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Road vehicles — Circuit breakers —

Part 2:
User's guide

Véhicules routiers — Coupe-circuits —

Partie 2: Guide de l'utilisateur

Reference number
ISO 10924-2:2014(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information/TC 22, *Road vehicles*, Subcommittee SC 3, *Electric and electronic equipment*.

ISO 10924 consists of the following parts, under the general title *Road vehicles — Circuit breakers*:

— *Part 1: Definitions and general test requirements*

— *Part 2: User's guide*

— *Part 4: Medium circuit breakers with tabs (Blade type), Form CB15*

The following parts are under preparation:

— *Part 3: Miniature circuit breakers*

— *Part 5: Circuit breakers with tabs with rated voltage of 450 V*

Road vehicles — Circuit breakers —

Part 2:
User's guide

1 Scope

This part of ISO 10924 gives guidance for the choice and application of automotive circuit breakers. It describes the various parameters which have to be taken into account when selecting circuit breakers.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8820-1, *Road vehicles — Fuse-links — Part 1: Definitions and general test requirements*

ISO 10924-1, *Road vehicles — Circuit breakers — Part 1: Definitions and general test requirements*

ISO 16750-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-2, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 8820-1 and ISO 10924-1 and the following apply.

4 General

The various parts of ISO 10924 define basic requirements and test methods for nominal voltage, rated current, I_R, and time/current characteristics to give comparable and reproducible results of circuit breakers.

In practice, however, there are other parameters to be considered for the correct selection of circuit breakers in road vehicles, such as

— continuous current,

— operating time,

— overload protection of one or more electrical/electronic devices,

— connection resistance,

— types of cables, e.g. different cross section, length, insulation, bundling,

— internal resistances (voltage drop) of the circuit breakers, contacts, cables, and devices,

— power dissipation of the components comprising the system,

— short-circuit parameters,

— inrush parameters of devices,

— operating mode of the load,

— operating of one or more electrical/electronic devices,

— orientation and location of the circuit breakers, e.g. engine, passenger or luggage compartment,

— different currents, voltages, and temperatures of the system and surroundings,

— distances or clearances inside circuit breaker boxes or holders,

— different circuit breakers, circuit breaker holders and boxes (see Annex B),

— environmental conditions (mechanical loads, climatically loads, chemical loads), and

— forced cooling of the circuit breakers.

NOTE Users are advised to consult the manufacturers of circuit-breaker, contacts and cables, because not all of the above points can be addressed in this guide.

The parameters listed are not intended to cover all the possible parameters that need to be taken into consideration for circuit breaker selection nor is it intended that all parameters will need to be considered in each vehicle applications.

4.1 Circuit breaker nominal voltage

See ISO 16750-1

4.2 Supply voltage maximum (U_{smax})

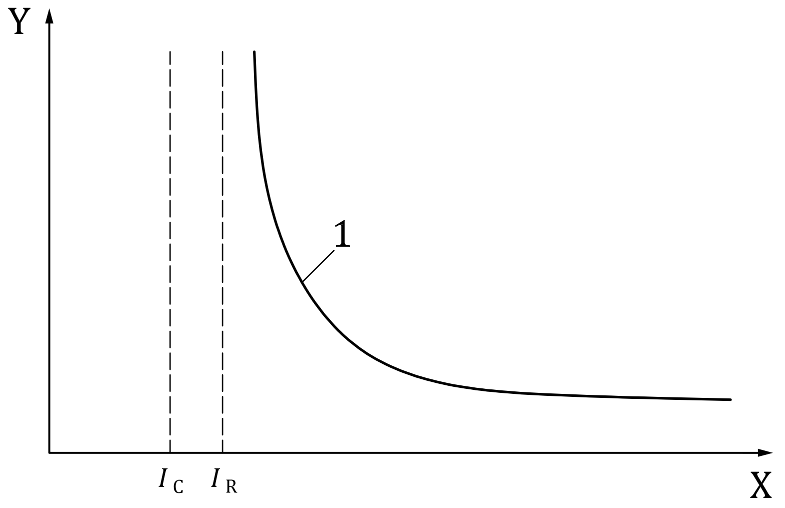
See ISO 16750-2

4.3 Rated current (I_R) and continuous current

The rated current (I_R) is the current used for identifying the circuit breaker.

The continuous current (I_C) in Figure 1 is the maximum current which the circuit can continuously carry under specified conditions: ambient temperature (23 °C), duration maximum 1 h, standard test holder, cross sections of wires. The continuous current can be lower than the rated current, I_R.

See A.2.2.3



Key

X current, *I*

Y operating time, *t*

I_C continuous current

I_R rated current

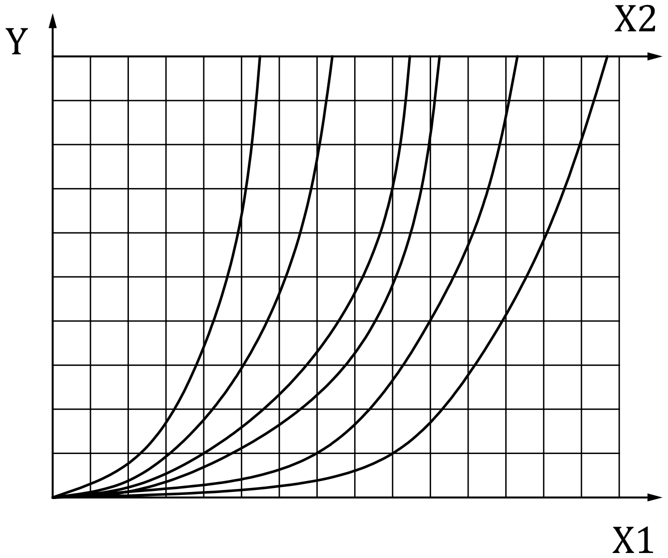
Figure 1 — Rated current (I_R), continuous current, and time-current characteristic

5 Current and conductors (cables)

The temperature rise of a cable is a function of current, conductor cross-section, strands, insolating materials time duration, and ambient temperature.

See A.2.2.4

Figure 2 shows stabilized temperature rise for various conductor cross sections at *RT*.



Key

X1 current, *I*

X2 conductor cross section

Y conductor temperature, *T*

Figure 2 — Conductor temperatures for different conductor cross sections vs. current at *RT*

6 Current and contact resistance

A higher resistance of mated terminals will result in a temperature rise and reduced thermal conduction away from the circuit breaker. Hence, the temperature of the circuit breaker terminal will be higher and the continuous current for the application lower.

