 + P2, both pumps are in operation, independent of the float switches (Caution! Tank may possibly overflow).
On the version of duplex pump control with automatic load sharing (T0(3)-4-15915), S12 has a further position: the sequence of operations is automatically reversed after each cycle.

All about Motors

Fully automatic pump control

With pressure switch for air tank and domestic water supply without water failure (run dry) safety device



With 3-pole pressure switch MCSN (main circuit)

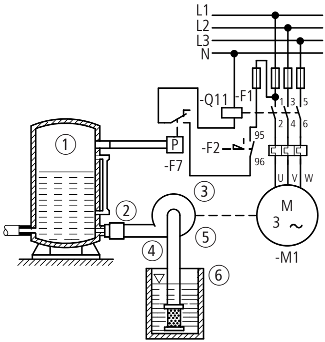
F1: Fuses (if required)
Q1: Motor-protective switch, manual (z. B. PKZ)
F7: Pressure switch MCSN, 3-pole
M1: Pump motor

① Air or pressure tank
② Non-return valve
③ Pressure pipe
④ Centrifugal (or reciprocating) pump
⑤ Suction pipe with filter
⑥ Well

All about Motors

Fully automatic pump control

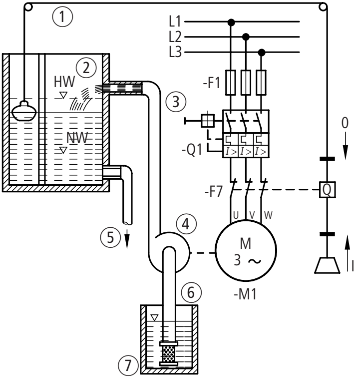
With single-pole pressure switch MCS (control circuit)



F1: Fuses
Q11: Contactor or automatic star-delta starter
F2: Overload relay with automatic reset
F7: Pressure switch MCS, 1-pole
M1: Pump motor
① Air or pressure tank
② Non-return valve
③ Centrifugal (or reciprocating) pump
④ Pressure pipe
⑤ Suction pipe with filter
⑥ Well

All about Motors
Fully automatic pump control

With 3-pole float switch SW (main circuit)



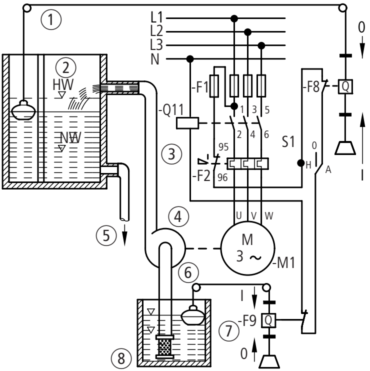
F1: Fuses (if required)
Q1: Motor-protective switch, manual (z. B. PKZ)
F7: Float switch 3-pole (circuit: pump full)
M1: Pump motor
HW: Highest level
NW: Lowest value
① Cable with float, counterweight, pulleys and clamps
② Storage tank
③ Pressure pipe
④ Centrifugal (or reciprocating) pump
⑤ Outlet
⑥ Suction pipe with filter
⑦ Well

8

All about Motors

Fully automatic pump control

With single-pole float switch SW (control circuit)



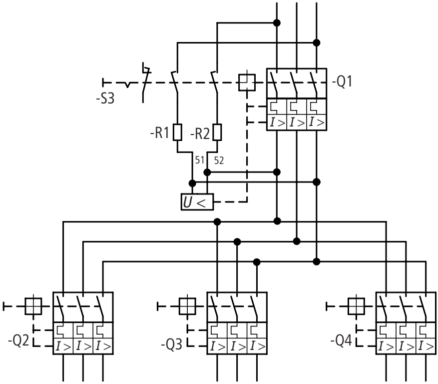
F1: Fuses
Q11: Contactor or automatic star-delta starter
F2: Overload relay with automatic reset
F8: Float switch 1-pole (circuit: pump full)
S1: Changeover switch MANUAL-OFF-AUTO
F9: Float switch 1-pole (circuit: pump full)
M1: Pump motor
1. Cable with float, counterweight, pulleys and clamps
2. Storage tank
3. Pressure pipe
4. Centrifugal (or reciprocating) pump
5. Outlet
6. Suction pipe with filter
7. Water-failure monitoring by means of a float switch
8. Well

All about Motors

Off position interlock of the loads

Solution using NZM circuit-breakers

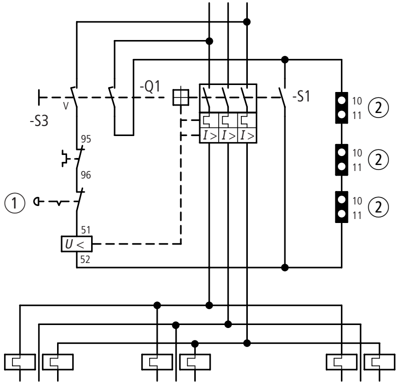
Off position interlock for control switches (Hamburg circuit) with auxiliary contact VHI (S3) and undervoltage release. Cannot be used with motor operator.



All about Motors

Fully automatic main transfer switch with automatic reset

Off position interlock for control or master switches by means of auxiliary contacts VHI (S3), NHI (S1) and undervoltage release. Cannot be used with motor operator.



1. Emergency-Stop
2. Off position interlock contacts on the control or master switches

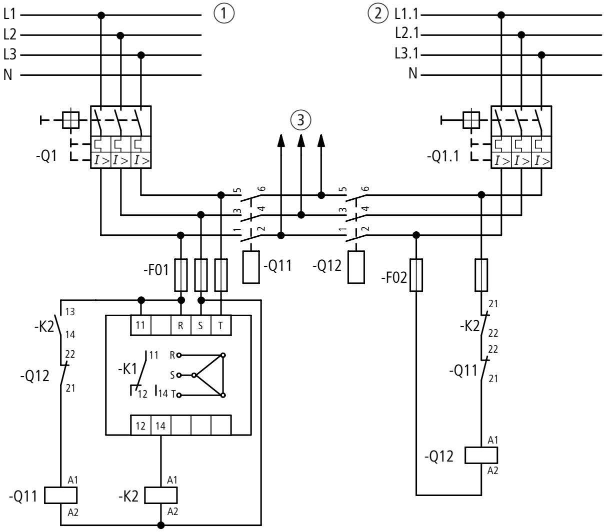
All about Motors

Fully automatic main transfer switch with automatic reset

Changeover device to DIN VDE 0108 – Power systems and safety power supply in buildings for public gatherings:

Automatic resetting, the phase-monitor is set to:

Pick-up voltage $U_{on} = 0.95 \times U_n$
Drop-out voltage $U_b = 0.85 \times U_{on}$



① Main supply
② Auxiliary supply
③ To load

Method of operation

Main switch Q1 is closed first, followed by main switch Q1.1 (auxiliary supply).

Phase monitor K1 is energized via the main supply and immediately energizes contactor relay K2. Normally closed contact K2/21–22 blocks the circuit of Contactor Q12 (auxiliary supply) and normally open contact K2/13–14 closes the circuit of contactor Q11. Contactor Q11 energizes and switches the mains supply on the loads. Contactor Q12 is also interlocked against main supply contactor Q11 via normally closed contact Q11/22–21.

Specifications, Formulae, Tables

Specifications, Formulae, Tables
Marking of electrical equipment

General

Extracts from the DIN Standards with VDE Classification are quoted with the permission of the DIN (Deutsches Institut für Normung e.V.) and the VDE (Verband der Elektrotechnik Elektronik Informationstechnik e.V.) It is imperative for the use of the standards that the issue with the latest date is used. These are available from VDE-VERLAG GMBH, Bismarckstr. 33, 10625 Berlin and Beuth Verlag GmbH, Burggrafenstr. 6, 10787 Berlin.

Marking to DIN EN 61346-2:2000-12 (IEC 61346-2:2000)

Moeller has decided, with a transitional period, to use the above mentioned standards.

Deviation from the, up to now, normal marking determines now in the first place the function of the electrical equipment in the respective circuit of the code letter. The outcome is that there is a lot of freedom in the selection of the code letters.

Example for a resistance

- Normal current limiter: R
- Heater resistor: E
- Measurement resistor: B

As well as that, Moeller specific decisions have been made with regard to the interpretation of the standard that sometimes deviate from the standard.

- The marking of connection terminals are **not** readable from the right.
- A second code letter for the marking of the use of the equipment is **not** given, e. g.: timer relay K1T becomes K1.
- Circuit-breakers with the main function of protection are still marked with Q. They are numbered from 1 to 10 from the top left.
- Contactors are newly marked with Q and numbered from 11 to nn. e. g.: K91M becomes Q21.
- Relays remain 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 installations and the various circuit documents (wiring diagrams, parts lists, circuit diagrams, instructions). For simpler maintenance, the complete marking or part of it, can be affixed on or near to the equipment.

Selected equipment with a comparison of the Moeller used code letters old – new → Table, Page 9-3.

Specifications, Formulae, Tables

Marking of electrical equipment

Code letter old	Example for electrical equipment	Code letter new
B	Measuring transducer	T
C	Capacitors	C
D	Memory device	C
E	Electro filter	V
F	Bimetal release	F
F	Pressure monitor	B
F	Fuses (fine, HH, signal fuse)	F
G	Frequency inverters	T
G	Generators	G
G	Soft starter	T
G	UPS	G
H	Lamps	E
H	Optical and acoustic indicators	P
H	Signal lamps	P
K	Relays	K
K	Contactor relays	K
K	Semiconductor contactor	T
K	Contactor	Q
K	Time-delay relay	K
L	Reactor coil	R
N	Buffer amplifier, inverting amplifier	T
Q	Switch disconnector	Q
Q	Circuit-breaker for protection	Q
Q	Motor-protective circuit-breaker	Q

Specifications, Formulae, Tables

Marking of electrical equipment

Code letter old	Example for electrical equipment	Code letter new
Q	Star-delta switches	Q
Q	Disconnect switch	Q
R	Variable resistor	R
R	Measurement resistor	B
R	Heating resistor	E
S	Control circuit devices	S
S	Push-button	S
S	Position switch	B
T	Potential transformer	T
T	Current transformer	T
T	Transformers	T
U	Frequency converter	T
V	Diodes	R
V	Rectifier	T
V	Transistors	K
Z	EMC filter	K
Z	Suppressors and arc quenching devices	F

Specifications, Formulae, Tables

Marking of electrical equipment

Component marking in the USA and Canada to NEMA ICS 1-2001, ICS 1.1-1984, ICS 1.3-1986

In order to differentiate between devices with similar functions, 3 figures and/or letters can be added to the marking. When using two or more of these markings, the function marking is usually put first.

