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

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

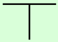
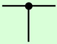
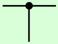
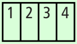
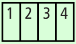
Specifications, Formulae, Tables

Circuit symbols, European – North America

Circuit symbols to DIN EN, NEMA ICS

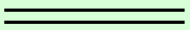
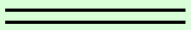
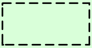
The following comparison of circuit symbols is based upon the following international/national specifications:

- 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	 03-02-03	
Conductor	—— 03-01-01	——

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	

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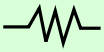
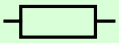
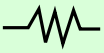
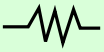
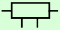
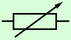
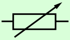
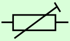
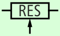
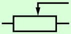
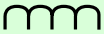
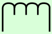
Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Passive components		
Resistor, general symbol	 or  04-01-02 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	 or  04-03-01 04-03-02	
Winding with fixed tapping	 04-03-06	
Capacitor, general symbol	 or  04-02-01 04-02-02	 or 
Variable capacitor	 104-02-01	

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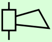
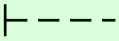
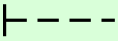
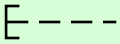
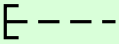
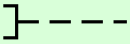
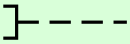
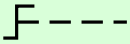
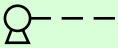
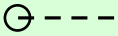
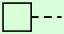
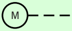
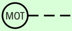
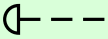
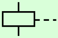
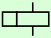
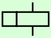
Specifications, Formulae, Tables

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		

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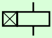
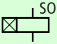
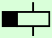
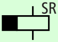
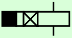
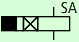
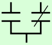
Specifications, Formulae, Tables

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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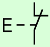
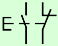
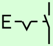
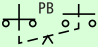
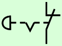
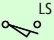
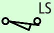
Specifications, Formulae, Tables

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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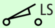
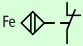
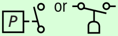
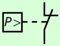
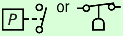
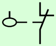
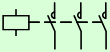
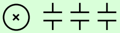
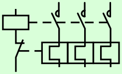
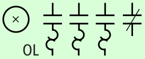
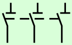
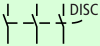
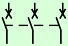
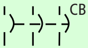
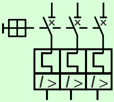
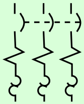
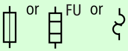
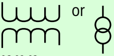
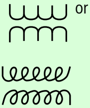
Specifications, Formulae, Tables

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	
Pressure switch, break contact		
Float switch, make contact		
Float switch, break contact		

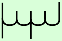
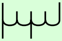
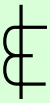
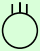
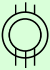
Specifications, Formulae, Tables

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 06-09-01	

Specifications, Formulae, Tables

Circuit symbols, European – North America

Description	DIN EN	NEMA ICS
Autotransformer	 06-09-07 or  06-09-06	 or 
Current transformer	  06-09-11 or  06-09-10	
Machines		
Generator	 06-04-01	 or 
Motor, general symbol	 06-04-01	 or 
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	

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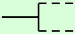
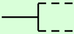
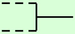
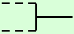
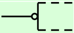
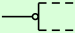
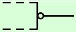
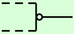
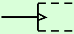
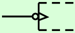
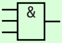
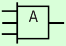
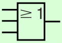
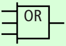
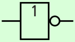
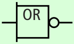
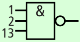
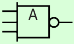
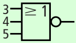
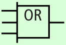
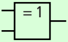
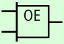
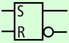
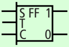
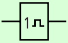
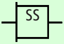
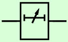
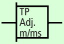
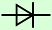
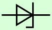
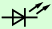
Specifications, Formulae, Tables

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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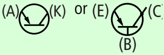
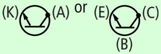
Specifications, Formulae, Tables

Circuit symbols, European – North America

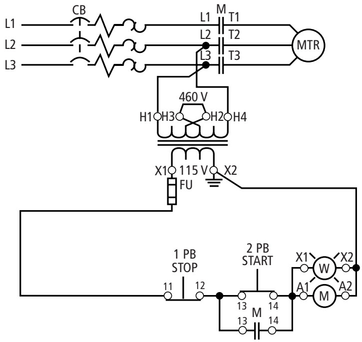
Description	DIN EN	NEMA ICS
PNP transistor	 05-05-01	
NPN transistor, in which the collector is connected to the enclosure	 05-05-02	

