Installation Manual

Freedom Lite Home and Business

Range of Lithium Iron Phosphate Battery Modules

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1. Introduction

This manual is intended to provide assistance to an installer for the installation and commissioning of the range of **Freedom Lite** lithium iron phosphate (LiFePO4) energy storage modules. 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 simply doing the installation and final commissioning. Supplementary information relating to the internals of Freedom Lite and programming of the built in battery management system for specific applications is available to approved integrators directly from Freedom Won.

2. Product Description

The Freedom Lite technology is available in various standard sizes to meet most residential and small commercial applications. The standard voltage is 52V nominal (to suit 48V systems). Larger systems are provided by Freedom Won based on specific project requirements. Freedom Won also provides higher voltage UPS lithium batteries (Freedom Lite UPS range), which are covered in a separate document. The Lite Marine and Leisure range if lithium batteries is available on request with similar specifications to the Home range including 26V and 13V options to suit 24V and 12V systems respectively.

Table 2.1 provides an overview of the standard 52V Freedom Lite Home and Business range.

There are eight Freedom Lite models as included in the table. An image with labels pertaining to this text is provided in Figure 2.1 below. 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 The second number [2] denotes the average amount of energy in kWh that should be withdrawn per cycle in order to optimise the life if the lithium cells. This equates to roughly 70% of the total for each model.

The range is designed with a tall and slim profile with the “Home” models intended to be wall mounted (floor mounting is also possible), while the larger “Business” range is floor standing. The battery can lie on its back if desired such as for marine applications.

The Ah capacity is also provided in Table 2.1 for each model for easy reference.

The maximum current for each model is governed by the rating of the built in circuit breaker [3], which has been sized well below the maximum current capability of the lithium cells. For this reason there is no noticeable temperature rise during operation and no cooling of the cells is required. There is no specific time limit for operation at the maximum current, however 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. Special High Power Output (HPO) models for short term high power UPS applications are available on request.

Table 2.1 Freedom Lite Range Overview

Freedom Lite	Home 5/4	Home 10/7	Home 15/11	Home 20/14	Home 30/21	Business 40/28	Business 60/42	Business 80/56
Max Energy [kWh]	5	10	15	20	30	40	60	80
Energy, 70% DoD [kWh] (1)	3.5	7	11	14	21	28	42	56
Current Capacity [Ah]	100	200	300	400	600	800	1200	1600
Max/Cont Current [A]	125/100	125/100	125/100	250/200	375/300	375/300	500/400	500/400
Nominal Voltage [V]	52V, to suit 48V Inverters, min 45V, max 60V							
Weight [kg]	63	116	169	222	328	429	626	823
Dimensions on or against wall - Height x Width x Depth [mm]	736x508x 130	896x626x 146	906x600x 246	1156x600x 246	1656x600x 246	1656x584x 306	1656x854x 306	1656x1130x 306
Enclosure	Aluminium – powder coated silver rear and white front, IP54 enclosure rating, Home – wall mount, Business – floor mount							
DC Connection – Fly Leads, [no. per electrode] (2)	1 x 35mm^2	1 x 35mm^2	1 x 35mm^2	2 x 35mm^2	3 x 35mm^2	3 x 35mm^2	4 x 35mm^2	4 x 35mm^2
External Interfacing – (3)	Potential Free Contact Pairs – Remote Enable for Inverter, Charger, Solar Charge Controller Analogue Output – 0-5V for charge current limit and State of Charge, CAN Bus for compatible inverters and charge controller communication and control							
Protection	Shunt Trip Circuit Breaker sized to suit max current, can be tripped by BMS if critical fault, manual reset. overcurrent, cell under and over voltage, temperature, weak cell detection, minimum SOC control							
Human Interface	State of Charge Display (0 to 100%), Error light, Error Reset Button, Serial RS232 Plug for Programming							
Service Life [4]	10 year (or 3500 cycles) warranty for 70% DoD, 13 yrs (5000 cycles) expected life at 70% DoD, 15-20 years at 50% DoD (7 000 cycles)							

Notes to Table 2.1

1) DoD = Depth of Discharge, recommended 70% DoD for extended life, 50% DoD for optimal life
2) Fly Leads 1,6m long, power cable Red = Positive, Black = Negative, conductors in table refer to one electrode i.e. per positive and negative connections
3) The hardwired control is via a 12 core cable and the CAN control is via a 2 core shielded pair cable
4) End of Life (EoL) defined as cell dropping to 60% of Beginning of Life (BoL) capacity for expected life and 70% of BoL capacity for warranty.

All standard Freedom Lite models operate at a nominal voltage of 52V, which suits the most commonly available residential battery inverters and offers greater efficiency than the lower voltage options used by some inverters. The absolute maximum voltage when fully charged is 60V, however a more typical setting is 55.9V. The voltage normally used as the minimum cut off is 47V, however this will not typically be reached if operating down to 70% Depth of Discharge (DoD), the BMS will trip the battery breaker beforehand, at approximately 50,0V, which roughly equates to 15% SoC or 85% DoD).

The weight of each model is given above. The Freedom Lite Home 5/4 and 10/7 can be manually lifted by two people onto its hanging points. 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 the circuit breaker handle.

The DC cables exit the unit through glands located on the top right hand side of the casing and vary in number according to the model [4]. The correct cable lugs for connecting these leads to the inverter must be in hand when doing an installation. If there are several inverters 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 to branch out to all the equipment.