Example:
The relay which introduces the first jog function is marked with “1 JCR”. That means here:

1 = numerical specification

J = jog function of the equipment

CR = control relay (contactor relay) – type of equipment

Specifications, Formulae, Tables

Marking of electrical equipment

Component or function code letters to NEMA ICS 1-2001, ICS 1.1-1984, ICS 1.3-1986

Code letter	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
MS	Master switch

Specifications, Formulae, Tables
Marking of electrical equipment

Code letter	Device or Function
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

Specifications, Formulae, Tables
Marking of electrical equipment

As an alternative to device designation with code letter to NEMA ICS 1-2001, ICS 1.1-1984, ICS 1.3-1986 the designation to class designation is permissible. Class designation marking should simplify harmonization with international standards. The code letters used here are, in part, similar to those of IEC 61346-1 (1996-03).

Class designation code letter to NEMA ICS 19-2002

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 Convertor
BT	Battery
C	Capacitor • Capacitor, General • Polarized Capacitor Shielded Capacitor
CB	Circuit-Breaker (all)

Specifications, Formulae, Tables

Marking of electrical equipment

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

Specifications, Formulae, Tables

Marking of electrical equipment

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

Specifications, Formulae, Tables

Marking of electrical equipment

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

Specifications, Formulae, Tables
Marking of electrical equipment

Code letter	Device or function
S	Switch • Combination Locking and Nonlocking 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

Specifications, Formulae, Tables

Marking of electrical equipment

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

Specifications, Formulae, Tables

Circuit symbols, European – North America

Circuit symbols to DIN EN, NEMA ICS

The following comparison of circuit symbols is based upon the following international/national specifications:

- DIN EN 60617-2 to DIN EN 60617-12
- NEMA ICS 19-2002

Description	DIN EN	NEMA ICS
Conductors, connectors		
Junction of conductors	 03-02-04 or 03-02-05	 or
Connection of conductors (node)	● 03-02-01	●
Terminal	○ 03-02-02	○
Terminal strip/block	1 2 3 4 03-02-03	1 2 3 4
Conductor	——— 03-01-01	———

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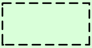
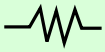
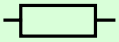
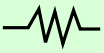
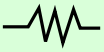
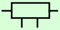
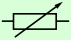
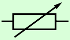
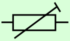
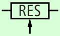
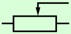
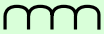
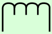
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
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	
Screen	 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	 03-03-05 or  03-03-06	
Isolating point, lug, closed	 03-03-18	

Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Passive components		
Resistor, general symbol	 04-01-02 or  04-01-02	 or 
Resistor with fixed tappings	 04-01-09	 or 
Variable resistor, general symbol	 04-01-03	
Adjustable resistor		
Resistor with sliding contact, potentiometer	 04-01-07	
Winding, inductance, general symbol	 04-03-01 or  04-03-02	
Winding with fixed tapping	 04-03-06	
Capacitor, general symbol	 04-02-01 or  04-02-02	 or 
Variable capacitor	 104-02-01	

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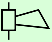
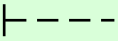
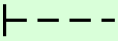
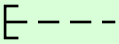
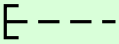
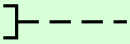
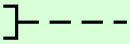
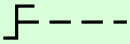
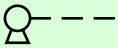
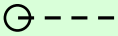
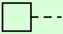
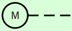
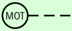
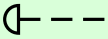
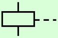
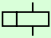
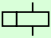
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Signalling units		
Visual indicator, general symbol		 *with colour stated
Indicator light, general symbol	 08-10-01	 or  or  *with colour stated
Buzzer	 08-10-11 or  08-10-10	 ABU
Horn, claxon	 08-10-05	 HN
Operating devices		
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	

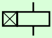
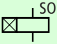
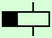
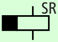
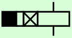
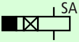
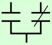
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
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	 OL
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	 or  or  × device code letter
Operating device with special features, general symbol		

Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Electromechanical operating device with On-delay	 07-15-08	 SO
Electromechanical device with Off-delay	 07-15-07	 SR
Electromechanical device with On- and Off-delay	 07-15-09	 SA
Electromechanical device of a thermal relay	 07-15-21	
Contacts		
Make contact	 07-02-01 or  07-02-02	 or 
Break contact	 07-02-03	 or 
Changeover contact with interruption	 07-02-04	 or 
Early-make contact of a contact assembly	 07-04-01	 TC, TDC, EM
Late-break contact of a contact assembly	 07-04-03	 TO, TDO, LB
Make contact, delayed when closing	 07-05-02 or  07-05-01	 T.C.
Break contact, delayed when reclosing	 07-05-03 or  07-05-04	 T.O.

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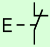
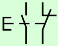
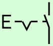
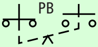
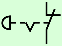
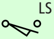
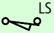
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Control devices		
Push-button (not stay-put)	 07-07-02	
Spring-return switch with break contact, manually operated by pushing, e.g. push-button		
Spring-return switch with make and break contacts, manually operated by pushing		
Spring-return switch with latching position and one make contact, manually operated by pushing		
Spring-return switch with latching position and one break contact, manually operated by striking (e.g. mushroom button)		
Position switch (make contact) Limit switch (make contact)	 07-08-01	
Position switch (break contact) Limit switch (break contact)	 07-08-02	
Spring-return switch with make contact, mechanically operated, make contact closed		

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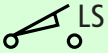
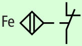
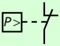
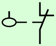
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Spring-return switch with break contact, mechanically operated, break contact open		
Proximity switch (break contact), actuated by the proximity of iron	 07-20-04	
Proximity switch, inductive, make contact		
Proximity switch, block diagram	 07-19-02	
Under-pressure relay, make contact	 07-17-03	 or 
Pressure switch, break contact		 or 
Float switch, make contact		
Float switch, break contact		

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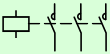
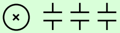
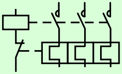
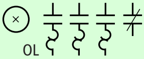
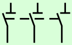
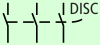
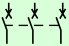
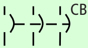
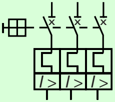
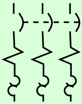
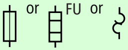
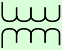
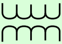
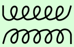
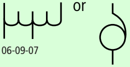
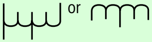
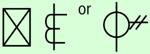
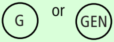
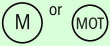
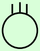
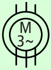
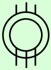
Specifications, Formulae, Tables
Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Switchgear		
Contactor (make contact)	 07-13-02	 × code letter
3 pole contactor with bimetal relay (3 thermal elements)		 × code letter
3 pole switch-disconnector	 07-13-06	
3 pole circuit-breaker	 07-13-05	
3 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	
Transformers, current transformers		
Transformers with two windings	 06-09-02 or  06-09-01	 or 

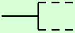
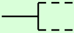
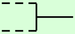
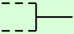
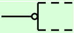
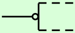
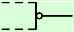
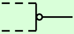
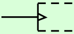
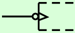
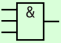
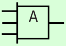
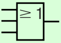
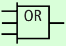
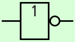
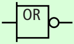
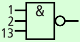
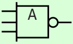
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Autotransformer	 06-09-07 or 06-09-06	
Current transformer	 06-09-11 or 06-09-10	
Machines		
Generator	 06-04-01	
Motor, general symbol	 06-04-01	
DC motor, general symbol	 06-04-01	
AC motor, general symbol	 06-04-01	
Three-phase asynchronous motor with squirrel-cage rotor	 06-08-01	
Three-phase asynchronous motor with slip-ring rotor	 06-08-03	

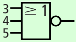
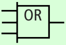
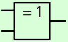
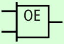
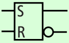
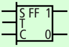
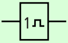
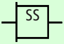
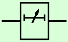
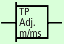
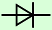
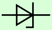
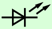
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
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	 12-28-01	

Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
OR with negated output, NOR	 12-28-02	
Exclusive OR gate, general symbol	 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	

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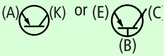
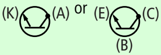
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
PNP transistor	 05-05-01	
NPN transistor, in which the collector is connected to the enclosure	 05-05-02	

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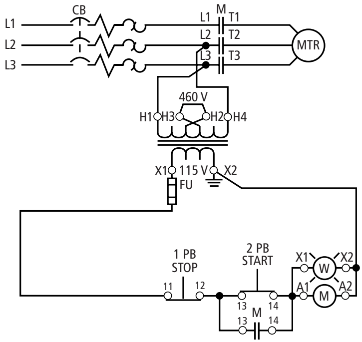
Specifications, Formulae, Tables
Circuit diagram example to North American specifications

Direct-on-Line Motor-Starters

Fuseless with circuit-breakers



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Specifications, Formulae, Tables

Approval authorities worldwide

Abbreviation	Full title	Country
ABS	**A**merican **B**ureau of **S**hipping	USA
AEI	**A**ssociazione **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	USA
ASTA	**A**ssociation of **S**hort-Circuit **T**esting **A**uthorities	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 electrotechnical 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
CEMA	**C**anadian **E**lectrical **M**anufacturer’s **A**ssociation	Canada
CEN	Comité Européen de Normalisation European standards committee	Europe
CENELEC	**C**omité **E**uropéen de **N**ormalisation **Él**e**c**trotechnique European committee for electrotechnical standards	Europe

Specifications, Formulae, Tables

Approval authorities worldwide

Abbreviation	Full title	Country
CSA	**C**anadian **S**tandards **A**ssociation	Canada
DEMKO	**D**anmarks **E**lektriske **M**aterriel**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	Europe
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	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	–

Specifications, Formulae, Tables

Approval authorities worldwide

Abbreviation	Full title	Country
JEM	**J**apanese **E**lectrical **M**anufacturers Association Electrical industry association	Japan
JIC	**J**oint **I**ndustry **C**onference	USA
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	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	USA
NEMKO	**N**orges **E**lektriske **M**ateriell**ko**ntroll Norwegian testing institute for electrotechnical products	Norway
NEN	**Ne**derlandse **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**och**l**eistungs**a**pparate Electrical high-performance apparatus test laboratory of the association for electrical high-performance testing	Germany

Specifications, Formulae, Tables
Approval authorities worldwide

Abbreviation	Full title	Country
PRS	**P**olski **R**ejestr **S**tatków Ship classification association	Poland
PTB	**P**hysikalisch-**T**echnische **B**undesanstalt German physical/technical federal agency	Germany
RINA	**R**egistro **I**taliano **Na**vale 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**ko**ntrollanstalten Swedish test institute for electrotechnical products	Sweden
SEV	**S**chweizerischer **E**lektrotechnischer **V**erein Swiss electrotechnical association	Switzerland
SFS	Suomen Standardisoimisliito r.y. Finnish standardisation association, Finnish standard	Finland
STRI	The Icelandic Council for Standardization	Iceland
SUVA	**S**chweizerische **U**nfall**v**ersicherungs-**A**nstalt Swiss accident insurance federal agency	Switzerland
TÜV	**T**echnischer **Ü**berwachungs**v**erein 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**entral**v**erband **E**lektrotechnik- und Elektronik**i**ndustrie Central association of the electrical and electronic industry	Germany

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Specifications, Formulae, Tables

Test authorities and approval stamps

Test authorities and approval stamps in Europe and North America

Moeller devices have in their basic design all worldwide necessary approvals including those for the USA.