Specifications, Formulae, Tables

Circuit diagram example to North American specifications

Direct-on-Line Motor-Starters

Fuseless with circuit-breakers



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 **Élec**trotechnique European committee for electrotechnical standards	Europe

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Specifications, Formulae, Tables

Approval authorities worldwide

Abbreviation	Full title	Country
CSA	**C**anadian **S**tandards **A**ssociation	Canada
DEMKO	**D**anmarks **E**lektriske **M**ateriel**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

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)	VDE	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)		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

Specifications, Formulae, Tables

Protective measures

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.

Protective measures

- Protection against **direct** as well as **indirect** contact
  - Protection by extra-low voltage:
    – SELV
    – PELV
- Protection against **direct** contact
  - Protection by insulation of active parts
  - Protection by covering or encapsulating
  - Protection by partitioning
  - Protection by distancing
- Protection against **indirect** contact
  - Protection by automatic disconnection of the power supply
  - Protective insulation (Total insulation) ⧈
  - Protection by non-conductive spaces
  - Protection by non-earthed local equipotential bonding
  - Protective isolation

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).

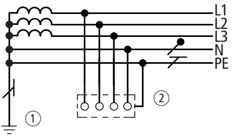
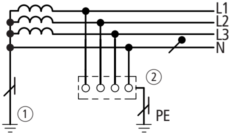
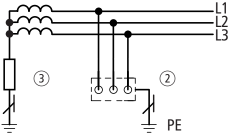
Specifications, Formulae, Tables

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

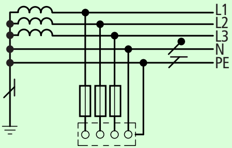
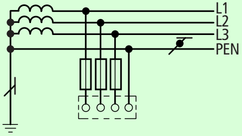
Earth continuity type systems	Meaning of designation
TN system 	T: direct earthing of a point (system earth) N: chassis directly connected to the system earth
TT system 	T: direct earthing of a point (system earth) T: chassis directly earthed, independent of the earthing of the power supply (system earth)
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

Specifications, Formulae, Tables

Protective measures

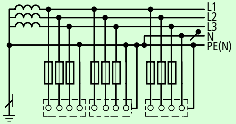
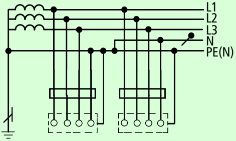
Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

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*: ($\leqq$ 50 V AC, $\leqq$ 120 V DC)
Residual voltage protection device (in special case)			
Insulation monitoring devices			

* → Table, Page 9-41

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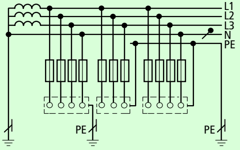
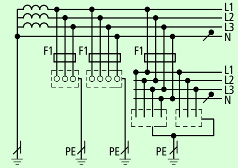
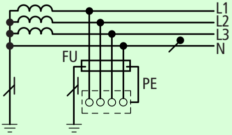
Specifications, Formulae, Tables

Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

Type of distribution system	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 $\leqq$ 5 s U_L = Maximum permissible touch voltage*: ($\leqq$ 50 V AC, $\leqq$ 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

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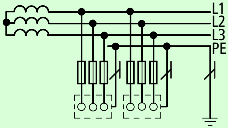
Specifications, Formulae, Tables

Protective measures

Protective devices and conditions for disconnection to IEC 364-4-1/VDE 0100 Part 410

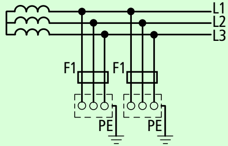
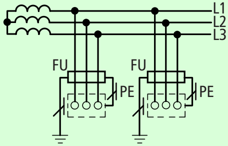
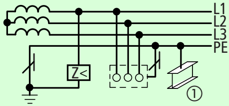
Type of distribution system	**TT system**		
Protection with	System circuit	Description up to now	Conditions for indica-tion/disconnection
Insulation monitoring device	–		
Overcurrent protection device	 	Feed back to protective multiple earthing	$R_A \times I_d \leqq U_L$ (1) $Z_S \times I_a \leqq U_o$ (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*: ≦ 50 V AC, ≦ 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