A gland with control cables emanating is located below the DC fly lead glands for connection in installations where an interface compatible inverter is used. Two cables run separately out of the connector and are 1,6m long, one is a CAN Bus shielded pair cable and the other is a multi-core hard wired control cable.

A DB9 Serial Connector [6 - concealed] is fitted to the upper left hand side of the housing for use by technicians for programming the required profile onto the BMS. This is typically completed by Freedom Won prior to delivery but installers are advised to obtain a DB9 RS232 to USB adapter cable for self-programing (Figure 2.2). The DB9 plug must have the male pins.

Freedom Lite is also fitted with a State of Charge (SoC) display [7], which includes a red LED error indicator [8] and below it a “low power” indicator. The error reset button [9] is positioned beside the display.

Figure 2.1 Labelled Image of the Freedom Home 5/4 Lying on Bench (Labelling corresponds with the above text)

Figure 2.2 RS232 DB9 (male) to USB Adapter for Programming Freedom Lite Profiles

3. 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 Home 5/4 and 10/7 models are easily handled by two people. The 15/11 and 20/14 models may be manually handled by sufficient people but are best handled by a pallet jack or forklift. The

30/21, 40/28, 60/42 and 80/56 models must be handled with care by a forklift or pallet jack of the required lifting capacity rating.

If it is necessary to transport the larger units (typically 40/28 and larger) up or down stairs in order to get them to the point of installation in the premises it may be preferable to deliver the unit with the lithium cells separate and then Freedom Won will fit them into the unit on site. This must be arranged with Freedom Won at the time of order placement and will attract a nominal fee.

The "Home" series is designed for wall mounting in order to preserve room and floor space and offer a convenient obstruction free and aesthetically pleasing solution. Each model is fitted to the wall using two Rawl Bolts. The Rawl Bolts are inserted into correct dimeter pre drilled holes in the wall. The bolts must first be tightened substantially so that the internals of the Rawl Bolt have gripped tightly into the wall, and then the bolt must be turned out slightly with the head protruding so that about 5mm of the bolt shank is visible. The Freedom Lite has two keyhole shaped holes in the reverse, which are shaped to fit over the bolt heads and then a narrowed section secures around the bolt shank as the unit is lowered into its final position. The 5/4, 10/7 and 15/11 models are hung using M8 bolts whilst the 20/14 and 30/21 models are hung on M10 bolts.

Figure 3.1 Bolt Mounting Keyhole on Rear of Lite Casing

The 10/7, 15/11, 20/14 and 30/21 models have hard points on top for fitting eye bolts. These eye bolts can be used for hoisting the unit up to the required height for fitting to the wall. This is easily achieved by drilling a Diameter 16mm hole in the wall about 800mm above the mounting bolts, inserting a steel rod of 16mm diameter and using a chain block of adequate lifting capacity to lift the Freedom Lite up to the required height. The hole for the steel rod must be angled about 10 degrees downwards into the wall so that the inserted rod is also at this angle, which prevents the chain block hook from sliding off. This is not necessary for the 10/7 if the mounting height is the normal waist height but this technique must be used if the unit is to be lifted abnormally high. The 5/4 is not fitted with an eye bolt attachment point because it is light enough to be handled manually. The eye bolt(s) should

be removed after installation and the hole in the wall closed up. Eye bolts are not supplied with Freedom Lite. Ensure that you have M12 x 1,75 thread eye bolts rated for 450kg or more (one for the 10/7 and 15/11, two for the 20/14, 30/21, 40/28, 60/42 and 80/56 models).

Figure 3.2 Eye bolt Example

Figure 3.3 Eye bolt Installation on a 30/21 model with two eye bolts

The units can alternatively be lifted to the right height and onto the hanging bolts using a high lift pallet jack such as shown in Figure 3.4.

Figure 3.4 High Lift Pallet Jack

Caution:

1. *Great care must be taken to ensure that the Rawl Bolt has properly located into the narrowed section of the mounting hole before removing the support.*
2. *Handle the Freedom Lite with great care when lifting and manoeuvring. It should remain either lying flat on its back or vertically upright (it should not be placed upside down or on its front face.*
3. *Do not allow the pallet jack to over centre if it is a model with longer forks than lower arms*
4. *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.*
5. *Take care not to scratch the Lite during handling. Foam should be used to protect the paint when being handled on a trolley or pallet jack.*
6. *Always ensure that lifting equipment and slings are adequately rated for the lifting weight.*
7. *Ensure that the eye bolts are fully screwed into the hard point thread on the top of the unit before lifting. Tip: Use a plastic washer under the eye bolt to prevent damage to the paint.*
8. *Wear personal protective equipment such as safety shoes and gloves while handling and mounting Freedom Lite*
9. *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 pallet jack.*

4. Connecting up the Freedom Lite

4.1 Power Cables

The Freedom Lite is simple to connect to the battery inverter. First of all you will connect the 48V positive and negative cables to the inverter terminals.

***Caution:* Prior to connecting the positive and negative cables to the inverter 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, 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 and also to match the size of the cable. The positive cable is red and the negative cable is black. See Table 4.1 for the cable size and quantity fitted to each Freedom Lite model. The sizes are based on the inverter being mounted on the wall adjacent to the Freedom Lite battery so that the cable run is less than 2m.

