VARTA

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ASB TECHNICAL HANDBOOK

EASY BLADE AND EASY BLOCK MODELS

www.varta-storage.com

Content

Legal notice

Original Instruction Manual

Nürnberger Straße 65
86720 Nördlingen
Germany

www.varta-storage.de

Tel.: 0049 9081 240 86 60
power@varta-storage.com

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About this manual

Please read this instruction manual carefully before beginning any kind of work. It contains important information, in order to ensure problem free performance of your batteries.

Please ensure that you have the latest version of all technical materials by downloaded from below link:

https://www.varta-storage.com/de/produkte/power/asb

1 Caution/warning statements

1.1 General safety signs

Symbol	Meaning
	Prohibition symbols are circular, showing a black pictogram on a white background surrounded by a red edge with a crossbar.
	Warning signs are triangular, showing a black symbol and edge on a yellow background.
	Environmental regulations are information on statutory requirements, which have to be complied with, especially during disposal.

1.2 General hazard sources

If the following instructions for handling the device are not observed, this might lead to personal injury or damage to the battery or your device, for which VARTA Storage GmbH will accept no liability.

a. Danger of electrical voltage

⚠ WARNING

Contact with electrical voltage!

Risk of fatal injury from electric shock!

- ➡ Keep the module always sealed.
- ➡ Pay attention to any damage of electrical equipment! Eliminate defects immediately!
- ➡ Don´t open the module.
- ➡ Don’t connect the modules in serial only in parallel.
- ➡ Don´t connect the module or charger in reverse polarity.

	➡ You are not allowed to disconnect the module in active mode. Hot-plugging or hot-swapping is not allowed in active mode! There is a risk of short circuit between the battery modules. Only in shut-down mode old or damaged modules can be replaced with new modules. Even modules with new cell chemistries are supported if available in the future.

b. Danger from water

	**⚠ WARNING** **Entry of water or other liquids into the module!** Possible mortal danger and material damage! ➡ Do not use water for cleaning the module. ➡ Never put down containers with fluids (beverage containers and the like) on electrical systems. ➡ The relative humidity inside the room must not exceed 85%. ➡ Do not clean the system with agents containing acid, lye or solvents.

c. Danger from heat

	**ATTENTION** **Insufficient ventilation of the system!** Overheating of the system possible! ➡ Keep the ventilation openings clear. ➡ Ensure sufficient ventilation.
	**ATTENTION** **Heat input due to direct sunlight or devices emitting heat!** Overheating and damage of the system possible! ➡ Protect the system against direct sunlight. ➡ Do not use fan heaters or the like near the module.

1.3 Safety Overview on Battery Management System (BMS)

The battery contains three levels of safety, which is controlled by the BMS.

1st Level Protection for over voltage/ under voltage / over current / short circuit / over temperature / under temperature. It is controlled by the BMS software and is non-permanent.

2nd Level Protection for over voltage/ under voltage / over current / short circuit / over temperature/ under temperature. It is controlled by the BMS software and is permanent.

3rd Level Protection (passive) with current fuse on board.

1.4 Certification

The battery is qualified acc. to UN Recommendations on the Transportation of Dangerous Goods, UN Manual of Test and Criteria, Part III, subsection 38.3 (ST/SG/AC.10/11/Rev. 5). The battery is qualified acc. to IEC 62133-2:2017.

3 Introduction of ASB

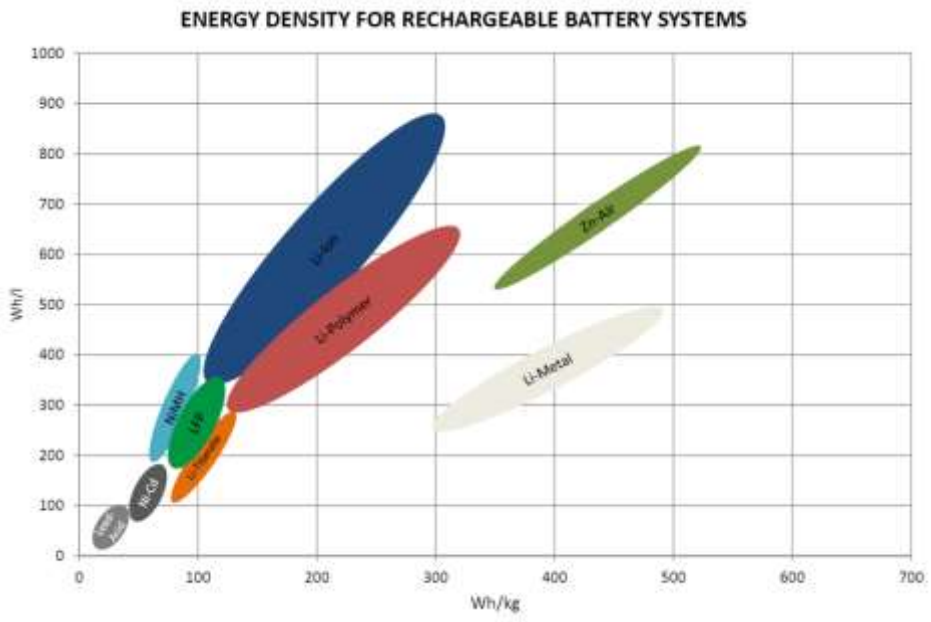
Application Specific Batteries (ASB) is VARTA's new range of lithium-rechargeable battery products from VARTA Storage GmbH, offering products in the voltage range of 24V – 48V for modern systems and applications.

We offer a growing range of battery packs that are immediately available for high-energy or high-power applications. All ASB battery packs are fitted with an electronic battery management system (BMS) with protection against unsafe conditions. All cells used comply with the requirements of the safety standard UL1642 and the packs in this handbook are certified to additional safety standard IEC62133-2:2017 as well as UN38.3 requirements for transportation.

SYSTEM HIGHLIGHTS OF VARTA STORAGE ASB RANGE:

▶ Excellent energy density	▶ Zero maintenance requirements
▶ Different form factors	▶ Low self-discharge and wide temperature range
▶ ~24V and ~48V versions	▶ Up to 40kWh systems using modular approach
▶ IEC62133-2:2017 certification	▶ Mechanical stacking/locking design
▶ CAN Bus Communications (CANopen)	▶ ISO9001 certified for design and manufacture
▶ Excellent cycle life (see PI-Sheet)	▶ 2 year manufacturer's limited warranty

Comparison of different rechargeable battery systems regarding their energy densities



3.1 Definitions and Standards

BASICS

Unless otherwise stated the technical values and definitions are based on room temperature conditions (RT = 22°C ± 3°C).

VOLTAGE DEFINITIONS

Open Circuit Voltage (OCV):

is the difference of electrical potential between two terminals of a device when disconnected from any circuit, dependent on battery model, temperature, storage duration and state of charge.

End of Discharge Voltage (EoD):

The voltage at the end of discharging depending on discharge rate and temperature.

End of Charge Voltage (EoC) should also be referenced from the individual specifications.

CAPACITY DEFINITIONS

The capacity C of a cell is defined by the discharge current I and the discharge

time t: C = I * t

I = constant discharge current

t = duration from the beginning of discharge until the end of discharge voltage is reached

Available Capacity:

Factors which affect the available capacity are:

- Rate of discharge
- End of discharge voltage
- Ambient temperature
- State of charge
- Battery age
- Cycle history of the battery

Nominal Capacity: The nominal capacity C denotes the capacity amount in Ah (Ampère hours) that the battery can deliver at the 5h discharge rate (0.2 C). The reference temperature is +22°C ± 3°C, if not otherwise stated and the final discharge voltage will also be stated.

At higher than usual discharge rates the available capacity is accordingly reduced.

CURRENT DEFINITIONS

Charge and discharge rates may be given as multiples of the Rated Capacity (C) in Ampères (A) with the term C.