Some devices, such as circuit-breakers, are in their basic design usable worldwide with the exception of USA and Canada. For export to North America devices are available with a special UL and CSA approval.

In all cases special country specific installation and operating specifications, installation ,materials and types must be taken into account as well as special circumstances such as difficult climatic conditions.

Since January 1997 all devices that conform to the European low-voltage guidelines and are for sale in the European Union must be marked with the CE mark.

The CE mark shows that the marked device corresponds with all relevant requirements and standards. This marking duty allows unlimited use of this device within the European economic area.

Approval and marking for their own country is no longer necessary when a device is marked with the CE mark that corresponds to the harmonised standards. (→ Table, Page 9-32).

An exception is the instalation material. The device group of circuit-breakers and earth-fault protection switches are in certain areas still to be labelled and are therefore marked with the relevant label.

Country	Test authority	Stamp	included in CE mark
Belgium	Comité Electrotechnique Belge Belgisch Elektrotechnisch Comité (CEBEC)	CEBEC	yes, except installation material
Denmark	Danmarks Elektriske Materielkontrol (DEMKO)	D	Yes
Germany	Verband Deutscher Elektrotechniker (VDE)	DVE	yes, except installation material
Finland	FIMKO	FI	Yes
France	Union Technique de l'Electricité (UTE)	NF USE	yes, except installation material

Specifications, Formulae, Tables

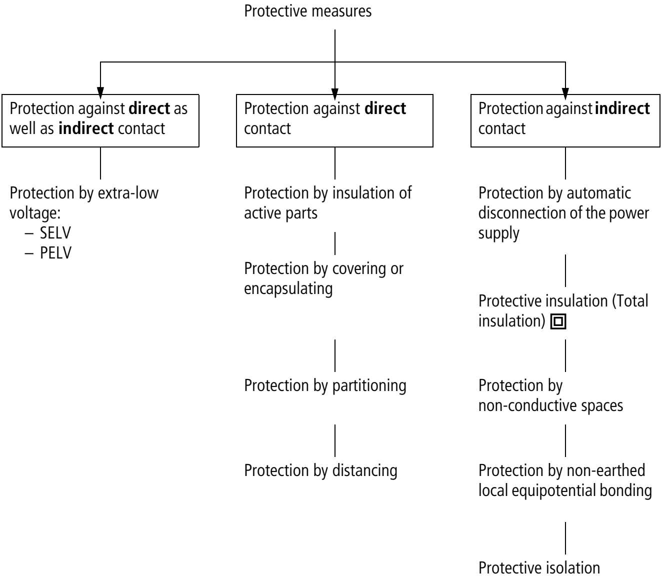
Test authorities and approval stamps

Country	Test authority	Stamp	included in CE mark
Canada	Canadian Standards Association (CSA)		no, extra or seperate the UL an CSA approval mark
Netherlands	Naamloze Vennootschap tot Keuring van Electrotechnische Materialen (KEMA)	KEMA KEUR	Yes
Norway	Norges Elektriske Materiellkontrol (NEMKO)		Yes
Russia	Goststandart(GOST-)R		No
Sweden	Svenska Elektriska Materiel-kontrollanstalten (SEMKO)		Yes
Switzerland	Schweizerischer Elektrotechnischer Verein (SEV)		yes, except installation material
Czech Republic	–	–	no, manufacture declaration is enough
Hungary	–	–	no, manufacture declaration is enough
USA	Underwriters Laboratories Listing Recognition		no, extra or seperate the UL an CSA approval mark

Protection against electrical shock to IEC 364-4-41

A distinction is drawn here between protection against direct contact, protection against indirect contact and protection against both direct and indirect contact.

- **Protection against direct contact**
  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.
- **Protection against indirect contact**
  This is the protection of personnel and working animals from dangers which may arise from accidental contact with components or extraneous conductive parts.



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).

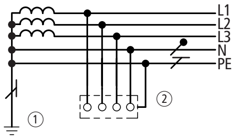
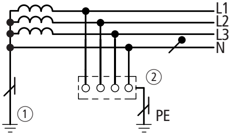
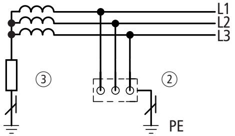
Specifications, Formulae, Tables

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 IEC 364-3/VDE 0100 Part 310

Earth continuity type systems	Meaning of designation
TN system 	T: direct earthing of a point (system earth) N: chassis directly connected to the system earth
TT system 	T: direct earthing of a point (system earth) T: chassis directly earthed, independent of the earthing of the power supply (system earth)
IT system 	I: All live parts isolated from earth or one point connected to earth via an impedance. T: chassis directly earthed, independent of the earthing of the power supply (system earth)

① System earth
② Chassis
③ Impedance

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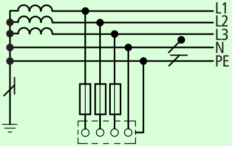
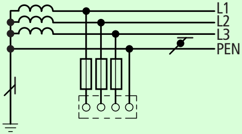
Specifications, Formulae, Tables

Protective measures

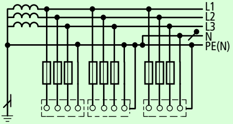
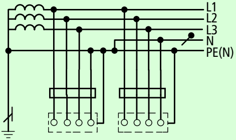
Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**TN system**		
Protection with	System circuit	Description so far	Condition for disconnection
Overcurrent protective device	TN-S system separated neutral and earth conductors throughout the system  		$Z_s \times I_a \leqq U_0$ Z_s = Impedance of the fault circuit I_a = current, which causes disconnection in: • $\leqq$ 5 s • $\leqq$ 0.2 s in circuits up to 35 A with sockets and hand-held components which can be moved 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.  	Protective multiple earthing	

Specifications, Formulae, Tables

Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

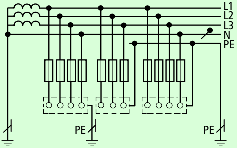
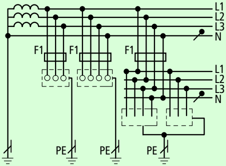
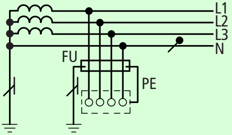
Type of distribution system	**TN system**		
Protection with	System circuit	Description so far	Condition for disconnection
Overcurrent protective device	TN-C-S system Neutral conductor and protection functions are in a part of the system combined in a single PEN conductor  		
Residual-current protective device	 	Residual-current protective circuit	$Z_s \times I_{\Delta n} \leqq U_0$ $I_{\Delta n}$ = rated fault current U_0 = maximum permissible touch voltage*: (≦ 50 V AC, ≦ 120 V DC)
Residual voltage protection device (in special case)			
Insulation monitoring devices			

*→ Table, Page 9-41

Specifications, Formulae, Tables

Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

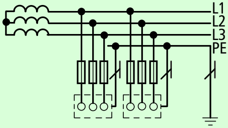
Type of distribution system	**TT system**		
Protection with	System circuit	Description so far	Conditions for indication/disconnection
Overcurrent protective device Fuses Miniature circuit-breakers Circuit-breakers		Protective earth	$R_A \times I_a \leqq U_L$ R_A = Earthing resistance of conductive parts of the chassis I_a = Current which causes automatic disconnection in ≦ 5 s U_L = Maximum permissible touch voltage*: (≦ 50 V AC, ≦ 120 V DC)
Residual-current protective device		Residual-current protective circuit	$R_A \times I_{\Delta n} \leqq U_L$ $I_{\Delta n}$ = rated fault current
Residual-voltage protective device (for special cases)		Residual-voltage protective circuit	R_A: max. 200 Ω

* → Table, Page 9-41

Specifications, Formulae, Tables

Protective measures

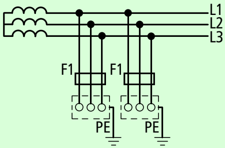
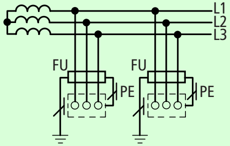
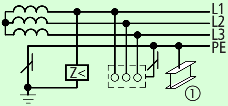
Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**TT system**		
Protection with	System circuit	Description up to now	Conditions for indication/disconnection
Insulation monitoring device	–		
Overcurrent protection device		Feed back to protective multiple earthing	$R_A \times I_d \leqq U_L$ (1) $Z_S \times I_a \leqq U_o$ (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*: $\leqq$ 50 V AC, $\leqq$ 120 V DC

*→ Table, Page 9-41

Specifications, Formulae, Tables
Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	**IT system**		
Protection with	System circuit	Description so far	Conditions for indication/disconnection
Residual-current protective device		Residual-current protective circuit	$R_A \times I_{\Delta n} \leqq U_L$ $I_{\Delta n}$ = rated fault current
Residual voltage protective device (for special cases)		Residual-voltage protective circuit	R_A: max. 200 Ω
Insulation monitoring device	 ① additional potential equalisation	Protective-conductor system	$R \times I_a \leqq U_L$ R = Resistance between components and extraneous conductive parts which can be touched simultaneously

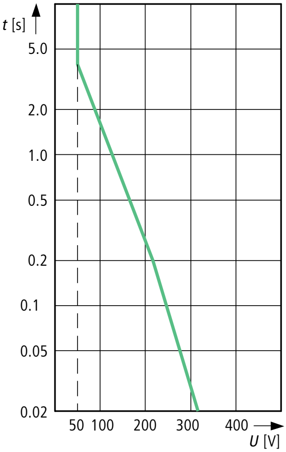
* → Table, Page 9-41

Specifications, 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. The internationally agreed limit voltage with a maximum disconnect time of 5 s is 50 V AC or 120 V DC.

Maximum permissible effective duration dependent on touch voltage to IEC 364-4-41



Anticipated touch voltage		Max. permissible disconnection time
AC $_{rms}$ [V]	DC $_{rms}$ [V]	[s]
< 50	< 120	●
50	**120**	**5.0**
75	140	1.0
90	160	0.5
110	**175**	**0.2**
150	200	0.1
220	250	0.05
280	310	0.03

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Notes

Specifications, Formulae, Tables

Overcurrent protection of cables and conductors

Cables and conductors must be protected by means of overcurrent protective devices against excessive warming, which may result both from operational overloading and from short-circuit.

Overload protection

Overload protection means providing 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 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

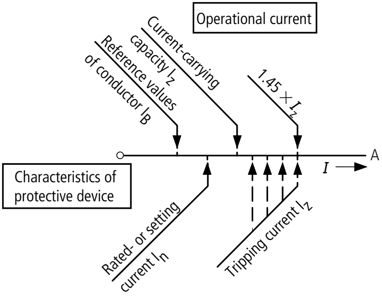
I_Z current-carrying capacity of the cable or conductor

I_n rated current of protection device

Note:

For adjustable protective devices, In corresponds to the value set.

