Installation Manual

Freedom Lite Marine

Range of Lithium Iron Phosphate Batteries

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1. Introduction

This manual is intended to aid an installer with the installation and commissioning of the range of **Freedom Lite Marine** lithium iron phosphate (LiFePO4) energy storage units. This document is not intended to provide detailed information of the inner workings of Freedom Lite that is not relevant to a person that is performing the installation and final commissioning. Supplementary information relating to programming of the built-in battery management system for specific applications is available to approved integrators directly from Freedom Won.

This manual does not attempt to cover all the details pertaining to the setup of third-party equipment in relation to the interface and necessary functionality to work with the Lite. Freedom Won however is available at the contact details on page 1 to provide direct support where necessary for supported third party brands.

2. Range Overview

The Freedom Lite technology is available in various standard sizes to meet all residential, commercial and industrial applications ranging from 5kWh up to 2500kWh. Larger systems are provided by Freedom Won based on specific project requirements by installing multiple units in parallel. Models designed for mobile applications including Marine and Mobility are also included in the range line up.

Freedom Won offers the following ranges in the LiFePO4 technology:

1. Lite 12V
2. Lite Home and Business
3. Lite Home and Business HV
4. **Lite Marine**
5. Lite Mobility (golf carts, forklifts etc)
6. Lite Commercial (including Lite Commercial HV and HV+)
7. Lite Industrial

This manual covers the models of the **Lite Marine** range from 5kWh up to 30kWh. Please refer to the manuals specific to the applicable range required.

The Lite Marine range of lithium batteries offers 13V, 26V and 52V options to suit ‘12V’, ‘24V’ and ‘48V’ systems, respectively. These models are water and corrosion resistant (IP65) and designed for mounting on the floor in land-based applications or on a horizontal deck inside lockers and compartments for marine applications. These models have different dimensions to the Lite Home models but are similar internally.

3. Product Description – Lite Marine

The Lite Marine range of lithium batteries is specifically designed to provide high end energy storage performance to the boating industry. It is designed for below deck applications

away from direct saltwater exposure. For applications for open deck operation such as ski boats please contact Freedom Won for a solution.

The range is available in 13V and 26V options to suit '12V' and '24V' systems used in the marine industry. 52V is also available to accommodate land-based applications where moisture and corrosion resistance is desired such as houses located particularly close to the coast.

The Lite Marine range is water resistant (IP65) and resistant to corrosion associated with sea moisture exposure. Note that the product is not suitable for repeated direct exposure to sea water contact.

The range is designed with a low profile to fit into height restricted lockers etc. All models are supplied standard with plastic feet. It is permissible to stack the Marine models on top of each other up to three high (this relates to land-based applications).

Table 3.1 provides an overview of the Freedom Lite Marine range. The models are classified in terms of energy capacity [kW].

An image with numbered labels pertaining to the following paragraphs is provided in Figure 3.1. The model number denotes with the first number [1] the total energy storage capacity in kWh of each model. The second number [2] denotes the average amount of energy in kWh that should be withdrawn per cycle (on average) in order to optimise the life of the lithium cells. This equates to 80% of the total for each model i.e. 80% depth of discharge (DoD). Older models denoted a 70% DoD as in this picture. **Note that all Freedom Lite batteries offer a maximum of 90% DoD as standard**.

The available voltage options are also provided in Table 3.1. For assistance with comparing the Lite Marine against other batteries the Ah ratings have been provided in Table 3.2. Note that the Ah rating of a Lite Marine need only be about half of the rating of a typical lead battery in order to offer equivalent useful capacity performance.

The maximum and continuous current for each model is governed by the rating of the built-in circuit breaker [3], which has been sized below the maximum current capability of the lithium cells. Even at maximum current the temperature rise inside the battery is negligible and no cooling of the cells is required. The time limits for operation at the maximum current should be observed (see notes to Table 3.1). To ensure that the circuit breaker does not trip in normal operation it is advised that the design of the system aims to remain at or below the continuous current value.

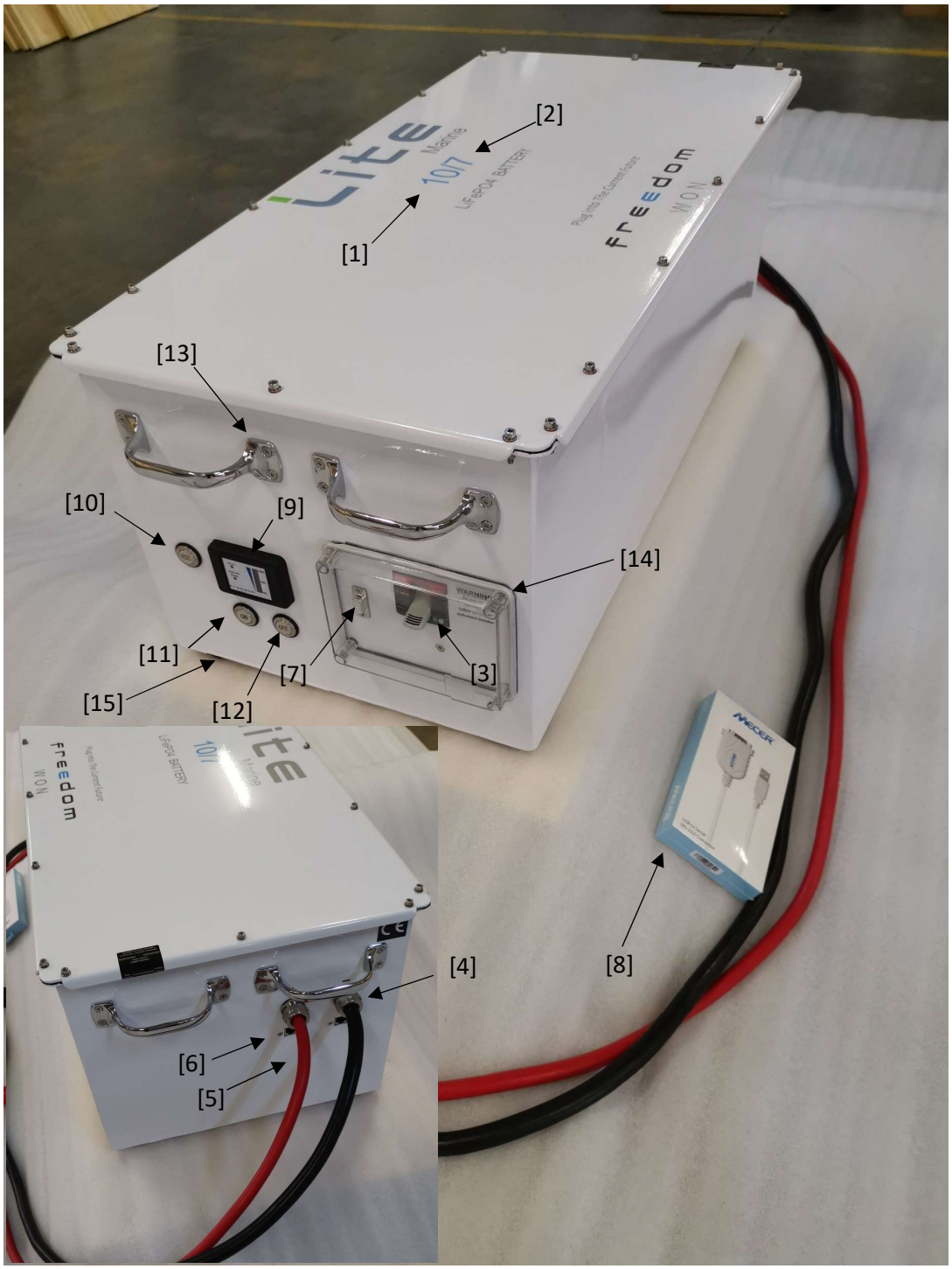
For assistance with setting up the inverters and charge controllers please refer to Table 3.3 for the voltage values required for operation of the battery.