Longer runs should be assessed and larger cables considered for extending the Freedom Lite cables, minimising voltage drop. Permopower welding and power cable from Alvern Cables or equivalent is recommended. Multiple lengths are used instead of using larger cable so as to ensure easier routing and bending of cables in trunking.

Table 4.1 Cable Sizes and Quantity for the 48V DC Connections (per Positive and Negative) – Standard Models (enquire about Higher Power Output options).

Freedom Lite Model	Freedom Lite Cable Size and Qty [mm^2]
5/4	1 x 35
10/7	1 x 35
15/11	1 x 35
20/14	2 x 35
30/21	3 x 35
40/28	3 x 35
60/42	4 x 35
80/56	4 x 35

The cables may be routed through trunking and connected into the inverter on the positive and negative terminals respectively. The inverter terminals can then be used for linking up the charge controller(s) to the DC Bus. On Installations where there are too many inverters and/or charge controllers to connect to the DC bus using the inverter terminals as a junction point a DC connector box is required.

4.2 Parallel Configurations

It is permissible to connect multiple Freedom Lite's in parallel provided that the Freedom Lite model used is the same throughout. It is however more cost effective to purchase one larger Freedom Won model than connecting multiple units in parallel. This type of

installation should be reserved for future expansion where it is not feasible to purchase a model large enough upfront for future requirements (financial constraints).

The positive and negative terminals of the multiple Freedom Lite's must all be connected to a Parallel Control Box that contains a contactor that will disconnect all Lite's at the same time the moment any one of the BMS's requires an intervention. The inverters and charge controllers will be connected to separate terminals in this control box.

If this control box fails to operate then the affected battery will trip. Once the failure in the control box function is rectified the batteries must all be at the same voltage before the tripped unit is reset.

For hard wired installations the control NO and COM pairs from the Lite's can be daisy chained before going into the inverter or charge controller so that one Freedom Lite in the chain can disable the respective function.

CAN Bus control of the inverter(s) and charge controller(s) with parallel connected Freedom Lite's requires a specialised central controller to integrate the multiple CAN inputs into one set of outputs. This control unit is not yet available from Freedom Won.

Freedom Won offers a fair trade in on Freedom Lite's on the purchase of new units, which is a good option for somebody wishing to expand their battery capacity without having to install parallel units.

If additional inverters are required it is also more effective to install new Freedom Lite's to new inverters such that there is not a mix of older units in parallel with new units. This ensures that the batteries can operate independently. In a parallel configuration the newer unit would otherwise be limited to the capacity of the older unit. The AC bus may only be tied when using inverters with the capability of acting in parallel on different batteries.

4.3 Control Cable

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

There are two cables emanating from the control cable gland on the Freedom Lite. One is a 12 core cable with 0,2mm^2 wires to provide the hard wired control connections. The other is a 2 core plus ground cable used for the CAN communication.

The connection details of the open ends of the cables depend on the model of inverter and the method of control. There are two main control options for the inverter, namely hard wired potential free contacts that are connected to auxiliary inputs or remote on/off switches on the inverter and charge controller, or CAN Bus. A third option exists for inverters that do not have an interface, namely the control of external contactors on the AC input and Output and/or on the DC connection to ensure that no overcharge or discharge can occur. There are three relays inside the Freedom Lite that can be used for this purpose.

The hard wired control cable contains 12 wires, each of a different colour. Three colours are not used but the remainder represent their respective functions. Table 4.2 below provides the colour coding for the hard wired 12 core control cable.

Table 4.3 contains the information regarding the connection of the CAN cable.

Further explanation of the functions is laid out in the rest of this section.

Table 4.2 Colour Coding for 12 Core Control Cable

Wire Colour in 12 Core Control Cable	**Wire Function [NO = Normally Open, COM = Common]**
Red	Solar Charge Controller Enable NO
Turquoise	Solar Charge Controller Enable COM
Yellow	Inverter Enable NO
Blue	Inverter Enable COM
Orange	Charger Enable NO
Grey	Charger Enable COM
White	Charge Current Limit (CCL) 0-5V Analogue Output
Pink	State of Charge (SoC) 0-5V Analogue Output
Brown	Analogue Output Ground (main battery ground)
Purple	Multi-purpose Output NO (optional)*
Green	Multi-purpose Output COM (optional)*
Black	Not Used

*The Multi-purpose output can be programmed for various functions based on SoC, voltage, and temperature ranges. Please request this option specifically when placing your order with Freedom Won as this feature is not included as standard.

Table 4.3 Colour Coding for CAN Bus Control Cable

Wire Colour in 2 Core CAN Cable	**Wire Function**
Red	CAN High
Black	CAN Low
Bare Wire	Ground – do not connect to anything

4.3.1 Hard Wired Control

This method of control is used when the inverter or charge controller 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. A very good example of equipment containing this type of interface is the range of Victron Multiplus and Quattro inverters, as well as the Victron Blue Solar 150/70 and 150/85 models (please confirm that the Blue Solar you purchase indeed contains a remote on/off switch as some 150/70 models were released without it).

The digital control signals are provided by a 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). The control circuit is designed to carry only light loads up to 1A. Should a larger draw be required an additional external relay must be used. These pairs are not fused. In the case of the Victron range it is not necessary to install a fuse on the remote enable or Auxiliary Inputs (AI's) but it would be prudent to include a 1A fuse for other control applications that do not have current limit protection.