Example:

Rated Capacity C = 1000 mAh

0.1 C = 100 mA, 1 CA = 1000 mA

Nominal Discharge Current:

The nominal discharge current of an ASB battery is the 5 hour discharge current (0.2 C). It is the current at which the nominal capacity of a cell is discharged in 5 hours.

I = C/t = C/5 = 0.2 C when t = 5 h

3.2 General Design and Application Criteria

Choose the best suitable battery from our range of ASB batteries according to your needs relating to the specific application and its corresponding planned operation conditions:

The most important criteria for the type-selection are these:

- Required minimum operating time
- Charging rates required vs. calendar life target
- Max. and average current drain
- Min. and max. voltage of operation
- Operating temperature range
- Mechanical properties
- Available space
- Environmental conditions

All ASB batteries are equipped with our specially selected and carefully designed safety electronic modules (BMS) which prevent the risks of hazards due to any foreseeable abuse / misuse. Nevertheless, it is required that any application is designed so that the battery may operate within its normal specification without the safety features being triggered by end-user behavior.

3.3 Features

VARTA Storage ASB batteries are first choice for a number of modern high-tech products in fields such as robotics, Automated Guided Vehicles (AGV), related Logistics and Agricultural solutions and more. They provide long lasting, reliable main power, occupying a minimum of space and weight in the corresponding devices.

VARTA Storage ASB batteries fulfill the most important design-in requirements: Reliable high-power output, design flexibility with minimized space requirements and a long life.

Feature	Advantage	Customer Benefit
UN38.3 Certified	Approved for Transport	Supplier's Test Summary Available
IEC62133-2:2017 Certified	Ready for design-in for certified applications	Reduced design-in cost
Multiple form-factors with modular design	Design flexibility	Product design convenience
Excellent overall performance	High energy and high cycle life	Lower total cost of ownership and highly satisfying over the long-term
Complete battery module solution, zero maintenance	Fit and forget design	Low cost of maintenance in the field
CAN Communications	Smart battery management, regardless of module size	Battery behavior, charging, safety can all be controlled and monitored

4 Reference Table: Easy Blade

*illustration only

Product	Easy Blade 24 V	Easy Blade 48 V
Order Number (VKB)	56654 799 098	56654 799 097
State of Charge	< 30 %	< 30 %
Typical Capacity (Ah)	58	29
Nominal Voltage (V)	25.9	51.8
Operating Temperature		
Charging	0°C to +45°C	0°C to +45°C
Discharging	-20°C to +55°C	-20°C to +55°C
Storage	1 to 3 month at -20°C to +45°C 1 year at -20 °C to +24 °C	1 to 3 month at -20°C to +45°C 1 year at -20 °C to +24 °C
Life Expectance (typical)		
No. of cycles (on Cmin)	1,200 (80%)	1,200 (80%)
Miscellaneous		
NTC	Yes	Yes
Certification	UN38.3 IEC62133-2:2017	UN38.3 IEC62133-2:2017

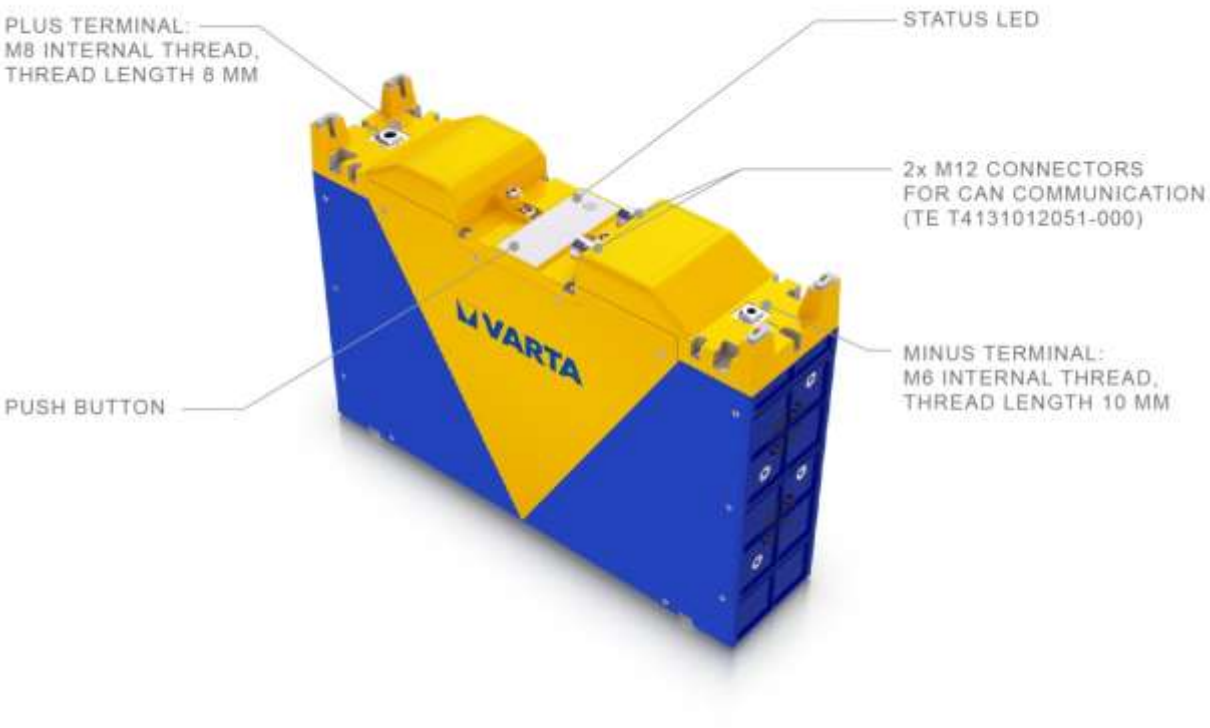
5 Reference Table: Easy Block

*illustration only

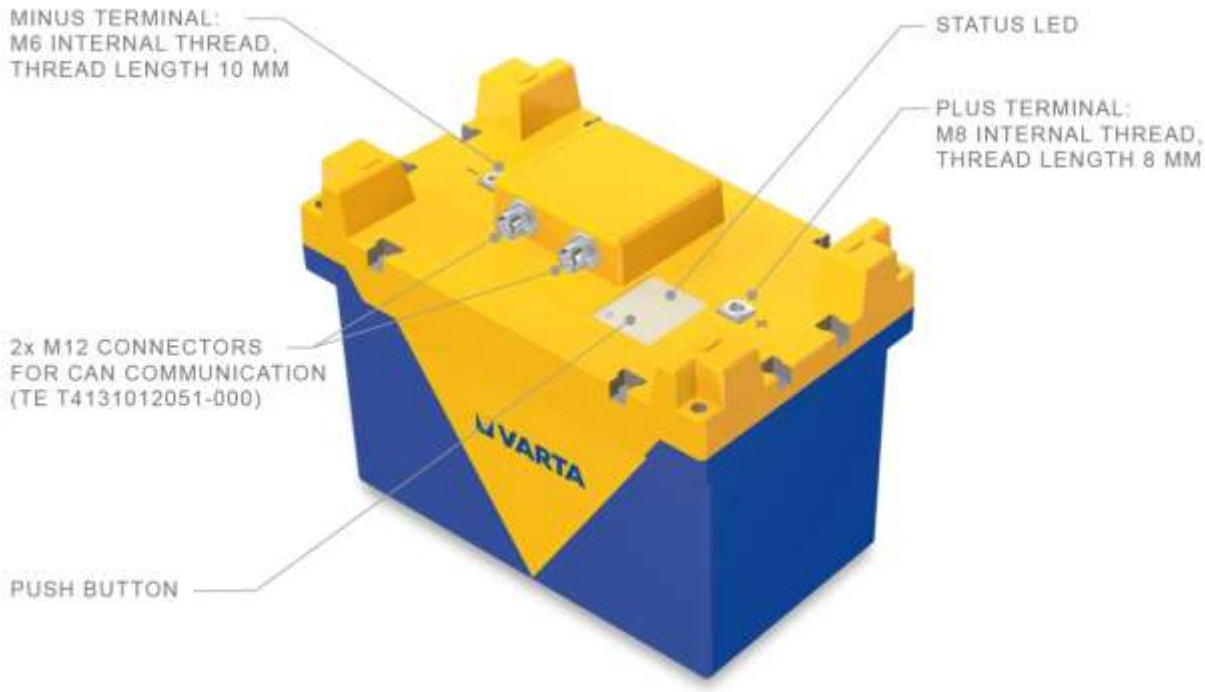
Product	Easy Block 24 V	Easy Block 48 V
Order Number (VKB)	56650 764 099	56650 764 098
State of Charge	< 30 %	< 30 %
Typical Capacity (Ah)	22.8	11.4
Nominal Voltage (V)	25.6	51.2
Operating Temperature		
Charging	0°C to +50°C	0°C to +50°C
Discharging	-20°C to +60°C	-20°C to +60°C
Storage	1 to 3 month at -20°C to +45°C 1 year at -20 °C to +24 °C	1 to 3 month at -20°C to +45°C 1 year at -20 °C to +24 °C
Life Expectance (typical)		
No. of cycles (on Cmin)	4,000 (80%) 10,000 (60%)	4,000 (80%) 10,000 (60%)
Miscellaneous		
NTC	Yes	Yes
Certification	UN38.3 IEC62133-2:2017	UN38.3 IEC62133-2:2017