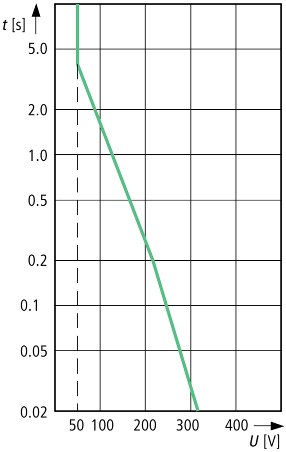
Type of distribution system	IT system		
Protection with	System circuit	Description so far	Conditions for indication/disconnection
Residual-current protective device		Residual-current protective circuit	$R_A \times I_{\Delta n} \leqq U_L$ $I_{\Delta n}$ = rated fault current
Residual voltage protective 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

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)

$I_B \leqq I_n \leqq I_Z$

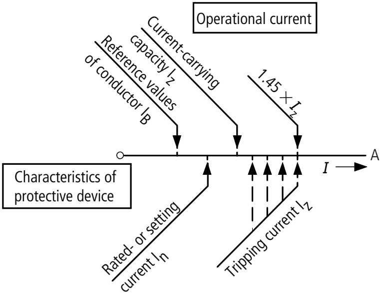
$I_2 \leqq 1{,}45\,I_Z$

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:

$$t = \left(k \times \frac{S}{I}\right)^2 \quad \text{or} \quad I^2 \times t = k^2 \times S^2$$

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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.

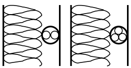
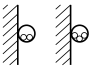
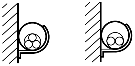
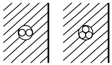
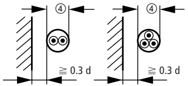
2. In installations without a directly earthed neutral point **(IT system)**

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 In heat-insulating walls, in conduit under the surface	B1 In electrical conduit or cable channel Single-core cable	B2 On or under the wall surface, under plaster Multi-core cable	C Installed directly in the wall	E 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.

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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)

Phase conductor		Protective conductor or PEN conductor [1)]		Protective conductor [3)] laid seperately		
		Insulated power cables	0.6/1-kV cable with 4 conductors	Protected		Unprotected [2)]
mm²		mm²	mm²	mm² Cu	Al	mm² Cu
to	0.5	0.5	–	2.5	4	4
	0.75	0.75	–	2.5	4	4
	1	1	–	2.5	4	4
	1.5	1.5	1.5	2.5	4	4
	2.5	2.5	2.5	2.5	4	4
	4	4	4	4	4	4
	6	6	6	6	6	6
	10	10	10	10	10	10
	16	16	16	16	16	16
	25	16	16	16	16	16
	35	16	16	16	16	16
	50	25	25	25	25	25
	70	35	35	35	35	35
	95	50	50	50	50	50
	120	70	70	70	70	70
	150	70	70	70	70	70
	185	95	95	95	95	95
	240	–	120	120	120	120
	300	–	150	150	150	150
	400	–	185	185	185	185

1) PEN conductor ≧ 10 mm² Cu or 18 mm² Al.
2) It is not permissible to lay aluminium conductors without protection.
3) With phase conductors of ≧ 95 mm² or more, it is advisable to use non-insulted conductors

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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.