The following functions are available for this type of installation:

1. Charger Enable – this is achieved using a pair of potential free contacts from a relay inside the Freedom Lite. 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 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 are able to 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 45°C)
    iv. the charge re-enable timer has counted through the defined period since the last charge (usually 60 minutes), which will allow a top up charge to restore the battery to 100% SOC.
    v. The defined delay time for a repeated operation of this relay has elapsed (3 minutes)
2. Inverter Enable - this is achieved using a pair of potential free contacts from a relay inside the Freedom Lite. 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 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 are able to 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 45°C)
   iv. The State of Charge (SOC) is above the defined minimum discharge setting (usually 15%)
   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 35%)
   vi. The defined delay time for a repeated operation of this relay has elapsed (3 minutes)

3. Solar Charge Controller Enable – this is achieved using a pair of potential free contacts from a relay inside the Freedom Lite. 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 closing of this relay will then enable the external charge equipment, in this case a Solar Charge Controller with a remote enable switch. The standard parameters for determining this are programmed into the BMS by Freedom Won prior to delivery. Freedom Won or approved installers are able to alter these parameters if a non-standard configuration is required. The standard configuration is to enable the solar charge controller 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 45°C)
   iv. The State of Charge (SOC) has dropped below a defined level since the last charge enable period (98%).
   v. The defined delay time for a repeated operation of this relay has elapsed (3 minutes)
   vi. The defined delay time for cancelling a zero latch of the Charge Current Limit (CCL) as expired
4. Charge Current Limit (CCL) – some inverters or solar charge controllers may be equipped with an analogue input that allows the BMS to define the charge current limit. If this charge current limit defined 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 and is connected to the external measuring input using the battery ground. Both wires are provided in the control cable. ***Caution – do not allow these two wires to touch each other during installation while the BMS is powered up. This may cause damage to the internal circuitry of the BMS. Note that the BMS could receive***

power from an active inverter from the DC terminals even if the main breaker on the Freedom Lite is switched off. It can be seen whether the BMS has power if the SOC display lights are illuminated. The CCL is calculated by the BMS using several parameters. It is particularly useful for reducing the charge current near the end of a charge to continue the charge for longer prior to reaching the maximum cell voltage. If the inverter is set up correctly with the correct maximum charge voltage the internal inverter function can provide current tapering based on pack voltage as an alternative. If other voltage ranges are required you will need some external circuitry that uses 0-5V as an input and delivers the required range as an output.

4.3.2 CAN Bus Control

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 type 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 or charge controller 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 equipment:

- Schneider Battery Inverters XW+ and SW
- Schneider Conext Solar Charge Controllers
- SMA Sunny Island Battery Inverters
- Ingeteam Sun Storage Battery Inverters
- Victron Multiplus and Quattro Battery Inverters and MPPT Controllers (CAN integration is a recent development with Victron)
- Goodwe ES Hybrid Inverter Series (still in testing phase)

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

The CAN interface can provide the following functionality to compatible devices using the same logic where applicable as that explained in the Hard Wired control explanation:

i. Charger Enable
ii. Inverter Enable
iii. Solar Charge Controller (SCC) Enable
iv. Charge Current Limit to both SCC and mains charger
v. Battery State of Charge

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). One is already inside the Freedom Lite, so it is necessary to install another on the end that connects to the inverter or the charge controller, whichever happens to be furthest from the Freedom Lite. Most devices operating on CAN have two plugs to connect in and out again on the CAN Bus. The last device in the chain must have a termination resistor plugged into the spare (second) plug. These resistor plugs are available from the device manufacturer. SMA, Schneider and Victron operate on this basis. 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.

The third party device manuals must be referenced for all details regarding connecting the CAN interface.

5. Programming the Freedom Lite

The serial DB9 connector on the left hand side of the Freedom Lite is used for setting up the profile of the BMS. A serial to USB adaptor is required for connecting Freedom Lite 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 15% SoC (or 85% DoD), which is accompanied by the standard 10 year or 3500 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 discharge below 70% DoD i.e. only on odd occasions should a lower DoD be allowed. The operating data is recorded by the BMS. For applications where total life cycle is less of a concern than performance, the maximum DoD can be set to 90%. This will result in a warranty of 5 years or 2500 cycles, whichever should first occur. Where life cycle is of paramount importance the average DoD should be 50% with no change in the standard warranty but a much extended expected life of 7000 cycles or 20 years.

6. Settings Required for Setting up Inverters and Charge Controllers

The maximum and continuous discharge currents are provided in Table 2.1. For charge current settings the same limit can be used as the continuous discharge current, however this is usually not possible owing to limitations of the charger or of the incoming grid supply. An average recommended charge current is one third of the continuous rating of the battery. This will usually ensure that the combination of the mains charger and the Solar

Charge Controller (SCC) does not exceed the maximum continuous charge current, although this must be specifically checked.