6 Description of the battery

6.1 Easy Blade



6.2 Easy Block



6.3 Included in the box

Two module connectors (including the two screws) will be delivered together with the battery. (see 7.1)

6.4 Additional systems requirements

a. Power cable

Power cables are not provided by VARTA as requirements differ in all use cases. These are available from our distributors. See contact details on page 7. VARTA recommends using an M6 screw type for the negative terminal and an M8 screw type for the positive terminal. For connection of the modules an additional bus bar or wires with cable lug are needed.

b. Communication cable

The communication cable is not provided by VARTA. These are available from our distributors. See contact details on page 7. VARTA recommends to use Tyco Amphenol LTW 12-05BMMA-SL8001 or similar.

c. CAN termination resistor

The CAN termination resistor is not provided by VARTA. These are available from our distributors. See contact details on page 7. VARTA recommends using Phoenix Contact 1507816 or similar.

A system without CAN communication to the Host needs two CAN termination resistors of 120 Ohm each. One CAN termination resistor has to be connected to the M12 connector of the first module and one CAN termination resistor has to be connected to the M12 connector of the last module. In this way the resistors are placed at the physical ends of the CAN bus.

Systems with CAN communication to the Host only need to have one CAN termination resistor of 120 Ohm on the last module which is connected. In this case the Host needs its own termination resistor.

Please make sure that the system is terminated at both physical ends of the CAN Bus!

d. Charger

We recommend VARTA approved chargers which are already programmed with compatible firmware and tested. The charger datasheets can be provided on request. (for more information on charging see chapter 10).

Description	Material number	Remark
Easy Charger – 24 V	57020101401	Easy Blade 24 V + Easy Block 24 V
Easy Charger – 48 V	57021101401	Easy Blade 48 V + Easy Block 48 V
AC Cord 3m USA	37000727150	Available additionally
AC Cord 3m EU	37000800751	Available additionally

6.5 Push Button

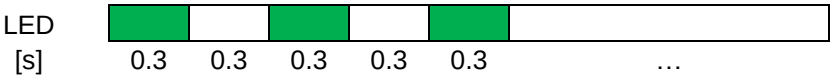
Push the button to wake up and to shut-down the module. For more than one battery in parallel the button only needs to be pushed on one module. (see 7.4)

6.6 LED indications

The LED is able to show three different colors steady or blinking.

a. Switch from Deep Sleep to Active Mode

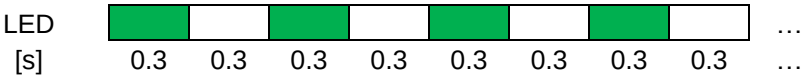
b. Switch from Active Mode to Deep Sleep



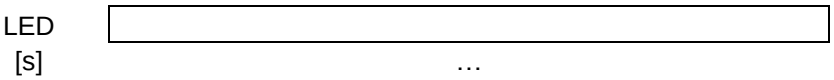
Note: As long as voltage is applied on the power terminals, the battery will continue the sequence

c. Active Mode and DSG FET or CHG FET is closed

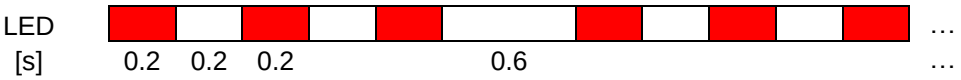
d. Active Mode and DSG FET and CHG FET opened



e. Deep Sleep

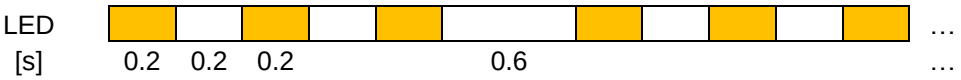


f. Irreversible error (e.g. defect fuse, defect FET, …)

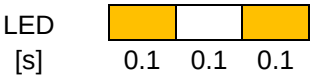


g. Reversible error (e.g. over-temperature, over-current, …)