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

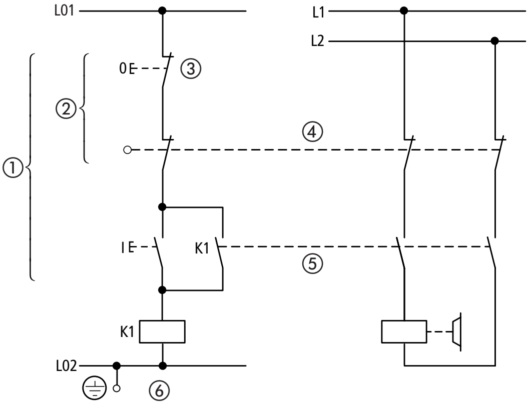
Measures for risk reduction

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



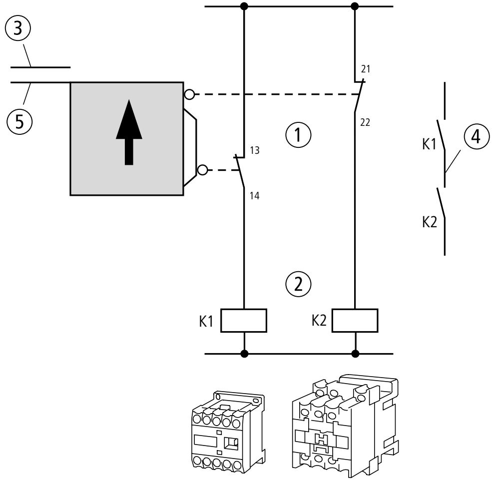
① All switching functions on the non-earthed side
② Use of break devices with positively opening contacts (not to be confused with interlocked opposing contacts)
③ Shut-down by de-excitation (fail-safe in the event of wire breakage)
④ Circuit engineering measures which make undesirable operational states 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

First numeral

Second numeral

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 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 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		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 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

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.

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

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			

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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

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

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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.

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	–	–	–	–	–	–

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Specifications, Formulae, Tables

Rated operational currents

Motor rating			500 V			690 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	0.17	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.

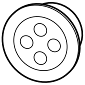
3) For motor full-load currents of 208 V motors/200 V motors, use the appropriate values for 230 V motors, increased by 10–15 %.

Specifications, Formulae, Tables
Conductors

Wiring and cable entries with grommets

Cable entry into closed devices is considerably simplified and improved by using cable grommets.

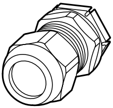
Cable grommets
For direct and quick cable entry into an enclosure and as a plug.

Membrane-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 ther-moplastic 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 mm^2	Cable gland part no
	M12	12.5	3–7	H03VV-F3 × 0.75 NYM 1 × 2.5	V-M12
• with locknut and integrated strain relief	M16	16.5	4.5–10	H05VV-F3 × 1.5 NYM 1 × 16/3 × 1.5	V-M16
• IP68 up to 5 bar, polyamid, halogen free	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-M32G1)
	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 mm^2

USA/Canada	Europe	
AWG/circular mills	mm^2 (exact)	mm^2 (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	Short-circuit current		Rated current
	I_n	I_K''		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] $\qquad I = \frac{U}{R}$ [A] $\qquad R = \frac{U}{I}$ [Ω]

Resistance of a piece of wire

$R = \frac{l}{\chi \times A}$ [Ω]

l = Length of conductor [m]

χ = Conductivity [m/Ωmm²]

A = Conductor cross section [mm²]

Copper:	$\chi = 57 \frac{m}{\Omega mm^2}$
Aluminium:	$\chi = 33 \frac{m}{\Omega mm^2}$
Iron:	$\chi = 8.3 \frac{m}{\Omega mm^2}$
Zinc:	$\chi = 15.5 \frac{m}{\Omega mm^2}$

Resistances

Transformer	$X_L = 2 \times \pi \times f \times L$ [Ω]	
Capacitors	$X_C = \frac{1}{2 \times \pi \times f \times C}$ [Ω]	
Impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$Z = \frac{R}{\cos\varphi}$ [Ω]

L = Inductance [H]

C = Capacitance [F]

X_L = Inductive impedance [Ω]

X_C = Capacitive impedance [Ω]

f = Frequency [Hz]

φ = Phase angle

Parallel connection of resistances

With 2 parallel resistances:

$R_g = \frac{R_1 \times R_2}{R_1 + R_2}$ [Ω]

With 3 parallel resistances:

$R_g = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_2 \times R_3 + R_1 \times R_3}$ [Ω]

General calculation of resistances:

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots [1/\Omega]$

$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots [1/\Omega]$

$\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \frac{1}{X_3} + \ldots [1/\Omega]$

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	$P = \sqrt{3} \times U \times I \times \cos\varphi[W]$	$I = \frac{P}{\sqrt{3} \times U \times \cos\varphi}[A]$