The BMS will command a connected inverter with CAN Bus interface to stop discharging the battery at 10% SoC (90% DoD). Under high load the voltage may drop lower than the estimated voltage provided in Table 3.3 whilst still above 10% SoC. The standby current draw on the battery and the inverter can cause the battery to be discharged below 10% SoC.

The battery breaker will eventually trip the battery at or around the minimum cut-out to protect the cells from undervoltage.

Table 3.1 provides the maximum charge and discharge current and power ratings of the battery and the associated maximum recommended installed inverter power.

Figure 3.1 Labelled Image of the Freedom Lite Marine 10/8 (Labelling corresponds with the text)



1. *Gross Capacity*
2. *80% Capacity recommended for daily cycling (max available is 90%)*
3. *Breaker*
4. *Power Cables*
5. *Analogue and Relay Control Cable (available on special request) (not shown in this picture but located near the power cables if fitted)*
6. *CAN Bus Sockets x 2 (RJ45) (one socket must contain a termination resistor if end of line)*
7. *USB Programming Port (note in models produced prior to July 2020 the port is a DB9 plug)*
8. *Supplied RS232 Adapter (in models after July 2020 a USB cable is supplied instead)*
9. *State of Charge Display*
10. *Reset Button*
11. *On Button*
12. *Off Button*
13. *Handles for Manual Lifting (larger models have eye bolts)*
14. *Moisture protection breaker cover*
15. *Feet*

The weight of each model is given in Table 3.1. The Freedom Lite Marine 5/4 and 10/8 can be manually lifted with the fitted handles by two people. The larger units require lifting equipment of varying degrees for handling and installation as explained later in this document.

The dimensions given are for the principle outlines of the aluminium housing and exclude items that protrude such as the DC cable glands and handles.

The DC cables [4 inset] exit the unit through glands located on one end of the casing (opposite end to the breaker). The cable sizes are provided in Table 3.1 for each model. The correct cable lugs for connecting these leads to the inverter must be in hand when doing an installation. If there are several inverters, alternators and charge controllers that need to be connected to the battery it is advisable to install a DC connector box to use as a junction point from which to branch out to all the battery connected equipment. In boats these cables would typically be routed to the DC busbars in the power distribution and control console.

An analogue and relay control cable [5 inset] is an optional item located near the DC cable glands for use in installations where an analogue or dry contact (relay) interface compatible alternator, inverter or charge controller is used *(note that from 9 September 2019 this cable is not standard supply and it is only supplied on special request)*. Where dry contact control is required an **external relay must be installed**, which will be controlled by the control pins in the optional control lead (more detail later in manual).

Table 3.1 Freedom Lite Marine Range Overview

Lite Marine	**5/4**	**10/8**	**20/16**	**30/24**
Total Energy Capacity [kWh]	5	10	20	30
Nominal Voltage [V]	Available in 13V, 26V and 52V options			
Max/Cont. Discharge Current [A] (2)	200/100 (52V) 300/200 (26V) 300/300 (13V)	300/200 (52V) 300/300 (26V) 300/300 (13V)	480/400 (52V) 480/480 (26V) 480/480 (13V)	480
Max & Cont. Charge Current [A]	100 (52V) 200 (26V) 300 (13V)	200 (52V) 400 (26V) 480 (13V)	400 (52V) 480 (26V) 480 (13V)	480
Max. Daily DoD Suggested (average) [%]	80%DoD			
80% DoD Energy [kWh]	4	8	16	26
Round Trip Efficiency [%]	96-98			
Height [mm]	275			
Width [mm]	320			460
Length (including end handles or eye bolts) [mm]	600	905	1 510	1 512
Total Weight [kg]	49	89	173	260
Enclosure	Aluminium, powder coated, tamper proof, waterproof IP65, corrosion resistant, handles or eye bolts for lifting, rubber feet			
DC Connection – Fly Leads, [no. per electrode] (3)	1x 50mm2	1x 50mm2	2 x 50mm2	2 x 50mm2
External Interface	CAN Bus *(Note that an external relay control harness is an optional item and must be specified with the order if the application needs the battery to control relays such as for alternator regulator remote enable)*			
On-board Management	Full battery management system and internal trip protection			
Human Interfaces	USB Plug for Programming and data access with PC, main breaker, error reset button, SoC display, error light			
Protection	Shunt Trip Circuit Breaker sized to suit max current, can be tripped by BMS if critical fault, manual reset. Protection for overcurrent, cell under and over voltage, temperature, weak cell detection and other critical events			
Battery Chemistry	Lithium Iron Phosphate (LiFePO4)			
Cell Form Factor	Large Format ultra-heavy-duty prismatic cells of 100Ah each and 3,2V nominal voltage			
Battery Cooling	Natural Convection (heat generation is negligible inside the battery)			
Suitable Ambient Temp [°C] (4)	0°C to +40°C			
Extreme Operating Temp [°C]	-20°C to +60°C			
Remote Monitoring	Optional: Real time data logging and transmission via WiFi to online portal of key battery information			
Warranty (5)	10 years or 4 000 cycles for average 80% DoD, and max 90% DoD			
Service Life	>16 years (>5 500 cycles) expected life at 80% DoD (1), >20 years (>7 500 cycles) at 50% DoD			
Essential Accessories	USB “printer” cable (one is supplied with each battery) CAN Bus Termination Resistor – one included with battery CAN Bus Cable (RJ45 LAN Cable) – one required per battery (not supplied). Some inverters require a (non-standard pin configuration) cable – see manual			

Notes to Specification Sheet:

1. *This range is not designed for direct exposure to saltwater such as for us above deck on a small boat. The intended use is below deck away from actual water spray. The product is also recommended for use on seaside properties where airborne sea moisture is a corrosion concern. For above deck applications please contact Freedom Won for a solution.*
2. *Max discharge load (current) duration where lower than continuous – 30 seconds per 40 second cycle. 1.5 x Max overload can be handled for 5 seconds.*
3. *DC Cables 1,8m long, power cable Red = Positive, Black = Negative, conductors in table refer to one electrode i.e. per positive and negative connections*
4. *Charging below 0°C not permitted. Extended time above 45°C not recommended for optimal battery life.*
5. *Warranty is 10 years or 4 000 cycles at an average of 80% DoD per cycle, 70% capacity guaranteed by end of warranty.*

Two RJ45 sockets [6 inset] are provided, one for connecting the CAN interface from the battery to the system controller (or directly to the inverter depending on the inverter brand), and another for connecting the battery to another battery or for a termination resistor (more detail later in manual).