The voltage settings for the Freedom Lite range of nominally 52V batteries when operating in a system where the BMS can control the external devices as explained above are as follows:

- Minimum (cut off) – 47V (the Lite should never reach this low voltage but is it good to have this set as a redundancy protection measure.
- Low Battery Voltage Warning (if applicable, often used to revert back to grid power in increased self-consumption applications because it approximates 40% SoC) – 51,5V
- Max Charge Voltage – 55,9V

If the BMS is not able to control the external devices with remote enable functions then the voltages must be set at slightly conservative values. This is to reduce the likelihood that an outlying cell will reach its voltage limit ahead of the pack, which the external devices would not be aware of because they can only monitor the total pack voltage. Using a lower pack voltage to monitor and control charging and a higher voltage for discharge will allow a greater spread in cell voltage values without any of them reaching their limits. The BMS inside the Freedom Lite will deal with an excessive spread of cell voltages by balancing them out using the cell tap wires attached to each cell and its internal circuitry. If a cell voltage does reach its limit the BMS will be forced to intervene. This would be either by:

- switching off a contactor on the AC in, AC out, or DC bus as mentioned earlier in this manual, or if the relevant one of these functions does not exist in a particular system,
- the BMS shutting down the main breaker on the battery

Frequent occurrences of these two situations is not desirable so the voltages should be set to the following to reduce this occurrence to abnormal circumstances:

- Minimum (cut off) – 49V
- Low Battery Voltage Warning (if applicable) – 52V
- Max Charge Voltage – 55.4V

The lower end voltage conservativism should not impact on performance if the cut-off is set to 85 DoD as is the standard. The high end voltage cut-off will reduce available capacity of the battery by less than 1%.

The Freedom Lite BMS is programmed to shut down the inverter if the SoC drops below 15% (85% DoD). If the BMS is not able to control the inverter then the inverter should be set to shut itself down at the following voltages depending on the desired minimum SoC:

- 85% DoD – 49,5V
- 70% DoD – 50,5V

For instances where a Solar Charge Controller (SCC) is connected to the DC bus and the inverter does not have the applicable internal setup features it is advisable to set the maximum charge voltage in the battery inverter/charger to a lower value than the nominal charge voltage set on the SCC in order to promote self-consumption of PV power.

A voltage can also be set according to user requirements on the actual inverter depending on how much battery power may be used before grid power will charge 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.

The recommended voltage for forcing the inverter back to grid power in a self-consumption setup is:

- 52,0V for approximately 60% DoD
- 51,5V for approximately 70% DoD

The higher voltage that the charger should stop charging at to allow the remainder of the charge to be performed by the SCC is:

- 53.5V as the maximum voltage to which the grid charger should be allowed to reach

The SCC voltage set point would be set to 55,9V if BMS control is functional and 55,4V without BMS control. Note that it may be necessary to use a slightly lower voltage initially if the cells have not had sufficient balancing time – if the battery trips prior to reaching 55,4V it is because one cell has reached its maximum too early. Try starting with 54,5V and then after several days of balancing increasing it to 55,4V.

Note: For applications where voltages are measured during high current discharge it might be necessary to adjust slightly the values given above to cater for cell internal resistance.

7. Typical Installations

Some examples of how to integrate Freedom Lite into a battery backup and solar installations are provided below.

7.1 Victron Installations

Victron provides a range of battery inverters with built in mains controller that are equipped with auxiliary inputs that provide a method for independently enabling the charger and the inverter. This range includes the models known as Multiplus and Quattro, providing sizes from 3kVA up to 10kVA (only the 48V units are suitable hence the units smaller than 3kVA are excluded here). The charger and inverter enable potential free control wires (see Table 4.2) from the Freedom Lite are simply connected to the Auxiliary Input 1 and 2 respectively. These inverters offer a range of features and are extremely robust, usually carrying a 5 year manufacturer warranty. They can be synchronised to offer three phase (one unit per phase) and can also be connected in parallel to increase power per phase. More than one unit can

be fitted to the same Freedom Lite. In such cases one becomes a master and they are connected together using “Ve. Bus” connector cables.

These inverters do not support parallel connection with a tied AC bus when using separate batteries. If two Lite’s and two inverters are used they should not be tied on the AC bus – each inverter must supply separate circuits in the building.

To get the inverter to work with this external control it is necessary to install version XXXX 4XX of the firmware so that the “Assistants” programs are available. To ascertain what firmware you have on your device you must find the label providing such on the microprocessor chip on the main PC Board (remove the front cover, the number is preceded by the word “HEX”). This number must be provided when requesting the XXXX 4XX version. Most units are shipped with XXXX 1XX firmware. To load firmware onto Victron inverters the correct programming dongle is required for connecting to your PC.

There are several assistants that can be used depending on the type of installation as described later. Table 7.2 provides the connection details for the hard wired control cable for the applicable inverter chargers and solar charge controllers.

Table 7.1 Hard Wired Control Cable Connection Details for the applicable Victron Multiplus and Quattro Inverter Chargers and Blue Solar Charge Controllers

Wire Colour in 12 Core Control Cable	**Wire Function [NO = Normally Open, COM = Common]**	**Connection on Victron Inverter**
Orange	Charger Enable NO	Aux 1 – Terminal 1
Grey	Charger Enable COM	Aux 1 – Terminal 2
Yellow	Inverter Enable NO	Aux 2 – Terminal 1
Blue	Inverter Enable COM	Aux 2 – Terminal 2
Red	Solar Charge Controller Enable NO	Remote Enable – Terminal 1
Turquoise	Solar Charge Controller Enable COM	Remote Enable – Terminal 2
White	Charge Current Limit (CCL) 0-5V Analogue Output	Not used
Pink	State of Charge (SoC) 0-5V Analogue Output	Not used
Brown	Analogue Output Ground (main battery ground)	Not used
Purple	Not Used	Not used
Green	Not Used	Not used
Black	Not Used	Not used

The BMS assistants are loaded using the Victron configuration software and a profile is set up including assigning the Aux Inputs to their proper functions and setting the voltage limits according to the Freedom Lite requirements. Please reference the Victron Energy website (www.victronenergy.com) or contact your Victron supplier for more detail and assistance with setting up your Victron inverter for operation with the Freedom Lite lithium BMS. Freedom Won is also available for technical assistance should the Victron or supplier sources not be sufficiently clear.