I_2 The current which causes tripping of the protective device under the conditions specified in the equipment regulations (high test current).



Arrangement of protection devices for overload protection

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.

Specifications, 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 must 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:

- 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:

$$t = \left(k \times \frac{S}{I}\right)^2 \quad \text{or} \qquad I^2 \times t = k^2 \times S^2$$

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: current in the cast of short-circuit in A

k: constants with the values

- 115 for PVC-insulated copper conductors
- 74 for PVC-insulated aluminium conductors
- 135 for rubber-insulated copper conductors
- 87 for rubber-insulated aluminium conductors
- 115 for soft-solder connections in copper conductors

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.

Note:

This condition is met provided that there is a cable protective fuse up to 63 A rated current present and the smallest cable cross-section to be protected is at least 1.5 mm² Cu.

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 unless a protective device fitted upstream can ensure the necessary protection in the event of a short circuit.

Specifications, Formulae, Tables
Overcurrent protection of cables and conductors

Note:
Causes for the reduction in the short-circuit 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.

Protection of the phase conductors and the neutral conductor

Protection of the phase conductors
Overcurrent protection devices must be provided in every phase conductor: 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 phase conductor could prove hazardous, as for example, with three-phase motors, suitable precautions must be taken. Motor-protective circuit-breakers and circuit-breakers disconnect in three poles as standard.

Protection of the neutral conductor:

1. In installations with directly earthed neutral point **(TN or TT systems)**

Where the cross-section of the neutral conductor is less than that of the phase conductors, 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 is not necessary where:

- the neutral conductor is protected in the event of a short circuit by the protective device for the phase conductors
- 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 phase conductors, for example where the total power consumption of the load connected between phase and neutral conductors, lamps and sockets is much less than the total power transferred via the circuit. The cross-section of the neutral conductor must not be less than the values in the table on the next page.

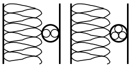
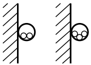
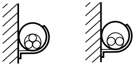
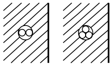
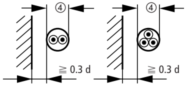
2. In installations without a directly earthed neutral point **(IT system)**

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 section 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 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	B1	B2	C	E
			On or under the wall surface, under plaster		
	In heat-insulating walls, in conduit under the surface	In electrical conduit or cable channel			
		Single-core cable	Multi-core cable	Installed directly in the wall	In free air
					
	Multi-core cable under the surface	Single wires in conduit on the wall surface	Multi-core cable in conduit on the wall surface or on the floor	Multi-core cable Spur wiring in the wall or under plaster	
Number of cores	2 3	2 3	2 3	2 3	2 3

Current-carrying capacity I_z in A at 25 °C ambient temperature and 70 °C operating temperature.
The selection of overcurrent protective devices is governed in general by conditions Ib F $I_n \leqq I$z and $I_2 \leqq 1.45\, I$z. For overcurrent protection devices with a tripping current of $I_2 \leqq I_n$ only apply the condition:

$I_b \leqq I_n \leqq I_z$ (I_b: operating current of the circuit). Circuit-breakers and switch-disconnectors fulfil this condition. For overcurrent protective devices with other tripping currents, the following formula applies:

$$I_n \leqq \frac{1.45}{x} \cdot I_n \;; = \frac{I_z}{I_n}$$

Specifications, 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	
Cross section Cu conductor in mm²	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n
1.5	16.5	16	14	13	18.5	16	16.5	16	16.5	16	15	13	21	20	18.5	16	21	20	19.5	16
2.5	21	20	19	16	25	25	22	20	22	20	20	20	28	25	25	25	29	25	27	25
4	28	25	25	25	34	32	30	25	30	25	28	25	37	35	35	35	39	35	36	35
6	36	35	33	32	43	40	38	35	39	35	35	35	49	40	43	40	51	50	46	40
10	49	40	45	40	60	50	53	50	53	50	50	50	67	63	63	63	70	63	64	63
16	65	63	59	50	81	80	72	63	72	63	65	63	90	80	81	80	94	80	85	80
25	85	80	77	63	107	100	94	80	95	80	82	80	119	100	102	100	125	125	107	100
35	105	100	94	80	133	125	118	100	117	100	101	100	146	125	126	125	154	125	134	125
50	126	125	114	100	160	160	142	125	–	–	–	–	–	–	–	–	–	–	–	–
70	160	160	144	125	204	200	181	160	–	–	–	–	–	–	–	–	–	–	–	–
95	193	160	174	160	246	200	219	200	–	–	–	–	–	–	–	–	–	–	–	–
120	223	200	199	160	285	250	253	250	–	–	–	–	–	–	–	–	–	–	–	–

For overcurrent protective devices whose rated current *In* does not conform to the values given in the table, select the next lower available rated current value.

Specifications, Formulae, Tables

Overcurrent protection of cables and conductors

Minimum cross section for protective conductors to DIN VDE 0100-510 (1987-06, t), DIN VDE 0100-540 (1991-11)

		Protective conductor or PEN conductor 1)		Protective conductor 3) laid seperately		
Phase conductor		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 $\geqq$ 10 mm^2 Cu or 18 mm^2 Al.
2) It is not permissible to lay aluminium conductors without protection.
3) With phase conductors of $\geqq$ 95 mm^2 or more, it is advisable to use non-insulted conductors

Specifications, 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 Part 4

Insulation material*)	NR/SR	PVC	EPR
Permissible operational temperature	60 °C	70 °C	80 °C
Ambient 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	–	–	0.55
70	–	–	0.45

*) Higher ambient temperatures in accordance with information given by the manufacturer

Specifications, Formulae, Tables

Overcurrent protection of cables and conductors

Converstion factors to VDE 0298 part 4

Grouping of several circuits

	Arrangement	Number of circuits								
		1	2	3	4	6	9	12	15 16	20
1	Embedded or enclosed	1.00	0.80	0.70	0.70 0.65	0.55 0.57	0.50	0.45	0.40 0.41	0.40 0.38
2	Fixed to walls or floors	1.00	0.85	0.80 0.79	0.75	0.70 0.72	0.70	–	–	–
3	Fixed to ceilings	0.95	0.80 0.81	0.70 0.72	0.70 0.68	0.65 0.64	0.60 0.61	–	–	–
4	Fixed to cable trays arranged horizontally or vertically	1.00	0.97 0.90	0.87 0.80	0.77 0.75	0.73 0.75	0.72 0.70	–	–	–
5	Fixed to cable trays or consoles	1.00	0.84 0.85	0.83 0.80	0.81 0.80	0.79 0.80	0.78 0.80	–	–	–

Specifications, Formulae, Tables
Electrically critical equipment of machines

Extract from IEC/EN 60204-1: (VDE 0113 part 1)

This world wide binding standard is used for the electrical equipment of machines, provided that for the type of machine to be equipped there is no product standard (Type C).

Safety requirements regarding the protection of personnel, machines and material according to the European Machinery Directive are stressed under the heading "Safety of machines". The degree of possible danger is to estimated by risk assessment (EN 1 050). 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 main switch, henceforth referred to as a 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.

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Protection against electric shock

The following measures must be taken to protect personnel against electric shock:

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 IEC 50274 or VDE 0660 part 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 IP 2X or IP XXB degree of protection in accordance with IEC/EN 60529.

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 IEC 60364 or VDE 0100 must be used. An additional measure is the use of protective insulation (protection class II) to IEC/EN 60439-1 or VDE 0660 Part 500.

Specifications, Formulae, Tables

Electrically critical equipment of machines

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 supply to the control 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 incoming supply. All other circuits must be protected by means of fuses or circuit-breakers.

The stipulation for fuses is that replacement must be freely obtainable in the country in which the fuses are used. This difficulty can be avoided by using circuit-breakers, with the added benefits of disconnection in all poles, rapid operational readiness and prevention of single-phasing.

Overload protection of motors

Continously operating motors above 0.5 kW must be protected against overload. 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 by stalled rotor.

Specifications, Formulae, Tables

Electrically critical equipment of machines

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 EN 954-1 has been published:

„Safety-related parts of control systems Part 1: General rules for design".

The use of risk assessment to EN 954-1 is dealt with in the Moeller manual "Safety Specifications for Machines and Plant" (Order No. TB 0-009).

Emergency-Stop device

Every machine which could potentially cause danger must be equipped with an Emergency-Stop device which, in a main circuit may be an Emergency-Stop switch, and in a control circuit an Emergency-Stop control circuit 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.

For direct manual operation, Emergency-Stop control circuit devices must have a mushroom-head push-button and positively opening contacts. Once the Emergency-Stop control 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 switch and Emergency control circuit device:

- The handle must be red with a yellow background
- Emergency-Stop devices must be quickly and easily accessible in the event of danger
- The Emergency-Stop 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-Stop areas, it must be clearly discernible to which area an Emergency-Stop device applies

Emergency operations

The term Emergency-Stop is short and concise, and should continue to be used for general usage.

It is not clear however from the term Emergency-Stop which functions are carried out with this. In order to be able to give a more precise definition here, IEC/EN 60204-1 describes under the generic term "Emergency operations" two specific functions:

1. Emergency-Stop
This involves the possibility of stopping dangerous motions as quickly as possible.

2. Emergency-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.

Specifications, Formulae, Tables

Electrically critical equipment of machines

Colours of push-buttons and their meanings

To IEC/EN 60073, VDE 0199, IEC/EN 60204-1
(VDE 0113 Part 1)

Colour	Meaning	Typical application
RED	Emergency	• Emergency-Stop • Fire fighting
YELLOW	Abnormal condition	Intervention, to suppress abnormal conditions or to avoid unwanted changes
GREEN	Safe condition	Start from safe conditon
BLUE	Enforced action	Resetting function
WHITE	No specific meaning assigned	• Start/ON (preferred) • Stop/OFF
GREY		• Start/ON • Stop/OFF
BLACK		• Start/ON • Stop/Off (preferred)

Specifications, Formulae, Tables
Electrically critical equipment of machines

Colours of indicator lights and their meanings

To IEC/EN 60073, VDE 0199, IEC/EN 60204-1
(VDE 0113 Part 1)

Colour	Meaning	Explanation	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 • Resetting
GREEN	Safe condition	Indication of safe operating conditions or authorization to proceed, clear way	• Cooling liquid circulating • Automatic tank control switched on • Machine ready to be started
BLUE	Enforced action	Operator action essential	• Remove obstacle • Switch over to Advance
WHITE	No specific meaning assigned (neutral)	Every meaning: may be used whenever doubt exists about the applicability of the colours RED, YELLOW or GREEN; or as confirmation	• Motor running • Indication of operating modes

Colours of illuminated push-buttons and their meanings

Both tables are valid for illuminated push-buttons, Table 1 relating to the function of the actuators.

