Batteries Division

ZVEI: Die Elektroindustrie

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Dimensioning, assignment and types of plug devices and connecting cables for traction batteries and chargers

1. Assigning plug devices

When assigning plug devices and connecting cables in the system

electric industrial truck
↔
traction batteries
↔
charger

you should note:

- correct and consistent plug assignment
- adjusted rated voltage
- adjusted rated current in each case
- necessary conductor cross-section
- and cable lengths.

Assignment should be carried out according to the checklist (see section 9).

2. Basic demands on battery connecting cables

The demands on cables are defined as follows, in line with the standards DIN EN 60204-1 "Safety of machinery – Electrical equipment of machines", DIN EN 1175-1 "Safety of industrial trucks – Electrical requirements", and DIN EN 62485-3 "Safety requirements for secondary batteries and battery installations":

Insulate connecting cables and connectors to avoid short-circuits.

If, for battery-specific reasons, you cannot protect against short-circuits using overcurrent protection devices, then safeguard the connecting cables between charger or battery backup and battery, and between vehicle and battery, against short-circuits and ground faults.

The requirements of DIN EN 60204-1 apply to these cables.

If trailing cables are used, protection against short-circuits should be reinforced using single-core cables in line with DIN EN 60204-1. But if the DC voltage of the battery is 120 V or below, the trailing cables are permitted to be of class H01 N2D due to their higher flexibility.

Attach the connecting cables to the battery in such a way to avoid tension or twisting at the battery poles.

The insulation must be resistant to external influences like temperature, electrolytes, water, dust, common chemicals, gases, vapor, and mechanical stresses.

3. Dimensioning of cable cross-sections and cable lengths

3.1. Traction battery

The cross-sections of battery terminal leads are dimensioned in such a way that inadmissible temperature increases cannot happen in regular operation.

Larger cross-sections can be necessary above the standard length of battery terminal leads (1.5 m).

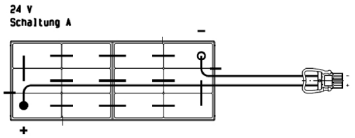

Fig. 1

The cable lengths for positive and negative terminal leads can differ (see Fig. 1), so they should be specified separately. When the cable lengths differ, only one cable cross-section – the arithmetically larger one – can be used.

This information leaflet was compiled by the Working Group Industrial Batteries of the ZVEI - German Electrical and Electronic Manufacturers' Association, Batteries Division

3.2. Charger

The cross-sections of the charging cable are dimensioned specific to manufacturer depending on the nominal device current. The charging cables have a standard length of approx. 3 m.

If longer cables are needed, the cross-sections should be adjusted accordingly to compensate for the higher voltage drop.

For chargers with programmable cable lengths, it is not usually necessary to enlarge the cross-section.
Adjusting the nominal cross-section can change the size of the plug device (see Table 2).

The nominal cross-section must be adjusted according to the cable calculation for DC current, in line with Formula (1):

$$A = \frac{2 \times I \times L}{\kappa \times U_a} \qquad (1)$$

A nominal cross-section of the cable [mm²]

L simple cable length [m]

I conductor current or nominal current of the charger [A]

U_a voltage drop (typically max. 1% of the nominal voltage of the battery) [V]

κ specific conductivity [$m\Omega^{-1}\ mm^{-2}$] (κ_{copper} = 56 $m\Omega^{-1}\ mm^{-2}$)

In a simplified derivation, we recommend increasing the cable cross-section in relation to the cable length (L_{neu} : L_{Std}), in line with Formula (2):

$$A_{neu} = A_{Std} \times \frac{L_{neu}}{L_{Std}} \qquad (2)$$

in which

A_{neu} is the necessary minimum cross-section in the case of an extended charging cable

A_{Std} is the necessary minimum cross-section in the case of a charging cable of standard length

L_{neu} is the length of the extended charging cable

L_{Std} is the standard length of the charging cable

Example calculation:

- Standard charging cable: 3 m, 25 mm²
- Extended charging cable (new): 5 m, X mm²
- A_{neu} = 25 mm² x 5 m / 3 m = 41.66 mm² selected: 50 mm²

We recommend that you round up the calculated value.