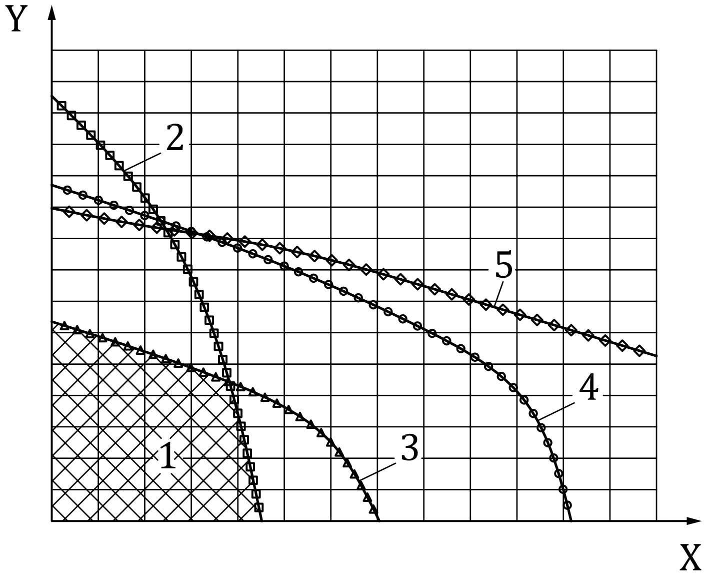
A temperature rise test can be conducted using circuit breakers, circuit breaker holders and connections as specified by the vehicle manufacturer. At a specified test current, the temperature of the connections shall be measured at the points, either tabs or bolt connection of the circuit breaker that protrude from the base of the circuit breaker body (specified in the appropriate part of the ISO 10924 according to the type of the circuit breaker). After thermal equilibrium has been achieved, the temperature rise of the connection shall not exceed the limits specified for terminals and cable.

7 Current and ambient temperature

All components of a circuit and their parts have their own characteristic curve as shown in Figure 3.

Each component in a circuit has an upper temperature limit. An increase of temperature results in increased resistance, which can increase the temperature by itself. As a result, the circuit breaker can trip. It is always recommended to consult with specific manufacturers of circuit breakers for current versus temperature curves as both design and thermal materials used result in different curve characteristics.

See A.2.2.4 and Annex C



Key

X ambient temperature, *T*

Y current, *I*

1 application area

2 cable

3 connection

4 insulator

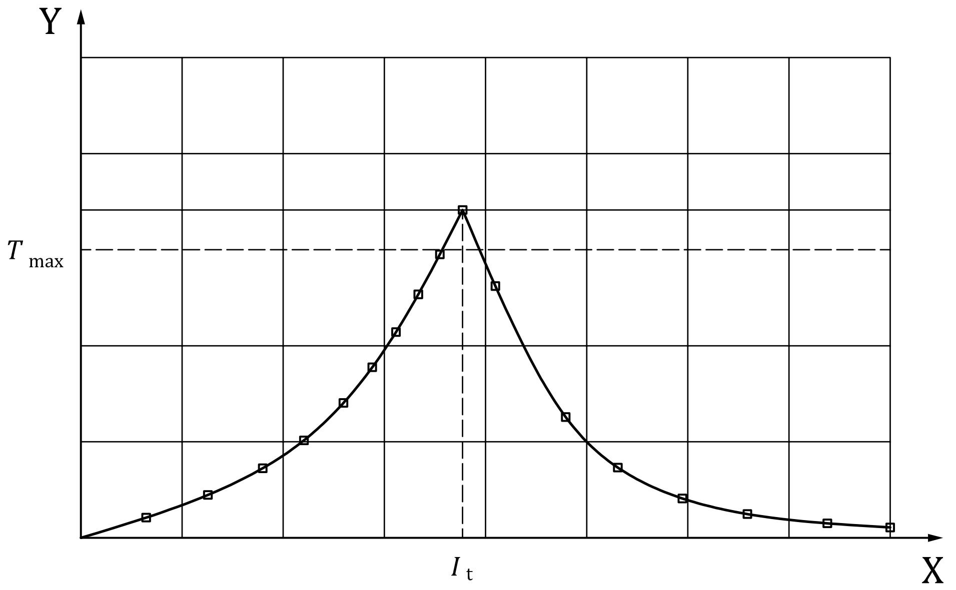
5 circuit breaker

Figure 3 — Maximum continuous currents of circuit components vs. ambient temperature

8 Cable protection: temperature versus current characteristics

To ensure satisfactory cable protection, circuit breakers shall be chosen such that they will always open before the maximum allowed cable temperature, T_{max}, exceeds. Figure 4 shows the correct circuit breaker selection. The maximum allowed temperature never exceeds, because above a certain minimal operating current (I_f), the circuit breaker will trip before the maximum permitted temperature of the cable exceeds.

See Annex A



Key

X times rated current

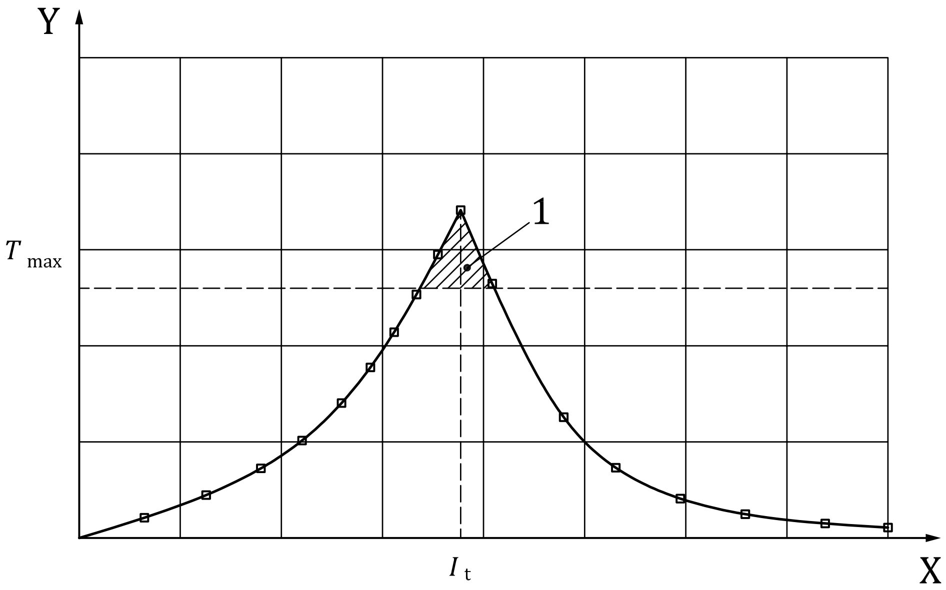
Y cable temperature, T

I_t trip current

T_{max} maximum allowed cable temperature

Figure 4 — Correct circuit breaker selection

Figure 5 shows incorrect circuit breaker selection. The circuit breaker allows some potentially damaging current to flow for too long, causing the cable to overheat.