A USB socket [7] is fitted adjacent to the breaker for use by technicians for programming the required profile onto the BMS. The required profile is typically loaded by Freedom Won prior to delivery but installers are advised to obtain the correct adapter (a USB cable [8](Figure 3.2) is required) to allow Freedom Won or authorised distributors to program batteries remotely on behalf of the installer or user via a Windows laptop. The DB9 RS232 adapter must have male pins. One is supplied by Freedom Won with each battery (note that only the unit supplied by Freedom Won is guaranteed to work, inferior brands do not always work properly).

Freedom Lite is also fitted with a State of Charge (SoC) display [9], which includes a red LED error indicator and below it a “low power” indicator.

An error reset button [10] is positioned near the SoC display.

Figure 3.2 “Printer” USB Cable for Programming Freedom Lite Marine models

The ON button [11] and OFF button [12] is located beside the SoC display.

The Marine 5/4 and 10/8 models are fitted with handles for lifting the battery manually [13]. The larger models are fitted with eye bolts to enable slinging the batteries. A metal bar can also be placed through the eye bolts for carrying manually by four or more people.

A clear cover is provided to prevent moisture entering the battery through the breaker [14]. This cover must be removed using an Allen key to switch the battery on for commissioning and then replaced immediately after commissioning to maintain the IP65 rating.

All Lite Marine models have feet (one on each corner) as standard [15].

A warranty seal is fixed to the lid of the battery to prevent unauthorised removal of the lid. Damage to this seal will void the battery warranty.

Table 3.2 Ah Ratings of the Marine Range

Model	**13V**	**26V**	**52V**
Lite 5/4 Marine	400Ah	200Ah	100Ah
Lite 10/8 Marine	800Ah	400Ah	200Ah
Lite 20/16 Marine	1600Ah	800Ah	400Ah
Lite 30/24 Marine	2400Ah	1200Ah	600Ah

Table 3.3 Suggested Voltage Values Required for Setting Up Inverters and Charge Controllers

Model	**13V**	**26V**	**52V**
Absolute Max Voltage [V]	14,4	28,1	56,2
Ideal Charge Voltage [V]	13,9 to 14.2	27,8 to 27,9	55,8
Approx. 80% DoD Voltage [V]	12,6	25,5	51,0
Approx. 90% DoD Voltage [V]	12,2	25,0	50,0
Min Cut-out Voltage [V]	11,5	23,0	47,0

4. Transport, Handling and Mounting

The Freedom Lite units are packaged in protective layering and fastened into a wooden crate with feet, which allows lifting with a forklift or a pallet jack. The Freedom Lite Marine 5/4 and 10/8 models are easily handled by two people. The 20/16 model may be manually handled by sufficient people but is best handled by a pallet jack or forklift. The 30/24 and model must be handled with care by a forklift or pallet jack. A light crane will be required for lowering this model below deck through a hatch.

For small boats with restricted access the 10/8 would typically be the largest option. Multiple of this model can be connected in parallel to provide the required storage capacity.

Larger boats with facilities for handling heavy items or with deck hatches above the battery room will favour the larger models such as the 20/16 and 30/24. It is acceptable to sling the 20/16 and 30/24 models by one end in order to fit them through deck hatches.

The Marine batteries are usually strapped down into place using ratchet straps secured to tie down points in the boat deck. The strap is placed over the casing. The units with eye bolts on each end can be fastened down to the deck using turnbuckles secured to the eyed bolts on each corner. For Marine and other mobile applications it is advisable to secure the battery to the deck.

Caution:

1. *Handle the Freedom Lite with great care when lifting and manoeuvring. The Freedom Lite Marine can be handled at any angle during installation but must be fitted on its feet for operation.*
2. *Take care not to knock any of the protruding items against obstacles during handling such as the DC cabling and plugs and the circuit breaker handle and circuit breaker cover.*
3. *Take care not to scratch the Lite during handling. Packaging foam should be used to protect the paint when being handled on a trolley or pallet jack.*
4. *Always ensure that lifting equipment and slings are adequately rated for the lifting weight.*
5. *Ensure that the eye bolts fixing point shows no signs of damage before lifting.*
6. *Wear personal protective equipment such as safety shoes and gloves while handling and mounting the Freedom Lite*
7. *Always ensure that you have enough people on hand to perform the operation safely, i.e. at least one person to guide and stabilise and one person to hoist or handle the lifting equipment.*
8. *Do not allow persons or parts of persons to be positioned underneath the load while lifting*

Mounting and Environmental Requirements

The Lite Home and Business models are designed strictly for indoor use away from moisture and direct sunlight.

No specific venting is required since the Lite emits no hazardous gases, however air circulation may be required to ensure room temperature is maintained at reasonable levels, preferably below 30˚C (see Lite warranty for information upper temperature limits for hot environments).

Room heating may be required in cold climates to keep the room above 0˚C, since charging of the Lite is not permitted below 0˚C. Ambient environments that regularly exceed 40˚C should employ room cooling if practicable to ensure optimal Lite service life.

Temporary storage or transport of the battery is permitted in the range -20˚C to 45˚C, however extended storage should be between 0˚C and 30˚C.

The Lite may be mounted directly against a wall or on the floor. There is no minimum requirement for spacing around the battery from other objects provided that these objects do not generate heat and that the vents on the sides of the battery are not blocked. Note however that access is required to the USB programming port on the left side, and the CAN Bus plug sockets and cable exits on the right side.

The Lite should be installed at least 500mm way from a heat source.

The Lite Home and Business IP rating is IP20. The breaker is rated for IP40.

5. Connecting the Freedom Lite Marine

5.1 Power Cables

The Freedom Lite is simple to connect to the DC bus or battery inverter. First, you will connect the battery positive and negative cables to the inverter terminals or DC bus bar using the applicable lugs.