h. No valid Node ID or double Node ID detected

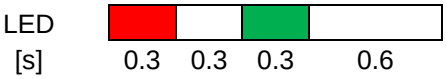


i. Switch to Bootloader Mode



j. Bootloader is active

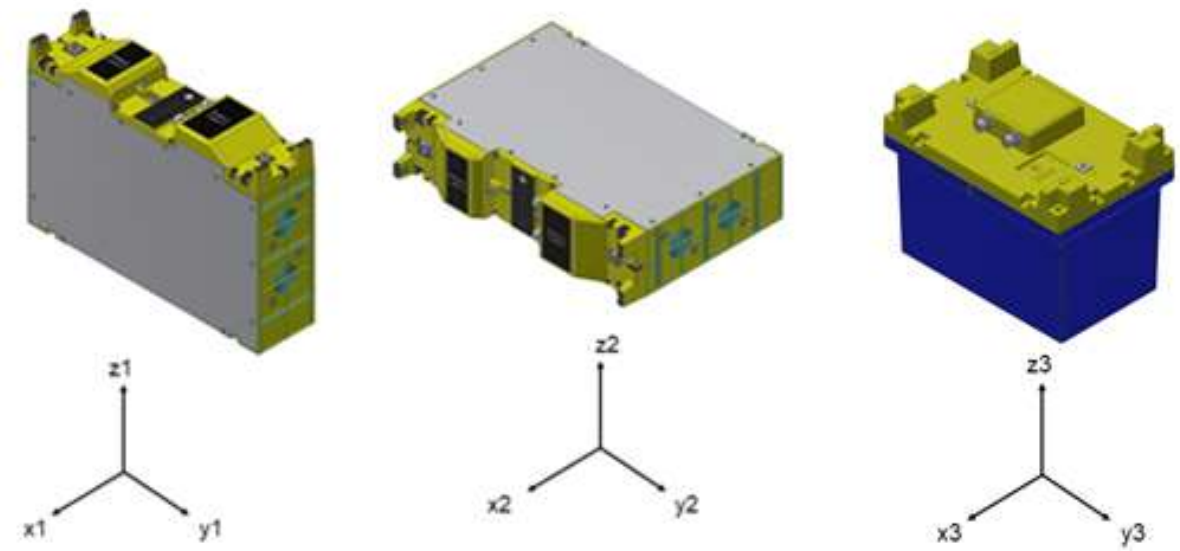
k. Node ID assignment in process



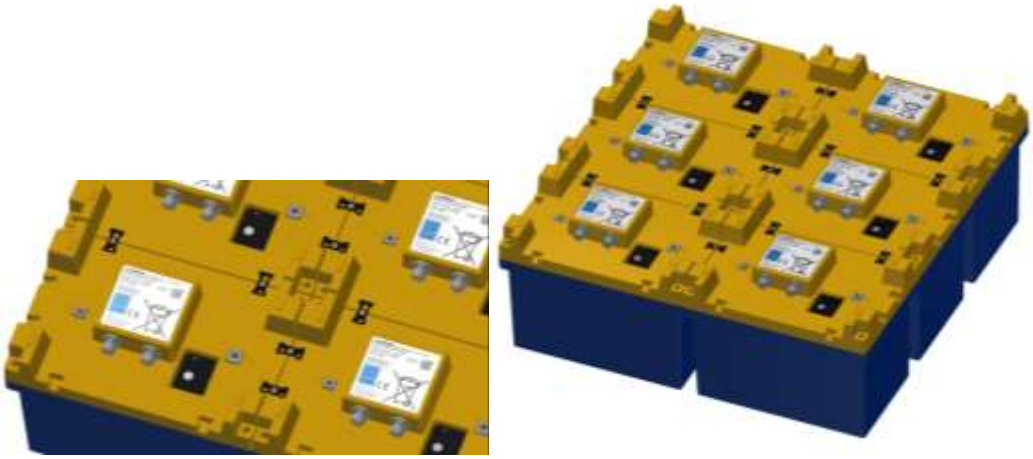
7 Setup a system

7.1 Mechanical connection

Important! When installing the module in your application, it is important to ensure that load-bearing is evenly spread. Pressure or weight in a single area, especially on the metal plate is not allowed and may cause damage to the battery and internal components. For example, it is not allowed to fix the modules with a strap or similar where all of the weight could be carried in one small area. The pressure must be spread over the whole module.



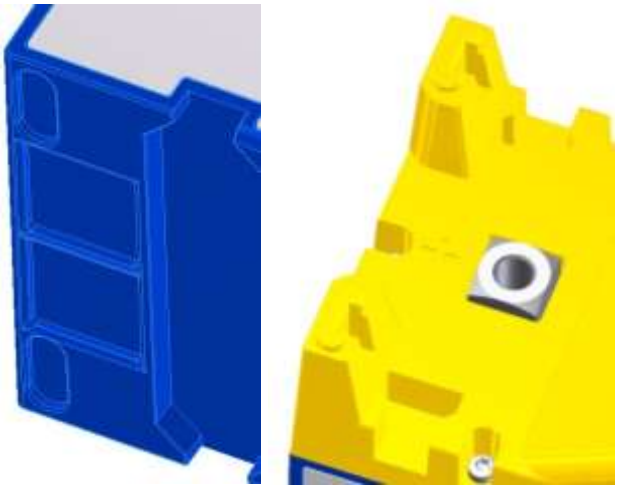
The modules can be connected in “x1” or “z2” direction for Easy Blade. For Easy Block “x3” and or “y3” directions are possible via two module connectors, shown below in black. Place the module connectors inside the recess of two modules (see below picture). The module connectors are asymmetric and have a broad and a narrow side. If the orientation of the modules is wrong (e.g. in case of serial connection of the modules), the connectors will not fit properly. When the module connector is placed, insert a screw (Screw Wuerth Wueplast W1423 3x8, TX8 or Screw EJOT Delta PT WN5454 30x8, TX10) and tighten it with a torque of max 0.16 Nm). The module connector will expand and jam in the recess.

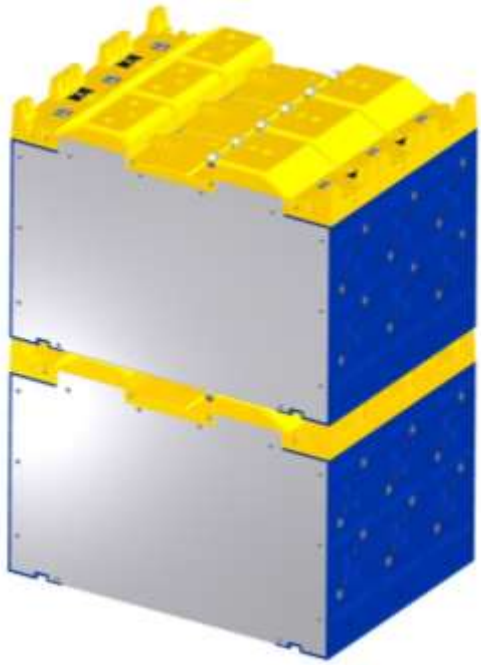


Important: The module connector will ensure correct position of the modules and add stability. The end user is responsible for creating sufficient stability of the battery system within the device with respect to the requirements of the application and variation of battery systems which can be assembled. In some cases it is necessary to consider that additional support of the module structure should be considered in the final design of the application.

For removal of the module connector loosen the screw and remove the module connector. If the connector is stuck, use a screwdriver for pulling it out of the recess via the side opening in the connector.

The modules can be connected in z1 (Easy Blade) and z3 (Easy Block) directions. You can stack the batteries via the design features on the bottom and on the top of each module. (see below picture). Please note the stacking features are only for orientation and guidance not for fixation. The user is responsible, to make sure that the module can´t move during operation.





Below table shows the permitted layers in a specific direction:

Direction	Maximal Layers	Comments
Z1	3 layers	To avoid too much weight
Y1	1 layer	To ensure proper ventilation
Z2	5 layers	To avoid too much weight
Y2	1 layer	To ensure proper ventilation
Z3	3 layers	To avoid too much weight

7.2 Electrical connection

It is not allowed to connect the modules in series! Only connect the battery modules in parallel. Do not mix up 24V and 48V battery modules within a single system.

The next steps describe how to connect the battery modules in parallel.

Step 1: Minus terminal

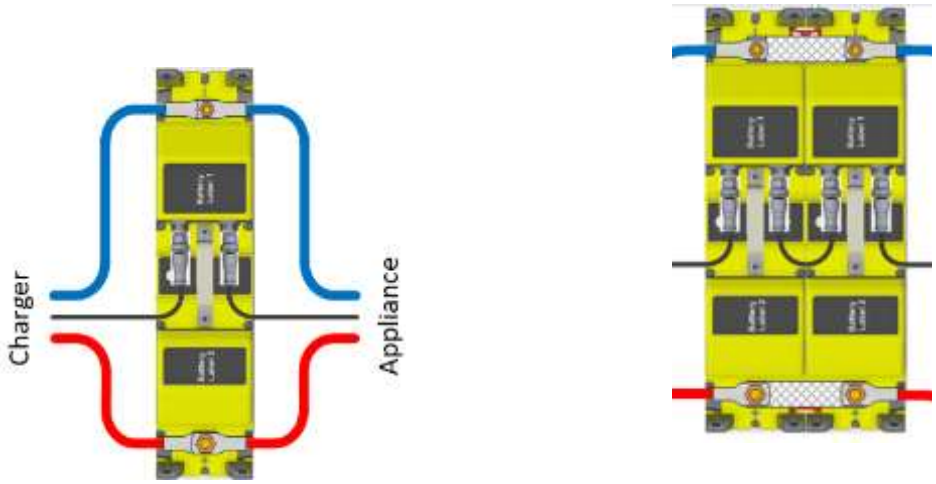
Connect the Power Minus of all modules in parallel. Tighten it with a torque of max 3.9 Nm. Please note the Power minus is marked with the symbol -. For connection of the modules an additional bus bar or a wires with cable lug is needed.

Step 2: Plus terminal

Connect the Power Plus of all modules in parallel. Tighten it with a torque of max 9 Nm. Please note the Power Plus is marked with the symbol +. For connection of the modules an additional bus bar or a wires with cable lug is needed.

Step 3: CAN cables

Connect the CAN cables. Tighten it with a torque of max 0.6 Nm. Connect always modules next to each other (see below picture).



Step 4: CAN termination resistor

Connect the CAN termination resistor. Please make sure that the system is terminated at both physical ends of the CAN Bus.

7.3 Configuration of a system

It is necessary under the following conditions:

1. If the modules are connected the very first time.
2. If one or more modules are replaced in an already configured system.
3. If new modules are added to an already configured system.