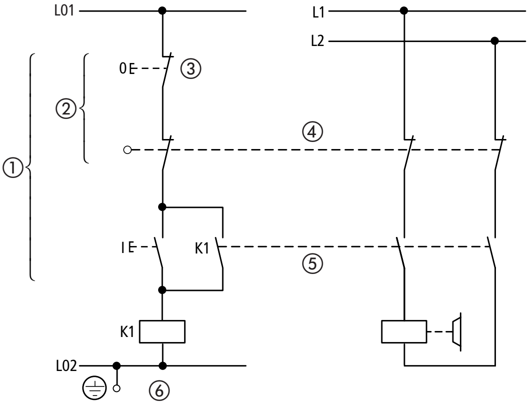
Specifications, Formulae, Tables
Measures for risk reduction

Risk reduction in the case 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 IEC/EN 60204 -1 specifies a range of measures which can be taken to reduce danger in the event of a fault.

Use of proven circuit engineering 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 operational states in the event of a fault 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 control circuit for operational purposes (not used as a protective measure)

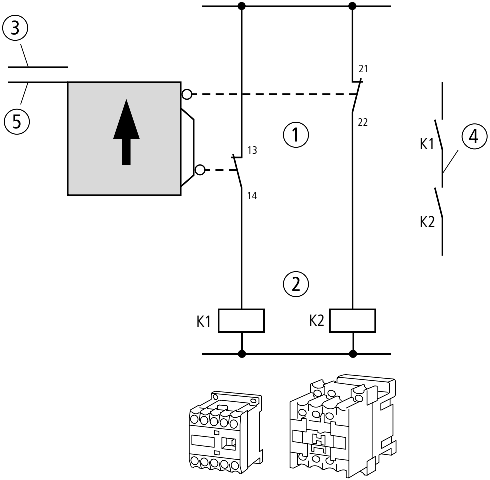
Redundancy
This means the existence of an additional device or system which takes over the function in the event of a fault.

Specifications, Formulae, Tables

Measures for risk avoidance

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 normally open and normally break 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

Function tests

The correct functioning of the equipment can be tested either manually or automatically.

Specifications, Formulae, Tables

Degrees of protection for electrical equipment

Degrees of protection for electrical equipment by enclosures, covers and similar to IEC/EN 60529 (VDE 0470 part 1)

The designation to indicate degrees of enclosure protection 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 suffient distance from dangerous parts. The probe, sphere 12,5 mm diameter, must not fully penetrate.

Specifications, Formulae, Tables

Degrees of protection 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 wire. The entry probe, 1,0 mm diameter, must not fully penetrate. The probe, 1,0 mm diameter, must not penetrate.
5	Protection against accumulation of dust	Protection against contact with live parts with a wire. 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 wire. The entry probe, 1,0 mm diameter, must not penetrate. No entry of dust.

Example for stating degree of protection: IP 4 4

Characteristic letter (IP)
First numeral (4)
Second numeral (4)

Specifications, Formulae, Tables

Degrees of protection 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.

Specifications, Formulae, Tables

Degrees of protection 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.
9K*	Protected during cleaning using high-pressure /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

* This characteristic numeral originates from DIN 40050 -9.

Specifications, Formulae, Tables

Degrees of protection for electrical equipment

Degree of protection for electrical equipment for USA and Canada to IEC/EN 60529 (VDE 0470 part 1)

The IP ratings quoted in the table represent a rough comparison only. A precise comparison is not possible since the degree of protection tests and the evaluation criteria differ.

Designation of the enclosure and the degree of protection		Designation of the enclosure and the degree of protection to CSA-C22.1, CSA-C22.2 NO. 0.1-M1985 (R1999)[3)]	Comparable IP degree of protection to IEC/EN 60529 DIN 40050
to NEC NFPA 70 (National Electrical Code) to UL 50 to NEMA 250-1997	to NEMA ICS 6-1993 (R2001)[1)] to EEMAC E 14-2-1993[2)]		
Enclosure type 1	Enclosure type 1 General purpose	Enclosure 1 Enclosure for general purpose	IP20
Enclosure type 2 Drip-tight	Enclosure type 2 Drip-proof	Enclosure 2 Drip-proof enclosure	IP22
Enclosure type 3 Dust-tight, rain-tight	Enclosure type 3 Dust-tight, rain-tight, resistant to sleet and ice	Enclosure 3 Weather-proof enclosure	IP54
Enclosure type 3 R Rain-proof	Enclosure type 3 R Rain-proof, resistant to sleet and ice		
Enclosure type 3 S Dust-tight, rain-tight	Enclosure type 3 S Dust-tight, rain-tight, resistant to sleet and ice		
Enclosure type 4 Rain-tight, water-tight	Enclosure type 4 Dust-tight, water-tight	Enclosure 4 Water-tight enclosure	IP65

Specifications, Formulae, Tables

Degrees of protection for electrical equipment

Designation of the enclosure and the degree of protection to NEC NFPA 70 (National Electrical Code) to UL 50 to NEMA 250-1997	 to NEMA ICS 6-1993 (R2001)[1)] to EEMAC E 14-2-1993[2)]	Designation of the enclosure and the degree of protection to CSA-C22.1, CSA-C22.2 NO. 0.1-M1985 (R1999)[3)]	Comparable IP degree of protection to IEC/EN 60529 DIN 40050
Enclosure type 4 X Rain-tight, water-tight, corrosion-resistant	Enclosure type 4 X Dust-tight, water-tight, corrosion-resistant		IP65
Enclosure type 6 Rain-tight	Enclosure type 6 Dust-tight, water-tight, immersible, resistant to sleet and ice		
Enclosure type 6 P Rain-tight, corrosion-resistant			
Enclosure type 11 Drip-tight, corrosion-resistant	Enclosure type 11 Drip-tight, corrosion-resistant, oil-immersed		
Enclosure type 12 Dust-tight, drip-tight	Enclosure type 12 For use in industry, drip-tight, dust-tight	Enclosure 5 Dust-tight enclosure	IP54
Enclosure type 12 K (As for type 12)			
Enclosure type 13 Dust-tight, drip-tight	Enclosure type 13 Dust-tight, oil-tight		

1) NEMA = National Electrical Manufacturers Association

2) EEMAC = Electrical and Electronic Manufacturers Association of Canada

3) CSA = Canadian Electrical Code, Part I (19th Edition), Safety Standard for Electrical Installations

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Specifications, Formulae, Tables
Degrees of protection for electrical equipment

Notes

Specifications, Formulae, Tables

Degrees of protection for electrical equipment

Type of current	Utilisation catorgory	Typical examples of application	Normal conditions of use	
		I = switch-on current, I_c = switch-off current, I_e = rated operational current, U = voltage, U_e = rated operational voltage U_r = recovery voltage, $t_{0.95}$ = time in ms to reach 95 % of the steady state curent. $P = U_e \times I_e$ = rated power in Watts	Make $\frac{I}{I_e}$	$\frac{U}{U_e}$
AC	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	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

to IEC 60947-5-1, EN 60947-5-1 (VDE 0600 part 200)

Specifications, Formulae, Tables

Degrees of protection for electrical equipment

				Abnormal conditions of use					
Break				Make			Break		
$\cos \varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos \varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos \varphi$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos \varphi$
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	–	–	–	–	–	–
$6 \times P$[1]	1	1	$6 \times P$[1]	1.1 $6 \times P$[1]	1.1	$6 \times P$[1]	1.1	1.1	
15 ms	1	1	15 ms	10	1.1	15 ms	10	1.1	15 ms

1) The value "$6 \times P$" 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.

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Specifications, Formulae, Tables

North American classification for control switches

Classification	Designation At maximum rated voltage of			Thermal uninterrupted current
AC	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				
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

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Specifications, Formulae, Tables

North American classification for control switches

Switching capacity				
Rated voltage V	Make A	Break A	Make VA	Break VA
120 240 480 600	60 30 15 12	6 3 1.5 1.2	7200 7200 7200 7200	720 720 720 720
120 240 480 600	30 15 7.5 6	3 1.5 0.75 0.6	3600 3600 3600 3600	360 360 360 360
120 240 480 600	15 7.5 3.75 3	1.5 0.75 0.375 0.3	1800 1800 1800 1800	180 180 180 180
120 240	3.6 1.8	0.6 0.3	432 432	72 72
125 250 301 to 600	2.2 1.1 0.4	2.2 1.1 0.4	275 275 275	275 275 275
125 250 301 to 600	1.1 0.55 0.2	1.1 0.55 0.2	138 138 138	138 138 138
125 250 301 to 600	0.55 0.27 0.10	0.55 0.27 0.10	69 69 69	69 69 69
125 250 301 to 600	0.22 0.11 –	0.22 0.11 –	28 28 –	28 28 –

Specifications, Formulae, Tables
Utilisation categories for contactors

Type of current	Utilisation category	Typical examples of application I = switch-on current, I_c = switch-off current, I_e = rated operational current, U = voltage, U_e = rated operational voltage U_r = recovery voltage	Verification of electrical lifespan		
			Make		
			$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$
AC	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	Squirrel-cage motors: stating, switch-off, switch-off during running[4)]	$I_e \leqq 17$ $I_e > 17$	6 6	1 1
	AC-4	Sqirrel-cage 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 incandescent 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 household appliances			
	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 releases[5)]			
	AC-53a	Switching of squirrel-cage motor with semi-conductor contactors			

Specifications, Formulae, Tables

Utilisation categories for contactors

				Verification of switching capacity						
	Break			Make				Break		
cos φ	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	cos φ	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	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 0.35	1 1	0.17 0.17	0.65 0.35	$I_e \leqq 100$ $I_e > 100$	8 8	1.05 1.05	0.45 0.35	8 8	1.05 1.05	0.45 0.35
0.65 0.35	6 6	1 1	0.65 0.35	$I_e \leqq 100$ $I_e > 100$	10 10	1.05 1.05	0.45 0.35	10 10	1.05 1.05	0.45 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]	
					8.0	1.05	0.35	8.0	1.05	0.35

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Specifications, Formulae, Tables

Utilisation categories for contactors

Type of current	Utilization category	Typical examples of application I = switch-on current, I_c = switch-off current, I_e = rated operational current, U = voltage, U_e = rated operational voltage, U_r = recovery voltage	Verification of electrical endurance		
			Make		
			$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$
DC	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 incandescent lamps			

To IEC/EN 60 947-4-1, VDE 0660 Part 102

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 incandescent lamp load connected.

3) Here, the test data are to be derived from the AC-3 or AC-4 test values in accordance with TableVIIb, IEC/EN 60 947-4-1.