7.2 Victron Inverter as Backup Power Only

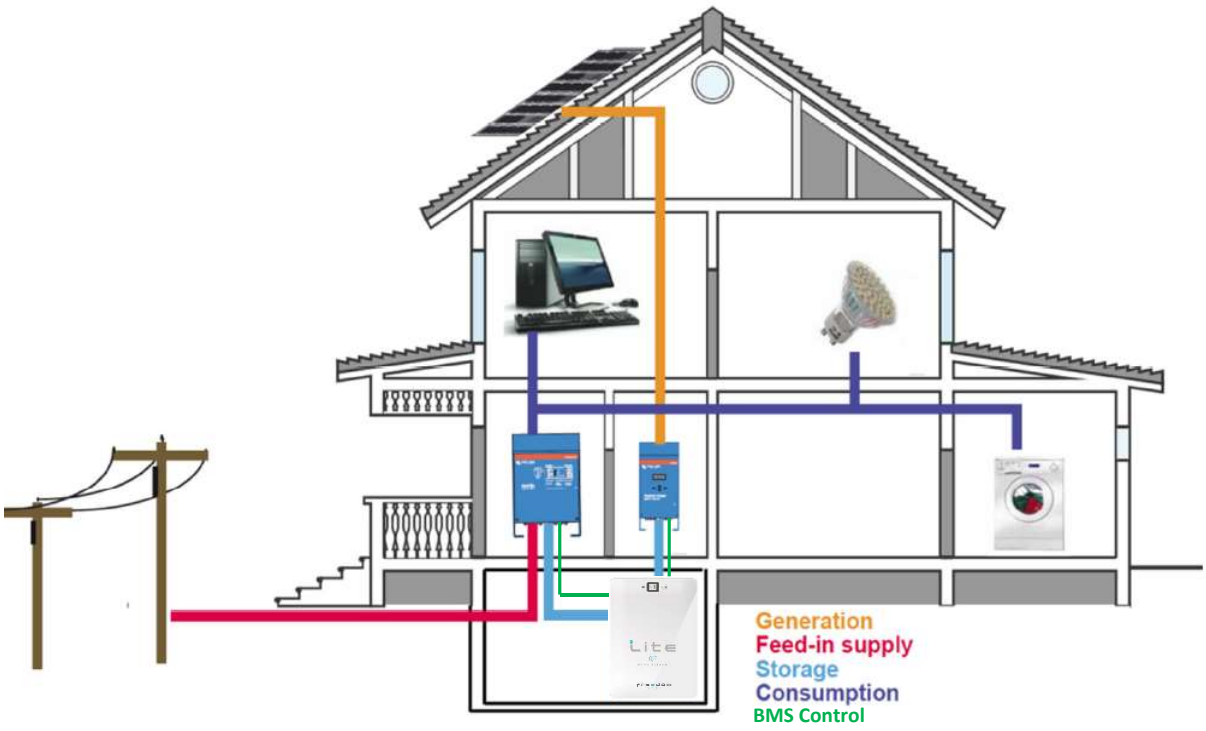
In this setup the Victron inverter operates only for providing backup power to the AC loads when the grid is off. There is no solar power. It is possible however to programme the inverter to start a generator when necessary to provide power instead of the grid.

For this setup the Lynx Ion BMS assistant is to be used. The Victron documents explaining how to configure this assistant are available on line. Table 7.1 provides the Lite connection details for the control wiring using Aux 1 and Aux 2 on the inverter, which are programmed for their respective functions using the assistant.

7.3 Victron Inverter and Solar Charge Controller

Figure 7.1 below provides a schematic of a PV solution with battery backup and a connection to the grid.

Figure 7.1 Example of a Grid Connected PV System with Battery Backup using a Victron Multiplus or Quattro Inverter Charger and a Blue Solar Charge Controller with a Freedom Lite Home 10/7



In Figure 7.1 the grid is connected to the input AC terminals of the Multiplus or Quattro battery inverter. The AC output is connected to the house circuits that require battery backup. The 48V DC connections on Freedom Lite are connected to both the inverter and the solar charge controller (SCC). There is also a BMS control connection between the Freedom Lite and the inverter and SCC. At this stage this is by use of the hard wired option describer earlier in this document, but will also be achievable in the near future using CAN

Bus. Multiple inverter and SCC units can be installed in parallel. The Master inverter must have the control cables connected and then it will control the slaves. All slaves must be configured with the BMS assistant. In order to control multiple SCC's the enable wires from the Lite must simply be connected in parallel onto the remote enable terminals.

