Lithium-Ion RS series battery module

- Manual -

MGRS12S4P176, MGRS14S3P132, MGRS16S3P132, MGRS24S2P088

MG Energy Systems B.V.

Revision:	**2.5**
Date:	**5-12-2019**

TABLE OF CONTENTS

1 GENERAL

Before continuing read the instructions in this chapter carefully and be sure the instructions are fully understood. If there are questions after reading the instructions please consult MG Energy Systems.

1.1 Document history

Table 1 - Document history

Rev.	Date	Changes	Revision author
2.0	28-01-2019	Initial document.	Mark Scholten
2.1	02-04-2019	Minor changes, corrections, and additions in sections 7.4, 7.5, 7.6, 8.2, 9.1, and chapter 11.	Ane Tjitze Rienstra / Mark Scholten
2.2	27-05-2019	Additions in chapter 10.1.	Wilco Portinga
2.3	12-07-2019	Minor changes, corrections.	Mark Scholten
2.4	25-11-2019	Revised the complete document.	Ane Tjitze Rienstra
2.5	5-12-2019	Minor changes, corrections.	Mark Scholten

1.2 Terms, abbreviations, and definition

Table 2 - Terms, abbreviations, and definitions

Battery cell	*Battery cell;* the smallest building block in a battery, a chemical unit. or cell is the bare Lithium-Ion battery cell.
Battery module	*Battery module;* is an assembly of submodules, BMS, fluid cooling and outer enclosure.
Battery stack	*Battery stack;* is a set of multiple cells in cell cassettes constructed as one.
BMS	*Battery Management System;* The BMS is the electronics that monitors the battery cell parameters to keep it within the operation specifications.
CAN-bus	*Controller Area Network bus;* CAN-bus is a standard serial databus that provides data communication between two or more devices.
	C-Rate; the current (A) used to charge/discharge the battery system divided by the rated ampèr-hours (Ah).
DeviceNet	*DeviceNet*; is a network protocol used in the automation industry to interconnect control devices for data exchange, standardised in the IEC 62026-3.
EMS	*Energy Management System;* The EMS controls all power sources and consumers in a system.
Ethylene glycol	*Ethylene glycol;* is an organic compound with the formula $(CH_2OH)_2$ *(IUPAC name: ethane-1,2-diol)*. This name is often used for a mixture of Ethylene Glycol and water too. Only Ethylene glycol based coolant is allowed to be used with the RS series battery.
HVIL	*High Voltage Interlock Loop;* is a wire loop which is created for protection of pulling cables from the battery system while in operation. It shuts down the system when loop is not closed.
IC	*Integrated Circuit;* is a chip containing an electronics circuit;
MSDS	*Material Safety Data Sheet;* is a document that lists information relating to occupational safety and health for the use of various substances and products.
NMEA 2000	*National Marine Electronics Association's* NMEA 2000 is a plug-and-play communications standard used for connecting marine sensors

	and display units within ships and boats, standardised in the IEC 61162-1.
PCB	*Printed Circuit Board;* is a board containing an electronic circuit;
PCBA	*Printed Circuit Board Assembly;* is a board containing an electronic circuit including passive and active components;
PPS	*Propagation Prevention System*; a fluid based protection system to prevent cell-to-cell and module-to-module propagation in case of a thermal runaway of one cell.
Propylene glycol	*Propylene glycol;* is a synthetic organic compound with the chemical formula $C_3H_8O_2$ (IUPAC name: propane-1,2-diol). This name is often used for a mixture of Propylene Glycol and water too. Propylene glycol based coolant must NOT be used with the RS series battery.
SoC	*State-Of-Charge;* is the remaining capacity in a battery cell or module in percent (%).
SoH	*State-Of-Health;* is a figure of merit of the condition of a battery (or a cell, or a battery pack), compared to its ideal conditions.

2 SAFETY INSTRUCTIONS

2.1 Safety message level definition

Table 3 - Safety message levels overview

WARNING:
A hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION:
A hazardous situation which, if not avoided, could result in minor or moderate injury.

ELECTRICAL HAZARD:
The possibility of electrical risks if instructions are not followed in a proper manner.

NOTICE:

- A potential situation which, if not avoided, could result in an undesirable result or state.
- A practice not related to personal injury.

2.2 User health and safety

2.2.1 General precautions

This product is designed and tested in accordance with international standards. The equipment should be used according the intendend use only.

WARNING:
A battery is a permanent energy source which cannot be turned off.

ELECTRICAL HAZARD:

- Wear applicable personal protective equipment when working on a battery system.
- Use insulated tools when working on a battery system.
- Make sure the locale health and safety regulations for working on battery systems are followed.

2.2.2 Qualifications and training

The personnel responsible for the assembly, operation, inspection, and maintenance of the battery system must be appropriately qualified. The user company must do the following tasks:

- Define the responsibilities and competency of all personnel working on the battery system.
- Provide instruction and training.
- Ensure that the contents of the operating and safety instructions have been fully understood by the personnel.
- Check the local safety rules and guidelines they have higher preference over the manufacturers specification in case of regulatory conflicts.

Instruction and training can be carried out by MG Energy Systems B.V. by order of the user company.

2.2.3 Non-compliance risks

Failure to comply with all safety precautions can result in the following conditions:

- Death or serious injury due to electrical, mechanical, and chemical influences.
- Environmental damage due to the leakage of dangerous materials.
- Product damage.
- Property damage.
- Loss of all claims for damages.

2.2.4 Unacceptable modes of operation

The operational reliability of this product is only guaranteed when it is used as intended. The operating limits on the identification tag and in the data sheet may not be exceeded under any circumstances. If the identification tag is missing or worn, contact MG Energy Systems B.V. for specific instructions.

WARNING:
The battery modules may only be used in combination with a master BMS.

3 TRANSPORT, STORAGE AND UNPACKING

3.1 Transport

The Package and transport instructions provided by the manufacturer must be followed under all circumstances.

Notes on transport:

- Use original packaging.
- Lithium-Ion batteries are dangerous goods and must be transported according to the applicable rules.
- Transport company and shipper must be qualified to transport and package dangerous goods.
- The SoC during transport must be ≤ 30%.

For details on transport of this battery module see the MSDS.

CAUTION:
It is not allowed to transport, connect or operate a damaged battery.

NOTICE:
No liability can be accepted for damage during transport if the equipment is not transported in its original packaging or if the original packaging is opened before the destination is reached.

NOTICE:
The SoC of the battery as delivered from factory is ≤ 30%.

3.2 Storage

The storage instructions provided by the manufacturer must be followed in all circumstances.

Notes on storage:

- Battery module must be stored in its original packaging.
- Store in a dry, clean, and conditioned location.
- Local regulations for storage of dangerous goods may be applicable.
- Recommended storage temperature of the battery module is between +10°C to +25°C.
- It is recommended to limit the battery charge to 50% SoC. This will limit calenderic aging.

Applying the above notes on storage of the battery module will cause every six months a decrease in SoC of 5%.

NOTICE:
Check the voltage of the stored battery module every six months.
When the battery module voltage is in the range of the cut-off voltage stated in the specifications, recharging is required. Contact MG Energy Systems for specific instruction and tools.

3.3 Unpacking

Follow these handling guidelines when handling the product to prevent damage during unpacking:

- Use care when handling the product.
- Leave protective caps and covers on the product until installation.

CAUTION:
Always take the local applicable standards and regulations regarding the prevention of accidents into account when handling the product. Be aware of the total mass of the product and do not lift heavy objects unassisted.

3.3.1 Scope of delivery

The scope of delivery is as following:

- MG RS battery module of type as described in chapter 5.

NOTICE:
Not within the scope of delivery:
- Power cables and connectors (details can be found in chapter 6.3.2).
- Communication cables and connectors (details can be found in chapter 6.3.1).
- Exhaust parts.

4 GENERAL DESCRIPTION

High safety and flexible system configurations were the design principles during the development of the RS series Lithium-Ion battery. A modular and compact design makes system integration more flexible, especially in refit applications. Adding redundant BMS and a unique cell-to-cell propagation protection takes safety to the next level. The fluid thermal management keeps the battery cells on temperature to extend cycle life and to improve the peak power performance. These features make this battery suitable for large energy storage applications as well as small peak power packs in hybrid solutions.

4.1 Battery system components

MG Energy Systems Lithium-Ion battery system consists of the following components:

- One or more **MG RS battery modules**;
- One or more **MG Master HV** or **MG Master LV** battery management systems; Details of these battery management controllers can be found in their separate description documents;

Consult MG Energy Systems B.V. for compatibility of battery models with the MG Master LV and MG Master HV.

4.2 Functional description

MG Energy Systems battery system philosophy is to have one master BMS, e.g. a MG Master HV, per string of battery modules which communicates with one or more slave BMSs integrated in the Lithium-Ion battery module(s). The slave BMSs are monitoring the battery cell parameters like cell voltage, cell temperature, and humidity inside the enclosure. Besides monitoring, the slave BMS also controls balancing of cells based on the input of the master BMS.

All these parameters are send to the MG Master HV via a dedicated CAN-bus which collects all the data and monitors these parameters with different thresholds. When a parameter exceeds the threshold this will first be communicated to the user via the, separated, auxiliary CAN-bus. If the exceeded threshold stays, the master BMS has the possibility to disconnect the batteries from the system by opening the main contactors.

Functional and safety features of the MG RS battery module are:

- Modular design in combination with flexible rack design makes integration in small spaces possible.
- Robust enclosure with high IP rating.
- Exhaust system with over-pressure mechanism, used to output toxic gasses to a safe area during a thermal runaway of a battery cell. This avoids containment of gases within the battery space and therefor lowers the systems complexity to limit the risks involved.
- Cell level fluid thermal management (cooling/heating) to increase performance, safety, and cycle life.
- Redundant Battery Management System in each MG RS battery module to guarantee maximum safety and stable operation.
- Unique cell-to-cell and module-to-module propagation protection during a failure.
- Each string of batteries has its own MG Master BMS for protection, control, and logging.

4.3 Battery module schematic overview

Figure 1 shows the internal schematic overview of the MG RS battery module.