If the cross-section cannot be enlarged, you should clarify whether the characteristic curve of the charger can be adjusted.

3.3. Industrial truck

The cross-sections of the connecting cables for electric industrial trucks are specified taking the nominal currents of the motors into account.

4. Pole connections and pole screws

To guarantee a fully insulated connection with permanent contact reliability, you should only use the pole screws specified by the manufacturer to attach the connecting cables. Take the prescribed tightening torques into account here.

The pole screws should be equipped with a screw lock. Always use new pole screws in repairs.

5. Dimensioning and type of plug devices

5.1. Device socket and device plug in line with DIN VDE 0623-589

With these standardized plug devices,

- the device socket is attached to the battery using contact jacks
- the device plug is attached to the charger using contact pins
- the device plug is attached to the electric industrial truck using contact pins.

There are also versions with flat contacts – here, no distinction is made between plug and socket.

5.2. Rated current and rated voltage of the plug device

5.2.1 Rated current

When selecting the system plug device, always take into account the maximum nominal current of the electric industrial truck or charger.

Four plug device sizes (types) are defined in line with DIN VDE 0623-589 "Plug device for battery powered industrial trucks, Type 80, 160, 320, 640 / 150 V". For Types 80, 160 and 320, there are two different rated currents. Type 640 is designed for a rated current of 640 A only.

The rated current is the maximum continuous current allowed. This is the current that a plug device can draw through the contacts continuously (not intermittently), without exceeding the maximum temperature of 90 °C (starting temperature 20 °C ± 5 °C) (in line with DIN EN 1175-1 Appendix A).

These plug devices must fulfil the requirements and tests in line with DIN EN 1175-1 including Appendix A.

For a permanently secure plug-in connection, certain things must be ensured, such as the dimensional stability of the plug housings, contacts and cable connection points and the acid resistance of the connector housing materials.

The demand for higher currents means that higher-rated currents (BS II) can be defined as a result of the cable and contact connections defined by the manufacturer using larger cable cross-sections and using the operating temperatures allowed by the standard.

80, 160 and 320 originally referred to the rated current (BS I) in amperes. Since the definition "rated current II" (BS II) was introduced by the manufacturers of plug devices, these figures no longer refer to the current – they indicate the type only.

In particular, the rated currents II can lead to higher surface temperatures on the housings of the plug devices when the operating conditions display an ambient temperature over 25 °C.

The conductor cross-sections should be adjusted accordingly. The conductor insulation must be adjusted to match the increased expected temperature.

The following minimum cross-sections must be used if the maximum rated current in each case is used:

	Rated current I (BS I)		**Rated current II (BS II)**	
Type	**Current** [A]	**Cable cross-section** [mm²]	**Current** [A]	**Cable cross-section** [mm²]
80	80	16 *)	120	25
160	160	35 *)	250	50
320	320	95 *)	400	95
640	640	240 *)	---	---

*) In line with DIN EN 1175-1 (VDE 0117-1): 2011-06, A 3.11.

Table 1

Note:

The rated current I is geared to the type, so it corresponds with the nominal currents in DIN 43589-1: 1984-04.

The rated current decreases when smaller cable cross-sections are used.
The testing of the appliance plug device with a rated current of 640 A is not taken into account in DIN EN 1775-1 VDE 0117-1.

The maximum rated current of the industrial truck or charger defines the assignment of the plug device. Plugs must be coded accordingly.
If a device plug is used for the rated current II, prevent intermating with a device socket for the rated current I.

The plugging combinations allowed are listed in 5.4. Coding.

5.2.2 Rated voltage of the plug device

Besides the rated currents, the maximum voltages allowed must also be taken into account. Standard plug devices in line with DIN VDE 0623-589 are designed for a maximum DC voltage of 150 V. Because the maximum charging voltage is the basis for this rated voltage, this for example corresponds with a maximum nominal battery voltage of 96 V for a wet battery.

Suitable special plug devices must be used for higher voltages.

5.3. Nominal cross-section of the cable connections

The following nominal cross-sections of the cable connections are available for the 4 sizes of plug device, in line with DIN VDE 0623-589.