It is not necessary to connect the inverter to the charge controller using a VE. Bus to Ve. CAN adapter in cases where there is no feeding back into the grid. If a Color Control GX is installed however the inverter and SCC should be connected using Ve. Bus and Ve. CAN into the Color Control GX to ensure full functionality of this unit. Because the Color Control unit can accept both protocols it is not necessary to purchase the Ve. Bus to Ve. CAN adapter.

Note that to comply with the legislation of your country it may be a requirement to include an appropriate anti-islanding device between the grid supply and the inverter. The Victron inverter does have a transfer switch that disconnects the grid from back feeding when the grid power is down but in present models (2015) this transfer switch may not comply with local legislation.

The inverter will within 20ms transfer power in the house to battery backup if the grid power fails. This is sufficiently fast to prevent appliances from being affected. The unit can also exclude voltages higher than a user adjustable value within a 20ms period.

Once transferred to battery power the inverter will continue to operate until the relay connected to Aux Input 2 is opened by the BMS. This should only occur if the Freedom Lite has dropped to 15% SoC (85% DoD). The inverter will not function off battery until either the solar charge controller has recharged the battery to at least 35% SoC and will thereafter continue to operate provided that the SoC remains above 20%. When grid power is restored the inverter will immediately revert back to the grid source. The system design should be based on assuming only 70% DoD will be used on a routine basis with 85% DoD being the absolute cut-off for occasional scenarios.

The Victron Multiplus and Quattro inverters should be connected with the Blue Solar 150/xx unit in a "HUB 1" configuration. For this setup the HUB 1 assistant must be loaded and configured. Please refer to the Victron website for further information on the HUB configurations. The Ve.Direct solar chargers can also be used.

It is also possible to configure the Victron inverter to feed energy to the grid if the battery voltage is above a defined value. This must be set up properly using the configuration software and the connection must be authorised by the utility and any other applicable body in your country.

Note that the above diagram is a simplification. In many household installations the inverter may not be intended to run heavy consumers such as electric geysers, stoves and household heating. These are often connected to the grid directly and do not pass through the inverter.

It is also necessary to ensure that the AC output of the inverter is fed to either a separate Distribution Board (DB) or to a section of the main DB that is physically apart from the incoming utility supply and the other breakers that are fed from the utility directly. This is to

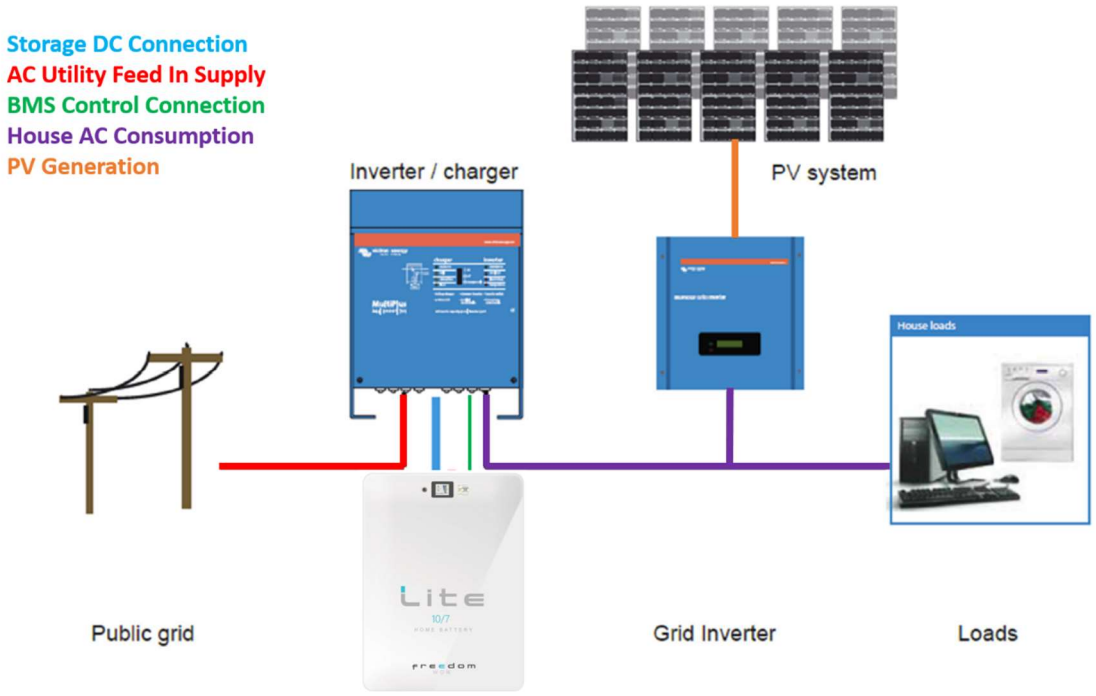
ensure that it is practical to clearly label the inverter output section of the DB so that it is clearly evident that this section will remain live despite the utility incomer being off. Observe the relevant regulations

7.4 Victron Inverter and Grid Tie Inverter

The main alternative to installing a DC charge controller is shown in Figure 7.2. This system incorporates a grid tie inverter (GTI) or PV inverter on the consumption side of the battery inverter.

Aside Note: It is also possible to install a GTI on the grid side of the battery inverter but this option is not recommended when connected to an unreliable grid because the PV potential cannot be utilized during an outage as the GTI will shut down without the grid power being present.