Key

X times rated current

Y cable temperature, T

I_t trip current

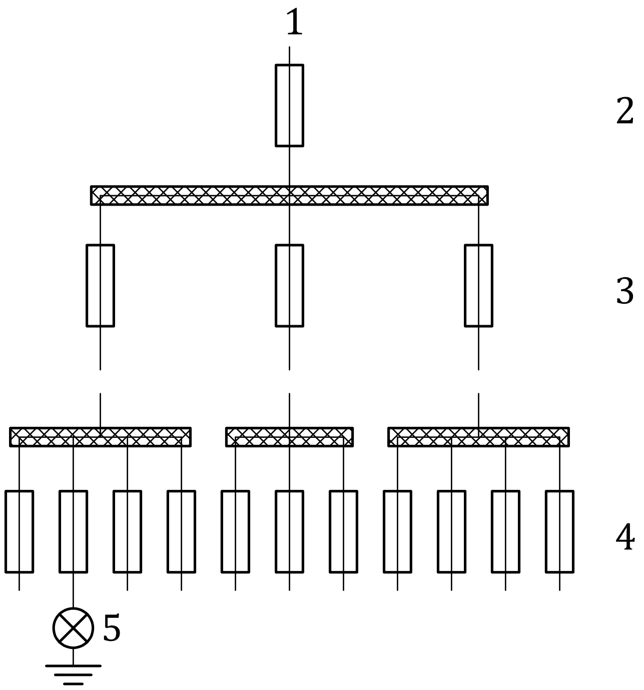
T_{max} maximum allowed cable temperature

1 unprotected region

Figure 5 — Incorrect circuit breaker selection

9 Selectivity

It shall be ensured that higher level circuit breakers do not trip when lower level circuit breakers are opening (see Figure 6).



Key

1 battery

2 circuit breaker level 1

3 circuit breaker level 2

4 circuit breaker level n

5 load

Figure 6 — Example for a structure hierarchy

10 Replacement of circuit breakers

The replacement of circuit breakers in a circuit shall be performed with the circuit de-energised.

11 Voltage peaks during opening of circuit breakers

During the opening process of the circuit breaker, voltage peaks can occur. The peaks can achieve six times the rated voltage, depending on the load and the supply.

12 Inrush withstand characteristics of circuit breakers

In selecting a circuit breaker, not only the continuous current and the rated current, I_R, are to be considered, but also the inrush characteristics of electrical devices.

The inrush characteristic describes the time-current behaviour of electrical devices until the stabilized continuous current has been attained.

It is important to consider the inrush withstand characteristics as there are different requirements on the circuit breaker depending on the type of load. The circuit breaker shall withstand the inrush energy without opening. If the inrush energy is either too high or too long, or a combination thereof, it can be necessary to select a higher rated circuit breaker to eliminate nuisance openings.

See A.2.2.5

13 Electromagnetic compatibility (EMC)

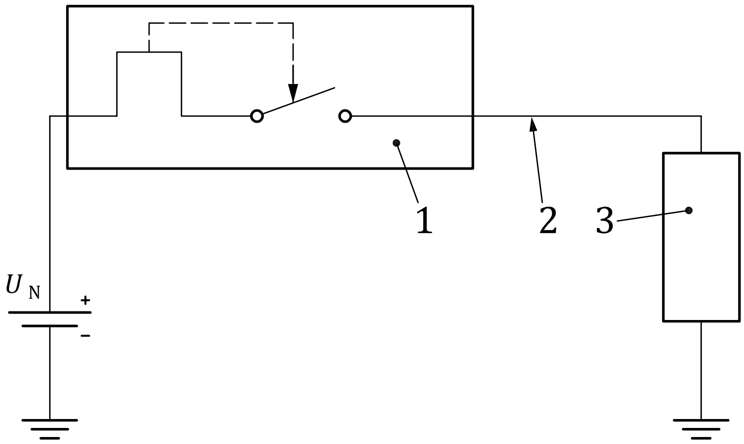
EMC test for circuit breakers are not required by this International Standard.

Annex A
(informative)

Selection procedure for circuit breakers and cables

A.1 Introduction

In any given application, the characteristics of load, connecting cable, and circuit breaker should be carefully matched. This is necessary if the circuit breaker is to provide the expected degree of protection in the event of an overcurrent in the circuit and to maintain that level of protection throughout the lifetime of the vehicle.



Key

U_N nominal voltage

1 circuit breaker

2 cable

3 load

Figure A.1 — Scheme of a generic circuit with a circuit breaker

The protection of a load in a vehicle electrical system is typically performed by a protection element close to the load. But there are loads where the protection of the cable is also a sufficient protection for the load itself at the same time.

Conventional cables consist in general of a copper-core and an insulation-layer. The copper-core heats up when the cable is exposed to current. If an overload occurs, the insulation-layer can be damaged or can even start to melt.

There are three main reasons that can lead to this failure:

— the cross-section of the cable is too small to carry the current, which means voltage drop of the cable is too high;

— not intended overcurrent leads to critical overheating of the copper-core and the insulation-layer, although it was dimensioned correctly;

— wire breakage, loose contact, or other damages of the cables lead to an arc.

To reliably master the first and second cause, it's mandatory to evaluate the cross section of the cable and the rated current, I_R, of the circuit breaker. After the evaluation of the cable cross section and the rated current, I_R, of the circuit breaker, these figures shall be adjusted to the cable insulation class. If possible, the behaviour of the load should be considered.

Regarding the third point, there are solutions available in means of arc tracking to detect low current flow between two conductors. This is not part of this user guide. For further information, the manufacturer shall be contacted.

There are various factors that should be taken into account (see Clause 4) when determining the value of rated current, $I_{R,}$ to be used for selection of circuit breakers and cables. In the example below, the following factors are considered:

— continuous current;

— ambient temperature [set to room temperature (*RT*) and 60 °C];

— operating mode of the load (shall be continuous duty);

— inrush withstand characteristics of circuit breakers (see Clause 12).

Other factors should be discussed between the circuit breaker manufacturer and the user.

The procedure that follows in A.2.1 and A.2.2 gives guidelines for selecting the correct size of cable and rated current, I_R, of circuit breaker.

For miniature and medium circuit breakers with tabs (according ISO 10924-3 and 10924-4), the load current should be chosen between 70 % and 100 % of the rated current, I_R, of the circuit breaker, depending on characteristic of the circuit breaker.

There are two possibilities (selection procedures) how circuit breakers and cables can be dimensioned:

— classical method (see A.2.1);

— selecting the graphic method (see A.2.2).

A.2 Selecting the correct connecting cable and the rated current (I_R) of circuit breaker

A.2.1 Procedure for selecting the rated current (I_R) of circuit breakers - classic method

The flow chart illustrating the various stages explains the selection process of the rated current, I_R, of the circuit breaker and the required conductor cross section.

Start

— Determine the typical load current.

— Determine the theoretical rating current of the circuit breaker.

— Determine the typical circuit breaker rated current, I_R, at ambient temperature.

— Calculate current required to operate circuit breaker before cable is damaged.

— Calculate maximum circuit resistance to obtain the operating current.

— Select the minimum size of cable that gives a circuit resistance not exceeding the value in A.2.1.4.

— Select the minimum size of cable to supply the load current from A.2.1.1.

— Select the larger cable size as calculated in A.2.1.7 and A.2.1.8.