Connect the batteries as described in chapter 7.1 and 7.2.

Step 1: Turn on the system by pressing the button on any battery for 3s to 5s until the LEDs starts flashing orange. Alternatively, the ON/OFF signal at the M12 connector can be connected to GND by an external switch.

Step 2: Press the button on any battery for at least 5s until the LED on this battery turns red (300ms), off (300ms), green (300ms) and off (600ms) until the configuration is done (LED green). See also chapter 6.6 k.

We recommend to check/update the firmware of your battery here: https://filecloud.varta-microbattery.com/?t=d3787575f81651bda7f959279b063658

Technical details:

Batteries which are not configured will not have a valid Node ID and will also not send any messages on the CAN bus. When configuring the system by pushing the button for at least 5s, the batteries will determine the master of the system dependent on the highest serial number of the batteries. The Node IDs will be assigned in order of the serial numbers. When all Node IDs are assigned, the battery

with Node ID 2 switches to Node ID 1 and becomes the master of the system. Because of this, there will never be an active Node ID 2 available in the system.

Example of system with four batteries in parallel:

Network Overview

	Device Name	NMT State
0	Network	-
1	b	Operational
2	b	Pre-Op
3	b	Operational
4	b	Operational
5	b	Operational

7.4 Start the battery/system

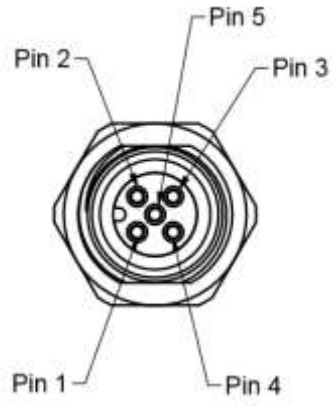
Step 1: Wake-up:

- Method 1: Push the Button (3 to 5 seconds) on one battery module (doesn´t matter which module) until the LED is flashing green. The batteries will not turn on if the button is pushed longer than 5 seconds. This prevents turning on the battery accidentally if something blocks the button continuously.
- Method 2: Pull the ON / OFF Pin (Pin 2) of the CAN connector permanently to ground (Pin 3).

Note: Wake-Up by the external switch is prioritized. In case the battery has been turned off while the external switch was active and will be turned on again via the push button, the button only needs to be pressed for 500ms.

Please wait at least 3 seconds before turning on the battery again after turning off to ensure internal energy has been discharged.

Pin-out of the M12-5 connector (female connector on the battery)



Pin 1: Wake-Up
Pin 2: ON / OFF
Pin 3: GND
Pin 4: CAN High
Pin 5: CAN Low

Note: All connectors (and all pins) are connected in parallel. The Wake-Up signal (Pin 1) is used in a system to wake up all batteries by pushing the button of any battery in the system. The ON/OFF signal (Pin 2) is used to wake up all batteries in a system by an external switch.

After Wake-Up the battery is ready for discharge. Charging is only possible if an approved VARTA CAN charger is connected, or a suitable CAN-charger has been developed under the VARTA protocol.

Step 2: Check Battery Status

- Method 1: Check if the green LED on all modules is solid green.
- Method 2: Read the Battery Status Register via CAN.

If all modules are activated, continue with Step 3.

Step 3: Discharging or Charging

- Discharging: Discharging is going to start once a load is connected to the system. Discharging is possible without CAN communication to the device.
- Charging: Connect a VARTA approved CAN charger to the system. Charging starts once there is a CAN communication between Master and charger.

7.5 Shut-down

- Method 1: Push the Button on a module twice quickly within one second (doesn´t matter which module).
- Method 2: Switch off the external ON / OFF switch, which is connected to the ON / OFF pin in the CAN connector
- Method 3 (only applies for single modules): If no charging / discharging below a set threshold (5A default) is detected within 3h, the single module shuts-down automatically. This 3h value and the current threshold is a default and can be changed in the CAN device settings. For multi-module systems, there is no auto shut-down.

8 CAN Communication

The CAN Protocol Overview can be found on page 25.

There is no customized Service software available. VARTA recommends the standard CANopen Software for debugging / read-out of CAN Objects, which is CAN Device Explorer from Emotas (https://www.emotas.de/produkte/canopen-device-explorer)

CAN EDS file is available on our website to preconfigure the CAN Device Explorer Tool. https://www.varta-storage.com/de/produkte/power/asb

9 Easy Blade - Cooling concept

The Easy Blade has two radial fans to cool the battery in case of increasing temperature. You can see in below spreadsheet the performance of the fans, which depends on the temperature inside the battery. There are different threshold for charging and discharging.

Discharging:	Charging:	Fan
<30°C	<30°C	off
30°C – 35°C	30°C – 32,5°C	25%
35°C – 40°C	32.5°C – 35°C	50%
40°C – 45°C	35°C – 37.5°C	75%
>45°C	>37.5°C	100%

Please note for a good circulation, the modules need at least a distance of 5cm between the battery and the device on both sides.

10 Charging

Charge algorithm is controlled by the battery itself. Either a VARTA-approved charger can be used or also a customized charger which follows the CANopen standard and the VARTA ASB charger specification, which is available on request for custom developments. Charging will not start without CAN communication.

There is a specific area for “User Specific Changeable Parameters” which also includes the charge current parameters. These parameters can be accessed via CANopen Protocol and SDO transfer. For changing the charge current, proceed the following steps:

1. Get Write permission:
   Write ‘1815dez’ in object 0x2010.1

2. Change Current Value to e.g. 20A (=20,000 mA) in “Normal Temp Range”:
   Write ‘20000dez’ in object 0x3F00.6

3. Change Current Value to e.g. 15A (=15,000 mA) in “High Temp Range”:
   Write “15000dez” in object 0x3F00.7

4. Save values permanent in EEPROM:
   Write “7211dez” in object 0x2010.1

Check the Parameters after a Reboot of the battery:
Read object 0x3100.2 and 0x3100.4

11 Error

In case of an unexpected behavior of the battery or if any threshold limit is violated, the battery will store an internal error event. The LED of the battery will be steady red as long as the operating state does not change. This means, that the battery will be operating again, if the cause of the error is not present any more and the battery is turned off and on again. In case of a non-reversible error, the LED will blink red and the battery cannot be used anymore.

If an error occurs while charging, the charger will be commanded to shut down the charge current and the Charge FET will be opened to prevent any further charging. If an error occurs while discharging, the discharge FET will be opened to prevent any further discharging.

The battery saves the record of every individual error in the internal memory which can be read via CAN from object 0x201A sub 1 to sub 64. The history of the error which occurred can be read from object 0x2018 sub 1 to sub 16 which stores the last 16 events.

