Safety Unit for Lithium Battery Packs

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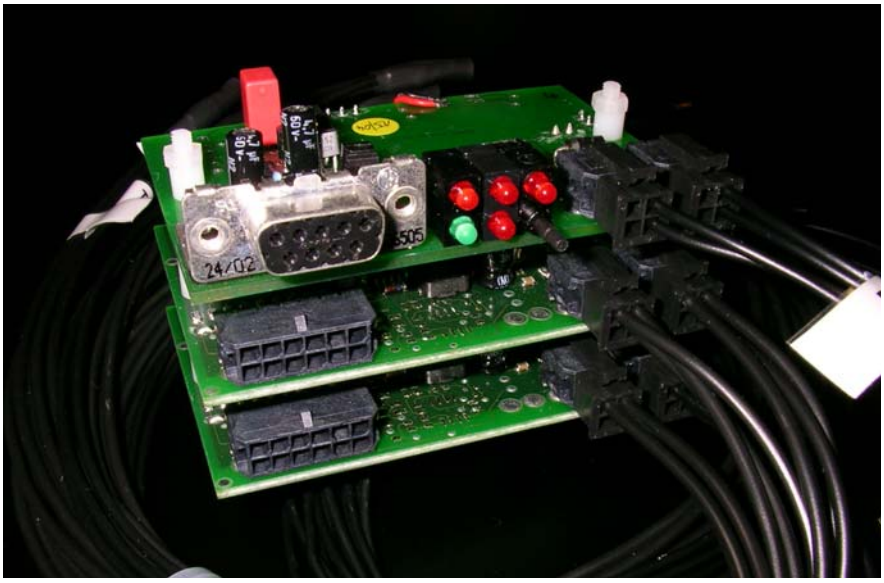
Manual
for
Lithium Battery Safety Unit

LBSU-4-100

Version: 2.0



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This safety unit is a prototype and therefore you must agree the terms and conditions defined below; before you use the safety unit.

You acknowledge and agree that use of the safety unit is at your own risk and that it is sold under LEO Energy Terms and Condition of Sale. You assume responsibility for selecting the safety unit to achieve your intended results, and for the results obtained from the safety unit.

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2. INTRODUCTION

Lithium is the lightest metal on earth. It also has the greatest energy potential of any solid material. With this unique combination of light weight, high energy and temperature endurance, lithium is an ideal material for making batteries. But, because lithium is flammable, it requires careful handling during charging and discharging. Therefore lithium batteries must be controlled in voltage and temperature during their whole lifecycle.

The Lithium Battery Safety Unit is designed to control the single cell voltages and watch the temperature of a Lithium Battery.

3. DESCRIPTION OF THE HARDWARE

3.1 Structure of the Safety Unit

The LBSU-4-1 00 consists of 1 main module and 4 measurement modules. Each measurement module can monitor up to 7 cell voltages and 2 temperatures. The measurement modules gather all the information and optically coupled to the main module.

The main module will determine if any error occur from the data collected from the measurement modules. It will transmit the information to the PC via RS232 at an interval of one minute. Measurement data plus error message (if any) will then be displayed.

If error occurs, the main module will shuts down the battery. Once the battery is shut down (load relay is open), you must fix the error and press the RESET button to restart the safety unit.

3.2 Power Supply

The measurement modules are powered by the cells that they are connected to. The minimum voltage is 2.7V (1 cells) and the maximum voltage is 30V (7 cells). The voltage at the measurement module is regulated to a value of 5V. This is the reason, why the current consumption of the module is lower when more cells are connected (approximately 25mA, at 7 cells)

Caution: The measurement modules are drawing current from the cells they are connected to, even if the LBSU is powered down. Therefore yon must not leave the battery unloaded when the LBSU switched off the relay after any error.

3.3 Voltage Inputs

For the measurement of the cell voltages, an A/D converter is used. The A/D converter is able to measure voltage from 0V to 5V for each cell with an accuracy of 0.5% (25mV).

The single cells are connected to the measurement modules with a module cable consisting of 8 wires and a plug. By connecting the wires to the battery, following rules are to be observed in order to prevent hazardous situations:

- For each wire, a fuse is to be connected to the battery as near as possible.
- The nominal rating of the fuse must be between 0.5 –1A.
- The fuse resistance must be as small as possible (R_{FUSE} < 1 Ohm), as there will be voltage drop across the fuse. This reduces the measurement voltage and therefore reduces the accuracy of the measurement value.

Caution:

The connector must not be connected to the safety unit during the cable is mounted to the battery.

To connect 7 cells of a battery to a measurement module, you need 8 fuses and 1 module cable.