End

The following criteria should be known prior to calculation selection procedure:

Table A.1 — Known criteria in an electrical circuit of a vehicle

Term	Acronym	Value
Load power at nominal voltage	P	95 W
Nominal voltage	U_N	12 V
Supply voltage maximum	U_{Smax}	16 V
Room temperature	RT	(23 ± 5) °C
Cable length in the circuit	l	10 m

A.2.1.1 Determine the typical load current (I_l)

$$I_{12V} = P \div U_N = 95W \div 12V = 7{,}92A \quad (A.1)$$

$$P_{16V} = U_{S\max} \times I_{12V} = 16V \times 7{,}92A = 126{,}7 \quad (A.2)$$

$$I_L = P_{16V} \div U_N = 126{,}7W \div 12V = 10{,}56A \quad (A.3)$$

A.2.1.2 Determine the theoretical rating current of the circuit breaker (I_{Rth})

$$I_{Rth} = I_l \div 70\% = 10{,}56A \div 0{,}7 = 15{,}09A \quad (A.4)$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$I_{Rth} = I_l \div 100\% = 10{,}56 \div 1 = 10{,}56A \quad (A.5)$$

The load of the CB is 100 % of the rated current, I_R, of the CB.

A.2.1.3 Determine the typical circuit breaker rated current (I_R) at ambient temperature

After determination of the load current and rated current of the CB, the next step is to consider the ambient temperature where the circuit breaker should be installed. Circuit breakers are thermal devices; therefore, their operating characteristics will be affected by ambient temperature. Their specification data are usually related to *RT*. When the ambient temperature is different, the rating of the circuit breaker has to be recalculated based upon the characteristic curves which are available from the CB manufacturer.

By referring to Table C.1 (rerating factor), it can be seen that at 60 °C, a rerating factor shall be selected by 1.24.

$$I_{Rd} = I_{Rth} \times 1{,}24 = 15{,}09A \times 1{,}24 = 18{,}71A \quad (A.6)$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$I_{Rd} = I_{Rth} \times 1{,}24 = 10{,}56A \times 1{,}24 = 13{,}09A \quad (A.7)$$

The load of the CB is 100 % of the rated current of the CB.

The next higher circuit breaker rated current, I_R, should be selected; therefore, 20 A (15 A) is chosen as the correct circuit breaker rated current, I_R.

$$I_R = 20A$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$I_R = 15A$$

The load of the CB is 100 % of the rated current, I_R, of the CB.

NOTE In this example, if a selection had been made based on the simple assessment of load current alone (15,09 A/10,56 A), a circuit breaker with a rated current, I_R, of only 15 A/20 A would have been chosen with adverse consequences for long-term reliability.

A.2.1.4 Calculate current required to operate circuit breaker before cable is damaged

If the circuit breaker is to protect the cable against overheating, it should operate before an overcurrent can cause thermal damage. Calculate the current value required to cause the circuit breaker to operate in a short time. This should be 2 × I_R (rated current, I_R) for miniature and medium tab circuit breakers.

The value of circuit breaker rated current, I_R, used in this calculation is adjusted based on Table 1 (rerating factor). In our example, the adjusted rating of a 20 A (at 70 % load) and 15 A (at 100 % load) medium circuit breaker with tabs at *RT* leads to an operating current I_O:

$$I_O = I_R \div 1{,}24 \times 2 = 20A \div 1{,}24 \times 2 = 32{,}24A \tag{A.8}$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$I_O = I_R \div 1{,}24 \times 2 = 15A \div 1{,}24 \times 2 = 24{,}19A \tag{A.9}$$

The load of the CB is 100 % of the rated current, I_R, of the CB.

A.2.1.5 Calculate maximum circuit resistance to obtain the operating current

Calculate the maximum value of circuit resistance required to guarantee this operating current by correcting the ambient temperature of the cable. If the cable is at 60 °C, the circuit resistance will be:

$$R_{\max 60°C} = U_N \div I_O = 12V \div 32{,}24A = 0{,}37\Omega \tag{A.10}$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$R_{\max 60°C} = U_N \div I_O = 12V \div 24{,}19A = 0{,}5\Omega \tag{A.11}$$

The load of the CB is 100 % of the rated current, I_R, of the CB.

Correcting this result to room temperature (*RT*) and using the coefficient of resistance of copper gives:

$$R_{\max} = 0{,}37\Omega \times [1 + 0{,}00393 \times (23°C - 60°C)] = 0{,}32\Omega \tag{A.12}$$

The load of the CB is 70 % of the rated current of the CB.

$$R_{\max} = 0{,}5\Omega \times [1 + 0{,}00393 \times (23°C - 60°C)] = 0{,}43\Omega \tag{A.13}$$

The load of the CB is 100 % of the rated current of the CB.

A.2.1.6 Select the minimum size of cable that gives a circuit resistance not exceeding the value in A.2.1.4

Using the required cable length, determine its resistance per unit length. If the cable is 10 m long, the resistance per unit length will be:

$$R_{max} = R_{max} \div m = 0{,}32\Omega \div 10m = 0{,}032\Omega / m \quad (A.14)$$

The load of the CB is 70 % of the rated current, I_R, of the CB.

$$R_{max} = R_{max} \div m = 0{,}43\Omega \div 10m = 0{,}043\Omega / m \quad (A.15)$$

The load of the CB is 100 % of the rated current, I_R, of the CB.

By consulting tables of copper cable unit resistance (as per DIN ISO 6722), it can be determined that a 0,75 mm^2 cable is sufficient for 70 % load of the circuit breaker and a 0,5 mm^2 cable is sufficient for 100 % load of the circuit breaker. These cable cross sections guarantee a sufficient operating current.

A.2.1.7 Select the minimum size of cable to supply the load current from A.2.1.1

By reference to cable manufacturer's data, determine the minimum cable size necessary to carry the load current, taking the ambient temperature of the cable into account. A cable of 0,75 mm^2 is needed to carry load current, I_l = 10,56 A at 60 °C.

A.2.1.8 Select the larger cable size of A.2.1.7 and A.2.1.8

Select the larger cable size as calculated in A.2.1.7 and A.2.1.8, i.e. 1 mm^2.

A.2.1.9 Summary

Table A.2 — Summary for selecting connecting cable and the rated current, I_R, of circuit breaker — classic method

I_l	Table load of the CB in % of rated current (I_R)	I_{Rth}	I_{Rd}	I_R	I_0	R_{max}	A at RT according to operating current	A at 60 °C
10,56 A	70 % × I_R	15,09 A	18,71A	20 A	32,24 A	0,32 Ω	0,75 mm^2	1,50 mm^2
	100 % × I_R	10,56 A	13,09 A	15 A	24,19 A	0,43 Ω	0,5 mm^2	1,00 mm^2

In this calculation figures like inrush current, overload and short current are only considered statically. Voltage drop of the conductor is not considered.

A.2.2 Selecting the correct connecting cable and circuit breaker - graphical method

Start

— Calculate the size of cable based on the admissible voltage drop of the cable to be protected.

— Determine the *I*-*t* - characteristic of the load (inrush characteristics of electrical device).

— Determine the *I*-*t* - characteristic of the circuit breaker.

— Determine the *I*-*t* - characteristic of the insulated conductor (cable).

— Determine rating based on the *I*-*t* - characteristic curves (load, circuit breaker, and cable).