Specifications, Formulae, Tables
Utilisation categories for contactors

				Verification of switching capacity						
	Break			Make				Break		
L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	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 1.5	1.05 1.05	15	4 1.5[2]	1.05 1.05[2]	15
					[2]	[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 refrigerant.

Specifications, Formulae, Tables

Utilisation categories for switch-disconnectors

Type of current	Utilisation category	Typical examples of application I = switch-on current, I_c = switch-off current, I_e = rated operational current, U = voltage, U_e = rated operational voltage, U_r = recovery voltage	Verification of electrical endurance Make $\frac{I_e}{A}$	 $\frac{I}{I_e}$
AC	AC-20 A(B)[2)]	Making and breaking without load	All values	[1)]
	AC-21 A(B)[2)]	Switching resistive loads including low overloads	All values	1
	AC-22 A(B)[2)]	Switching mixed resistive and inductive loads including low overloads	All values	1
	AC-23 A(B)[2)]	Switching motors and other highly inductive loads	All values	1
			$\frac{I_e}{A}$	$\frac{I}{I_e}$
DC	DC-20 A(B)[2)]	Making and breaking without load	All values	[1)]
	DC-21 A(B)[2)]	Switching resistive loads including low overloads	All values	1
	DC-22 A(B)[2)]	Switching mixed resistive and inductive loads, including low overloads (e.g. shunt motors)	All values	1
	DC-23 A(B)[2)]	Switching highly inductive loads (e.g. series motors)	All values	1

For load-break switches, switch-disconnectors and switch-fuse units to IEC/EN 60947-3 (VDE 0660 part 107)

1) If the switching device has a making and/or breaking capacity, the figures for the current and the power factor (time constants) must be stated by the manufacturer.
2) A: frequent operation, B: occasional operation.

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Specifications, Formulae, Tables

Utilisation categories for switch-disconnectors

					Verification of switching capacity						
		Break			Make				Break		
$\frac{U}{U_e}$	$\cos\varphi$	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	$\cos\varphi$	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	$\cos\varphi$	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	$\cos\varphi$
1)	1)	1)	1)	1)	All values	1)		1)	1)		1)
1	0.95	1	1	0.95	All values	1.5	1.05	0.95	1.5	1.05	0.95
1	0.8	1	1	0.8	All values	3	1.05	0.65	3	1.05	0.65
1	0.65	1	1	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
$\frac{U}{U_e}$	L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms	$\frac{I_e}{A}$	$\frac{I}{I_e}$	$\frac{U}{U_e}$	L/R ms	$\frac{I_c}{I_e}$	$\frac{U_r}{U_e}$	L/R ms
1)	1)	1)	1)	1)	All values	1)	1)	1)	1)	1)	1)
1	1	1	1	1	All values	1.5	1.05	1	1.5	1.05	1
1	2	1	1	2	All values	4	1.05	2.5	4	1.05	2.5
1	7.5	1	1	7.5	All values	4	1.05	15	4	1.05	15

Notes

Specifications, Formulae, Tables

Rated operational currents

Motor operational currents for three-phase motors (standard values for squirrel cage motors)

Minimum fuse size for short-circuit protection of three-phase motors

The maximum size is determined by the requirements of the switchgear or overload relay.

The rated motor currents are for standard 1500 r.p.m. motors with normal inner and outer surface cooling.

D.O.L. starting:	Maximum starting current: 6 × rated current Maximum starting time: 5 sec.
Y/Δ starting:	Maximum starting current: 2 × rated current Maximum starting time: 15 sec. Motor overload relay in phase current: set to 0.58 × rated current.

Rated fuse currents for Y/Δ 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 low-voltage h.b.c. fuses (NH type) with aM characteristics, fuses are to be selected according to their current rating.

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Specifications, Formulae, Tables
Rated operational currents

Motor rating			230 V			400 V		
			Motor operation rated current	Fuse Direct starting	Fuse Y/Δ	Motor operation rated current	Fuse Direct starting	Fuse 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	–	–	–	–	–	–

Specifications, Formulae, Tables

Rated operational currents

Motor rating			500 V			690 V		
			Motor operation rated current	Fuse Direct starting	Fuse Y/△	Motor operation rated current	Fuse Direct starting	Fuse Y/△
kW	cos φ	η [%]	A	A	A	A	A	A
0.06	0.7	58	0.17	2	–	0.12	2	–
0.09	0.7	60	0.25	2	–	0.18	2	–
0.12	0.7	60	0.33	2	–	0.24	2	–
0.18	0.7	62	0.48	2	–	0.35	2	–
0.25	0.7	62	0.7	2	–	0.5	2	–
0.37	0.72	66	0.9	2	2	0.7	2	–
0.55	0.75	69	1.2	4	2	0.9	4	2
0.75	0.79	74	1.5	4	2	1.1	4	2
1.1	0.81	74	2.1	6	4	1.5	4	2
1.5	0.81	74	2.9	6	4	2.1	6	4
2.2	0.81	78	4	10	4	2.9	10	4
3	0.82	80	5.3	16	6	3.8	10	4
4	0.82	83	6.8	16	10	4.9	16	6
5.5	0.82	86	9	20	16	6.5	16	10
7.5	0.82	87	12.1	25	16	8.8	20	10
11	0.84	87	17.4	32	20	12.6	25	16
15	0.84	88	23.4	50	25	17	32	20
18.5	0.84	88	28.9	50	32	20.9	32	25
22	0.84	92	33	63	32	23.8	50	25
30	0.85	92	44	80	50	32	63	32
37	0.86	92	54	100	63	39	80	50
45	0.86	93	65	125	80	47	80	63
55	0.86	93	79	160	80	58	100	63
75	0.86	94	107	200	125	78	160	100
90	0.86	94	129	200	160	93	160	100
110	0.86	94	157	250	160	114	200	125
132	0.87	95	184	250	200	134	250	160
160	0.87	95	224	315	250	162	250	200
200	0.87	95	279	400	315	202	315	250
250	0.87	95	349	500	400	253	400	315
315	0.87	96	436	630	500	316	500	400
400	0.88	96	547	800	630	396	630	400
450	0.88	96	615	800	630	446	630	630
500	0.88	97	–	–	–	491	630	630
560	0.88	97	–	–	–	550	800	630
630	0.88	97	–	–	–	618	800	630

Specifications, Formulae, Tables

Rated operational currents

Motor rated currents for North American three-phase motors[1)]

Motor rating	Motor rated operational current in Amperes[2)]			
HP	115 V	230 V[3)]	460 V	575 V
1/2	4.4	2.2	1.1	0.9
3/4	6.4	3.2	1.6	1.3
1	8.4	4.2	2.1	1.7
1 1/2	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
7 1/2		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: 1/2–200 HP = NEC Code, Table 430-150
= CSA-C22.1-1986, Table 44
250–500 HP = UL 508, Table 52.2

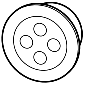
2) The motor full-load current values given are approximate values. For exact values consult the data stated by the manufacturer or the motor rating plates.

3) For motor full-load currents of 208 V motors/200 V motors, use the appropriate values for 230 V motors, increased by 10–15 %.

Wiring and cable entries with grommets

Cable entry into closed devices is considerably simplified and improved by using cable grommets.

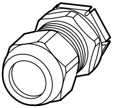
Cable grommets
For direct and quick cable entry into an enclosure and as a plug.

Membrane-grommit metric	Conductor entry	Hole diameter mm	Cable external diameter mm	Using cable NYM/NYY, 4 core mm^2	Cable grommit part no
 • IP66, with integrated push-through membrane • PE and thermoplastic elastomer, halogen free	M16	16.5	1–9	H03VV-F3 × 0.75 NYM 1 × 16/3 × 1.5	KT-M16
	M20	20.5	1–13	H03VV-F3 × 0.75 NYM 5 × 1.5/5 × 2.5	KT-M20
	M25	25.5	1–18	H03VV-F3 × 0.75 NYM 4× 10	KT-M25
	M32	32.5	1–25	H03VV-F3 × 0.75 NYM 4 × 16/5 × 10	KT-M32

Specifications, Formulae, Tables
Conductors

Wiring and cable entries with cable glands

Cable glands, metric to EN 50262
with 9, 10, 12, 14 or 15 mm long thread.

Cable glands	Conductor entry	Hole diameter mm	Cable external diameter mm	Using cable NYM/NYY, 4 core mm²	Cable gland part no
 • with locknut and integrated strain relief • IP68 up to 5 bar, polyamid, halogen free	M12	12.5	3–7	H03VV-F3 × 0.75 NYM 1 × 2.5	V-M12
	M16	16.5	4.5–10	H05VV-F3 × 1.5 NYM 1 × 16/3 × 1.5	V-M16
	M20	20.5	6–13	H05VV-F4 × 2.5/3 × 4 NYM 5 × 1.5/5 × 2.5	V-M20
	M25	25.5	9–17	H05VV-F5 × 2.5/5 × 4 NYM 5 × 2.5/5 × 6	V-M25
	M32	32.5	13–21	NYM 5 × 10	V-M32
	M32	32.5	18–25	NYM 5 × 16	V-M32G[1)]
	M40	40.5	16–28	NYM 5 × 16	V-M40
	M50	50.5	21–35	NYM 4 × 35/5 × 25	V-M50
	M63	63.5	34–48	NYM 4 × 35	V-M63

1) Does not correspond to EN 50262.