Error No.	Description
1	ERROR_NR_OVER_TEMP_LADEN_ZELLEN
2	ERROR_NR_UNDER_TEMP_LADEN_ZELLEN
3	ERROR_NR_OVER_TEMP_LADEN_FET
4	ERROR_NR_OVER_TEMP_ENTLADEN_ZELLEN
5	ERROR_NR_UNDER_TEMP_ENTLADEN_ZELLEN
6	ERROR_NR_OVER_TEMP_ENTLADEN_FET
7	ERROR_NR_OVER_TEMP_CLAMP
8	ERROR_NR_OVER_VOLTAGE
9	ERROR_NR_UNDER_VOLTAGE
10	ERROR_NR_DEEP_LOW_VOLTAGE
11	ERROR_NR_CELL_DISBALANCE
12	ERROR_NR_AKKU_PACK_SPN_MIN_ERROR
13	ERROR_NR_AKKU_PACK_SPN_MAX_ALARM
14	ERROR_NR_AKKU_PACK_FUSED_SPN_DIFF_ERROR
15	ERROR_NR_AKKU_PWR_SPN_DIFF_ERROR
16	ERROR_NR_AKKU_PWR_SPN_MIN_ERROR
17	ERROR_NR_AKKU_PWR_SPN_MAX_ERROR
18	ERROR_NR_AKKU_NETZ_SPN_MIN_ERROR
19	ERROR_NR_AKKU_NETZ_SPN_MAX_ALARM
20	ERROR_NR_AKKU_REKUPERATIOM_SPN_MAX_ALARM
21	ERROR_NR_I_CHARGE_SC
22	ERROR_NR_I_CHARGE_OCC_1
23	ERROR_NR_I_CHARGE_OCC_2
24	ERROR_NR_I_CHARGE_OCC_3
25	ERROR_NR_I_DISCHARGE_SC
26	ERROR_NR_I_DISCHARGE_OCD_1
27	ERROR_NR_I_DISCHARGE_OCD_2
28	ERROR_NR_I_DISCHARGE_OCD_3
29	ERROR_NR_I_AKKU_DIFF_ERROR
30	ERROR_NR_SCND_SPN_MIN_ERROR
31	ERROR_NR_SCND_SPN_MAX_ERROR
32	ERROR_NR_SCND_UC_FET_ENABLE
33	ERROR_NR_SCND_CURRENT_SENSE_EIN
34	ERROR_NR_SCND_VOLTAGE_SENSE_EIN
35	ERROR_NR_SCND_TEMP_CELL_SENSE_EIN
36	ERROR_NR_SCND_TEMP_FET_SENSE_EIN
37	ERROR_NR_SCND_PYRO_FUSE_EJECT_SENSE_EIN
38	ERROR_NR_SCND_I_DISCHARGE_FET_ERROR
39	ERROR_NR_SCND_I_CHARGE_FET_ERROR
40	ERROR_NR_SCND_VOLTAGE_ERROR
41	ERROR_NR_ADC_SPN_MIN_SCALE
42	ERROR_NR_ADC_SPN_MAX_SCALE
43	ERROR_NR_ADC_TEMP_ZELLEN_MIN_SCALE
44	ERROR_NR_ADC_TEMP_ZELLEN_MAX_SCALE
45	ERROR_NR_ADC_TEMP_FET_MIN_SCALE
46	ERROR_NR_ADC_TEMP_FET_MAX_SCALE
47	ERROR_NR_ADC_TEMP_CLAMP_MIN_SCALE
48	ERROR_NR_ADC_TEMP_CLAMP_MAX_SCALE
49	ERROR_NR_ADC_I_CHARGE_MIN_SCALE
50	ERROR_NR_ADC_I_CHARGE_MAX_SCALE

51	ERROR_NR_ADC_I_DISCHARGE_MIN_SCALE
52	ERROR_NR_ADC_I_DISCHARGE_MAX_SCALE
53	ERROR_NR_I_DISCHARGE_FET_ERROR
54	ERROR_NR_I_CHARGE_FET_ERROR
55	ERROR_NR_I_DISCHARGE_CHARGE_FET_ERROR
56	ERROR_NR_TEMP_DISCHARGE_ERROR_LOCK
57	ERROR_NR_TEMP_CHARGE_ERROR_LOCK
58	ERROR_NR_OVER_CHARGE_CURRENT_ALARM_RECUPERATION
59	ERROR_NR_OVER_CHARGE_CELL_VOLTAGE_ALARM_RECUPERATION
60	ERROR_NR_24V_SPN_MIN_ERROR
61	ERROR_NR_24V_SPN_MAX_ERROR
62	ERROR_NR_CAN_NETWORK_NOT_CONF_NODE_ID
63	ERROR_NR_CAN_NETWORK_DOUBLE_NODE_ID
64	ERROR_NR_PARAMETER_CONFIGURATION_ERROR

12 The CAN Protocol

The communication between all batteries in the system, the charger and the application (optional) is done via the standardized CANopen protocol. For more detailed information about CANopen please visit the official website from “CAN in Automation” (CiA) at https://www.can-cia.org/canopen/.

At normal operation, all necessary data is transmitted via PDOs in cyclic intervals. If the application needs more information in addition, more data can be accessed via SDO request to the master battery.

12.1 Communication within the battery system

All data, which is needed to operate a battery system, is transferred via Process Data Objects (PDOs). Each battery transmits data in cyclic intervals with the following definition based on Node ID 1. PDOs sent by other Node IDs increase the CAN-ID, e.g. TPDO_1 sent by Node ID 4 has CAN-ID 0x184.

PDO	CAN-ID	Type	Node-ID	Data		Event
				Battery Voltage	Battery Average Current	
TPDO_1	0x181	PDO	1	uint32 [mV]	int32 [mA]	1s

PDO	CAN-ID	Type	Node-ID	Data				Event
				Max. FET Temp.	Max. Cell Temp.	Charge Voltage Req.	Charge Current Req.	
TPDO_2	0x281	PDO	1	int16 [0.1°C]	int16 [0.1°C]	uint16 [mV]	uint16 [mA]	1s

PDO	CAN-ID	Type	Node-ID	Data				Event
				Battery Cap.	Battery Full Cap.	Battery Rem. Cap.	not used	
TPDO_3	0x381	PDO	1	uint16 [mAh]	uint16 [mAh]	uint16 [mAh]		1s

PDO	CAN-ID	Type	Node-ID	Data				Event
				Information Status	Warning Status	Error Status	Charge Control Status	
TPDO_4	0x481	PDO	1	uint16	uint16	uint16	uint16	100ms

12.2 Communication sent by the battery master (for application)

The battery, which is configured as the master, sends cyclic data of the complete system. Every state of each module is summarized in TPDO_8. In this way only one PDO needs to be checked in case of monitoring the system for faults and errors.

PDO	CAN-ID	Type	Node-ID	Data		Event
				Master Voltage (Max. Battery Voltage)	aster Current (sum of all module	
TPDO_5	0x19B	PDO	1	uint32 [mV]	int32 [mA]	1s

PDO	CAN-ID	Type	Node-ID	Data			Event
				Max. FET Temp.	Max. Cell Temp.	Master Design Cap.	
TPDO_6	0x29B	PDO	1	int16 [0.1°C]	int16 [0.1°C]	uint32 [mAh]	1s

PDO	CAN-ID	Type	Node-ID	Data		Event
				Master Full Charge Capacity	Master Remaining Cap.	
TPDO_7	0x39B	PDO	27	uint32 [mAh]	uint32 [mAh]	1s

PDO	CAN-ID	Type	Node-ID	Data				Event
				Information Status	Warning Status	Error Status	Charge Ctrl Stat.	
TPDO_8	0x49B	PDO	1	uint16	uint16	uint16	uint16	200ms

Battery Information Status Register	
Bit	Description (master / slave)
15	-
14	-
13	-
12	-
11	-
10	-
9	-
8	-
7	-
6	all modules / this module fully charged
5	-
4	bypass FET on
3	all modules / this module DSG FET closed
2	all modules / this module CHG FET closed
1	all modules / this module are almost empty
0	all modules / this module empty

Battery Warning Status Register	
Bit	Description
15	unknown
14	set node ID process enable
13	-
12	set deactivation enable
11	can network failed
10	-
9	-
8	-
7	max charge condition recuperation
6	-
5	-
4	over- or untertemperature charge
3	over- or undertemperature discharge
2	reserve SOC
1	low SOC
0	low voltage

Battery Error Status Register	
Bit	Description
15	unknown
14	module defect
13	over- or undertemperature discharge
12	over- or undertemperature charge
11	overcharge alarm
10	undercharge alarm
9	max. discharge current alarm
8	max. charge current alarm
7	charge FET error
6	discharge FET error
5	max. voltage alarm (pack)
4	shortcircuit discharge alarm
3	shortcircuit charge alarm
2	overcharge condition recuperation
1	error lock flag charge
0	error lock flag discharge

Battery Charge Control Status Register	
Bit	Description
15	Charger supply conditions ready
14	Master charger control charging ready
13	Charge FET disable temp range cells
12	charge Master set charger outpuff off
11	charge max charge cell voltage request
10	charge max charge current request
9	-
8	charge current high temp range
7	charge current normal temp range
6	charge current low temp range
5	charge current keep power
4	charge current enable
3	-
2	-
1	charge voltage keep power
0	charge voltage enable

Register description in TPDO_8 is similar to TPDO_4 with following interpretation:
Information Register: every state of each module is **"anded"** in this PDO and shows the summary of the system
Warning Register: bit 15…3 of every module is **"ored";** bit 2..0 is calculated by master
Error Register: every state of each module is **"ored"** in this PDO and shows the summary of the system

Charge Control Register: every state of each module is "ored" in this PDO and shows the summary of the system

12.3 Communication sent by the battery master (for charger)

The master also sends the system´s requirements for charging to the charging device.