***Caution:* Prior to connecting the positive and negative cables to the inverter or DC bus bar be sure to check that the main battery circuit breaker is switched off. This will ensure that there are no short circuits between the loose ends of the cables.**

The cables are supplied with the Freedom Lite Marine, permanently fixed into the unit, and secured onto the casing using compression cable glands. Attach crimp plugs to the ends of both cables ensuring that the correct terminal size is used. Also be sure to match the size of the cable to the lug. The positive cable is red, and the negative cable is black. See Table 2.1 for the cable size and quantity fitted to each Freedom Lite Marine model. The cable sizes are based on the inverter or main DC busbar being close to the Freedom Lite battery so that the cable run is less than 5m (note however that the standard cable length is 1,8m, longer cables available in request).

Runs longer than 5m should be assessed, and larger cables considered for extending the Freedom Lite cables, to minimise voltage drop. Double Insulation welding cable is recommended.

On Installations where there are too many inverters and/or charge controllers to connect to the DC bus directly from the battery using the inverter terminals as a junction point a DC connector box is required.

5.2 DC Bus Design Notes

The Lite range includes an integrated battery DC breaker/isolator that breaks the positive cable continuity inside the battery. This breaker, on all Home and Business models, is rated for a 36kA fault (short circuit) current. The system therefore does not require another DC isolator or breaker except where required in relation to conformance with the Clean Energy Council of Australia battery design Best Practice Guide, which states that, should the internal battery isolator not offer isolation of BOTH the positive and negative terminals of

the battery, an external isolator is required that can isolate both the positive and negative cables/terminals of the battery.

The approximate short circuit current values of each battery model are provided in the table below:

Table 3.1 Short Circuit Current for Lite Home and Business Models

Freedom Lite	Home 5/4	Home 10/8	Home 15/12	Home 20/16	Home 30/24	Business 40/32	Business 60/48	Business 80/64
Short Circuit Current [A]	1500	2100	3100	3600	4700	5100	5800	6200

The external isolating device required for installations in Australia should be designed to withstand these fault levels (short circuit currents).

5.3 Control Cables – Overview

For controlling external devices, you will need to connect the control wiring that allows the Battery Management System inside the Freedom Lite to control and interface with these devices.

The connection of the cables and the method of control depends on the model of inverter, alternator, or charge controller. There are three main control options for the connected equipment, namely:

1. hard wired potential free contacts that are connected to auxiliary inputs or remote on/off switches on the inverter, alternator regulator or charge controller,
2. analogue 0-5V signal,
3. or CAN Bus.

The primary control option is CAN Bus, which requires an ethernet cable to be plugged into one of the RJ45 plugs on the battery. The RJ45 connection is standard supply on the Freedom Lite Marine.

The second control connection method is an **optional** analogue signal and relay control cable. The cable is not supplied as standard because most modern applications use CAN Bus control, but it can be ordered as an option from Freedom Won where CAN Bus interfacing is not available on all connected equipment. All control methods can be used simultaneously.

The Lite does not contain internal relays for method 1 above, so external relays are required, which are controlled by the relay coil driver wires from the optional control cable. **The relay used must be rated for the voltage of the battery i.e. 12V, 24V or 48V.**

Relays controlled by the battery relay driver signals may also be used to control larger contactors. Note that it is not feasible to control overcharge by disconnecting the DC connection from an alternator, as disconnecting the DC power cable from an alternator

while it is running will result in regulator and/or alternator damage. To enable battery control over the alternator output it is necessary to use a regulator alternator combination that provides a remote enable/disable ignition input or a CAN Bus controlled regulator.

The optional control cable contains 12 wires, each of a different colour, of which eight are used. Table 5.1 below provides the colour coding for the Freedom Won supplied cable.

Table 5.1 Description of Functions on the Optional Control Cable

Wire Colour in 12 Core Control Cable Supplied by Freedom Won	**Wire Function**	**Remarks**
Red	Battery Positive (depends on battery voltage)	Used to supply power to external control relay coils
Black	State of Charge (SoC) Signal – 0-5V Analogue Output	Provides a linear analogue signal where 0V = 0% and 5V = 100% - used for inverters with 0-5V inputs for retrieving SoC and for remote analogue SoC displays
Orange	Charge Current Limit (CCL) Signal – 0-5V Analogue Output	Provides a linear analogue signal where 0V = 0A allowed for charge and 5V = 100% of battery charge current capacity - used for inverters and charge controllers with 0-5V inputs for retrieving the maximum allowed charge current in real time
White	Battery Negative	Provides a negative for contactor coils that are operated by control relay and a negative reference for the analogue signals
Turquoise	Solar Charger/Alternator Enable Open Drain Relay Driver Signal Output (also called Charge Safety)	Provides a current drain to sink current through an external control relay coil that is provided with battery power on the coil power supply terminal. The coil power is supplied by the red wire in the control cable. When the relay is closed the AC Charger in the inverter (or the alternator via the compatible regulator) is enabled to begin charging. When the relay is open the AC Charger or alternator (through the regulator) must be disabled to prevent over charging the battery.
Blue	Discharge (Inverter) Enable Open Drain Relay Driver Signal Output	Provides a current drain to sink current through an external control relay coil that is provided with battery power on the coil power supply. The coil power is supplied by the red wire in the control cable. When the relay is closed the inverter is enabled to begin discharging (supplying power to the loads from the battery). When the relay is open the inverter output must stop discharging the battery to prevent over discharging
Grey	Inverter Charge Enable Open Drain Relay Driver Signal Output (Also called Charge Enable)	Provides a current drain to sink current through an external control relay coil that is provided with battery power on the coil power supply terminal. The coil power is supplied by the red wire in the control cable. When the relay is closed the Solar Charger is enabled to begin charging. When the relay is open the Solar Charger must be disabled to prevent over charging the battery
Yellow	Multi-purpose Output Open Drain Relay Driver Signal Output	Provides a current drain to sink current through an external control relay coil that is provided with battery power on the coil power supply terminal from the red wire in the control cable. The Multi-purpose output can be programmed for

		various functions based on SoC, voltage, and temperature ranges. Please enquire with Freedom Won for programming of this output for any specific requirements.

The CAN Bus connection is made using the RJ45 plug with the pin configuration on the battery plug end provided in Table 4.2. The CAN Bus pairs are duplicated on three pin pairs to accommodate various inverter pin configurations. Most inverters can be accommodated without a special cable.

Table 5.2 Colour Coding and Pin Configuration for CAN Bus UTP Control Cable

RJ45 Pin No.	Standard Ethernet Cable Colours	Wire Function
Pin 1	Orange/White	CAN High
Pin 2	Orange	CAN Low
Pin 3	Green/White	Not connected
Pin 4	Blue	CAN High
Pin 5	Blue/White	CAN Low
Pin 6	Green	Not connected
Pin 7	Brown/White	CAN High
Pin 8	Brown	CAN Low

Fig 5.1 Pin Configuration of Type T-568B RJ45 Plug

Please refer to the respective inverter brands manuals for their pin configuration or contact Freedom Won for assistance. Additional CAN Bus pin connection information is also available in Section 4 of the Freedom Lite Home and Business Manual.