Specifications, Formulae, Tables

Conductors

External diameter of conductors and cables

Number of conductors	Approximate external diameter (average 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 × 1.5	10	11	9	10	12
2 × 2.5	11	13	13	11	14
3 × 1.5	10	12	10	10	13
3 × 2.5	11	13	11	12	14
3 × 4	13	17	–	14	15
3 × 6	15	18	–	16	16
3 × 10	18	20	–	23	18
3 × 16	20	22	–	25	22
4 × 1.5	11	13	9	11	13
4 × 2.5	12	14	11	13	15
4 × 4	14	16	–	15	16
4 × 6	16	17	–	17	18
4 × 10	18	19	–	23	21
4 × 16	22	23	–	27	24
4 × 25	27	27	–	32	30
4 × 35	30	28	–	36	31
4 × 50	–	30	–	42	34
4 × 70	–	34	–	47	38
4 × 95	–	39	–	53	43
4 × 120	–	42	–	–	46
4 × 150	–	47	–	–	52
4 × 185	–	55	–	–	60
4 × 240	–	62	–	–	70
5 × 1.5	11	14	12	14	15
5 × 2.5	13	15	14	17	17
5 × 4	15	17	–	19	18
5 × 6	17	19	–	21	20
5 × 10	20	21	–	26	–
5 × 16	25	23	–	30	–
8 × 1.5	–	15	–	–	–
10 × 1.5	–	18	–	–	–
16 × 1.5	–	20	–	–	–
24 × 1.5	–	25	–	–	–

NYM: sheathed conductor
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

Specifications, Formulae, Tables
Conductors

Cables and wiring, type abbreviation

Identification of specification

Harmonized specification	H
Recognized national type	A

Rated voltage U_0/U

300/300V	03
300/500 V	05
450/750 V	07

Insulating material

PVC	V
Natural- and/or synthetic rubber	R
Silicon rubber	S

Sheathing material

PVC	V
Natural- and/or synthetic rubber	R
Polychloroprene rubber	N
Fibre-glass braid	J
Textile braid	T

Special construction feature

Flat, separable conductor	H
Flat, non-separable conductor	H2

Type of cable

Solid	-U
Stranded	-R
Flexible with cables for fixed installation	-K
Flexible with flexible cables	-F
Highly flexible with flexible cables	-H
Tinsel cord	-Y

Number of cores …

Protective conductor

Without protective conductors	X
With protective conductors	G

Rated conductor cross-section …

Examples for complete cable designation

PVC-sheathed wire, 0.75 mm²flexible, H05V-K 0.75 black

Heavy rubber-sheathed cable, 3-core, 2.5 mm² without green/yellow protective conductor A07RN-F3 × 2.5

Notes

Specifications, Formulae, Tables
Conductors

Conversion of North American cable cross sections into mm²

USA/Canada	Europe	
AWG/circular mills	mm² (exact)	mm² (next standard size)
22	0.326	0.4
21	0.411	
20	0.518	0.5
19	0.653	
18	0.823	0.75
17	1.04	1
16	1.31	1.5
15	1.65	
14	2.08	
13	2.62	2.5
12	3.31	4
11	4.17	
10	5.26	6
9	6.63	
8	8.37	10
7	10.50	
6	13.30	16
5	16.80	
4	21.20	25
3	26.70	
2	33.60	35
1	42.40	
1/0	53.50	50
2/0	67.40	70
3/0	85	
4/0	107	95

Specifications, Formulae, Tables

Conductors

USA/Canada	Europe	
AWG/circular mills	**mm² (exact)**	**mm² (next standard size)**
circular mills		
250.000	127	120
300.000	152	150
350.000	177	185
400.000	203	
450.000	228	
500.000	253	240
550.000	279	
600.000	304	300
650.000	329	
700.000	355	
750.000	380	
800.000	405	
850.000	431	
12900.000	456	
950.000	481	
1.000.000	507	500
1.300.000	659	625

In addition to “circular mills”, cable sizes are often given in “MCM”: 250 000 circular mills = 250 MCM

Specifications, Formulae, Tables
Conductors

Rated currents and short-circuit currents for standard transformers

Rated voltage				
U_n	**400/230 V**			**525 V**
Short-circuit voltage U_K		4 %	6 %	
Rated capacity	Rated current I_n	Short-circuit current I''_K		Rated current I_n
kVA	A	A	A	A
50	72	1805	–	55
100	144	3610	2406	110
160	230	5776	3850	176
200	288	7220	4812	220
250	360	9025	6015	275
315	455	11375	7583	346
400	578	14450	9630	440
500	722	18050	12030	550
630	909	22750	15166	693
800	1156	–	19260	880
1000	1444	–	24060	1100
1250	1805	–	30080	1375
1600	2312	–	38530	1760
2000	2888	–	48120	2200

Specifications, Formulae, Tables
Conductors

		690/400 V		
4 %	6 %		4 %	6 %
Short-circuit current		Rated current	Short-circuit current	
I_K''		I_n	I_K''	
A	A	A	A	A
1375	–	42	1042	–
2750	1833	84	2084	1392
4400	2933	133	3325	2230
5500	3667	168	4168	2784
6875	4580	210	5220	3560
8660	5775	263	6650	4380
11000	7333	363	8336	5568
13750	9166	420	10440	7120
17320	11550	526	13300	8760
–	14666	672	–	11136
–	18333	840	–	13920
–	22916	1050	–	17480
–	29333	1330	–	22300
–	36666	1680	–	27840

Specifications, Formulae, Tables

Formulea

Ohm's Law

$U = I \times R \; [V]$	$I = \frac{U}{R} \, [A]$	$R = \frac{U}{I} \, [\Omega]$

Resistance of a piece of wire

$R = \frac{l}{\chi \times A} \, [\Omega]$	Copper:	$\chi = 57 \, \frac{m}{\Omega mm^2}$
l = Length of conductor [m]	Aluminium:	$\chi = 33 \, \frac{m}{\Omega mm^2}$
χ = Conductivity [$m/\Omega mm^2$]	Iron:	$\chi = 8.3 \, \frac{m}{\Omega mm^2}$
A = Conductor cross section [mm^2]	Zinc:	$\chi = 15.5 \, \frac{m}{\Omega mm^2}$

Resistances

Transformer	$X_L = 2 \times \pi \times f \times L \, [\Omega]$	
Capacitors	$X_C = \frac{1}{2 \times \pi \times f \times C} \, [\Omega]$	
Impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$Z = \frac{R}{\cos\varphi} \, [\Omega]$

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:	With 3 parallel resistances:
$R_g = \frac{R_1 \times R_2}{R_1 + R_2} \, [\Omega]$	$R_g = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_2 \times R_3 + R_1 \times R_3} \, [\Omega]$

General calculation of resistances:

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots [1/\Omega]$	$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots [1/\Omega]$
$\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + \ldots [1/\Omega]$	

Specifications, Formulae, Tables
Formulea

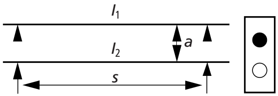
Electric power

	Power	Current consumption
DC	$P = U \times I \ [W]$	$I = \frac{P}{U} [A]$
Single-phase AC	$P = U \times I \times \cos\varphi [W]$	$I = \frac{P}{U \times \cos\varphi} [A]$
Three-phase AC	$P = \sqrt{3} \times U \times I \times \cos\varphi [W]$	$I = \frac{P}{\sqrt{3} \times U \times \cos\varphi} [A]$

Mechanical force between 2 parallel conductors

2 conductors with currents I_1 and I_2

$$F_2 = \frac{0.2 \times I_1 \times I_2 \times s}{a} [N]$$



s = Support spacing clearance [cm]

a = Support spacing clearance [cm]

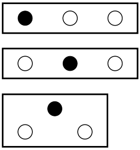
Mechanical force between 3 parallel conductors

3 conductors with current I

$F_3 = 0.808 \times F_2 [N]$

$F_3 = 0.865 \times F_2 [N]$

$F_3 = 0.865 \times F_2 [N]$



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Voltage drop

	Known power	Known current
DC	$\Delta U = \frac{2 \times l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times l \times I}{\chi \times A}$ [V]
Single-phase AC	$\Delta U = \frac{2 \times l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \frac{2 \times l \times I}{\chi \times A} \times \cos\varphi$ [V]
Three-phase AC	$\Delta U = \frac{l \times P}{\chi \times A \times U}$ [V]	$\Delta U = \sqrt{3} \times \frac{l \times I}{\chi \times A} \times \cos\varphi$ [V]

Calculation of cross-section from voltage drop

DC	Single-phase AC	Three-phase AC
Known power		
$A = \frac{2 \times l \times P}{\chi \times u \times U}$ [mm²]	$A = \frac{2 \times l \times P}{\chi \times u \times U}$ [mm²]	$A = \frac{l \times P}{\chi \times u \times U}$ [mm²]
Known current		
$A = \frac{2 \times l \times I}{\chi \times u}$ [mm²]	$A = \frac{2 \times l \times I}{\chi \times u} \times \cos\varphi$ [mm²]	$A = \sqrt{3} \times \frac{l \times I}{\chi \times u} \times \cos\varphi$ [mm²]

Power loss

DC	Single-phase AC
$P_{Verl} = \frac{2 \times l \times P \times P}{\chi \times A \times U \times U}$ [W]	$P_{Verl} = \frac{2 \times l \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi}$ [W]

Three-phase AC

$$P_{Verl} = \frac{l \times P \times P}{\chi \times A \times U \times U \times \cos\varphi \times \cos\varphi} \text{ [W]}$$

l = Single length of conductor [m];
A = Conductor cross section [mm²];
χ = Conductivity (copper: $\chi = 57$; aluminium: $\chi = 33$; iron: $\chi = 8.3 \frac{m}{\Omega mm^2}$)

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Power of electric motors

	Output	Current consumption
DC	$P_1 = U \times I \times \eta$ [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]
Three-phase AC	$P_1 = (1.73) \times U \times I \times \cos\varphi \times \eta$ [W]	$I = \frac{P_1}{(1.73) \times U \times \cos\varphi \times \eta}$ [A]

P_1 = Rated mechanical power at the motor shaft
P_2 = Electrical power consumption

Efficiency	$\eta = \frac{P_1}{P_2} \times (100\ \%)$	$P_2 = \frac{P_1}{\eta}$ [W]

No. 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

Specifications, 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
Luminous intensity	I_v	cd (Candela)	Mcd, kcd, mcd

Factors for conversion of old units into SI units

Conversion factors

Parameter	Old unit	SI unit exact	Approximate
Force	1 kp 1 dyn	9.80665 N $1 \cdot 10^{-5}$ N	10 N $1 \cdot 10^{-5}$ N
Momentum of force	1 mkp	9.80665 Nm	10 Nm
Pressure	1 at 1 Atm = 760 Torr 1 Torr 1 mWS 1 mmWS 1 mmWS	0.980665 bar 1.01325 bar 1.3332 mbar 0.0980665 bar 0.0980665 mbar 9.80665 Pa	1 bar 1.01 bar 1.33 bar 0.1 bar 0.1 mbar 10 Pa
Tension	$1 \frac{kp}{mm^2}$	$9.80665 \frac{N}{mm^2}$	$10 \frac{N}{mm^2}$
Energy	1 mkp 1 kcal 1 erg	9.80665 J 4.1868 kJ $1 \cdot 10^{-7}$ J	10 J 4.2 kJ $1 \cdot 10^{-7}$ J

Specifications, Formulae, Tables

International Unit System

Conversion factors

Parameter	Old unit	SI unit exact	Approximate
Power	$1\frac{kcal}{h}$	$4.1868\frac{kJ}{h}$	$4.2\frac{kJ}{h}$
	$1\frac{kcal}{h}$	1.163 W	1.16 W
	1 PS	0.73549 kW	0.740 kW
Heat transfer coefficient	$1\frac{kcal}{m^2h°C}$	$4.1868\frac{kJ}{m^2hK}$	$4.2\frac{kJ}{m^2hK}$
	$1\frac{kcal}{m^2h°C}$	$1.163\frac{W}{m^2K}$	$1.16\frac{W}{m^2K}$
dynamic viscosity	$1 \cdot 10^{-6}\ \frac{kps}{m^2}$	$0{,}\ 980665 \cdot 10^{-5}\ \frac{Ns}{m^2}$	$1 \cdot 10^{-5}\frac{Ns}{m^2}$
	1 Poise	$0.1\ \frac{Ns}{m^2}$	$0.1\ \frac{Ns}{m^2}$
	1 Poise 0.1	$Pa \cdot s$	
Kinetic viscosity	1 Stokes	$1 \cdot 10^{-4}\ \frac{m^2}{s}$	$1 \cdot 10^{-4}\ \frac{m^2}{s}$
Angle (flat)	1	$\frac{1}{360}$pla	$2{,}\ 78 \cdot 10^{-3}$pla
	1 gon	$\frac{1}{400}$pla	$2{,}\ 5 \cdot 10^{-3}$pla
	1	$\frac{\pi}{180}$rad	$17{,}\ 5 \cdot 10^{-3}$rad
	1 gon	$\frac{\pi}{200}$rad	$15{,}\ 7 \cdot 10^{-3}$pla
	57.296		1 rad
	63.662 gon		1 rad