End

The following criteria should be known prior to calculation selection procedure:

— required load power;

— nominal voltage;

— maximum supply voltage drop;

— admissible voltage drop from the conductor;

— cable length in the circuit.

Table A.3 — Known criteria in an electrical circuit of a vehicle

Term	Acronym	Value
Load power at nominal voltage	P	95 W
Nominal voltage	U_N	12 V
Supply voltage maximum	U_{Smax}	16 V
Voltage drop	U_D	1 V
Room temperature	RT	(23 ± 5) °C
Cable length	l	10 m
Specific el. resistance	ρ	0,0172 Ωmm²/m
Coefficient of resistance of copper	α	1/K
Power loss	P_D	W
Cable cross section	A	mm²
Cable resistance	R	Ω

A.2.2.1 Calculate the size of cable based on the admissible voltage drop of the cable to be protected

If the admissible voltage drop (U_V) of the cable is taken as a reference, the required size of cable (conductor cross section) can be determined with the following formulae:

$$A = \frac{P^2 \times \rho \times l}{P_V \times U_{Smax}^{\;2}} \qquad \text{(A.16)}$$

$$P_D = U_D \times I_1 = 1{,}2V \times 10{,}56A = 12{,}67W \qquad \text{(A.17)}$$

$$A = \frac{(126{,}7W)^2 \times 0{,}0178\Omega mm^2 / m \times 10m}{12{,}67W \times (16V)^2} = 0{,}87mm^2 \qquad \text{(A.18)}$$

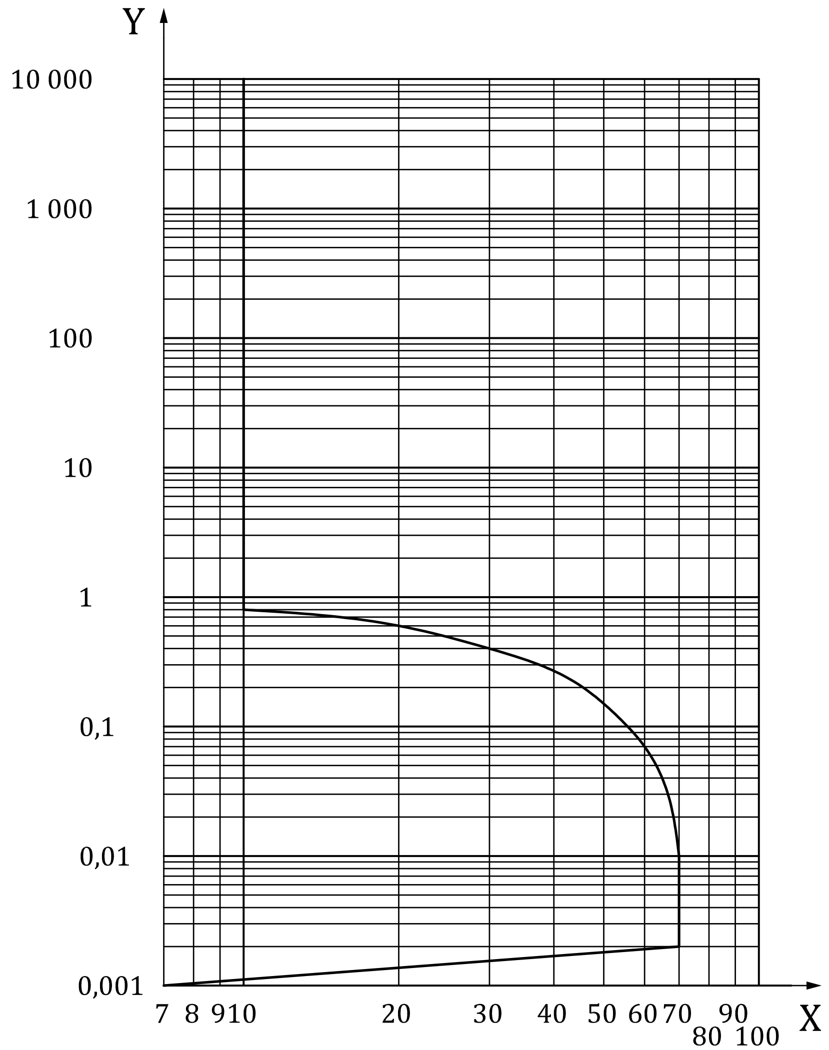
The calculated cross section should be rounded up to the afterwards higher standard value.

If the admissible voltage drop of the cable is taken as a reference, the required size of cable cross section is 0,87 mm².

Select the larger of the size calculated which gives a cable size of 1 mm².

A.2.2.2 Determine the *I-t* - characteristic of the load (inrush characteristics of electrical device)

The operating performance of a load can be shown as an *I-t* – characteristic curve. The *I-t* - characteristic of the load (inrush characteristics of electrical device) is generally detected by testing.



Key

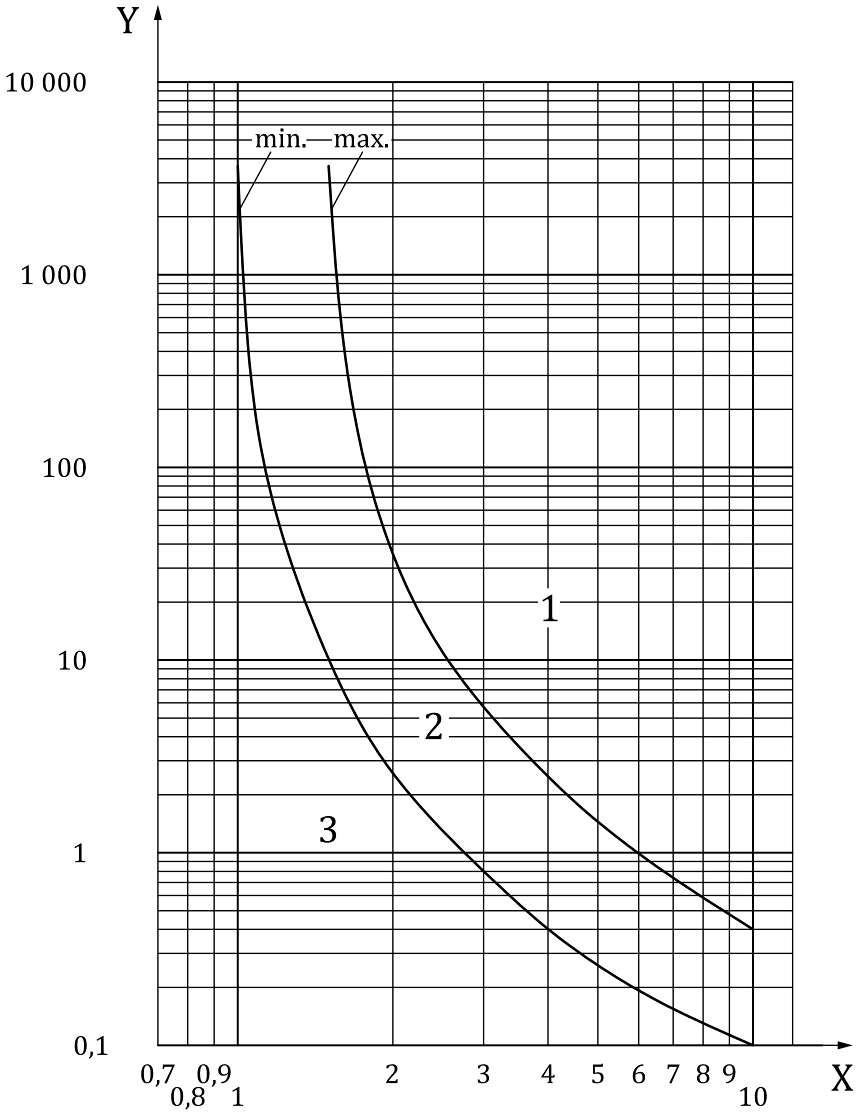
X current, *I* (A)