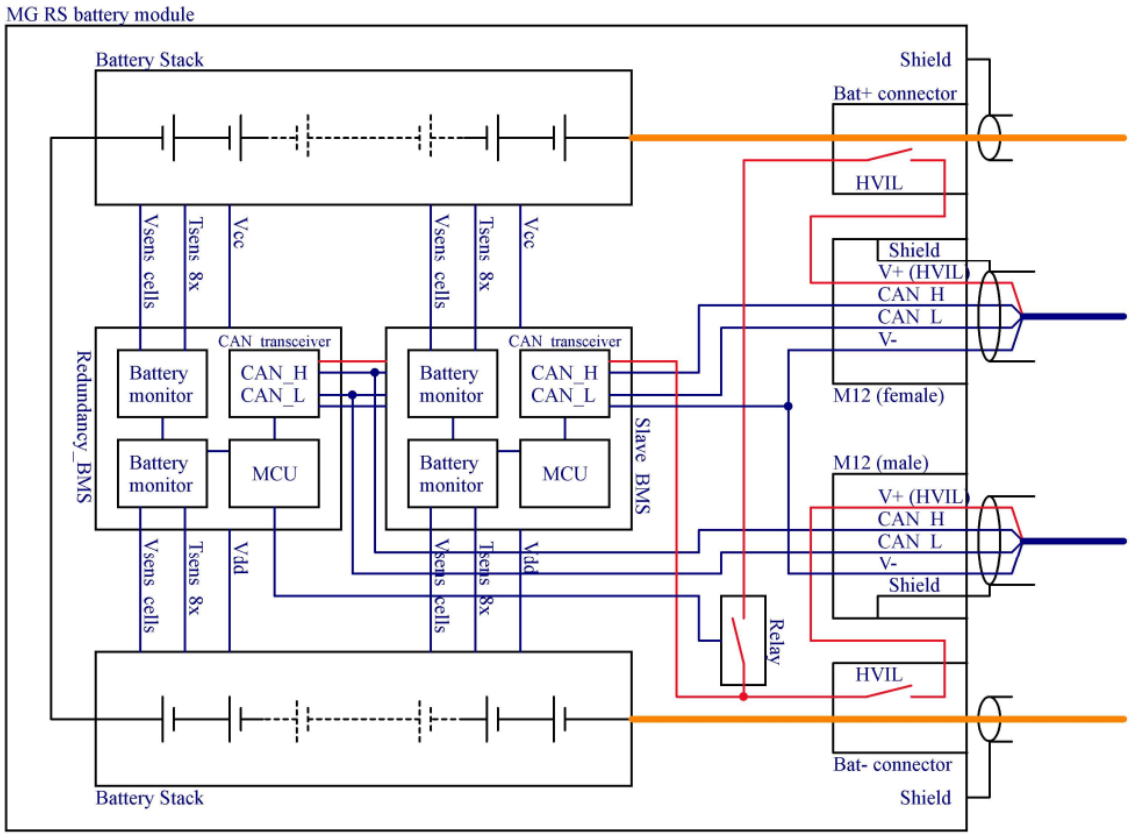


Figure 1 - Battery module schematic overview

4.4 Example systems

Different kind of battery systems can be created because of the modular design. Battery modules can be placed in series and parallel to create higher voltages and larger capacities.

Contact MG Energy Systems B.V. for more information about possible configurations.

4.4.1 Low voltage systems

Low voltage systems up to 96 VDC are setup with the MG Master LV series. For more information about the MG Master LV, please refer to the data sheet and manual.

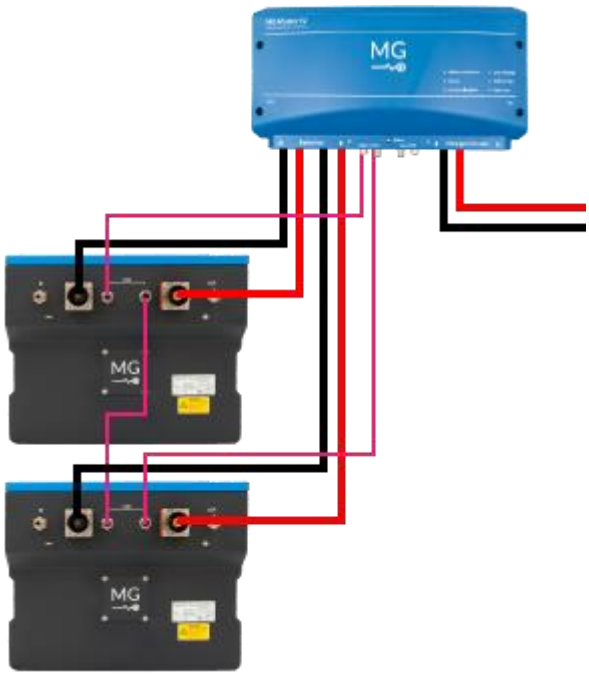
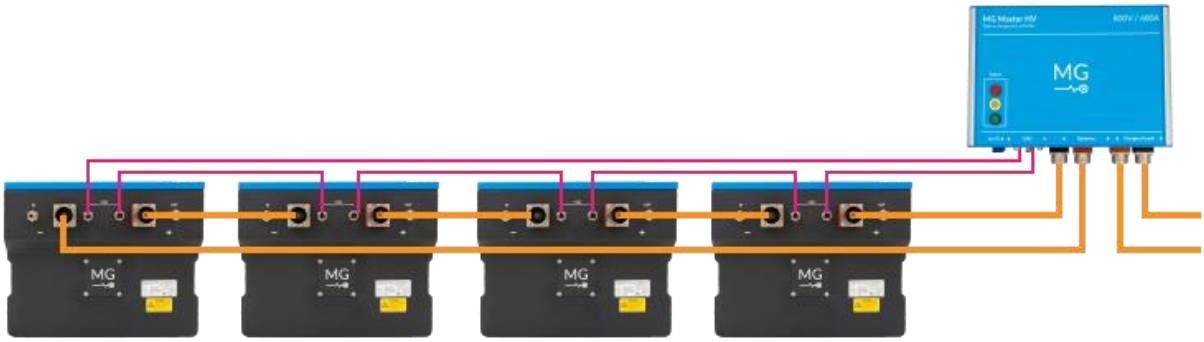


Figure 2 - 48 VDC system with 2x MGRS14S3P132

4.4.2 High voltage systems

High voltage systems from 144 VDC up to 800 VDC are setup with the MG Master HV series. For more information about the MG Master HV, please refer to the data sheet and manual.



5 MODELS

5.1 Models and configurations

Table 4 lists the available battery module configurations. All configurations have the same enclosure dimensions, safety features and components.

Table 4 - Battery module configurations

Article number	MGRS12S4P176	MGRS14S3P132	MGRS16S3P132	MGRS24S2P088
Cell configuration	12S4P	14S3P	16S3P	24S2P
Nr. of cells	48	42	48	48
Nominal voltage	43.8 V	51.1 V	58.4 V	87.6 V
Capacity	176 Ah	132 Ah	132 Ah	88 Ah
Energy capacity	7700 Wh	6700 Wh	7700 Wh	7700 Wh

5.1.1 Battery designation

As per IEC 62620:2014 it is required to state a standard designation per battery module configuration, these are given in table 5.

Table 5 - Battery module designation as per IEC 62620:2014

Article number	Designation
MGRS12S4P176	INP/593/355/323/[4P12S]M/-30+40/95
MGRS14S3P132	INP/593/355/323/[3P14S]M/-30+40/95
MGRS16S3P132	INP/593/355/323/[3P16S]M/-30+40/95
MGRS24S2P088	INP/593/355/323/[2P24S]M/-30+40/95

5.1.2 Power connector options

Each of the configurations is available with Amphenol PowerLok™ 300 Series or Amphenol PowerLok™ 500 Series power connectors. The difference of the power connectors is the handling of the continuous current. See chapter 6.3.2 for details.

5.1.2.1 Power connector ordering information

The power connector configuration can be ordered as following:

- <Article number> – 300 for the 300 series connectors.
- <Article number> – 500 for the 500 series connectors.

Example: **MGRS12S4P176-300** or **MGRS12S4P176-500**

5.2 Identification label

The identification label of the MG RS battery module is located at the front of the enclosure.

Example identification label:

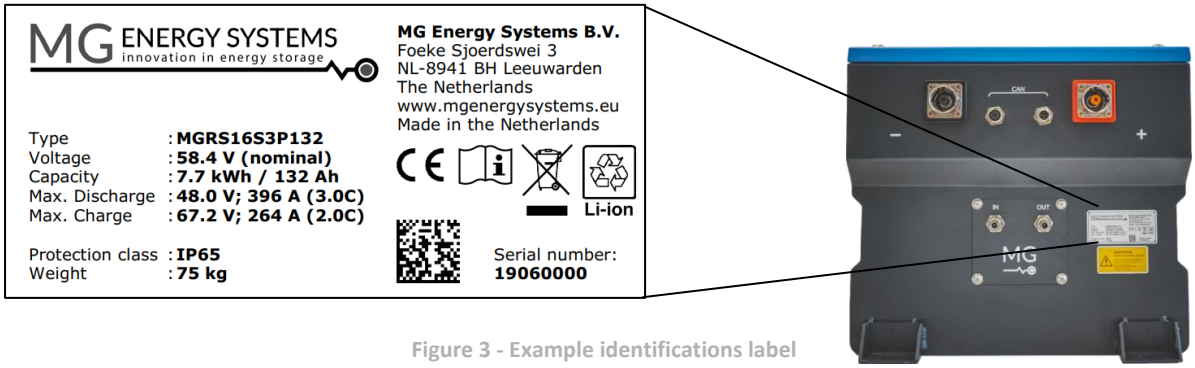


Figure 3 - Example identifications label

The identifications label shown in figure 3 contains written information about the product. The explanation of the symbols used on the identification label is stated in table 6.

Table 6 - Identification lable logo explaination

CE	Declaration of conformity with health, safety, and environmental protection standards for products sold within the European Economic Area as per directive 2014/35/EU.
	Symbol indication the manual must be red before installation and use of the device.
	Device is treated according the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU.
	GS1 data matrix type barcode containing detailed product information.

6 OVERVIEW

This chapter shows an overview of all connection and its functions.