				Data						
PDO	CAN-ID	Type	Node-ID	chg. ctrl.	not used	not used	Charge Voltage Req.	Charge Current Req.	Charge Enable	Event
TPDO_9	0x264	PDO	100	uint8	uint8	uint8	uint16 [1/256 V]	uint16 [1/16 mA]	uint8	100ms

The battery master will initialize the charger to the appropriate voltage and current needed to charge the battery system. The voltage and current values requested from the charger will be sent every 100ms. In case of a fully charged battery, the battery will set its “fully charged” flag in the battery information status register (bit 6) and opens its charge FET. When all batteries of the system are fully charged, the master sets its “fully charged” flag and sets the charger to a standby value for the next 5 minutes. After this delay, the battery system will shut down.

13 FAQs

13.1 Charger

Do we need to implement a termination resistor at the charger end?

Yes, for the Easy Charger 24 V (charger is without any resistor). This makes it easier to remove the charger while the bus is still terminated. The Easy Charger 48 V (ICL1500 58 V) includes already a selectable termination resistor. This could be used when the charger is used as on-board charger and stays connected at the system.

We want to use the Delta-Q charger as a stationary charger (so it will be usually disconnected from the vehicle after operation). Do we need to implement another termination resistor on the vehicle to close the charger end of the CAN-Bus?

Yes, the bus needs to be terminated at both physical ends of the bus. In case of short cables from charger to the battery, it is ok when there is no resistor at the charger, only at the battery itself.

How should the termination resistor be implemented? Would it need to be removed for charging/communication with the charger?

e.g. by a Y-cable: 1 plug for the termination resistor and one plug for the charger communication. It is also an option for you to integrate an “easier” way to connect the charger to the battery and to implement the termination resistor in your own adapter.

Does a CAN specification exist for a charger with different settings for charging current?

The charging current is always going to be defined from the master battery and communicated to the charger. However, this value can be changed during setup via CANopen SDO access.

What are the TE connector mating details to the Delta-Q charger?

Pinning at charger side:

Pin 1: CAN GND
Pin 6: CAN high
Pin 10: CAN low

The wiring should be as the following:

Pinning at charger side | Pinning at battery side
Pin 1 to Pin 3
Pin 6 to Pin 4
Pin 10 to Pin 5

Is a pre-charge circuit integrated in the battery?

No, there is no pre-charge circuit inside the batteries.

What happens if the modules in a battery system which are connected in parallel, have different states of charge (SOC)?

If the modules have different states of charge within the overall battery then a common state of charge is triggered by discharging the modules, which have a higher state of charge. Basically only the DSG FETs are opened when the modules are switched on (not the CHG FETs). This prevents a module with a higher state of charge from charging the modules with a lower state of charge and thus high equalizing currents from flowing between the modules. If a load is now connected, the modules are discharged from “full” to “empty” over time. This means that the CHG FETs are only closed when a module with a lower state of charge is within a maximum limit (voltage delta) from the voltage of the “fullest” module. Only at this moment is the power provided by the battery. In this way, there is an automatic balancing of the individual modules in a system.

Important: For this reason, if modules are changed within a system which have different state of charge levels, we recommend first to fully charge the pack, to equalize all modules. This will prevent one module being used within a system to handle high currents intended for multiple modules, which could cause a safety trip in the electronics.

Can the Module accept regenerative charging at any time (without indication from CAN bus)? So they should be able to accept charge current any time.

Yes, modules accept regenerative charging at any time within specified limits. E.g. max. 65A for 5s. You can charge the batteries in this operating mode. But if your charger current exceeds the spec. of the battery, this could lead to a charge current higher than recommended. E.g. the charger has 30A current capability and is charging two batteries, one battery could be charged at 20A and the other battery at 10A until equilibrium is reached. Of course, this depends on cycle life, age and SOC of the batteries. In addition, you can never charge the battery before it has closed the charge FET because of a recognized discharge current. E.g. start the battery and supply charge voltage will not work. By charging via a CAN controlled charger, the current will always be adjusted not to exceed any recommended charge current of any battery (also dependent on three different temperature levels). Due to this, we can always guarantee to be in a recommended operating status while charging.

What time is needed to switch from charging mode to discharging mode?

Max. 200ms.

Can I trickle charge the battery?

No, lithium ion has to be charged in a “constant current, constant voltage” method (CC/CV) and done so cyclically. The battery does not support trickle charging.

Charge rate: What are impacts of 0.7C or higher on Cycle life?

Easy Blade – cycle life will be significantly reduced and we would not recommend this product for daily fast-charge use case. Use of 1C charge rate for every cycle will reduce cycle life by 75%.
Easy Block – will not be adversely affected. 1C charge rate will have minor impact on total cycle life, full 4,000 cycles are achievable.

What is recommended for ‘Fast Charge’ and what is recommended for ‘Cycle Life’?

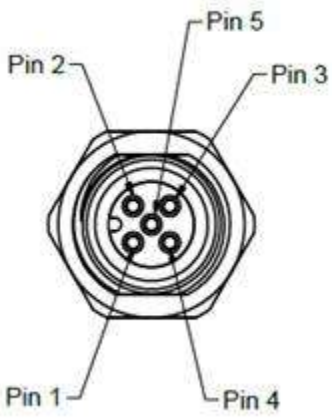
Easy Blade – to achieve cycle life of 1,200 cycles and beyond, the max charge current recommended is 0.5C, discharge current of 0.5C. High charge rates will have a significant negative effect on cycle life.

Easy Block – Max charge current allowed is 1C and it will have minimal impact on lifetime, due to the different cell technology.

In general, to extend cycle life, we would recommend reduction in max charge voltage and average state of charge over lifetime. These will have the biggest impact to maximize cycle life.

13.2 CAN-Communication

What is the PIN configuration?

1. 

Wire / PIN Configuration	
PIN# (TE Connector)	PIN Configuration
4	CAN high
5	CAN low
2	On/Off Switch
1	Charge Control
3	GND

What is the baud rate of the CAN bus and can it be configured to other values?

250kbit/s fixed baud rate which cannot be configured.

Is it possible to change the base CANopen ID that is given to the master battery as well as all the other slave batteries?

The Node IDs in the system are fixed and not changeable outside the specified range.

CAN bus messages: Has each Module got its own CANopen ID?

Correct. Each battery gets its own fixed Node ID while configuring the system. The range from 1 to 27 is reserved then for fixed Node IDs, even if the system consists only of 3 batteries. Each battery sends this PDO consisting of its own value. The master sends additional PDOs with Node 27 consisting of the summary of the whole battery system.

Is it required to charge the batteries having the CAN connected to the charger?

Yes, it is required.

Would it be enough to have a charger with a pre-defined charge profile?

No – the battery needs to communicate to the charger via CAN.

IS CAN optional or absolutely necessary?

CAN is absolutely necessary. Without CAN charging is not possible.

Is CAN required, that the batteries are communicating internally?

Yes, that is correct.

Is CAN required, that the batteries are communicating with the charger?

Yes, this is correct. Charging is only possible with CAN-communication.

Is the communication modulated onto the direct current signal or is a separate data line required here that has to be plugged in manually?

Additional signals via a separate plug connection are required for communication.

Does Varta provide some software tool to inspect the battery's state?