Here is an example on how to connect the first 7 cells of a battery to a module cable (see also figure in Appendix A):

1. Connect one end of the first fuse to the minus pole of the first cell (this is also the minus pole of the battery). Then connect the wire with **label 'G'** to the other end of the fuse
2. Connect one end of the second fuse to the point where the plus pole of the first cell and the minus pole of the second cell are connected. Then connect the wire with **label '1'** to the other end of the fuse
3. Connect one end of the third fuse to the point where the plus pole of the second cell and the minus pole of the third cell are connected. Then connect the wire with **label '2'** to the other end of the fuse
4. Connect one end of the fourth fuse to the point where the plus pole of the third cell and the minus pole of the fourth cell are connected. Then connect the wire with **label '3'** to the other end of the fuse
5. Connect one end of the fifth fuse to the point where the plus pole of the fourth cell and the minus pole of the fifth cell are connected. Then connect the wire with **label '4'** to the other end of the fuse
6. Connect one end of the sixth fuse to the point where the plus pole of the fifth cell and the minus pole of the sixth cell are connected. Then connect the wire with **label '5'** to the other end of the fuse
7. Connect one end of the seventh fuse to the point where the plus pole of the sixth cell and the minus pole of the seventh cell are connected. Then connect the wire with **label '6'** to the other end of the fuse
8. Connect one end of the eighth fuse to the point where the plus pole of the seventh cell and the minus pole of the eighth cell are connected. Then connect the wire with **label '7'** to the other end of the fuse

Now the first module cable is completely connected. With the second module cable, you must begin at that point where you end with the first module cable (the position, where the plus pole of the seventh cell and the minus pole of the eighth cell is connected) and repeat the procedure described above, if there are 7 cells remaining.

If there are less than 7 cells connected to the last module, all the remaining wires of the module cable must be connected to the plus pole of the last cell.

This is necessary so that the microcontroller at last module can detect that no voltage is present at the remaining inputs.

After all the module cables are wired, they then can be plugged into the safety unit connectors.
(Module 1 near the RS232 connector and Module 2 near Module 1 Connector and so on).

The software at the measurement modules will use the following numbering scheme:

- Cell**1**…Cell**7** at measurement module **1**
- Cell**8**...Cell**14** at measurement module **2**

And so on.

Upon the first measurement module cable being plug into the safety unit, the green led (near the Reset button) will turn on to indicate power on.

After all the cables are connected to the unit, you should press the RESET button. If the measurement modules are working properly with all the batteries in the correct condition, there will be one green led blinking (near the RS232 connector).

3.4 Temperature Sensors

The temperature sensors are connected to the safety unit. Place the sensors at specific points in the battery, where the highest temperatures are estimated. The accuracy of the temperature sensor is typically ±1°C at 25°C and ±2°C over the total rated temperature range between +5°C and +85°C. The value of the temperature sensor is sampled with a resolution of 12bits at the A/D-converter.

The batteries will be shut down, when the temperature at any sensor rises above 60.0°C.

3.5 Reset Button

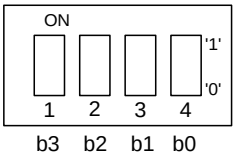
By pressing the button near the LEDs, all measurement modules are restarted. Sometimes it may be necessary, to press the button several times, until the complete unit is resetted properly (green LED flashing).

There is also a cable (2 wires) labelled with “Reset” attached to the unit. This cable allows you to reset the unit remotely. In this case a normally open switch button must be soldered at this cable.

Otherwise leave this cable isolated to avoid unintentional restart of the safety unit.

3.6 DIP Switch Setting on the Main Module

Number of measurement modules to be cascaded on to the main module is determined by the DIP switch setting as follows: (NOTE: Wrong setting will cause error and shut down the relay)



B3	b2	b1	b0	No. of Measurement Modules
0	0	0	0	1
0	0	0	1	2
0	0	1	0	3
0	0	1	1	4
0	1	0	0	5
0	1	0	1	6
0	1	1	0	7
0	1	1	1	8
1	0	0	0	9
1	0	0	1	10
1	0	1	0	11
1	0	1	1	12
1	1	0	0	13
1	1	0	1	14
1	1	1	0	15
1	1	1	1	16

3.7 Load Relay Output

There is another cable attached to the safety unit labelled “Relay”. This output is used to shut down the batteries (stop charging or discharging). This output is optically isolated, meaning that it has no electrical connection to any potential inside the safety unit. The battery must be shut down with a “normally open” contacts of an external load relay that can cut the current path between the battery and the load.

The coil of the load relay must be equipped with a rectifier that is able to clamp the inductive voltage peaks that occur, when the relay is shut down.