6.1 Front view

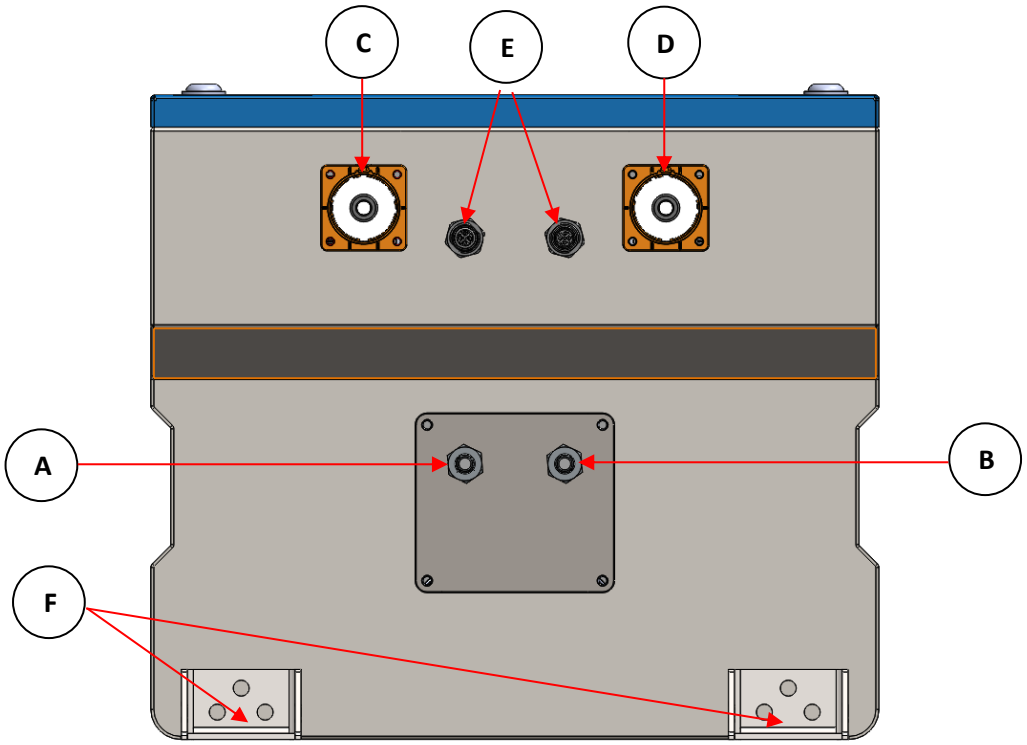


Figure 4 - RS module overview front

Table 7 - Battery module front view legend

Item	Description
A	Fluid cooling inlet
B	Fluid cooling outlet
C	Negative power connection
D	Positive power connection
E	CAN-Bus communication
F	Mounting connections and equipotential bonding connection

6.2 Rear view

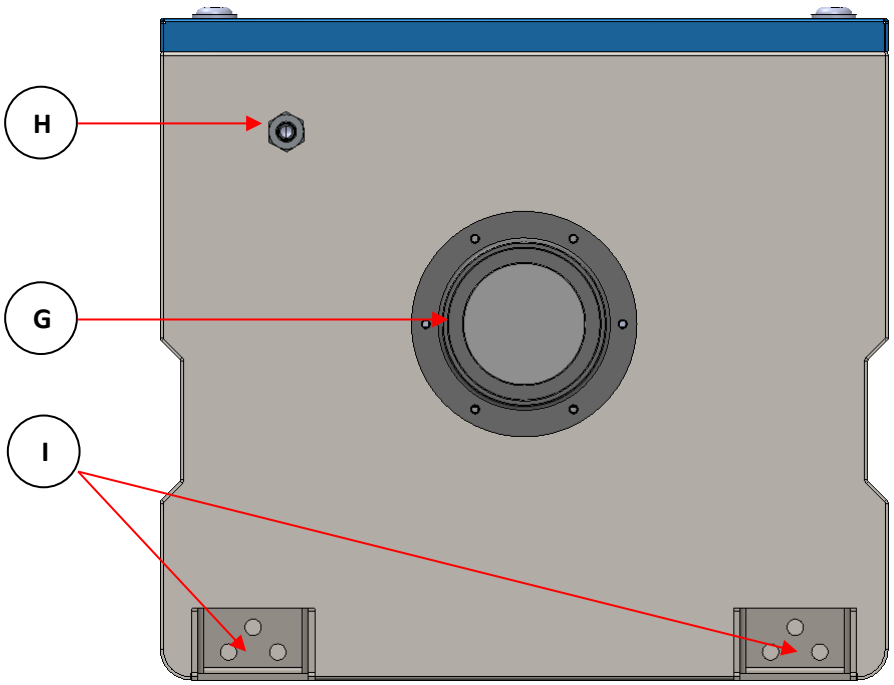


Figure 5 - RS module overview rear

Table 8 – Battery module rear view legend

Item	Description
G	Exhaust connection with pressure relief
H	PPS connection
I	Mounting connections and equipotential bonding connection

6.3 Connections details

6.3.1 CAN-bus connector details

A MG Master BMS communicates with the connected battery modules via CAN-bus. This is a dedicated CAN-bus where only MG battery modules of the same type or other MG devices may be connected.

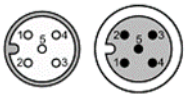
The CAN-Bus connection is used for several functions:

- Data communication between battery module(s) and master BMS;
- The battery module uses the CAN-Bus V+ voltage to enable the power of the internal BMS;
- The CAN-Bus V+ voltage is also used as HVIL voltage source;

6.3.1.1 Connector details

The connectors used for connecting the battery, auxiliary, and diagnostics CAN-bus are all of the same type, namely a circular M12 connector with 5 positions and A-coded keying.

Table 9 - Circular M12 connector with 5 positions A-coded details

Pin	Description	Connector view (mating side)
1	Shield	M12 plug/socket, 5-pin, A-coded  Male Female
2	V+	
3	GND	
4	CAN-H	
5	CAN-L	

Cables to be used for the battery system are typically referred to as NMEA 2000 or DeviceNet compatible cables. The minimum requirements for cables are:

- Twisted pair connected to pins 4 and 5 for communication with a minimum wire cross sectional area of 0.2 mm^2 (24 AWG).
- Pair of conductors connected to pin 2 and 3 for power and HVIL with a minimum wire cross sectional area of 0.34 mm^2 (22 AWG).
- Cable with braided shielding connected to pin 1.

NOTICE:
Do not use sensor/actor cables. They often don't have any twisted pairs and are therefore not suitable for this application.

6.3.2 Power connections

For the RS battery module's power connections, Amphenol PowerLok™ 300 Series or Amphenol PowerLok™ 500 Series are used. These power connectors can handle a voltage of 1000 VDC and have an integrated HVIL for safety.

The continuous current of the system is depending on the connected Amphenol PowerLok™ series and cable cross section.

6.3.2.1 Connector details

Table 10 and table 11 show an overview of the standard connector types in relation with the models and the maximum current. Contact MG Energy Systems B.V. for cable options and possibilities.

Table 10 - Amphenol PowerLok™ 500 series

Brand	Amphenol PowerLok™	
Series	500 series	
	Positive terminal (orange)	***Negative terminal (black)***
Receptacle types (mounted on MG RS module)	PL00X-501-10-M10	PL00Y-501-10-M10
Plug must be of HVIL type.	**Over-moulded cable assembly:** PL20X-501-120: 350A PL20X-501-135: 400A PL20X-501-150: 500A PL10X-501-120: 350A PL10X-501-135: 400A PL10X-501-150: 500A	**Over-moulded cable assembly:** PL20Y-501-120: 350A PL20Y-501-135: 400A PL20Y-501-150: 500A PL20Y-501-120: 350A PL20Y-501-135: 400A PL20Y-501-150: 500A

Table 11 - Amphenol PowerLok™ 300 Series

Brand	Amphenol PowerLok™	
Series	300 series	
	Positive terminal (orange)	***Negative terminal (black)***
Receptacle types (mounted on MG RS module)	PL00X-301-10-M10	PL00Y-301-10-M10
Plug must be of HVIL type.	**Over-moulded cable assembly:** PL20X-301-35: 150A PL20X-301-50: 200A PL20X-301-70: 250A PL20X-301-95: 300A PL10X-301-35: 150A PL10X-301-50: 200A PL10X-301-70: 250A PL10X-301-95: 300A **Plug connector:** PL28X-301-35: 150A PL28X-301-50: 200A PL28X-301-70: 250A PL18X-301-35: 150A PL18X-301-50: 200A PL18X-301-70: 250A	**Over-moulded cable assembly:** PL20Y-301-35: 150A PL20Y-301-50: 200A PL20Y-301-70: 250A PL20Y-301-95: 300A PL10Y-301-35: 150A PL10Y-301-50: 200A PL10Y-301-70: 250A PL10Y-301-95: 300A **Plug connector:** PL28Y-301-35: 150A PL28Y-301-50: 200A PL28Y-301-70: 250A PL18Y-301-35: 150A PL18Y-301-50: 200A PL18Y-301-70: 250A

6.3.3 Fluid thermal management connections

Figure 6 shows the fluid themal management connections that is used for the battery module. It is a hose tail for Ø 10 mm internal diameter hose made from nickel-plated brass.

Figure 6 - Fluid thermal mangagement in- and outlet connection

For connection to the fluid thermal management system a hose needs to be used with the following requirements:

- Ethylene glycol resistant.
- Inner diameter of Ø 10 mm.
- Temperature operating window of 0 °C to 60 °C.

6.3.4 Exhaust connection

The function of the exhaust connection with pressure relief is to release gasses in case of a thermal runaway event. The flammable and toxic gasses can be evicted from the module and released in a safe area (outside).

The diameter of the exhaust is dimensioned to connect piping with an inner diameter of 80 mm.