Figure 7.2 Installation Example using a Victron Battery Inverter and a Grid Tie Inverter with a Freedom Lite 10/7



In this installation the Freedom Lite need only control the battery inverter. The battery inverter will then be required to control the GTI. This is achieved by varying slightly the output frequency of the battery inverter. Compatible GTI's will measure this variation in frequency and adjust the power put into the consumption side AC bus accordingly. The battery inverter will determine when to 'throttle' back the GTI based on its own power (current) measurements. If the combination of the house consumption and the ability for the inverter to place charge into the battery is not sufficient to consume all the power the GTI can deliver there are two options for the battery inverter. If it is set up for feeding back to the grid, it can do so, which would mean that the GTI need not be 'throttled' back. If it is

not set up for feeding back to the grid and the voltage of the Freedom Lite has reached its maximum, OR the Freedom Lite has disabled the charger, it will reduce the power delivery of the GTI to that which is equivalent to the consumption in the house at that time.

This setup should be configured with the HUB 2 assistant in the Victron firmware on the inverter.

This option using a GTI is typically more expensive than using a DC SCC but it is useful if a system already exists using a GTI to which a battery inverter and Freedom Lite is to be added, because the GTI can usually be retained. Also, the GTI's are more suitable for larger installations (around 10kW plus) because SCC's are not made for much more then 5kWp PV power (they can be connected in parallel however). GTI's also typically have a much higher maximum PV voltage input, which reduces the amount of parallel connections required on the panels and thus makes installation easier and less costly.

7.5 System and Product Variations

The systems above are only examples of how to incorporate a Freedom Lite into a total solution based on Victron products.

Other inverter brands can be incorporated into the same types of configurations so long as they have the right interfacing requirements such as SMA Sunny Island battery inverter incorporated with a SMA Sunny Boy GTI or a Schneider Conext XW+ incorporated with a Schneider Conext MPPT Solar Charge Controller. Hybrid inverters that essentially contain both the battery inverter/charger function as well as the SCC in one unit can also be used.

Specific instructions on connecting to and configuring the following inverters, GTI's and SCC's can be obtained from Freedom Won:

- Schneider SW, XW+ inverters and MPPT Controllers
- SMA Sunny Island and Sunny Boy
- Ingeteam Hybrid Inverter, charger and SCC combination units
- Microcare
- MLT Inverters
- Goodwe

8. 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 one of our approved installers listed on our website. We will arrange that it is inspected and repaired.

The warranty will not cover damage to the control wiring resulting from draw of excessive current. 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 3500 cycles, 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 number. The BMS records the number of cycles used. If you suspect that your Freedom Lite is delivering substantially below its when new performance please contact Freedom Won for an investigation. We will request that you fully charge the battery and switch on a defined load and measure the operating time in order for us to estimate the amount of energy produced until the battery has reached 70% DoD. If the unit is found to be underperforming it will be serviced such that the 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.

Applications requiring more capacity per cycle may be installed using a 90% DoD, which will be given a 5 year or 2500 cycle warranty guaranteeing an 80% end of life capacity.

For more detailed warranty information please contact Freedom Won.

9. 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 15 years in a daily cycling scenario with an average of 70% DoD. For 3 cycles per week (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 7000 cycles. The defined end of life in this instance occurs when the battery capacity falls to 60% of the new capacity.

10. 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 10.1 Troubleshooting Guide

No	Problem Description	Cause/Solution
1	Eye bolts do not screw into hard point on top of Freedom Lite	Check that you have the correct eye bolt with the correct thread pitch – M10 x 1,5 for models up to the Lite 40/28 and M12 x 1.75
2	The rawl bolt head does not fit into the hole on the back of Freedom Lite (wall mounted models)	Check that you are using the correct size Rawl Bolt as specified in this manual and that you have after positively tightening the internal gripping collar turned the bolt out again so that there is about 5mm of the bolt shank exposed so that the back plate can fit easily behind the bolt head. If the wall is uneven it may be necessary to turn the bolt head out a little more. Do not turn it so far out that there is less than the full thread length engaging on the internal locking collar.
3	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 AC voltage onto the inverter output before switching this breaker on. Once switched on you will see that the SoC LED's light up.
4	The main breaker switch keeps tripping each time I attempt to switch it on	You may have an error or trouble code registering on the BMS. Check whether the red error light is illuminated on the SOC display. If it is then press the RESET button for about 2 seconds and release. This should clear the error and allow you to switch on the main breaker.
5	After resetting the BMS the main breaker still will not stay up.	This 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 disconnecting 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. This should increase the battery voltage to prevent further tripping. This problem should not occur is the inverter control is working properly.
6	I have switched off the main battery breaker switch to prevent use of the battery but the SOC display lights are still on.	This is no concern and is because the BMS is receiving power directly from the inverter DC terminals. The BMS cannot receive power from the battery when the main switch is off.

7	The inverter will not come on even though the switch is selected to 'on'.	The enable command may not be coming from the BMS or may not be properly connected or the inverter may not be properly configured to deal with the enable command. If you are using a hard wired interface you can confirm whether the enable signal is coming from the inverter by checking to see if there is continuity between the Inverter Enable NO and COM wires. 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 there is continuity 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 despite the CAN High and CAN Low wires being connected properly (ensure that you have the High and Low the right way around and that you have connected the end of line 120 Ohm resistor in the applicable place if required). 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. Contact Freedom Won for assistance.
8	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.
9	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.
10	The pack voltage 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 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.