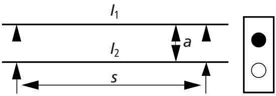
Mechanical force between 2 parallel conductors

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]



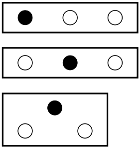
Mechanical force between 3 parallel conductors

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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Specifications, Formulae, Tables

Formulea

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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Specifications, Formulae, Tables

Formulea

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	$1 \frac{kcal}{m^2 h°C}$	$4.1868 \frac{kJ}{m^2 hK}$	$4.2 \frac{kJ}{m^2 hK}$
	$1 \frac{kcal}{m^2 h°C}$	$1.163 \frac{W}{m^2 K}$	$1.16 \frac{W}{m^2 K}$
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 · 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 · A · 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 · 10^{-6} at	= 9.87 · 10^{-6} at	= 7.5 · 10^{-3} Torr
1 bar	= 10^5 Pa	= 1.02 at	= 0.987 at	= 750 Torr
1 at	= 98.1 · 10^3 Pa	= 0.981 bar	= 0.968 at	= 736 Torr
1 atm	= 101.3 · 10^3 Pa	= 1.013 bar	= 1.033 at	= 760 Torr
1 Torr	= 133.3 Pa	= 1.333 · 10^{-3} bar	= 1.359 · 10^{-3} at	= 1.316 · 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 $\cdot 10^{-3}$

1 Ws	= 1 J	= 1 Nm	10^7 erg		
1 Ws	= $278 \cdot 10^{-9}$ kWh	= 1 Nm	= 1 J	= 0.102 kpm	= 0.239 cal
1 kWh	= $3.6 \cdot 10^6$ Ws	= $3.6 \cdot 10^6$ Nm	= $3.6 \cdot 10^6$ J	= $367 \cdot 10^6$ kpm	= 860 kcal
1 Nm	= 1 Ws	= $278 \cdot 10^{-9}$ kWh	= 1 J	= 0.102 kpm	= 0.239 cal
1 J	= 1 Ws	= $278 \cdot 10^{-9}$ kWh	= 1 Nm	= 0.102 kpm	= 0.239 cal
1 kpm	= 9.81 Ws	= $272 \cdot 10^{-6}$ kWh	= 9.81 Nm	= 9.81 J	= 2.34 cal
1 kcal	= $4.19 \cdot 10^3$ Ws	= $1.16 \cdot 10^{-3}$ kWh	= $4.19 \cdot 10^3$ Nm	= $4.19 \cdot 10^3$ 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 $\cdot 10^3$ kcal/h (Kilocalorie/hour.) = cal/h $\cdot 10^6$ kpm/s (Kilopondmetre/Sec.) PS (metric horsepower)

1 W	= 1 J/s	= 1 Nm/s			
1 W	= 10^{-3} kW	= 0.102 kpm/s	= $1.36 \cdot 10^{-3}$ PS	= 860 cal/h	= 0.239 cal/s
1 kW	= 10^3 W	= 102 kpm/s	= 1.36 PS	= $860 \cdot 10^3$ cal/h	= 239 cal/s
1 kpm/s	= 9.81 W	= $9.81 \cdot 10^{-3}$ kW	= $13.3 \cdot 10^{-3}$ PS	= $8.43 \cdot 10^3$ cal/h	= 2.34 cal/s
1 PS	= 736 W	= 0.736 kW	= 75 kpm/s	= $632 \cdot 10^3$ cal/h	= 176 cal/s
1 kcal/h	= 1.16 W	= $1.16 \cdot 10^{-3}$ kW	= $119 \cdot 10^{-3}$ kpm/s	= $1.58 \cdot 10^{-3}$ PS	= $277.8 \cdot 10^{-3}$ cal/s
1 cal/s	= 4.19 W	= $4.19 \cdot 10^{-3}$ kW	= 0.427 kpm/s	= $5.69 \cdot 10^{-3}$ 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	$1 \frac{mile}{h}$	1 Knot	$1 \frac{ft}{s}$	$1 \frac{ft}{min}$		
$\frac{m}{s}$	0.4470	0.5144	0.3048	$5.080 \cdot 10^{-3}$		
Pressure	$1 \frac{lb}{sq.in}$ 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	

Notes

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