Nominal cross-section [mm^2]	**TYPE 80**	**TYPE 160**	**TYPE 320**	**TYPE 640**
2.5	Auxiliary contacts	Auxiliary contacts	Auxiliary contacts	Auxiliary contacts
10	**X**[*)]			
16	**X**	**X**[*)]		
25	**X**	**X**[*)]		
35	**X**	**X**		
50		**X**	**X**[*)]	
70		**X**	**X**	
95			**X**	
120			**X**	**X**[*)]
150				**X**[*)]
185				**X**[*)]
240				**X**

[*)] Continuous current limited by conductor cross-section

Table 2

The connecting cables should be crimped according to the plug manufacturer's recommendations.

If the next smaller cross-section needs to be adjusted, this can be done using reducing sleeves approved by the plug device manufacturer. Do not combine two reducing sleeves, for technical reasons. Using reducing sleeves is generally not allowed with plug devices for the rated current II.

Reducing the cross-section of cables is not allowed.

5.4. Coding

Each plug device must have a coding feature that ensures a device plug can only be inserted into a device socket with the same nominal operating voltage.

There are codings for the nominal voltages 24, 36, 48, 72, 80 and 96 V. Coding differs between the rated currents I and II. There are also different codings for correctly assigning the correct assignment of the chargers to the battery technology using a liquid electrolyte (closed/wet) or a solid electrolyte (sealed/dry) (see Fig. 2 and Table 3).

Coding system overview (in line with DIN VDE 0623-589):

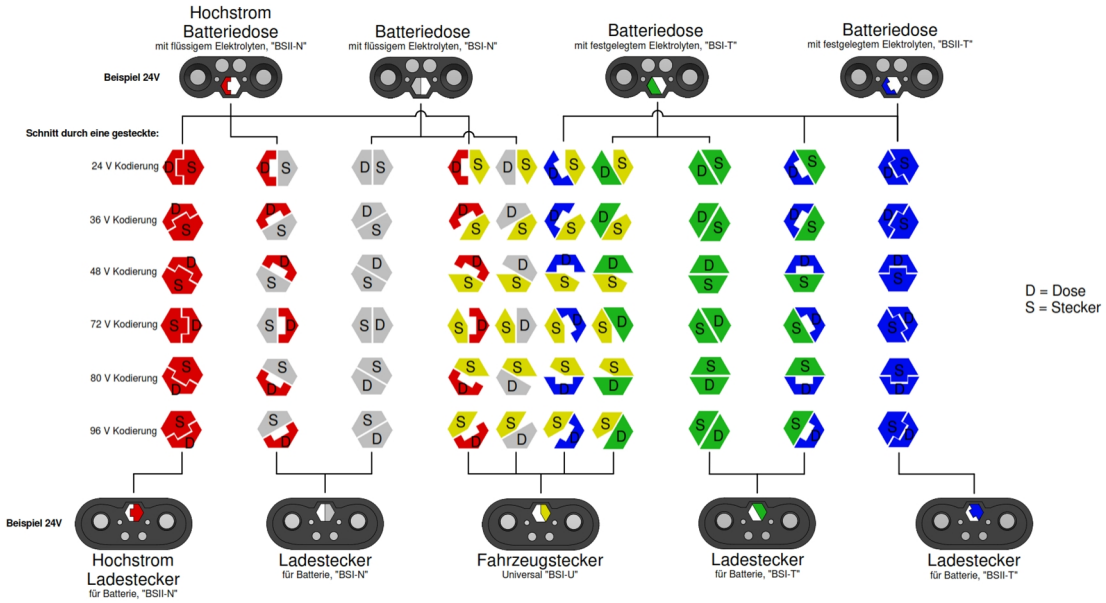

Fig. 2: Coding system overview (D = Dose = socket; S = Stecker = plug)

Table 3 lists all possible plugging combinations that can be derived from Fig. 2.
After plugging according to Fig. 2, check the voltage in the viewing windows in the plug-in connection (see Fig. 5).