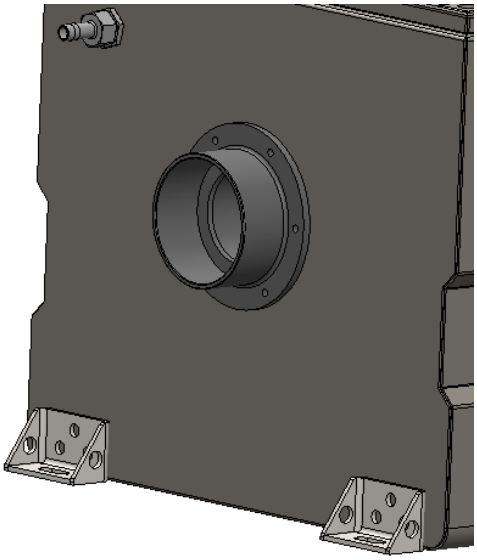


Figure 7 - Exhaust connection

6.3.5 PPS connection

The PPS connection is used to fill the battery with a PPS fluid to prevent thermal runaway propagation in case of a single cell thermal runaway event.

The connection is of the same type as the fluid cooling connections specified in chapter 6.3.3.

WARNING:
MG Energy Systems B.V. cannot be held responsible for any damage or costs caused by a thermal runaway event if the PPS connection is not connected to a pressurized container with at least 12 liters of PPS fluid.

7 INTEGRATION

This section describes the requirements for integration of the battery module.

7.1 Risk assessment

Integration of a battery system requires in any case an assessment of the risks. Depending on the application, rules need to be applied. MG Energy Systems can supply the necessary basic documentation for risk assessment.

7.1.1 Marine application

Specific rules are required when integrating a battery system in a marine application, e.g. a vessel, yacht or work boat. For example a large vessel can be build according to a class register like Lloyds, DNV-GL, or Bureau Veritas. In this case the class register need to be informed about the battery installation. Each class register has its own requirements and rules for integrating a battery system.

NOTICE:
Check the applicable rules for the application where the battery system will be integrated in before the integration design.

7.2 Location

The location of the battery system needs special attention, since some regulatory categorize Lithium-Ion battery systems as hazardous. Check for the local rules for the requirements of the battery system location in the used application.

General recommendations and requirements for the battery space concerning the MG RS series battery module are:

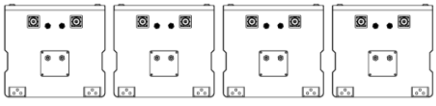
- Make sure the battery space is in accordance with the applicable rules.
- Keep the battery string connection cables as short as possible.
- Ensure that the equipment is used under the correct operating conditions.

7.3 Battery rack

It is recommended to mount the battery modules in a rack secured with all four mounting brackets. Different parameters need to be taken into account when designing the battery rack:

- Weight of the battery modules.
- Shock and impact requirements.
- Battery module spacing.
- Fluid cooling and exhaust pipes.

Depending on the battery module configuration and space available in the vessel, different physical setups can be created.



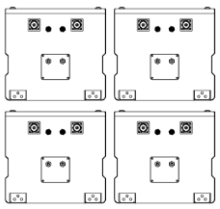


Figure 8 - Battery arrangement examples

7.3.1 Battery rack dimension requirements

Figure 9 shows the minimum spacing of the battery modules.

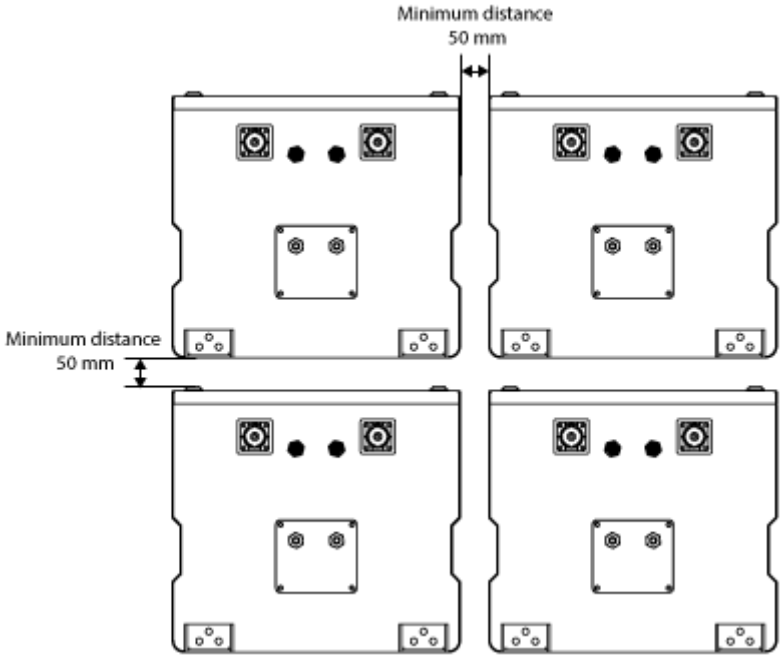


Figure 9 - Battery rack dimension requirements

7.3.2 Cables lengths

Cable lengths need to be taken into account when designing a battery rack. When designing the battery rack and configuration, cable lengths for different configurations are needed. Batteries can be placed in parallel, for example in 48 VDC systems, or in series up to 800 VDC.

7.3.2.1 Parallel configuration

To use the battery module in parallel configuration, each battery module is connected with a separate set of power cables to a junction box.

NOTICE:
When connecting battery modules in parallel to a junction box:

- The cable lengths from each battery module need to have exactly the same length.
- Each battery module must be fused separately when paralleld, e.g. in the junction box.

7.3.2.2 Series configuration

The battery modules can be connected in series up to 900 VDC which is the voltage limit of the Master HV. Table 12 and table 13 shows a list of the battery arrangements and which cable length is needed.

Table 12 - Horizontal battery arrangement

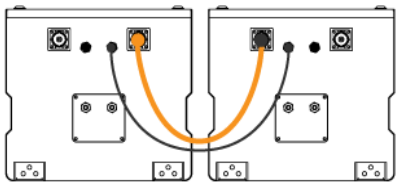
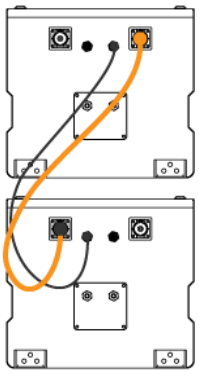
Battery arrangement	Cable length	Cable type	Cable layout
	0.55 m	Power	
	0.6 m	Communication	

Table 13 - Vertical battery arrangement

Battery arrangement	Cable length	Cable type	Cable layout
	0.95 m	Power	
	1 m	Communication	

NOTICE:
A separate document is available which contains an overview of all standard available cables and ordering information, ask MG Energy Systems for a copy.

Figure 10 shows a complete connected battery system.

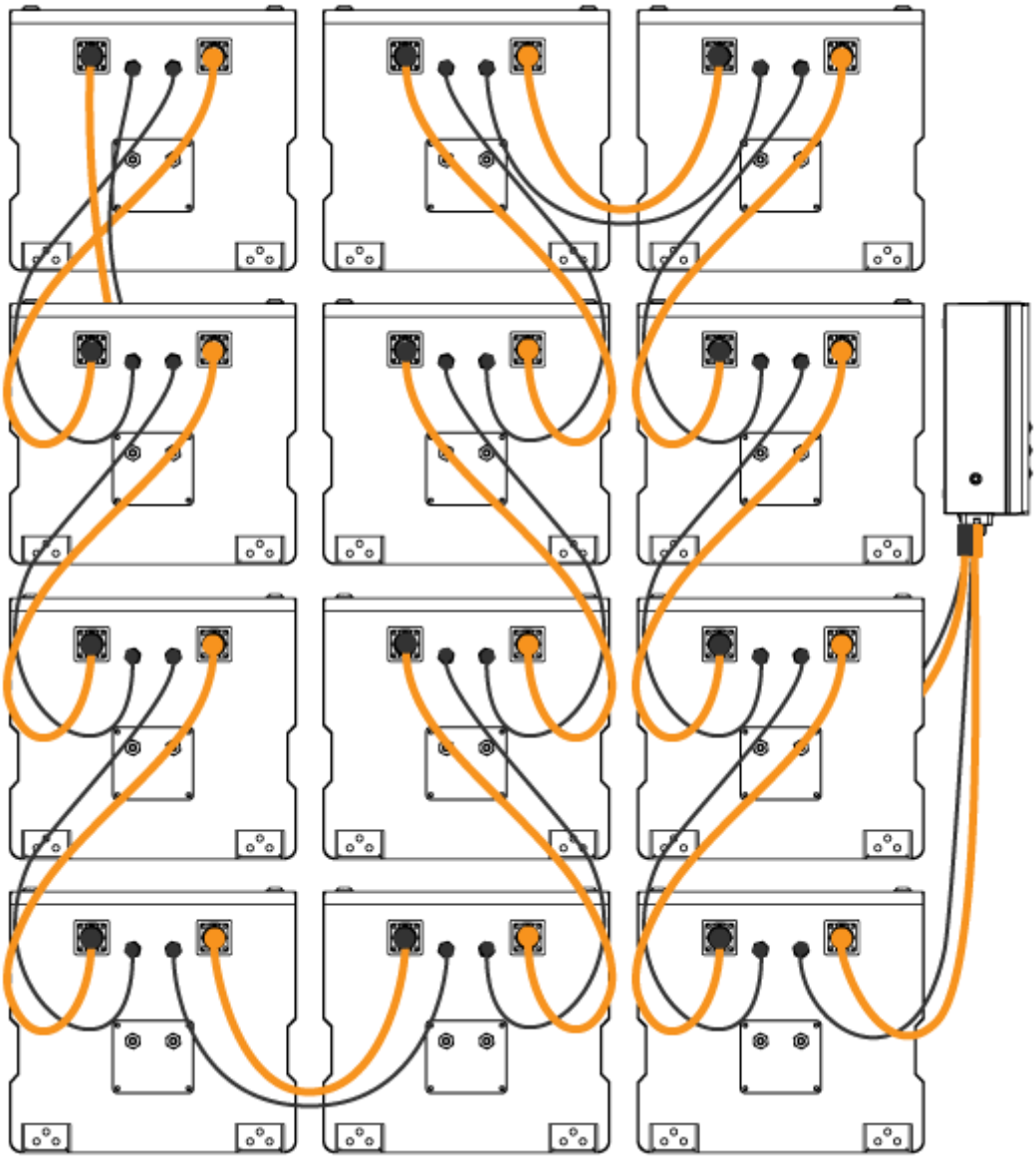


Figure 10 - Full connected series setup example

7.4 Thermal management

The battery module has fluid based thermal management capability. This is used to keep the battery cells within a defined temperature window, which will improve performance and extend cycle life. The fluid cooling also helps to prevent thermal propagation from a cell to adjacent cells inside a battery module. When the batteries are kept at a stable temperature, the ambient temperature will have less effect on the battery.