3.1.1 Hard Wired Control using optional control cable – Detailed Description

This method of control is used when the inverter or charge controller or alternator regulator is fitted with a remote enable (or on/off) switch, or inputs that can be used to enable or disable the respective functions as required. An example of equipment containing this type of interface used in the Marine industry is the Balmar MC-614 regulator.

The digital control signals for the regulator are provided by an external relay using a normally open pole pair. One wire in each pair is referred to as NO (Normally Open) and the other as COM (Common).

Remote enable or Auxiliary Inputs (AI's) should be fitted with a 2A fuse to protect the remote enable circuit from short circuits.

The following functions are available for this type of installation:

1. Solar Charge Controller or Alternator Enable (Turquoise wire) – this is achieved using a pair of potential free contacts from an external relay. This relay is normally open and is only closed if the Battery Management System (BMS) is satisfied that the battery may receive a charge current. The relay is closed when the BMS allows current to sink through its coil via the applicable signal wire (see Table 4.1). The closing of this relay will then enable the external charge equipment. The standard parameters for determining this are programmed into the BMS by Freedom Won prior to delivery. Freedom Won or approved installers can alter these parameters if a non-standard configuration is required. The standard configuration is to enable the solar charge controller or alternator so that it may begin charging if:
    i. there are no errors (trouble codes) registered by the BMS that would affect the ability of the battery to safely receive a charge (there are numerous protection algorithms and not all are detailed here)
    ii. the voltage of any individual cell is below the maximum cell voltage setting (3.75V)
    iii. the temperature of the pack is inside of its operating range for charging (0 to 50°C)
    iv. The State of Charge (SOC) has dropped below a defined level since the last charge enable period (99%).
    v. The defined delay time for a repeated operation of this relay has elapsed (3 minutes if below 99%, 15 minutes if 99% upwards)
2. Inverter Discharge Enable (Blue) - this is achieved using a pair of potential free contacts from an external relay. This relay is normally open and is only closed if the Battery Management System (BMS) is satisfied that the battery may provide a discharge current. The relay is closed when the BMS allows current to sink through it via the applicable signal wire (see Table 4.1). The closing of this relay will then enable the external discharge equipment, namely the inverter (note this is intended to control the inverter section of the inverter/charger device independently of the charger in the same device). The standard parameters for determining this are programmed into the BMS by Freedom Won prior to delivery. Freedom Won or approved installers can alter these parameters if a non-standard configuration is required. The standard configuration is to enable the inverter (discharge of the battery) so that it may begin providing power to the load only if:
    i. there are no errors (trouble codes) registered by the BMS that would affect the ability of the battery to safely provide a discharge current (there are numerous protection algorithms and not all are detailed here)

   ii. the voltage of any individual cell is above the minimum cell voltage setting (2.8V)
   iii. the temperature of the pack is inside of its operating range for discharge (-20 to 55°C)
   iv. The State of Charge (SOC) is above the defined minimum discharge setting (usually 10%)
   v. If this relay has had to disable the inverter because of reaching the minimum setting in (iv) above it will not re-enable until the State of Charge (SOC) has risen above the defined minimum re-enable SOC (usually 15%)
   vi. The defined delay time for a repeated operation of this relay has elapsed (3 minutes)
3. Inverter Charge Enable (Grey) – this is achieved using a pair of potential free contacts from an external relay. This relay is "normally open" and is only closed if the Battery Management System (BMS) is 'satisfied' that the battery may receive a charge current. The relay is closed when the BMS allows current to sink through it via the applicable signal wire (see Table 4.1). The closing of this relay will then enable the external charge equipment. The standard parameters for determining this are programmed into the BMS by Freedom Won prior to delivery. Freedom Won or certain approved installers can alter these parameters if a non-standard configuration is required. The standard configuration is to enable the mains charger (inside the inverter) so that it may begin charging if the mains (grid) power is available and only if:
   i. there are no errors (trouble codes) registered by the BMS that would affect the ability of the battery to safely receive a charge (there are numerous protection algorithms and not all are detailed here)
   ii. the voltage of any individual cell is below the maximum cell voltage setting (3.75V)
   iii. the temperature of the pack is inside of its operating range for charging (0 to 50°C)
   iv. The SoC has dropped to a pre-defined level (usually 30%). This is so that the grid is not used for charging unless it becomes really necessary i.e. solar preference is given.
4. Charge Current Limit (CCL) (Orange wire)– some inverters or solar charge controllers may be equipped with an analogue input that allows the BMS to supply the charge current limit. If this charge current limit supplied by the BMS is above the maximum capacity of the charger then the unit will operate at this maximum value. The output signal is 0-5V (representing 0-100%) and is connected to the external measuring input using the battery ground. Both wires are provided in the control cable.
5. State of Charge (SoC) (Black wire) – 0-5V analogue output representing 0-100% SoC

Caution – do not allow the analogue wires to touch any other wires during installation while the BMS is powered up. This may cause damage to the internal circuitry of the BMS. It can be seen whether the BMS has power if the SOC display lights are illuminated.

3.1.2 CAN Bus Control – Detailed Description

CAN is a widely used communication protocol in systems with many devices that must report their status or send commands to other devices on the same network. The Freedom Lite BMS can transmit messages and commands in CAN protocol to provide information to, but more importantly to control, external devices. The types of control functions are similar to the hard-wired option but CAN allows more versatility and provides a simpler installation because there are only two wires required in this form of communication, namely CAN High and CAN Low. In order for an inverter, charge controller or alternator regulator to be controlled by CAN it must first of all be equipped with a CAN interface as well as a suitable method of connecting the CAN wires. Further to this the Freedom Lite BMS must be programmed with a CAN messaging profile that is developed for the inverter or charge controller being used. This profile must be specifically developed for each inverter model or model range. To date Freedom Won has developed CAN profiles for the following inverter equipment:

- SMA Sunny Island Battery Inverters
- Ingeteam Sun Storage Battery Inverters
- Victron Multiplus and Quattro Battery Inverters and MPPT Controllers via the Color Control GX and Venus system controllers
- Studer
- Imeon
- Solax
- Goodwe
- MLT Drives (2019 models onwards)
- Socomec
- Koyoe
- ATESS (HPS and PCS ranges)
- Sunsynk
- Sunforce/Growatt
- Revo
- Axpert King
- Solis

Freedom Won welcomes any requests to produce BMS CAN profiles for other inverters that are CAN equipped for BMS interface.

For Marine alternator applications a CAN Bus compatible alternator regulator option is the:

- Wakespeed WS500

Using a CAN Bus compatible alternator regulator is preferable as it is far simpler to connect and offers more control versatility.