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Specifications, Formulae, Tables

International Unit System

Conversion of SI units, coherences

Conversion of SI units and coherences

Parameter	SI units name	Symbol	Basic unit	Conversion of SI units
Force	Newton	N	$1 \cdot \frac{kg \cdot m}{s^2}$	
Force momentum	Newton-metre	Nm	$1 \cdot \frac{kg \cdot m^2}{s^2}$	
Pressure	Bar	bar	$10^5 \frac{kg}{m \cdot s^2}$	$1\ bar = 10^5 Pa = 10^5 \frac{N}{m^2}$
	Pascal	Pa	$1 \cdot \frac{kg}{m \cdot s^2}$	$1\ Pa = 10^{-5} bar$
Energy, heat	Joule	J	$1 \cdot \frac{kg \cdot m^2}{s^2}$	1 J = 1 Ws = 1 Nm
Power	Watt	W	$1 \cdot \frac{kg \cdot m^2}{s^3}$	$W = 1\frac{J}{s} = 1\frac{N \cdot m}{s}$
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)	Grad 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	Volt	V	$1 \cdot \frac{kg \cdot m^2}{s^3 \cdot A}$	$1\ V = 1 \cdot \frac{W}{A}$
Resistor	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	$1 \cdot \frac{s^3 \cdot A^2}{kg \cdot m^2}$	$1\ M = 1 \cdot \frac{A}{V} = 1 \cdot \frac{A^2}{W}$
Electric charge	Coulomb	C	$1 \cdot A \cdot s$	

Specifications, Formulae, Tables

International Unit System

Conversion of SI units and coherences

Parameter	SI units name	Symbol	Basic unit	Conversion of SI units
Capacitance	Farad	F	$1 \cdot \frac{s^4 \cdot A}{kg \cdot m^2}$	$1\ F = 1 \cdot \frac{C}{V} = 1 \cdot \frac{s \cdot A^2}{W}$
Field strength		$\frac{V}{m}$	$1 \cdot \frac{kg \cdot m}{s^3 \cdot A}$	$1 \frac{V}{m} = 1 \cdot \frac{W}{A \cdot m}$
Flux	Weber	Wb	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A}$	$1\ W_b = 1 \cdot V \cdot s = 1 \cdot \frac{W \cdot s}{A}$
Flux density	Tesla	T	$1 \cdot \frac{kg}{s^2 \cdot A}$	$1\ T = \frac{W_b}{m^2} = 1 \cdot \frac{V \cdot s}{m^2} = 1 \cdot \frac{W \cdot s}{m^2 A}$
Inductance	Henry	H	$1 \cdot \frac{kg \cdot m^2}{s^2 \cdot A^2}$	$1\ H = \frac{W_b}{A} = 1 \cdot \frac{V \cdot s}{A} = 1 \cdot \frac{W \cdot s}{A^2}$

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	m	10^{6}	Mega	M
10^{-3}	Milli	m	10^{9}	Giga	G
10^{-2}	Centi	c	10^{12}	Tera	T

Specifications, Formulae, Tables
International Unit System

Physical units

Obsolete units

Mechanical force

SI unit:		N (Newton) J/m (Joule/m)		
Previous unit:		kp (kilopond) dyn (Dyn)		
1 N	= 1 J/m	= 1 kg m/s^2	= 0.102 kp	= 10^5 dyn
1 J/m	= 1 N	= 1 kg m/s^2	= 0.102 kp	= 10^5 dyn
1 kg m/s^2	= 1 N	= 1 J/m	= 0.102 kp	= 10^5 dyn
1 kp	= 9.81 N	= 9.81 J/m	= 9.81 kg m/s^2	= 0.981 10^6 dyn
1 dyn	= 10^{-5} N	= 10^{-5} J/m	= 10^{-5} kg m/s^2	= 1.02 10^{-5} kp

Pressure

SI unit:		Pa (Pascal) bar (Bar)		
Previous unit:		at = kp/cm^2 = 10 m Ws Torr = mm Hg atm		
1 Pa	= 1 N/m^2	= 10^{-5} bar		
1 Pa	= 10^{-5} bar	= $10.2 \cdot 10^{-6}$ at	= $9.87 \cdot 10^{-6}$ at	= $7.5 \cdot 10^{-3}$ Torr
1 bar	= 10^5 Pa	= 1.02 at	= 0.987 at	= 750 Torr
1 at	= $98.1 \cdot 10^3$ Pa	= 0.981 bar	= 0.968 at	= 736 Torr
1 atm	= $101.3 \cdot 10^3$ Pa	= 1.013 bar	= 1.033 at	= 760 Torr
1 Torr	= 133.3 Pa	= $1.333 \cdot 10^{-3}$ bar	= $1.359 \cdot 10^{-3}$ at	= $1.316 \cdot 10^{-3}$ atm

Specifications, Formulae, Tables

International Unit System

Work

SI unit:	J (Joule) Nm (Newtonmeter)
SI unit: (as before)	Ws (Wattsecond) kWh (Kilowatthour)
Previous unit:	kcal (Kilocalorie) = cal · 10^{-3}

1 Ws	= 1 J	= 1 Nm	10^7 erg		
1 Ws	= 278 · 10^{-9} kWh	= 1 Nm	= 1 J	= 0.102 kpm	= 0.239 cal
1 kWh	= 3.6 · 10^6 Ws	= 3.6 · 10^6 Nm	= 3.6 · 10^6 J	= 367 · 10^6 kpm	= 860 kcal
1 Nm	= 1 Ws	= 278 · 10^{-9} kWh	= 1 J	= 0.102 kpm	= 0.239 cal
1 J	= 1 Ws	= 278 · 10^{-9} kWh	= 1 Nm	= 0.102 kpm	= 0.239 cal
1 kpm	= 9.81 Ws	= 272 · 10^{-6} kWh	= 9.81 Nm	= 9.81 J	= 2.34 cal
1 kcal	= 4.19 · 10^3 Ws	= 1.16 · 10^{-3} kWh	= 4.19 · 10^3 Nm	= 4.19 · 10^3 J	= 427 kpm

Power

SI unit:	Nm/s (Newtonmetre/s) J/s (Joule/s)
SI unit: (as before)	W (Watt) kW (Kilowatt)
Previous unit:	kcal/s (Kilocalorie/sec.) = cal/s · 10^3 kcal/h (Kilocalorie/hour.) = cal/h · 10^6 kpm/s (Kilopondmetre/Sec.) PS (metric horsepower)

1 W	= 1 J/s	= 1 Nm/s			
1 W	= 10^{-3} kW	= 0.102 kpm/s	= 1.36 · 10^{-3} PS	= 860 cal/h	= 0.239 cal/s
1 kW	= 10^3 W	= 102 kpm/s	= 1.36 PS	= 860 · 10^3 cal/h	= 239 cal/s
1 kpm/s	= 9.81 W	= 9.81 · 10^{-3} kW	= 13.3 · 10^{-3} PS	= 8.43 · 10^3 cal/h	= 2.34 cal/s
1 PS	= 736 W	= 0.736 kW	= 75 kpm/s	= 632 · 10^3 cal/h	= 176 cal/s
1 kcal/h	= 1.16 W	= 1.16 · 10^{-3} kW	= 119 · 10^{-3} kpm/s	= 1.58 · 10^{-3} PS	= 277.8 · 10^{-3} cal/s
1 cal/s	= 4.19 W	= 4.19 · 10^{-3} kW	= 0.427 kpm/s	= 5.69 · 10^{-3} PS	= 3.6 kcal/h

Specifications, Formulae, Tables

International Unit System

Magnetic field strength

SI unit:		$\frac{A}{m}$ $\frac{\text{Ampere}}{\text{Metre}}$
Previous unit:		Oe = (Oerstedt)
$1\ \frac{A}{m}$	$= 0,001\ \frac{kA}{m}$	= 0.01256 Oe
$1\ \frac{kA}{m}$	$= 1000\ \frac{A}{m}$	= 12.56 Oe
1 Oe	$= 79,6\ \frac{A}{m}$	$= 0,0796\ \frac{kA}{m}$

Magnetic field strength

SI unit		Wb (Weber) μWb (Microweber)
Previous unit:		M = Maxwell
1 Wb	$= 1\ Tm^2$	
1 Wb	$= 10^6$ μWb	$= 10^8$ M
1 μWb	$= 10^{-6}$ Wb	= 100 M
1 M	$= 10^{-8}$ Wb	= 0.01 μWb

Magnetic flux density

SI unit:		T (Tesla) mT (Millitesla)
Previous unit:		G = Gauss
1 T	$= 1\ Wb/m^2$	
1 T	$= 10^3$ mT	$= 10^4$ G
1 mT	$= 10^{-3}$ T	= 10 G
1 G	$= 0.1^{-3}$ T	= 0.1 mT

Specifications, 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		
Speed	$1 \frac{\text{mile}}{\text{h}}$	1 Knot	$1 \frac{\text{ft}}{\text{s}}$	$1 \frac{\text{ft}}{\text{min}}$		
$\frac{\text{m}}{\text{s}}$	0.4470	0.5144	0.3048	$5.080 \cdot 10^{-3}$		
Pressure	$1 \frac{\text{lb}}{\text{sq.in}}$ 1 psi	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	$2.684 \cdot 10^6$	$1.055 \cdot 10^3$	$1.90 \cdot 10^3$			

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Specifications, 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 Surface mile	0.5399 mile Nautical 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	1cm^2	1 m^2	1 m^2	1 m^2	1 km^2
	0.1550 sq.in	10.7639 sq.ft	1.1960 sq.yd	$0.2471 \cdot 10^{-3}$ acre	0.3861 sq.mile
Volume	1cm^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	$0.1003 \cdot 10^{-3}$ long ton (UK)		$0.1123 \cdot 10^{-3}$ short ton (US)	7.2306 pdl (poundal)
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	
	$0.3725 \cdot 10^{-6}$ HPh	$0.9478 \cdot 10^{-3}$ BTU		$0.5263 \cdot 10^{-3}$ PCU	

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