NOTICE:
The use of the fluid cooling system is mandatory in case of a marine project where a class register is involved. It will add safety and will mitigate risks.

7.4.1 Fluid cooling requirements

A list with the basic thermal management system requirements is stated in table 14.

Table 14 - Fluid cooling requirements per module

Cooling system	Fluid cooling system with pressure-less return (battery module's outlet side).
Coolant type	Ethylene glycol based with a maximum ratio of 50% Ethylene glycol, e.g. Eurol Coolant XL -36°C (E504140).
Coolant inlet temperature	Range of 18 °C to 30 °C.
Maximum inlet pressure	0.7 bar (versus ambient)
Maximum outlet pressure	0.3 bar (versus ambient)
Operational flow	1 to 2 l/min with a pressure drop of 0.15 to 0.35 bar
Heat rejection	0.5 C = 70 W 1 C = 280 W 2 C = 1.200 W (recommended flow 2 l/min) 3 C = 2.500 W (recommended flow 2 l/min)

CAUTION:
The following aspects must be taken into account:

- Make sure the coolant solution is ethylene glycol based. The use of propylene glycol based coolants can lead to permanent damage of the battery module's interior.
- Make sure that the cooling inlet and outlet are not reversed. Reverse flow can lead to excessive pressure on the battery module's interior resulting in permanent damage.

NOTICE:
All fluid cooling circuit of the battery modules are connected in parallel. When system requirements are not clear or cannot be fulfilled, please contact MG Energy Systems to discuss other possibilities and solutions.

7.5 Exhaust

The exhaust system has the function to channel the released gasses during a thermal runaway event to a safe area. To be able to do this, an exhaust output with pressure relief is designed at the rear of the battery module. A ducting system can be connected to expel the toxic and flammable gasses from the module and prevent it from releasing the gasses in the battery area.

The battery module has a 80 mm external diameter round connection on the exhaust. The ducting needs to be connected to this connection. It is recommended to use steel or stainless steel ducts because the released gasses can reach high temperatures and the ducting must stay functional at all time.

To provide a connection to a standard ducting system there are two optional parts available.

NOTICE:
The ducting system must be of a gas-tight type which can handle high temperatures. For example steel ducting pipes with high temperature seals.

NOTICE:
The temperature of the released gasses during a thermal runaway event of a single cell is around 270 °C.
In this case the seal temperature of the two optional parts will be around 75 °C.

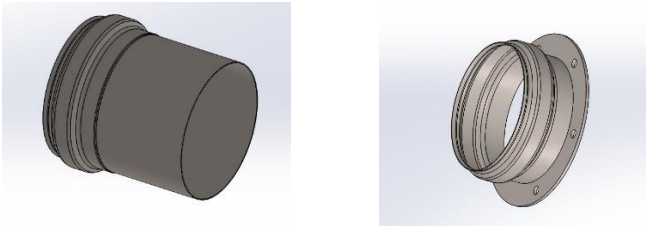


Figure 11 - Optional exhaust parts

The exhaust parts can be fitted on the battery modules exhaust to provide a flange or a sleeve to connect to standard 80 mm steel ducting system. The seal in the parts will make a gas-tight connection that can handle the temperatures during a thermal runaway event.

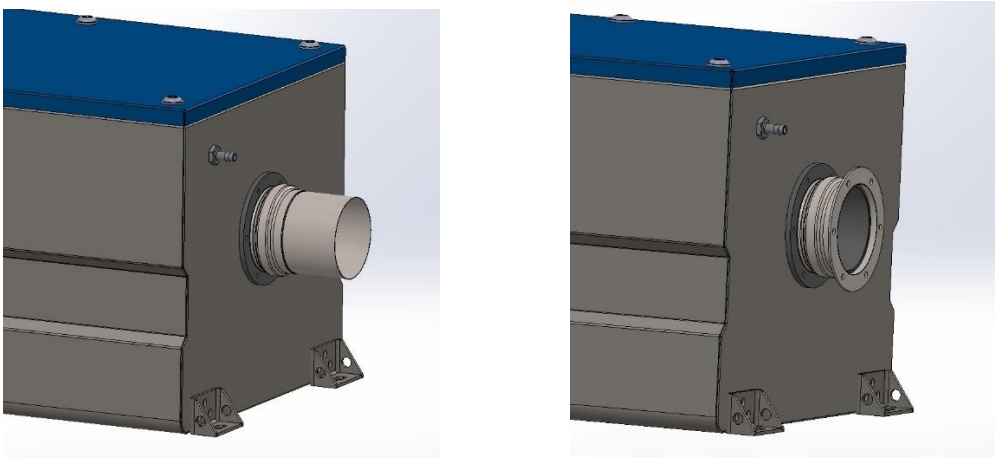


Figure 12 - Exhaust parts connected

NOTICE:
Water or other liquids may not enter the exhaust ducting. Make sure this is avoided by design.

CAUTION:
The output of the exhaust ducting must be routed to an area where the released toxic and flammable gasses cannot harm people or be ignited.

7.5.1 Example ducting arrangement

Figure 13 shows an example of a ducting arrangement of the battery modules.

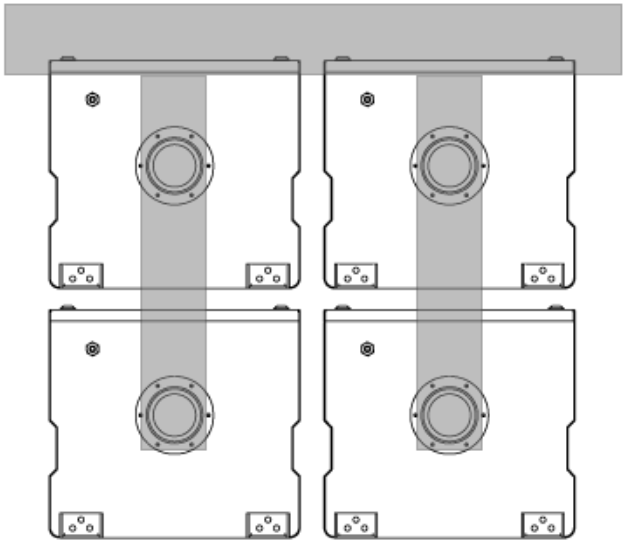


Figure 13 - Example ducting arrangement

Recommended options for the exhaust ducting are:

- Add a drain to the lowest points in the ducting system. This will help to remove any liquids for example the liquid of the PPS after a thermal runaway event;
- Add a nozzle to apply air pressure to the ducting system. This will help to clean the exhaust system from remaining gasses after a thermal runaway event and makes it safe to remove the broken battery module;

7.6 Propagation prevention system

The battery module is equipped with a thermal Propagation Prevention Systems (PPS). At the rear of each battery module a connection point is available to prevent cell-to-cell and module-to-module thermal runaway propagation.

WARNING:
Make sure the Propagation Protection System is used as described under all cicumstances.

When a thermal runaway event occurs the PPS fluid will be automatically released into the battery module. The propagation prevention fluid is normally contained in a pressurised vessel.

CAUTION:
When the PPS is activated, fluid will flow into the battery module. When there is flowing more than 12 litres into the battery module it will reach the exhaust output and fluid will flow into the exhaust ducting.

A pressure vessel with a propagation prevention fluid is connected as shown in figure 14. The requirements for the pressure vessel:

- PPS fluid with equivelant heat capacity as water;
- PPS fluid with equal or lower boiling point as water;
- PPS fluid with equal or higher latent heat as water;
- PPS fluid equal or lower viscosity as water;
- Minimum amount PPS fluid is 12 liters;
- Minimum pressure at the vessel 2 Bar and maximum pressure 3 Bar;

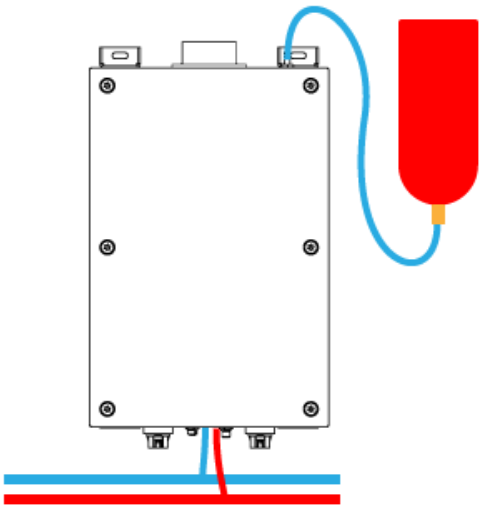


Figure 14 - Propagation prevention system connection scheme

NOTICE:
Multiple battery modules can be connected in parallel to one pressure vessel. It is recommended to connect no more than six modules per pressure vessel.

8 INSTALLATION

Read the installation instructions in this chapter before commencing installation activities.

WARNING:
Before continuing make sure the following instructions are met:

- Ensure that the connection cables are provided with fuses and circuit breakers.
- Never replace a protective device by a component of a different type. Refer to the ordering information sections of this manual or contact manufacturer for a correct replacement.
- Before switching the device on, check whether the available voltage source conforms to the configuration settings of the product as described in the manual.
- Ensure that the equipment is used under the correct operating conditions. Never operate it in a wet or dusty environment.
- Ensure that there is always sufficient free space around the product.
- Install the product in an environment that can sustain some heat. Ensure therefore that there are no chemicals, plastic parts, curtains or other textiles, etc. in the immediate vicinity of the equipment.

8.1 Installation procedures

Below the basic installation procedures at battery module level.

1. Mount the battery module: Mounting procedure;
2. Equipotential bonding of the battery modules: Equipotential bonding procedure;
3. Connect the battery module electrically: Electrical connection procedure.

NOTICE:
During installation a check form needs to be used to log the installation procedure. This log will be checked during commissioning.

8.2 Mounting procedure

This procedure describes how to mount the battery module with respect to the integration requirements stated in chapter 7.

1. Lift the battery module to its location using the mounting points specified in figure 15.
2. Use M8 bolts with washers and spring washers or a lock nut for mounting.
3. Tighthen the M8 bolts at the four mounting points with 20 Nm.