The CAN interface can provide the following functionality to compatible devices:

i. Charge Current Limit

ii. Discharge Current Limit
iii. Actual State of Charge
iv. Actual Temperature
v. Actual Voltage
vi. Actual Current
vii. Maximum real time charge voltage
viii. Minimum real time discharge voltage
ix. Battery Name

The CAN 2.0 Part A and Part B standard uses the SAE J1939 standard in the Lite. It is necessary to install a 120 Ohm resistor on each extreme end of the CAN cable (splices do not require a resistor). Most devices operating on CAN have two plugs to connect in and then out again on the CAN Bus. The first and the last device in the chain must have a termination resistor plugged into the spare (second) plug. The Lite resistor plugs are available from the inverter manufacturer and from Freedom Won. Ingeteam has a separate CAN terminal block for bare wires to be inserted from the BMS and these units have an internal resistor fitted into the device. From August 2018 all Freedom Lite models have two CAN plugs for parallel configurations (Figure 4.2) and allowing fitment of the termination resistors on the end of line units. Where one Lite is installed or where it is the end of line CAN device, **the Lite must be fitted with a termination resistor**.

The Lite is supplied with a termination resistor as standard. The other devices must be fitted with the correct termination resistor for that particular brand because the pin configuration may differ from the battery plug.

The third-party device manuals must be referenced for all details regarding connecting the CAN interface. Also refer to the Freedom Lite Home and Business manual for more CAN Bus pin connection information.

Most brands use 500kbps. If 250kbps is required it is available on the Lite with a specific profile loaded, which must be requested when ordering the Lite or can be loaded during commissioning by your distributor for Freedom Won technical support.

5.4 Parallel Configurations

It is permissible to connect multiple Freedom Lite's in parallel provided that the Freedom Lite model size used is the same throughout. It is however more cost effective to purchase one larger Freedom Lite model than connecting multiple units in parallel. Parallel configurations should be reserved for future expansion where it is not feasible to purchase a model large enough upfront for future requirements (financial constraints). In cases where physical access constraints to the battery bay or room exist please select a smaller model and install the number that is required to meet the capacity requirements.

The configuration of the Master and Slave's is automatic and therefore the batteries require no special configuration for parallel installations. The first battery to be switched on will be configured as the Master. The Master will assign the Slaves as they are seen on the CAN Bus

network. Should the Master trip for whatever reason one of the Slaves will automatically take the role of Master without interrupting the operation of the system.

For installations using hard wired control to control the inverter or charge controller it is necessary to assign a fixed master because it is the master that has the active control outputs. Contact Freedom Won for cases where this is required.

All batteries must be connected to each other using standard LAN Cable.

Where CAN Bus is used to control the inverter(s) and/or charge controller(s) and/or alternator(s), the CAN Bus from any battery can be connected to any of the other devices. This is achieved by providing two RJ45 sockets on the battery – refer to Figure 4.2. On the end of line device, one socket is used for an end of line (termination) resistor, and the other socket for connecting to the next item of equipment, whether it be a battery, an inverter, a solar charge controller, an alternator regulator or system controller.

Figure 4.2 Picture Showing 2 x RJ45 Sockets for CAN Bus (optional cable for Analogue and Relay Control not shown)

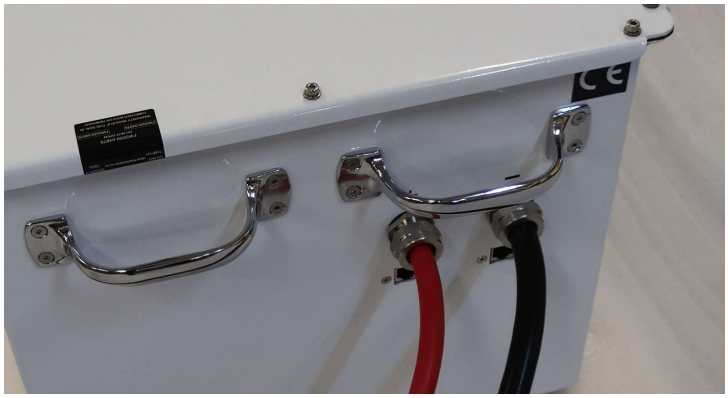
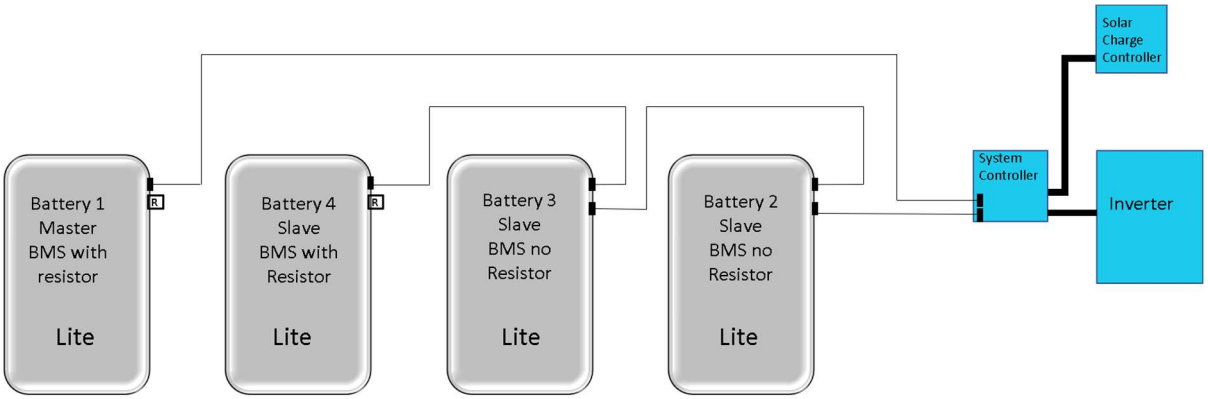


Figure 4.2 CAN Bus Connection Example with Four Lites



Freedom Won offers a fair trade in on Freedom Lite's on the purchase of new units, which is an option for somebody wishing to expand their battery capacity instead of installing parallel units. Please request more detail from Freedom Won if this is your upgrade preference.

New units can be placed in parallel with old units up to about 5 years or 1 500 cycles, after which it is preferable to trade in for a new larger unit or two new similar units.

4. Programming the Freedom Lite

The USB cable is used for setting up the profile of the BMS. A serial to USB adaptor is required for connecting the Freedom Lite Marine to a computer and the computer must have the correct utility software installed. Programming of the BMS is intended only as a function to be performed by Freedom Won and approved installers. The manual on how to operate the BMS along with the utility is available to approved installers from Freedom

Won. Write access to the BMS profile is password protected, however users and owners may request read only access.

As the user of a Freedom Lite there are some parameters that you may request to be customised. The most important of which is the minimum SoC (or maximum DoD) that the BMS may allow. The standard setting is 10% SoC (or 90% DoD), which is accompanied by the standard 10 year or 4000 cycle warranty, whichever should first occur. Note however that it is the responsibility of the installer and owner to ensure that on average the battery is not discharged below 80% DoD on a daily or frequent basis i.e. only occasionally should a lower DoD be allowed. The operating data is recorded by the BMS. Where life cycle is of paramount importance the average DoD should be 50% with no change in the standard warranty but an extended expected life of more than 7000 cycles or 20 years.