Battery	Charger	Industrial truck
BSI-N	BSI-N	BSI-U
BSI-T	BSI-T	BSI-U
BSII-N	BSI-N	BSI-U
BSII-N	BSII-N	BSI-U
BSII-N	BSII-N	BSII-N
BSII-N	BSI-N	BSII-N
BSII-T	BSII-T	BSI-U
BSII-T	BSII-T	BSII-T
BSII-T	BSI-T	BSI-U
BSII-T	BSI-T	BSII-T

Table 3

Key:

BS: Rated Current (I, II: Current level)
N: Wet (liquid electrolyte)
T: Dry (immobilized electrolyte)
U: Universal (liquid or gelled electrolyte)
BSI-N: Battery, wet (liquid electrolyte), light grey
BSII-N: Rated current II, wet, traffic red
BSI-T: Battery, dry (immobilized electrolyte), moss green
BSII-T: Rated current II, dry, traffic blue
BSI-U: Industrial truck, universal for wet and dry, zinc yellow

5.5. Auxiliary contacts

In addition to the main contacts, the plug device can be equipped with four auxiliary contacts, numbered 1–4 (Fig. 3). When disconnected, they are designed to close before the main contacts.

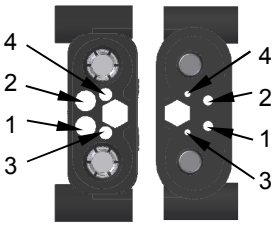

Fig. 3 Positioning of the auxiliary contacts

Auxiliary contacts ensure that if the plug devices (battery charger) are handled incorrectly, the charging current is deactivated before the main plug contacts are completely disconnected from the charger.

This safety function means the charger must have an optional pilot contact control (safety disconnect).

Here the auxiliary contacts 1 & 2 or 3 & 4 are usually bridged on the device socket of the battery. In this function, the term "pilot contacts" means the same as "auxiliary contacts".

The remaining auxiliary contacts can be used for the intermediate tapping of auxiliary voltages (e.g. partial voltages, data traffic, temperature sensors) from the battery.

NB: If an optional 2-channel air adapter (see Ch.6) is mounted instead of the auxiliary contacts 1 & 2 for electrolyte circulation, pilot contact control can occur via auxiliary contacts 3 & 4 if necessary.

If auxiliary contacts 1 & 2 are used as a pilot contact control for the charger, and 3 & 4 are used to tap an auxiliary voltage, the air supply for electrolyte

circulation can only be provided via a separate air coupling.

5.6. Air feed-through for batteries with electrolyte circulation (EC)

For traction batteries with EC, plug devices can sometimes be equipped with an optional 2-channel air adapter (Fig. 4) in the position of the auxiliary contacts 1 & 2.
The air feed-through for plug types, complying with DIN VDE 623-589, is compatible between different manufacturers.

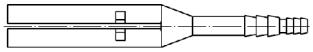

Fig. 4 Example: Air adapter for electrolyte circulation

5.7. Combination options

The following combinations of equipment are possible:

- Device plug / device socket
- Device plug / device socket with pilot contacts (charger)
- Device plug / device socket with air feed-through
- Device plug / device socket with air feed-through and pilot contacts (charger)
- Device plug / device socket with air feed-through and auxiliary contacts (voltage tapping)
- Device plug / device socket with pilot contacts (charger) and auxiliary contacts (voltage tapping)

5.8. Marking according to DIN EN 0623-589

The device socket and device plug must be marked with the following information (Fig. 5):

- Type
- When used for the rated current II: specification of the rated current II
- Rated voltage (150 V DC)
- Nominal battery voltage set
- Manufacturer's mark
- Protection class: at least IP23 (in line with DIN EN 60529 (DIN VDE 0470-1)), plugged state
- Polarity: + (plus) and – (minus)

The information given must be clear and indelible.

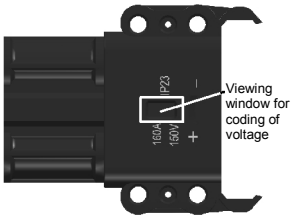

Fig. 5 Example marking of an appliance plug device

Dimensioning of the appliance plug device:

- Rated current I: 320 A
- Rated voltage: 150 V DC
- Coded nominal voltage: 24 V DC

If there is no special marking, the rated current corresponds with the type (= rated current I). The rated current II must be specified separately on the plug device (plug and socket).

6. Normative references

The following quoted documents are necessary for use of this document. If dated, only the referenced applies. If not dated, the last edition applies (including changes).