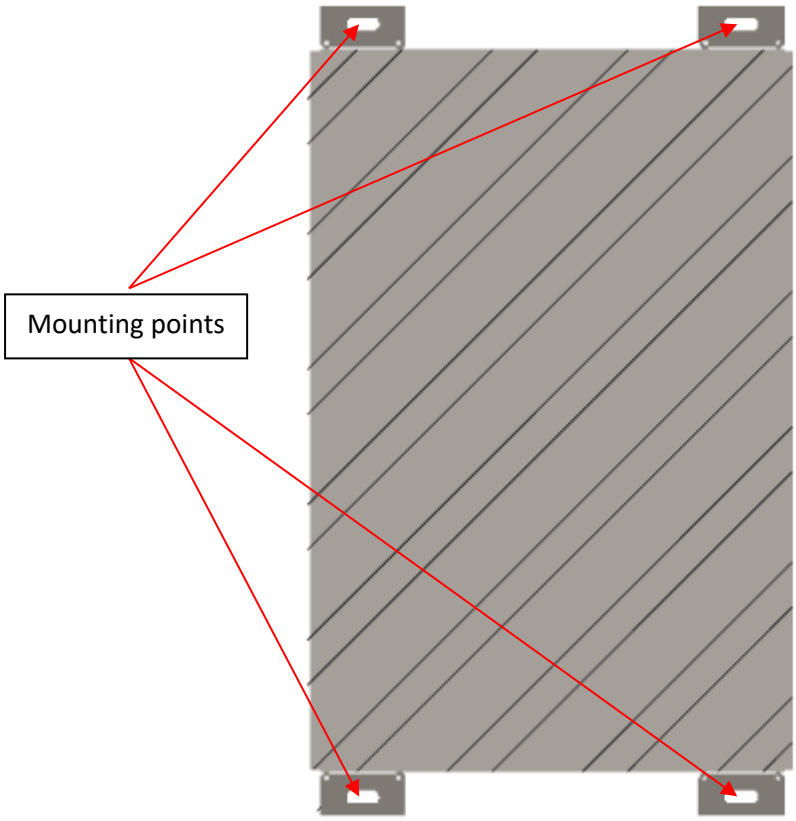


Figure 15 – Mounting points

8.3 Equipotential bonding connection procedure

The equipotential bonding connection location of the battery module is the same as the mounting bracket. One of the four mounting points can be used for this. Equipotential bonding connection scheme and the required wire cross-section depend on local standards and regulation. The typical used wire cross-section is 10 mm^2.

NOTICE:
Make sure a toothed contact washer is used to make a good connection through the powder coating.

8.4 Electrical connection procedure

The battery module can be used in combination with other battery modules of the same type and always in combination with a master BMS.

8.4.1 Power connection procedure

The power connections make use of the Amphenol PowerLok™ connectors. See section 7.3.2 for detailed information about types and cable sizes available.

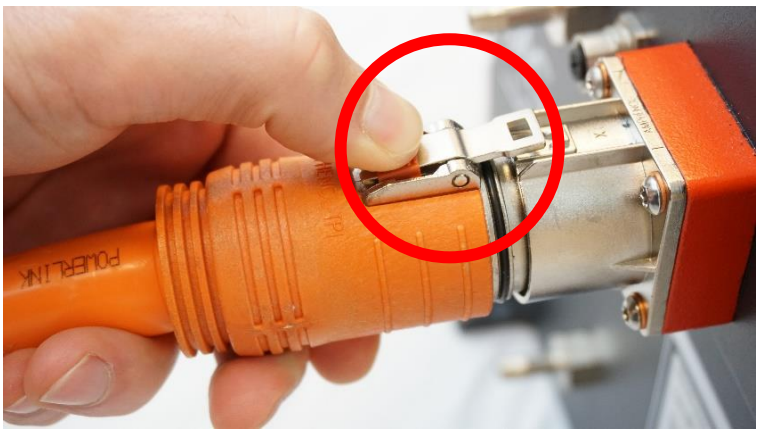
ELECTRICAL HAZARD:
The battery modules can be placed in series up to 900 VDC. Make sure to wear proper insulation gloves.

Follow this procedure to connect the Amphenol PowerLok™ connectors to the battery module:

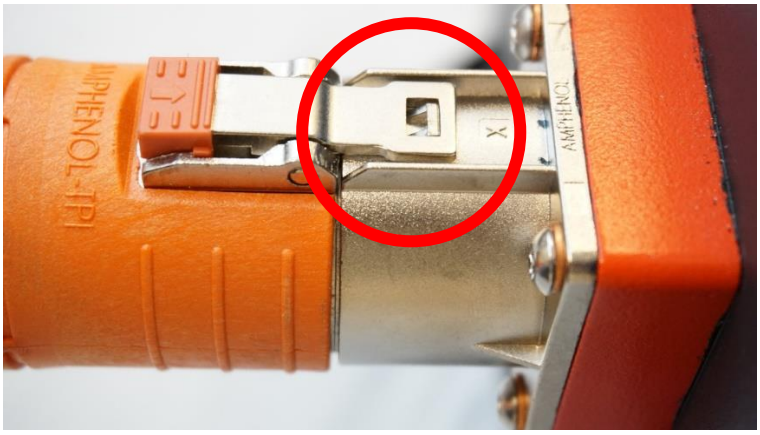
1. Plug in the Amphenol PowerLok™.

NOTICE:
Orange is the positive terminal of the battery and black is the negative terminal of the battery. This cannot be switched because connectors are keyed.

2. Push the orange/black lip forward to lift the locking mechanism.



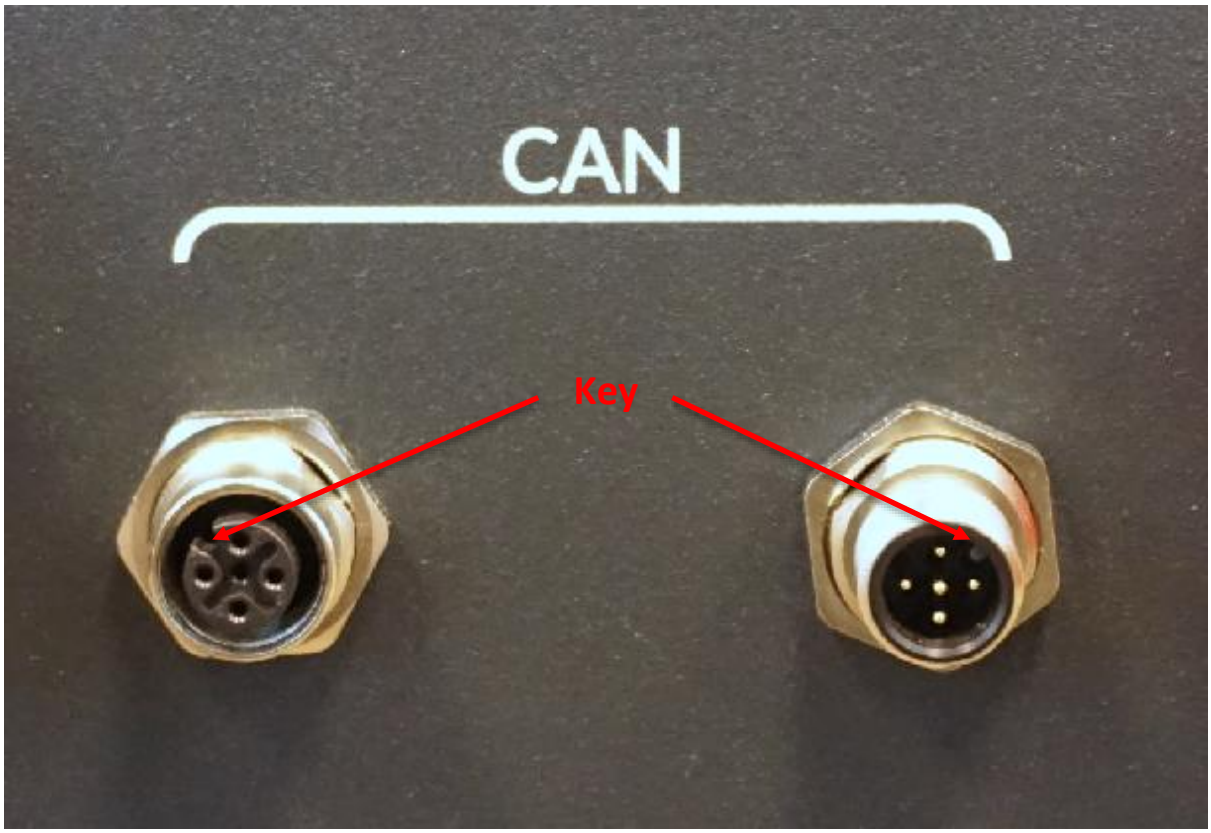
3. Push the connector to the end. Make sure it clicked and is locked.



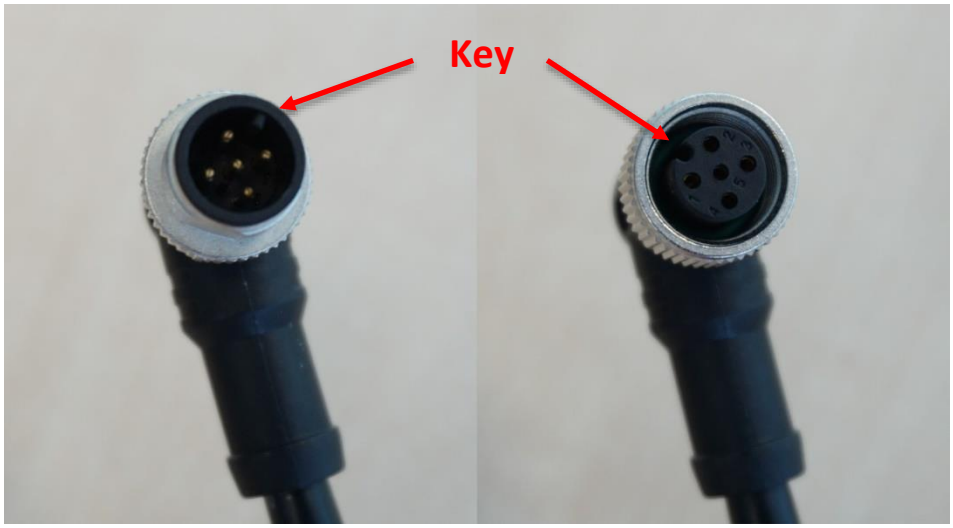
8.4.2 CAN-bus connection procedure

Connection of the CAN-bus cable connectors is done in the following way:

1. Locate the key in both connectors.



NOTICE:
To avoid EMC issues it is recommended not to route CAN-bus cables along side power cables.