Y time, *t* (s)

Figure A.2 — Example of *I-t* - characteristic of load (70 A inrush)

A.2.2.3 *I-t* - characteristic of the circuit breaker

The characteristic of a CB is directly shown in the *I-t* - diagram of the manufacturer (see Clause 4.3).



Key

X times rated current

Y trip time, *t* (s)

1 trip area

2 can trip, must not trip

3 non-trip area

Figure A.3 — Example of *I-t* - characteristic of circuit breakers

The area below or on the left from the *I-t* - characteristic shows the usual continuous operation and guarantees a safety function. In this area under normal conditions, the circuit breaker does not trip.

The area between the Min/Max- *I-t* - characteristic shows the transitional area. In this area, the circuit breaker can trip, it must not trip.

This area is determined by different factors of influence like prefabricated part dispersions or ambient temperature.

The area above or on the right from the *I-t* - characteristic can be signated as a trip area. In this area a circuit breaker must trip.

A.2.2.4 *I-t* - characteristic of the insulated conductor (cable)

The cable characteristic curve (load limit curve for PVC insulated cables) can be measured or be determined by using an adequate mathematic algorithm and also be shown in a time/current diagram. Using these mathematic models for cables, various ambient temperature scenarios can be simulated.

The energy balance of a freely arranged insulated conductor is determined by the following differential equation, with heat radiation neglected:

$$P \times dt = m \times c \times \Delta T + k \times A \times \Delta T \times dt \qquad \text{(A.19)}$$

where

P is the power (Watt);

ΔT is the temperature rise from ambient (difference between the cable end temperature and the ambient temperature);

dt is the duration of the heat transfer, s;

m is the mass from the conductor, kg;

c is the specific heat, $\frac{W_S}{gK}$;

k is the heat transfer coefficient, $\frac{W}{m^2K}$;

A is the cross section (mm2);

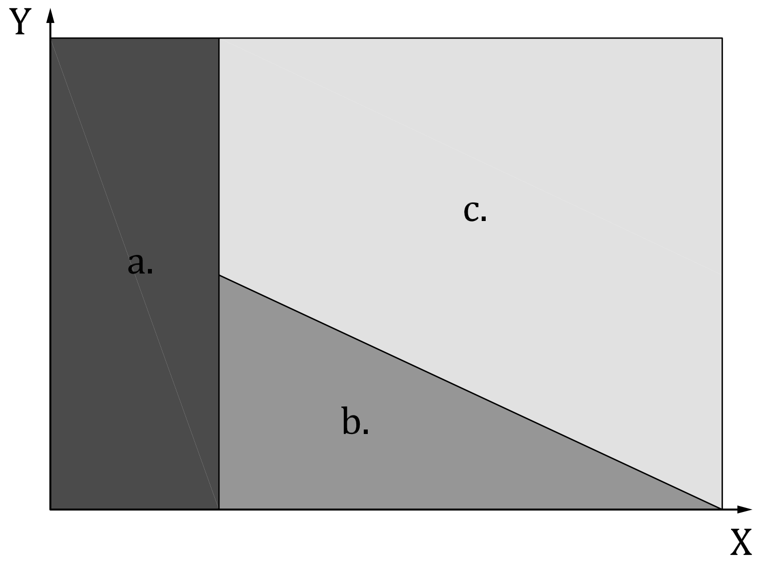
a is the thermal time constant;

A_W is the thermal conductance (resistance), W/K;

R_l is the cable resistance, $\frac{\Omega}{m} \times m$;

t is the time, s.

Analogues to the *I-t* - trip curve of a circuit breaker, the heating curve for an insulated conductors (insulated cables) can be transformed with an arithmetical model to an *I-t* - diagram of conductors (cable – characteristic) (See Figure A.5).



Key

X current, *I* (A)

Y time, *t* (s)

a Complete heat dissipation at continuous current (This means that in this area, there is no damage on the insulated conductor. The conductor is able to carry continuous current. The electric energy is led away completely in form of warmth to the surroundings and there is an energetic balance.)

b Limited heat dissipation at overload (This area describes the maximum current with which an insulated cable is able to carry for a short time.)

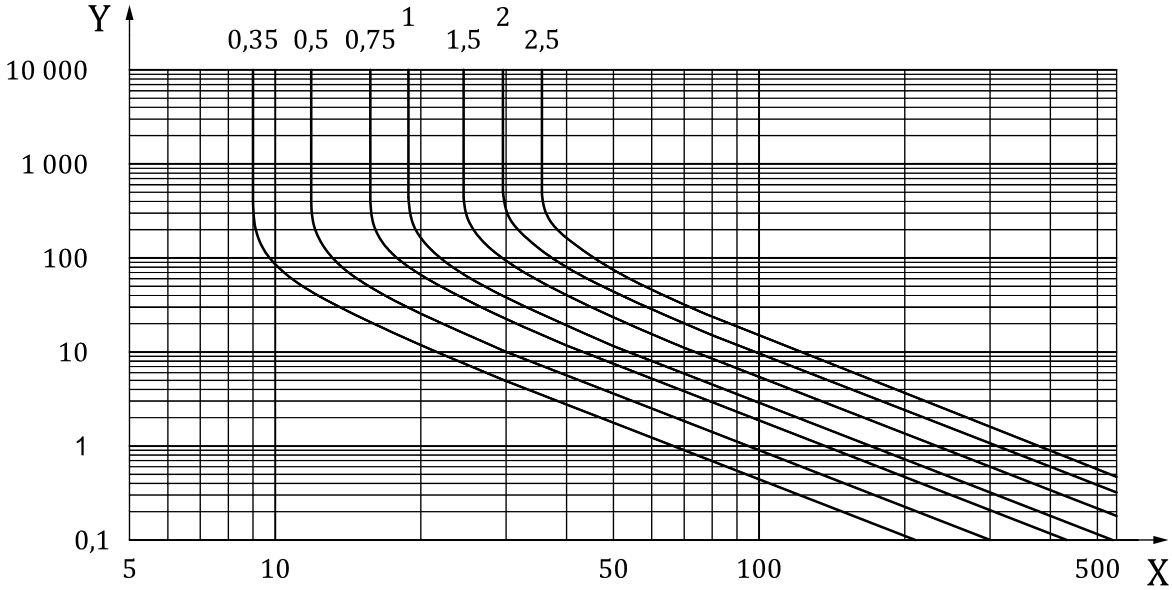
c No heat dissipation at short circuit (This area indicates the critical *I*-*t* - relations, with which the isolation of cable can be damaged or is destroyed by excessive warming.)