DIN EN 1175-1 (VDE 0117-1): 2011-06, Safety of industrial trucks – Electrical requirements.
DIN EN 62485-3: 2015-09; VDE 0510 Part 47, Safety requirements for secondary batteries and battery installations – Part 3: Traction batteries (formerly DIN EN 50272-3: 2003; VDE 0510 Part 3).

DIN EN 60204-1/A1: 2009-10; VDE 0113-1/A1, Safety of machinery – Electrical equipment of machines – Part 1: General requirements.

DIN VDE 0623-589: 2011-06, corrections 1: 2011-10 + 2: 2014-06; Plug devices for battery powered industrial trucks, Type 80, 160, 320, 640 / 150 V – Part 589: Dimensions of plug device, material, marking.

7. References

DIN 43531: 2012-06; 43535: 2012-06; 43536: 2012-06, Lead-acid batteries – Traction batteries 48 V, 24 V, 80 V with cells of dimension series L for industrial trucks.

DIN 43537: 2007-09, Lead-acid batteries – Traction batteries 24 V, 36 V, 48 V, 72 V, 80 V with cells of dimension series E for industrial trucks.

8. Annex (informative)

For most industrial trucks, a rated voltage of 150 V (DC) is enough for the plug devices, in line with DIN VDE 0623-589. For higher voltages, other plug devices and maybe also cables are needed. The Low Voltage Directive covers the range up to 1500 V DC, the current DIN EN 1175-1: 2011-06 covers the range up to 240 V DC, and the new edition of DIN EN 1175-1 (expected as of 2016) will cover ranges up to 1500 V DC; for example, usual commercially available battery cables have rated voltages of 100 V DC or 450 V / 750 V DC. It is the user's responsibility to use components with the appropriate voltages.

9. Checklist for specifying the plug devices and connecting cables

9.1. Electric industrial truck (device plug with contact pins)

	Information required for ordering			
Nominal current of industrial truck	Conductor cross-section	Plug type and make	Coding U_{Nenn} **	Option
..... A	..... mm²	..... A /	 V	BSII-N☐ BSII-T ☐

9.2. Battery (device socket with contact jacks)

	Information required for ordering ***											
Battery capacity	Terminal lead length	Conductor cross-section	Plug type and make	Coding **				Option				
				Wet	Dry	U_{Nenn}	BSII	1&2*	3&4*	EUW*	G	Z
..... Ah	pos. .... m neg. .... m	..... mm²	..... A /	☐	☐	 V	☐	PK☐	PK☐	☐☐	☐☐	☐
								HK☐	HK☐			

9.3. Charger (device plug with contact pins)

	Information required for ordering											
Nominal current of charger	Length of charging cable	Conductor cross-section	Plug type and make	Coding **				Option				
				Wet	Dry	U_{Nenn}	BSII	1&2*	3&4*	EUW*	G	Z
..... A	..... m	..... mm²	..... A /	☐	☐	 V	☐	PK☐	PK☐	☐	☐	☐
								HK☐	HK☐			

1&2, 3&4: Position of auxiliary contact
BSII-N: Rated current II, wet
BSII-T: Rated current II, dry
PK: Pilot contact assignment
HK: Auxiliary contact assignment

EUW: Air adapter for electrolyte circulation
G: Plug device with grip
Z: Strain relief (standard with DIN plugs)

* If an air adapter for electrolyte circulation (mounted in the position of the auxiliary contacts 1&2) and a pilot contact control are in use, pilot contact control can take place via the auxiliary contacts 3&4. NB: This configuration must be realized consistently for the battery device socket and the charger device plug.

** For coding pin combinations, see also Table 4.

*** If complete battery terminal leads are ordered separately, additional information is necessary on cable and connection type on the battery side.

Important notes:

I) Plug type + coding (U Nenn): This must be identical for industrial truck, battery and charger.

II) Plug type + plug make + coding (U Nenn): If the industrial truck or charger has a BSII device plug, the battery must also have a BSII device socket.

III) Plug type and conductor cross-section: These must be adjusted to match the maximum possible rated current of the industrial truck or charger.

IV) If the conductor cross-sections of the charging device or industrial truck are higher due to a high current load, the cross-section of the battery lead must be adjusted accordingly.

V) Cable type fulfils DIN EN 60204-1

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