2. Bring the connections face of the cable connector up the device connector in such a way that the position of the key matches to that of the opposing connector.

3. Lock the connector by rotating the locking nut clockwise. Hand-tightened will be sufficient, do not use tooling to tighten.

4. Connectors in place.

8.5 Exhaust connection

The installation of the exhaust systems depend on the specific requirements for the exhaust system and the used materials.

In general it is important that manufacturer instructions are followed when installing a ducting system. Make sure that seals are placed in the correct positions and the surface as well as the seal are pretreated as described by the ducting system manufacturer.

Depending on the required certification, it might be necessary to test the ducting system for approval, e.g. pressure test the ducting system for leakage.

8.6 Thermal management connection

The fluid thermal management of the battery system is a two-line system, consisting of a cold supply line and hot return line. Each battery module is connectect in parallel to the supply and return line, an example is shown in figure 16 below.

For more information about the thermal management setup, e.g. pumps, heat exchanger, etc., please refer to the manual for that specific system.

Figure 16 - Fluid thermal management system connection example

Connection of the hose to the hose tail is explained in the steps below.

NOTICE:
The steps below only surve as a reference example. The actual assembly instruction of the used material must always be taken into accout.

1. Place the unpinched hose clamp over the hose end.

Figure 17 - Hose clamp in place before fitting

2. Slide the hose onto the hose tail. Depending on the type of hose this can require a fair amount of force.

Figure 18 – Hose fitted on to the hose tail

3. Bring the hose clamp approximitly half-way over the hose tial for pinching. Pinch the hose clamp according the manufacturers instruction and correct tooling.

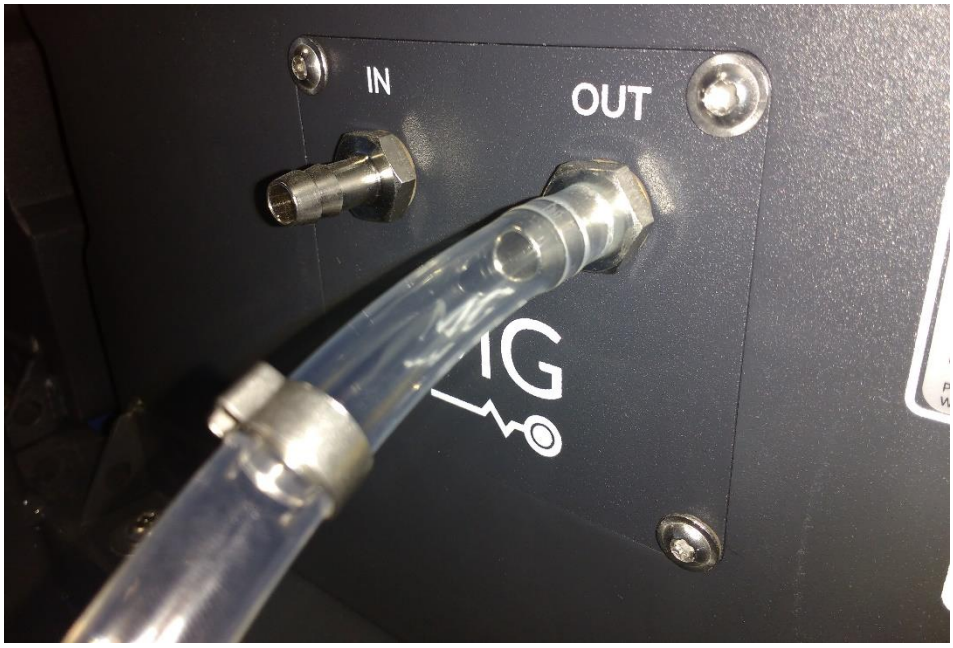


Figure 19 - Pinchin of the hose clamp

4. Hoses in place and secured. Pinch the hose clamp according the manufacturers instruction and with appropriate tooling.

When the themal management system is installed and connected, the battery module fluid channels are still full of air. For optimal performance the air must be removed from the battery module. In order to remove the air, the it is best to rinse each battery module with 3 liters per minute for approximately 5 minutes.

Make sure the fluid level in the thermal management system is sufficient and/or filled-up while rinsing the battery modules. Each module requires about 2 liters of fluid. Excessive air must be bled from the system if not done automatically.

8.7 PPS connection

Make sure the used tubing has an internal diameter of Ø 10 mm when connecting the PPS fluid. It is recommended to connect 12 liters of PPS fluid, presurrised to 2 – 3 bar gauge pressure, for up to 6 batteries modules in parallel at most.

It is advisible to equip the PPS with a electronic pressure measurement device so an automatic alarm can be raised if the pressure drops below a threshold.

An example setup is given in figure 20 below. It is wise to install a means to bleed air from the system at the end of a parallel connection line.

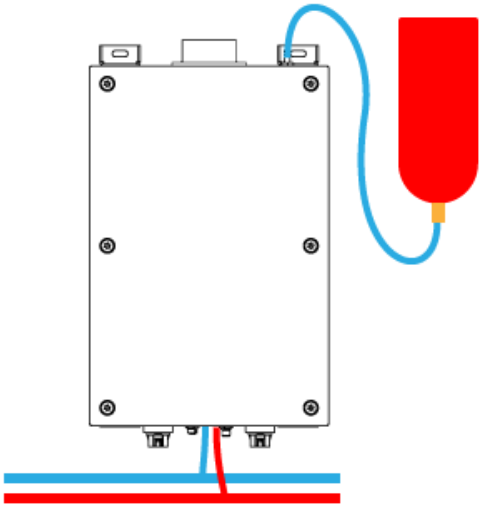


Figure 20 - Example PPS connection scheme

The hose tail connection is of the same type as the thermal management connection. Instruction stated in section 8.6 can be used as an example.

Once all connections are made, the system can be filled with the PPS fluid and pressurised to 2-3 bar gauge pressure. The last step is to bleed air out of the system. This can be done by opening the air beelding valve until the PPS fluid comes out. Check the pressure after bleeding the system and bring it back to 2-3 bar gage pressure.

9 SERVICE

9.1 Maintenance

The device does not require specific maintenance. When any maintenance or user intervention is required, the user will be notified via status information received by the auxiliary CAN-bus.

ELECTRICAL HAZARD:
Do not poor or spray water directly onto the device. When cleaning the device be aware that the connected battery string is a permanent energy source. Even when the device is turned off, the battery power connections might carry dangerous voltage levels.

9.1.1 Connections

It will suffice to check all connections once a year. Check if all connectors are mated correctly according the instructions given in section 6.3.2 of this manual.

9.1.2 Cleaning

Cleaning of the device is best done using a dry or slightly damp cloth. Limit the use of cleaning agents. If a cleaning agent is to be used, use an electrically non-conductive cleaning agent is advised.

It is important to keep the battery spaces clean and tidy in order to minimise the need for cleaning. Prevent the use of moisture, vaporizing agents, oil, grease, etc. in the vicinity of the device.

9.1.3 Desiccant

The battery module's interior is kept dry to prevent corrosion of critical parts. The humidity is kept low by means of a bag containing a desiccant. It is advised to regularly exchange the bag by a new one to prevent the desiccant from saturating, resulting in a increase in interior humidity over time.

Depending on the environment it is advised to exchange the desiccant once a year. The desiccant bag can be accessed by removing the inspection cover.

9.1.4 System pressure

It is recommended to check the PPS liquid pressure on a regular bases. The pressure must be in range of 2 - 3 bar gauge pressure. Frequency of this check depends on the applicable rules, but must be done at least annually.

10 THRESHOLD CONDITIONS

This chapter lists the thresholds conditions with associated times of the BMS, i.e. master BMS and slave BMS, as well as the redundancy BMS thresholds conditions.

Information about battery tresholds are compatible with the following Master firmware versions:

- Master HV 1.7 or higher
- Master LV 1.17 or higher

10.1 Master BMS thresholds

Table 15 – List of default threshold conditions and time-outs of the Lithium-Ion RS Battery Module

Name	Type of condition (set/clear)	Condition	Time
Cell voltages:			
Voltage cell almost charged	Set	>= 4150 mV	10 sec.
	Clear	< 4100 mV	10 sec.
Voltage cell charged	Set	>= 4200 mV	20 sec.
	Clear	< 4150 mV	10 sec.
Over voltage cell warning	Set warning	>= 4225 mV	40 sec.
	Clear warning	< 4200 mV	20 sec.
Over voltage cell critical	Set fail safe	>= 4250 mV	45 sec.
Voltage cell almost discharged	Set	<= 3225 mV	10 sec.
	Clear	> 3275 mV	10 sec.
Voltage cell discharged	Set	<= 3000 mV	20 sec.
	Clear	> 3225 mV	10 sec.
Under voltage cell warning	Set warning	<= 2800 mV	40 sec.
	Clear warning	> 3000 mV	20 sec.
Under voltage cell critical	Set fail safe	<= 2700 mV	45 sec.
Maximum cell voltage deviation in string	Set warning	Difference highest and lowest cell voltage >= 200 mV and lowest cell voltage >= 3225	5 min.
	Clear warning	Difference highest and lowest cell voltage < 160 mV and lowest cell voltage >= 3225	5 min.
Temperatures Charging:			
Over temperature warning charging	Set warning	>= 38 °C	5 sec.
	Clear warning	< 37 °C	5 sec.
Over temperature charging	Set	>= 40 °C	25 sec.
	Clear	< 38 °C	20 sec.
Over temperature critical charging	Set fail safe	>= 45 °C and charge current > 5% battery capacity	85 sec.
Under temperature warning charge	Set warning	<= 1 °C	5 sec.
	Clear warning	> 2 °C	5 sec.
Under temperature charge	Set	<= 0 °C	25 sec.
	Clear	> 1 °C	20 sec.
Under temperature critical charge	Set fail safe	<= -5 °C and charge current > 5% battery capacity	85 sec.
Temperatures Discharging:			
	Set warning	>= 48 °C	5 sec.