5. Switching on the Lite

The Lite is fitted with an "ON" button. Press this button to switch on the BMS inside the battery. Once the BMS has been energised you will observe the SoC display come to life with the SoC level. Confirm at this stage that the error lite is not illuminated. If it is, contact Freedom Won. If the Reduced Power light is illuminated, do not be concerned, it should extinguish after the battery has been charged and placed into operation for a few hours.

Once the BMS has been energised remove the breaker cover and switch on the breaker by pushing the breaker lever upwards (it may be necessary to push the beaker lever down first to reset the internal mechanism). Ensure beforehand that you have secured the DC cables to their proper locations and that the rest of the system is ready to receive battery voltage.

Note: On some inverters there is a large inrush current when switching on the DC supply. It is important in this instance to pre-charge the DC bus prior to switching on to prevent damaging the breaker when switching on. This is achieved in three ways:

1. Use a Solar Charge Controller (MPPT) to pre charge the DC Bus by switching it on and connecting its solar panels
2. Switch on the AC input to the inverter and switch on the inverter so that it can pre-charge its capacitors
3. Use a 60 to 100 Ohm 100W resistor with a pre-charge button to pre-charge the DC bus followed by closing a parallel link.

If the breaker trips after attempting to switch it on it is because of an error on the BMS or a system setup problem and Freedom Won or your authorised distributor should be contacted to assist with diagnosing and clearing the error.

To switch off the DC output from the Lite, pull down the breaker lever. To switch off the power to the BMS, press the "OFF" button situated to the right of the "ON" button. This will also trip the breaker if it is still on at the time. The Lite must be switched off fully when not in use to prevent self-discharge.

Fig 5.1 "ON" and "OFF" Buttons

6. Settings Required for Setting up Inverters and Charge Controllers

The maximum and continuous charge and discharge currents for the respective models are provided in Table 3.1. Ensure that the combination of the mains (shore power) charger, alternator, and the Solar Charge Controller (SCC) does not exceed the maximum continuous charge current.

Use the voltage settings provided in Table 3.3 for the setup of the inverters and chargers.

Note that if any of the voltage thresholds are exceeded the following sequence will occur:

- The battery will use CAN Bus or the analogue outputs to stop charge or discharge as applicable
- If CAN is not available, it will use a digital control output if connected to open a relay that controls the charging or discharging devices
- If this is not available, the battery will trip by switching off its own breaker.

Frequent occurrences of the last situation are not desirable.

The low battery warning can also be set according to user requirements on the inverter depending on how much battery power may be used before grid power will take over from the battery (if it is available). It should be determined based on how much battery SoC is desired at all times as a minimum to ensure adequate capacity to handle a grid outage or load shedding. The daily cycling depth is also a consideration for the user in terms of battery service life.

7. Accessories

Freedom Won offers the following accessories applicable to the Marine range:

Table 7.1 List of Accessories

Item	Description
Relay Control and Analogue Signal Cable	Pre-wired for connecting to terminals on other devices (analogue) or external relays. Note that the control cable is not standard on the Lite range and must be ordered as an extra item when ordering the Lite. It cannot be retrofitted to an existing battery without being returned to Freedom Won.
120 Ohm Termination Resistor – RJ45	For plugging into the second CAN port for an end of line Battery (one is supplied with each battery)
"Printer" USB Cable	This is needed for programming all the Lite models

1. Warranty and Repair

The Freedom Lite is sealed with a tamper proof warranty seal. It may not be opened by anyone other than Freedom Won and installers or repairers that have been explicitly approved by Freedom Won. The warranty on the unit will be void if the seal is damaged or missing.

If the Freedom Lite indicates an internal problem, please contact Freedom Won or the installer that installed the system. Freedom Won will arrange that it is inspected and repaired.

The warranty will not cover damage to the control wiring resulting from draw of excessive current or any damage resulting from lightning. Damage caused by physical means to the battery housing, external and internal fittings, such as impact with other objects, or being dropped, is not covered by the warranty.

The standard warranty period is 10 years or 4 000 cycles at an average of 80% DoD, whichever should first occur. The battery is required to provide at least 70% of its new capacity at the end of this period or cycle count. The BMS records the number of cycles used. If you suspect that your Freedom Lite is delivering substantially below its minimum performance, please contact Freedom Won for an investigation. If the unit is found to be underperforming it will be serviced such that the minimum performance guarantee is again restored. Freedom Won may arrange for an on-site service or for collection of the unit for servicing at our facility. This will be mostly determined by the geographic location, ease of access to or removal of the unit, and size of the unit.

For more detailed warranty information please contact Freedom Won.

Note: the above warranty statements apply to Lites sold by Freedom Won on or after 1 September 2019 only. For Lites sold by Freedom Won prior please contact Freedom Won for the correct documentation.

2. Expected Product Life

Freedom Lite is designed for optimal life cycle cost, which is a fraction of any other battery technology available on the market, in particular from 25% to 35% of the lifecycle cost of the range of lead acid and associated variants on the market. Please contact Freedom Won if you would like more detailed information for comparison with lead acid batteries than what is available on our web site.

Freedom Lite is expected to operate for about 16 years in a daily cycling scenario for more than 6 000 cycles with an average of 80% DoD. For occasional cycling applications (for typical load shedding for instance as is experienced in some countries) the service life expected is 20 years or more.

For applications where the cost per kWh delivered by the battery during its lifetime is of prime importance (i.e. maximum return on investment) we recommend that the battery be sized for an average cycle discharge of 50% DoD. In a daily cycling scenario such as for optimal solar self-consumption and off grid systems the expected service life is then 20 years or more than 7000 cycles. The defined end of life in this instance occurs when the battery capacity falls to 60% of the new capacity.

Troubleshooting Guide

Most issues with the Freedom Lite can be resolved using the guide below. If a problem cannot be resolved after referencing this table, please contact Freedom Won or your approved Freedom Won supplier.