Figure A.4 — Schematic representation of an *I*-*t* - characteristic of conductors

Current, as a function of time is calculated by including the time constant, thermal and electrical resistances and electrical power:

$$I_{(t)} = \sqrt{\frac{\Delta T}{\frac{R_1}{A_W} \times \left(1 - e^{-a \times t}\right)}} \tag{A.20}$$

Use formula to calculate and plot the *I*-*t* - characteristic of insulated conductors.



Key

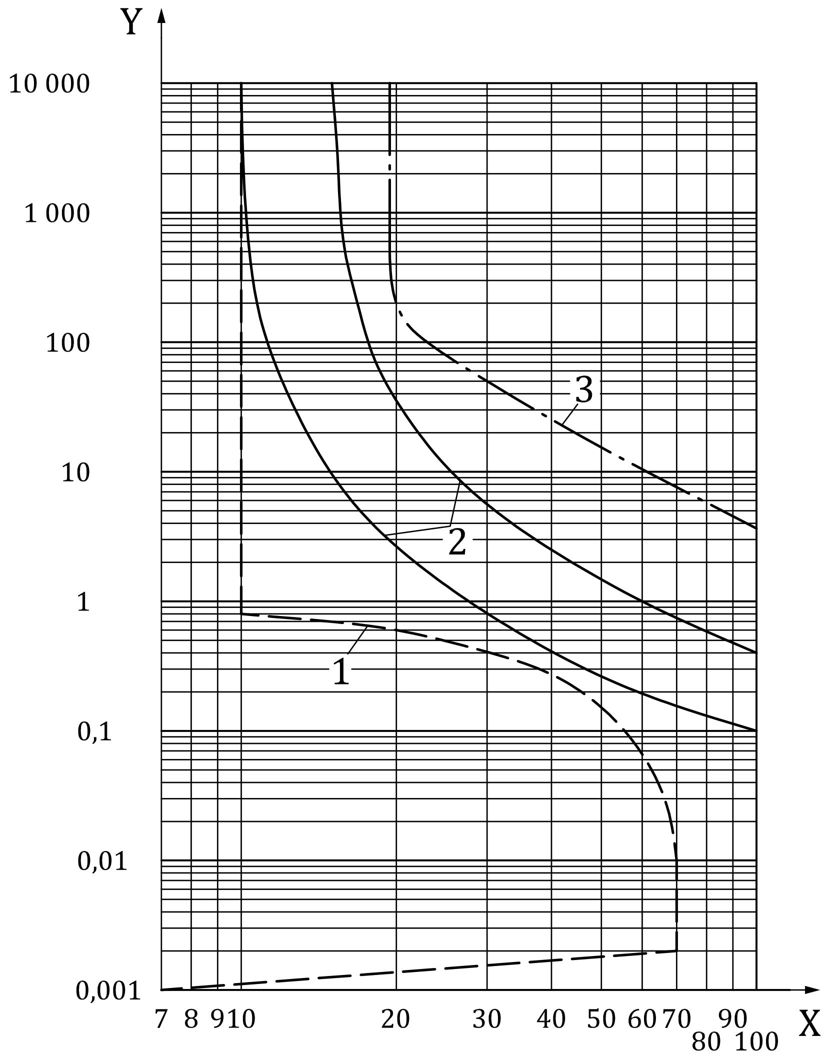
X current, *I* (A)

Y time, *t* (s)

Figure A.5 — Example of *I-t* - characteristics of conductors

A.2.2.5 Rating based on the *I-t* - characteristic curves (load, circuit breaker, and cable)

The protection device can be rated by plotting the cable curve together with the characteristic curve of the protection device and the load on a diagram, and using the cable curve as a basis so it will be possible to verify the assignment conditions over the entire current range (continuous load, overload, and short-circuit).



Key

X current, *I* (A)

Y time, *t* (s)

1 *I-t – characteristic load*

2 *I-t* – characteristic circuit breaker

3 *I-t* – characteristic cable, 1 mm^2

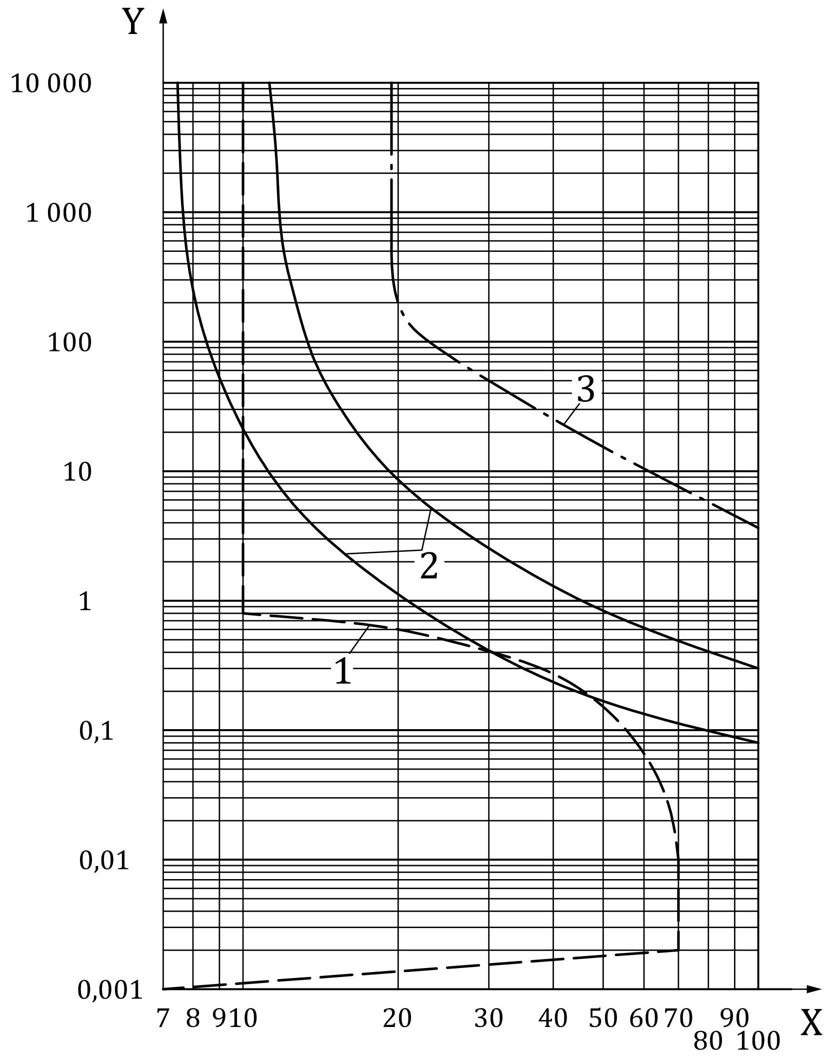
Figure A.6 — Example of rating based on the *I-t* - characteristic curves (load, circuit breaker, and cable)

There should be no point of intersection between the curves of the cable and the protection device on the one hand, and the curves of the protection device and the load curve on the other hand.