Name	Type of condition (set/clear)	Condition	Time
Over temperature warning discharging	Clear warning	< 47 °C	5 sec.
Over temperature discharging	Set	>= 50 °C	25 sec.
	Clear	< 48 °C	20 sec.
Over temperature critical discharging	Set fail safe	>= 55 °C	85 sec.
Under temperature warning discharge	Set warning	<= -29 °C	5 sec.
	Clear warning	> -28 °C	5 sec.
Under temperature discharge	Set	<= -30 °C	25 sec.
	Clear	> -29 °C	20 sec.
Under temperature critical discharge	Set fail safe	<= -35 °C and discharge current > 10% battery capacity	85 sec.
Temperatures deviation:			
Maximum cell temperature deviation in string	Set warning	Difference highest and lowest cell temperature >= 10 °C	5 min.
	Clear warning	Difference highest and lowest cell temperature < 8 °C	5 min.
Current:			
Exceeding maximum charge current	Set warning	> 2C	10 sec.
	Clear warning	<= 2C	10 sec.
Exceeding maximum discharge current	Set warning	> 3C	10 sec.
	Clear warning	<= 3C	10 sec.

10.2 Redundancy BMS thresholds

The redundancy BMS has thresholds that are beyond the regular trhesholds stated in chapter 10.1. When a redundancy BMS threshold is triggered, after 15 seconds the hard-wired interlock loop is interrupted causing the Master BMS to go to fail-safe.

Table 16 - Redundancy BMS thresholds

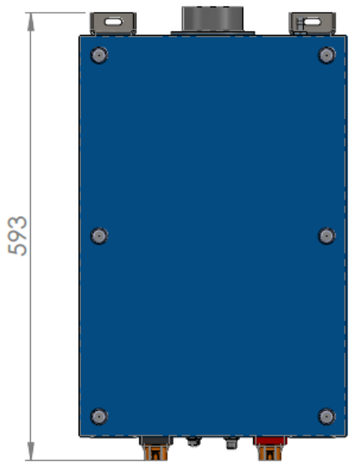
Name	Type of condition (set/clear)	Condition	Time
Cell voltages:			
Over voltage cell warning	Set warning	>= 4400 mV	1 sec.
	Clear warning	< 4400 mV	1 sec.
Over voltage cell critical	Set fail safe	>= 4400 mV	40 sec.
Under voltage cell warning	Set warning	<= 2200 mV	1 sec.
	Clear warning	> 2200 mV	1 sec.
Under voltage cell critical	Set fail safe	<= 2200 mV	40 sec.
Temperatures:			
Over temperature warning	Set warning	>= 65 °C	1 sec.
	Clear warning	< 65 °C	1 sec.
Over temperature critical	Set fail safe	>= 65 °C	75 sec.
Under temperature warning	Set warning	<= -40 °C	1 sec.
	Clear warning	> -40 °C	1 sec.
Under temperature critical	Set fail safe	<= -40 °C	75 sec.
Sensor check	Set fail safe	2 are more temperature sensor fail	75 sec.

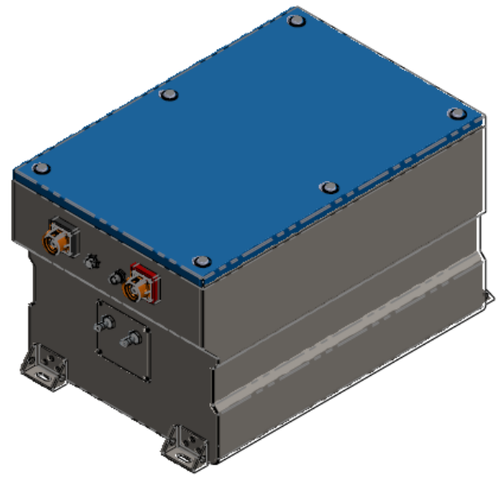
11 TECHNICAL SPECIFICATIONS

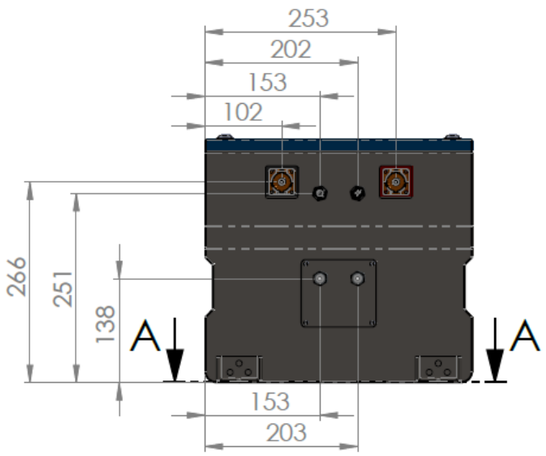
Table 17 - Technical specifications

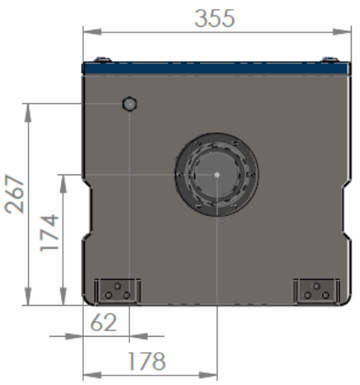
Technical specifications	MGRS12S4P176 44 V / 176 Ah	MGRS14S3P132 51 V / 132 Ah	MGRS16S3P132 58 V / 132 Ah	MGRS24S2P088 88 V / 88 Ah
Technology	Lithium-Ion NMC			
Cell configuration	12S4P	14S3P	16S3P	24S2P
Nominal voltage	43.8 V	51.1 V	58.4 V	87.6
Nominal capacity	176 Ah	132 Ah	132 Ah	88 Ah
Nominal energy	7.7 kWh	6.7 kWh	7.7 kWh	7.7 kWh
Weight	75 kg	69 Kg	75 kg	75 kg
Discharge				
Discharge cut-off voltage	36.0 V	42.0 V	48.0 V	72.0 V
Recommended discharge current (2C) [1]	352 A	264 A	264 A	176 A
Maximum continuous discharge current (3C) [1]	500 A [2]	396 A	396 A	264 A
Charge				
Maximum charge voltage (4.20V per cell)	50.4 V	58.8 V	67.2 V	100.8 V
Recommended charge voltage (4.05V per cell)	48.6 V	56.7 V	64.8 V	97.2 V
Recommended charge current (1C) [1]	176 A	132 A	132 A	88 A
Maximum continuous charge current (2C) [1]	352 A	264 A	264 A	176 A
Configuration				
Series configuration	Yes, up to 900 V			
Parallel configuration	Yes, unlimited			
Redundant mode	Yes, using multiple Master BMSs			
Cycle Life [3]				
80% depth of discharge	> 8000 cycles			
Environmental				
Recommended operating temperature	+15 to +30 °C			
Operating temperature charge	0 to +40 °C			
Operating temperature discharge	-30 to +50 °C			
Storage temperature (< 50% SoC)	-40 to +60 °C			
IP-Protection class	IP65			
Thermal management	Fluid cooling/heating			
Humidity (non-condensing)	≤ 95 %			
Connections				
Communication	CAN-bus (M12 connection)			
Power connections	Amphenol PowerLok™ 300 [4] / 500 series			
Safety				
Batteries are always used in combination with a MG Master.	Integrated Slave BMS Passive cell balancing Redundant BMS			
Compatible BMS master	MG Master LV, MG Master HV			
Safety features	Interlock circuit in HV and CAN-Bus connectors, cell level thermal runaway propagation protection, automatic thermal runaway suppression valve input			
Type approval	DNV-GL [5] / Lloyds Register			
In accordance with	IEC 62619:2017; IEC 62620:2014			

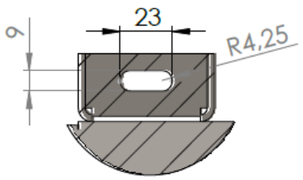
[1] Only valid when a proper designed fluid cooling circuit is running.
[2] Limited by the maximum continuous current rating of the Amphenol PowerLok™ 500 series with 150 mm^2 cable.
[3] End-of-Life is 70% of initial capacity at 25 °C. Charge up to max. 4.05V per cell.
[4] Continuous current ratings must be de-rated to ≤ 300 A.
[5] Type approval pending.











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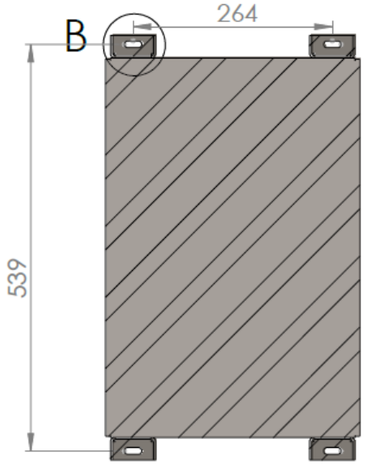
SCALE 3 : 7



SECTION A-A

Figure 21 - Dimensions

12 ORDERING INFORMATION

This chapter describes the MG order numbers for spare-, service-, and replacement-parts for the MG RS Series battery module.

Item	Description	Manufacturer	Type	MG order number
1	Power connector 300-series 200A orange positive terminal	Amphenol	PL28X-301-50	MGPL28X-301-50
2	Power connector 300-series 250A orange positive terminal	Amphenol	PL28X-301-70	MGPL28X-301-70
3	Power connector 300-series 200A black positive terminal	Amphenol	PL28Y-301-50	MGPL28Y-301-50
4	Power connector 300-series 250A black positive terminal	Amphenol	PL28Y-301-70	MGPL28Y-301-70
5	USB-CAN Transceiver	MG Energy Systems B.V.		MGUSBCAN001
6	USB-CAN Transceiver	Kvaser Inc.	Leaf Light HS v2 M12	MGUSBCAN002
7	Exhaust ducting flange type	MG Energy Systems B.V.		MGRS00100001
8	Exhaust ducting sleeve type	MG Energy Systems B.V.		MGRS00100002

13 CONTACT DETAILS

For specific questions please feel free to contact us.

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