Recommended Standard CANopen SW for Debugging / Read out CAN Objects is CANopen Device Explorer from Emotas (https://www.emotas.de/produkte/canopen-device-explorer)

Do you have any software drivers for communication/setup that are compatible with Ubuntu?

We do not have any special software. We are using standard USB to CAN Interfaces like Peak CAN Interface which is fully compatible with linux (drivers). The software itself must be developed by the customer in this case. If you want to use an open source CANopen stack, you can try to script with python.

13.3 TPDO/SDO

TPDO7: Master Full Charge Capacity: what is the difference to TPDO6's Master Design Capacity?

Design capacity (DC) is the initial capacity of the batteries. The Full Charge capacity (FCC) is the “learned” capacity during a learning cycle. FCC / DC = SOH

Master Remaining Capacity: this is relative to what value? Is it in mAh or some kind of percentage/ratio?

The Master Remaining Capacity is in mAh unit. FCC / RC = SOC

TPDO9: What are the conditions for the TPDO9 to be transmitted by the master battery?

The battery will send the PDO9 as soon it recognizes a heartbeat from Node ID 100dez (charger) and when the charger is configured by the battery via SDO read/write requests. When the charger sends its “Extended Charger Status” Bit with value “1”, the Charge FETs of the battery will be closed.

Is the TPDO mapping feature of CANopen functional?

No, the battery modules do not support dynamic PDO Mapping at the moment.

If I remap the values to other objects do the batteries comply with the remapping and may I do that for TPDOs 5 to 8 without compromising any of the batteries functionality?

Unfortunately, the system is not designed to support any external change of PDO configuration.

Are the SDO steps compulsory or is there a way to jump immediately to PDO-based communication?

Currently the SDO transfer is mandatory. Otherwise the battery will get stuck in SDO write errors

Will the battery perform SDO interactions with the charger even after PDO communication starts?

No, it will not.

13.4 Parallel Connection

Is it possible to add additional modules in parallel, after the system is already configured?

Yes it is possible. Please switch the batteries off before adding modules. After adding modules, start the system again. In case of orange blinking LEDs, press the push button of any battery for at least 5s to reconfigure the Node IDs.

Is it possible to connect 4 systems in parallel, if a system has 6 modules already connected?

Yes, it is possible. The module state has to be in OFF mode, while you connect the additional modules. As soon as the modules switch to ON mode, the master will be defined. If LEDs keep blinking orange, the push button of any module needs to be pressed for at least 5s.

13.5 Safety / Life time

Can the modules turn off while operating?

Yes, this will happen in case the protection is triggered.

What factors affect the total lifetime of the battery?

The total lifetime of lithium ion batteries in terms of both calendar life (age) and cycle life (number of full charge/discharge events) is affected by many factors. In general, the more “gently” a battery is

treated, the longer it will last and the better the lifetime will be (to a certain limit). The main factors which can negatively impact this would be extremes of temperature, sustained higher or lower temperatures and higher charge or discharge rates (especially if sustained or continuous).

Is it possible to switch off remotely during discharge…i.e. forced shut-down option?

Not via CAN, but via the on/off switch at the CAN connector it is possible.

What are the safety thresholds for the Module?

General:

Fuse: Siba 5005038.100 (one shot – 100A)
Short circuit protection: 300A / 0.1ms (reacts faster than the fuse)
Over discharge current protection 1: 65A / 5s
Over discharge current protection 2: 85A / 50ms
Over charge current protection 1: 65A / 5s
Over charge current protection 2: 85A / 50ms

Individual:

Over voltage protection **Easy Blade 24:** 29.75V / 4s. **Easy Blade 48:** 59.5V / 4s
Under voltage protection **Easy Blade 24:** 18.2V / 2s. **Easy Blade 48:** 36.4V / 2s

Over voltage protection **Easy Block 24:** 30V / 4s. **Easy Block 48:** 60V / 4s
Under voltage protection **Easy Block 24:** 16V / 2s. **Easy Block 48:** 32V / 2s

What is the recommended SOC level for lifetime management?

Easy Block - max 80% average SOC to extend the expected life up to 10+ years.

Easy Blade - max 80% average SOC to extend the expected life up to 4+ years.

What is the shelf life of the modules?

Easy Blade: Shelf life: 24 months when shipped from VARTA, conservative estimate
Easy Block: Shelf life: 24 month when shipped from VARTA, conservative estimate

Do you have any recommendations for the storage/charging of these batteries?

In general, storage around room temperature / lower temperatures will be better for long-term battery life (this is applicable to all lithium batteries). For best cycle life time, charge rates of max. 0.5C-rate would be recommended. Higher charge rates on a continuous basis will reduce the cycle life. **For the Easy Blade**, regular charge rates >0.7C will reduce cycle life significantly. For the Easy Block, the cell technology is not so affected. It should be avoided where possible to store the batteries when empty for an extended period; they are better stored with some charge. At the shipping condition of ~25% state of charge level, we estimate 24 months storage conservatively but for such long-term storage we would always recommend a basic voltage check once per year.

13.6 Mechanical

For parallel mechanical connection, we'll use the "module connectors". Where can I get it?

Two module connectors and two screws are included in every box.

Does the design feature that allows connection in height also provide a mechanical lock like the module connectors do?

No, they don't lock in the same way, it is more for stability.

Do you sell copper bus bars for parallel connection of batteries?

No, but this should be possible to organize with our distributors of the ASB range. Contact details are available on our website or in the Technical Handbook.

Do you sell CAN bus cables with the correct length for connection between cells?

No, but this should be possible to organize with our distributors of the ASB range. Contact details are available on our website or in the Technical Handbook.

13.7 General

How can the shutdown timer be configured?

The default value is 3h and the value of the shutdown timer can be set via object 0x3F00.4. This is only for standalone modules, not multi-module systems. Multi-module systems don't support this function.

Steps to follow:

1. Code for write permission
Write value 1815dez to object 0x2010.1

2.Timer value (in seconds)
Write value to object 0x3F00.4 (e.g. 604,800dez for 7 days)

3. Save changed parameter permanently
Write 7211dez to object 0x2010.1

We want to replace the batteries for charge and would like a platform that would monitor the battery level. This would recognize when the battery level had dropped below a set limit and signal that the batteries need replacing (by an operator). Is this possible to implement?

Yes, the batteries will be able to support this monitoring. We recommend you consider a proper shutdown of the system before removing or replacing and run testing before release to make sure the system configures correctly and behaves as expected in the field when replaced (and reset).

Contact details

The Netherlands

Elektrostraat 17
NL-7483 PG Haaksbergen

T: +31 (0)53 573 33 33
F: +31 (0)53 573 33 30
E: nl@texim-europe.com

Belgium

Zuiderlaan 14 bus 10
B-1731 Zellik

T: +32 (0)2 462 01 00
F: +32 (0)2 462 01 25
E: belgium@texim-europe.com

UK & Ireland

St. Mary's House, Church Lane
Carlton Le Moorland
Lincoln LN5 9HS

T: +44 (0)1522 789 555
F: +44 (0)845 299 22 26
E: uk@texim-europe.com

Germany North

Bahnhofstrasse 92
D-25451 Quickborn

T: +49 (0)4106 627 07-0
F: +49 (0)4106 627 07-20
E: germany@texim-europe.com

Germany South

Martin-Kollar-Strasse 9
D-81829 München

T: +49 (0)89 436 086-0
F: +49 (0)89 436 086-19
E: germany@texim-europe.com

Austria

Warwitzstrasse 9
A-5020 Salzburg

T: +43 (0)662 216 026
F: +43 (0)662 216 026-66
E: austria@texim-europe.com

Nordic region

Sdr. Jagtvej 12
DK-2970 Hørsholm

T: +45 88 20 26 30
F: +45 88 20 26 39
E: nordic@texim-europe.com

Italy

Via Matteotti 43
IT-20864 Agrate Brianza (MB)

T: +39 (0)39 971 3293
F: +39 (0)39 971 3293
E: italy@texim-europe.com

General information

info@texim-europe.com
www.texim-europe.com