The protection device has been correctly selected for a defined cable cross section if the time/current curve of the protection device does not intersect with the cable curve and the load curve.

It is best practice to leave sufficient safety space between the different curves. The closer the *I-t* - characteristic of the load, the *I-t* - characteristic of the cable, and the *I-t* - characteristic of the circuit breaker, the better the weight reduction.

If the circuit breaker *I-t* - *characteristic curve* has an intersection with the load *I-t* - *characteristic curve*, the circuit breaker will trip, although no damage can be expected. Select a higher rating of the circuit breaker in order to ensure continuous current.



Key

X current, *I* (A)

Y time, *t* (s)

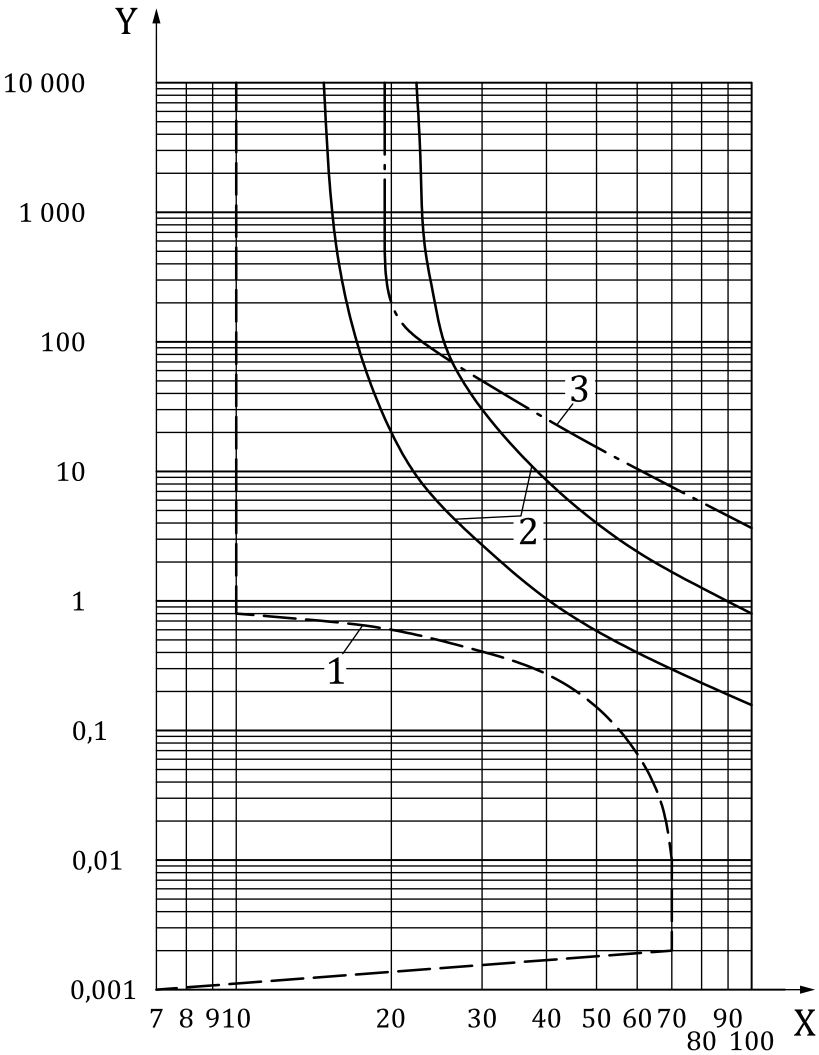
1 *I-t - characteristic load*

2 *I-t* - characteristic circuit breaker

3 *I-t* - characteristic cable, 1 mm^2

Figure A.7 — Example of intersection between the curve of the circuit breaker and the *I-t - characteristic curve* of the load

If the *I-t - characteristic curve* of the circuit breaker and the *I-t - characteristic curve* of the cable have an intersection, the cable might burn out before the circuit breaker trips. Select a lower rating of the circuit breaker or a higher cable cross-section in order to ensure circuit interruption before the maximum admissible cable temperature is reached.



Key

X current, *I* (A)

Y time, *t* (s)

1 *I-t - characteristic load*

2 *I-t* - characteristic circuit breaker

3 *I-t* - characteristic cable, 1 mm2

Figure A.8 — Example of intersection between the curve of the circuit breaker and the *I-t - characteristic curve* of the cable

Annex B
(informative)

Selection of circuit breakers

Table B.1 — Selection

Parameter	**Category**									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**J**	**K**
Rated voltage (V)	32			16				32		
Rated current I_R (A)	5.. 40	7,5 … 40			5 … 30					
Trip curve: fast	–	X	X	X	–	–	–	–	–	X
Trip curve: slow	X	–	–	–	X	–	–	–	–	–
Automatic reset (Type I)	–	–	–	X	–	X	–	–	–	–
Electrically reset (Type II)	–	–	–	–	X	–	X	–	–	–
Manual reset (Type III)	X	X	X	–	–	–	–	X	X	X
Switchable (Type IV)	X	X	–	–	–	–	–	–	X	–
Snap action mechanism	X	–	–	–	–	–	–	–	–	–
Cycling trip free mechanism	–	X	X	X	–	X	X	X	X	X
Fully trip free mechanism	X	–	–	–	–	–	–	–	–	–
NOTE – Not available										

Annex C
(informative)

Ambient temperature influence

To ensure optimum matching of the circuit breaker performance to the road vehicles requirements, thermal circuit breakers are not normally temperature compensated for fluctuations in ambient temperature. At higher ambient temperatures, a circuit breaker will respond faster to a given load or will trip more quickly to a given overload. Reciprocally, at lower ambient temperature, a circuit breaker will respond slower to a given load or overload. However, applications require the circuit breaker to operate continuously in either high or low ambient temperatures. Table C.1 shows the rerating factors (correction factors) that typically should be applied.

Table C.1 — Example: Rerating factor

Ambient temperature °C	Multiplication factors (approximate values)
−40	1,37
−30	1,28
−20	1,20
−10	1,12
0	1,05
+10	1,03
+23	1,00
+40	0,91
+50	0,86
+60	0,81
+70	0,75
+80	0,71
+85	0,70

NOTE The rerating factors are derived from practical experiences.

EXAMPLE Rated current: I_R = 10 A at + 60 °C.

By applying the factor of 0,81, the current value obtained is 8,1 A.

At 60 °C, a 10 A circuit breaker is only able to carry 8,1 A.

In road vehicles, the circuit breaker is usually not subjected to the same heat source as the system. It is always recommended to consult with specific manufacturers of circuit breakers for current versus temperature curves as both design and thermal materials used result in different curve characteristics and cable sizes. The design of the wiring harness of a vehicle considers design guidelines in such a way that the circuit breaker interrupts before the wire is damaged.

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Price based on 25 pages