Table 14.1 Troubleshooting Guide (applicable to units with On and OFF buttons)

No	Problem Description	Cause/Solution
1	The BMS (indicated by battery SoC display lighting up) does not stay on after the ON button is pressed	1. Error on the BMS. Check whether the red error light is illuminated on the SOC display when the ON button is held in. You can try to reset the error by pressing the RESET button for about 2 seconds and release. This should clear the error and allow the BMS to stay on after releasing the ON button. 2. Battery has been discharged to critically low level – remove all potential loads from the battery and switch off the inverter(s). Then try to switch on the BMS and then the breaker and get either a Solar Charger of AC Charger to charge as soon as possible – ensure that the loads are switched off. 3. Battery has been charged to critically high voltage level – usually leaving the battery for an hour will allow the cell levels to drop down within acceptable levels and allow the BMS to be switched on again. Ensure that the suspect charge device is not able to charge the battery until you have established by it is overcharging – it could be that the CAN communication is not set up correctly or in the absence of CAN the relay control, or in the absence of relay control the charge voltage setpoint could be set too high. 4. If the BMS still does not switch on, please contact Freedom Won or your Authorised Distributor for further assistance.
2	The Freedom Lite has no voltage on the main output cables	Check that you have switched on the main breaker switch. Note – only turn this on once you are satisfied that you have completed the installation and that there are no DC or control wires that can short out or touch ground or other wires. Also ensure that you are ready to accept DC voltage onto the inverter before switching this breaker on. Also confirm that you have energised the BMS first by pressing the “ON” button for 5 seconds and as evidenced by the lights on the SoC display. Remember to push the breaker lever down first before switching it on by pushing the lever upwards.

3	The main breaker switch keeps tripping each time I attempt to switch it on	There are several potential causes: 1. The Battery Management System has not been switched on. The ON button must be pressed for 5 seconds. On release the SoC Display must remain illuminated. 2. High inrush current on certain inverters – First preference is to pre charge the DC bus by switching on the solar charge controllers if present and in daytime. If this is not possible switch on the AC feed into the inverter and switch on the inverter. Some will then pre charge the DC bus. If this is also not possible (at night, off grid with no generator), try to close the breaker twice in quick succession – the second attempt must be within a second, before the inverter capacitors discharge again. This reduces the inrush current on the second closing attempt. If this does not work after the second attempt investigate the other options. Note that closing a breaker onto a DC bus without pre charging is not recommended. 3. Short circuit on the DC Bus or faulty inverter or MPPT causing high currents 4. In a system with multiple Lites in parallel the reason could be that the battery you are trying to switch on is at a vastly different voltage to the others – the voltages must be similar (within 2V of each other) on all batteries when switching them onto a common DC bus. If none of the above solves the problem you will need to contact Freedom Won or your authorised installer for assistance with this issue. It will be necessary to establish the reason for the error before continuing with normal operation of the system. Repeated tripping and resetting is potentially damaging for the breaker.
4	After resetting the BMS the main breaker still will not stay up.	First check whether the battery SOC is at 100% or below 10% by holding in the ON button and observing the SOC display. If the SOC is at or below 10% the tripping is most likely because the battery is fully discharged and the BMS is protecting the cells from further discharge. Ensure that there is no chance of load being applied to the battery by isolating the AC output from the inverter. Ensure that the AC input to the inverter is live so that the charger may begin charging the battery after you switch it on. Alternatively an MPPT can be used for this immediate charge if there is sunshine at the time. An alternator

		may also be used. This charge should increase the battery voltage to prevent further tripping. This problem should not occur if the inverter control is working properly. If this does not work, it is because the battery has been discharged too deeply and will need to be reset remotely by Freedom Won by accessing your Windows PC connected to the battery. The PC must have Anydesk installed and you will need the RS232 adapter to connect the PC to the battery. Please contact Freedom Won. If the SoC is at 100% it is most likely the tripping is because the battery has been over charged. Leave the battery for an hour and then try again. Ensure that all charging sources are disconnected or disabled. Once you have got the battery on again investigate what is wrong with the setup that is causing the over charge events.
5	I have switched off the main battery breaker switch to prevent discharge of the battery but the SOC display lights are still on.	The BMS and SoC display receive power directly from the battery and therefore the "OFF" Button must be pressed to switch off the internal electronics.
6	The inverter will not come on even though the inverter switch is selected to 'on'.	The enable command may not be coming from the BMS or the communication/control cable may not be properly connected to the inverter, or the inverter may not be properly configured to deal with the enable command. If you are using a hard-wired interface (using a relay) you can confirm whether the enable relay is energised. If not, then a battery parameter is outside of limits, most likely SoC or cell voltage, or there is a critical error on the BMS. Try resetting the BMS. If this does not work charge the battery and the inverter control should be re-enabled. If the relay is energised, then the problem lies with the control wire connection to the inverter or the inverter setup. Refer to the inverter manual or setup information to ensure that you have connected and set up the inverter properly. If you are running on a CAN Bus control with a compatible inverter and you are not observing the correct enable response from the inverter check that the CAN High and CAN Low wires are connected properly (ensure that you have the High and Low the right way around and that you have connected the two end of line 120 Ohm resistors in the applicable places). If this is not the problem then you need to confirm that you have the right CAN profile programmed onto the BMS for the inverter in use (baud rate or CAN messages may be set for another inverter brand) or that you have configured the inverter or system controller correctly. Contact Freedom Won or your Authorised Distributor for

		assistance if you need help setting up the inverter for the communication used i.e. CAN bus or hard wired.
7	The charger will not come on even though there is power on the AC input of the inverter and the charger is activated in the inverter settings	The battery might be full. Try discharging the battery for a while and observe if the charger then comes on. If not, then the fault-finding process is similar to above.
8	The Freedom Lite error light keeps illuminating after each reset	If the battery voltage is within limits this should not ordinarily occur. Contact Freedom Won or an approved installer for assistance with determining the problem. If the main breaker does not trip it is not a critical error and you may continue using the battery while you make contact for assistance.
9	The pack voltage and SoC is within limits but the main breaker still trips seemingly at random	This could be caused by many things but is most likely because the current draw is exceeding the battery current limit setting. Measure the current with a tong tester (clamp meter) while drawing your maximum typical load to determine if you are exceeding the rated current for the respective Freedom Lite model. If it is not the current causing the trip it could be a weak cell or extreme temperature of the surroundings. Both are unlikely. If the problem persists, contact Freedom Won.
10	Slave battery keeps tripping	The slave batteries may trip if they have not received communication from the master for more than 5 seconds. Check the CAN cables for faulty plugs or damage. Ensure that the termination resistors are fitted.
11	Master battery only reflects its own current on the system controller	Check the slave CAN Bus cables for faults and two termination resistors are fitted.
12	The alternator does not charge my battery	If you are using a remote enable regulator, ensure that you have wired the relay to connect ignition power to the regulator control wire input when the relay is closed by the BMS. Ensure that the relay is in fact closed. If it is open and the battery is at 100% SoC and at or near max charge voltage it is likely the alternator is not charging because the battery cannot take more charge. The relay should close again after a 15-minute interval or if the SoC drops below 99%.
13	SoC drops suddenly	If the SoC drops suddenly despite the loads not being high there are two explanations 1) the SoC has lost its calibration and the battery needs to be fully charged to regain SoC accuracy. This typically occurs if the battery has not received a full charge for several days 2) there is a problem with a cell, it may be defective or simply out of balance. Please contact Freedom Won for further investigation.