Caution: If the rectifier is missing, the safety unit will be destroyed.

To understand, how to connect the relay, see figure in Appendix A (the figure in Appendix A is for a 4 modules safety unit but the principle is the same for a 2 modules unit). The coil of the relay must be connected to the plus pole of an external power supply (24V or less) at one end. The other end of the coil must be soldered to one wire of the cable that is labelled with RELAY. The other wire of the cable must be connected to the minus pole of the power supply. Connect the minus pole of the power supply to earth ground if possible, otherwise the power supply has to be isolated against earth ground. To shut down the battery, the safety unit will cut the current through the coil of the load relay and so the relay will no longer be activated and the load current will be cut.

3.8 Serial Interface (RS232)

There is a 9 pin female D-Sub connector for the serial interface at the safety unit. Here you can plug a standard 9 pin PC serial cable. The serial interface is unidirectional, meaning data is only transmitting from the safety unit to the computer. Sending data from computer to safety unit will have no effect. Use the following settings at the PC, to ensure data transmission to work properly.

Baudrate	Databits	Parity	Stopbits	Protocol
9600	8	None	1	None

In this version the serial interface is just used for displaying data and status messages. For displaying the data at the computer, you can use any standard terminal program (i.e. Hyper Terminal© with Windows© operating system). During normal operation, a set of data is transmitted from the safety unit to PC at an interval of one minute. The dataset includes 28 cell voltages and 8 temperature values. Here is an example for one dataset.

C1= 3.24V; C2= 3.50V; C3= 3.51V; C4= 3.51V; C5= 3.52V; C6= 3.52V; C7= 3.52V; C8=3.99V; C9=3.37V; C10=3.40V; C11=3.41V; C12=3.39V; C13=3.39V; CI4=3.39V; C15=3.55V; C16= 3.47V; C17= 3.45V; C18= 3.48V; C19=3.45V; C20= 3.45V; C21= 3.45V; C22=2.93V; C23=2.71V; C24=2.91V; C25=3.02V; C26= 2.89V; C27= 2.77V; C28= 3.00V;

T1= 26.2DegC; T2= 25.2DegC; T3= 25.4DegC; T4= 25.1DegC; T5= 25.5DegC; T6= 24. 7DegC; T7= 25.2DegC; T8= 25.3DegC;

Each cell is shown with cell number and the voltage value in volts. C1= 3.24V meaning the cell number one has a voltage of 3.24V. If there are some inputs not connected at the last module, the corresponding cell numbers will always be displayed with 0V. Below the voltage values, the

temperature values are displayed. T3= 25.4DegC meaning temperature sensor 3, a temperature of 25.4 degrees centigrate was measured.

3.9 LEDS

At the main module of the safety unit, on board are 5 LEDs indicator to show the different modes of operation. The following states are as followed: Ok, Fault, OV, UV and OT. There is another green led located next to the RESET button to indicate power on.

The Ok LED (green color): When this LED is blinking, it shows that all the batteries are in normal condition.

The Fault LED (red color): When this LED is on, there is a fault at one of the measurement modules or there is an error in hardware DIP switch setting on the main module. In this case, error message will be transmitted to the computer. Two different possible messages are:

1. #Measurement error at Module X, Battery Shut Down! Check connection … Press Reset to restart.

   In this case the module with number X probably has a technical defect at the module. The battery is shut down and all measurement modules are powered down to reduce current consumption. If you can fix the problem, the modules can be restarted by pressing the RESET button.

2. #Error Detected at Module X, Battery Shut Down! Check hardware setting … Press Restart to restart.

   In this case the module X is not included in the main module. The DIP switch setting could be incorrect. To restart the safety unit press the RESET button.

The OV LED (red color): This LED indicates OVERVOLTAGE. When this LED is on, voltage of more than 4.2V is detected at any of the connected cells. In this case, the battery is shut down and all measurement modules are powered down to reduce current consumption. The following error message will also be transmitted to the computer:

#Overvoltage at Module X, Battery Shut Down!

Where X is the number of the measurement module that transmitted the error message. To find the cell that caused the error message, you must examine the last data set transmitted to the computer. You must check the voltages of the 7 cells connected to the measurement module X. The voltage that is nearest to 4.2V belongs to the cell that caused the battery shut down. You will not be able to restart the safety unit (by pressing the RESET button), until all cell voltages at the battery are below 4.2V.

The UV LED (red color): This LED indicates UNDERVOLTAGE. When this LED is on, there is a voltage of less than 2.7V at any of the connected cells. In this case the battery is shut down and all measurement modules are powered down to reduce current consumption. The following error message will also be transmitted to the computer:

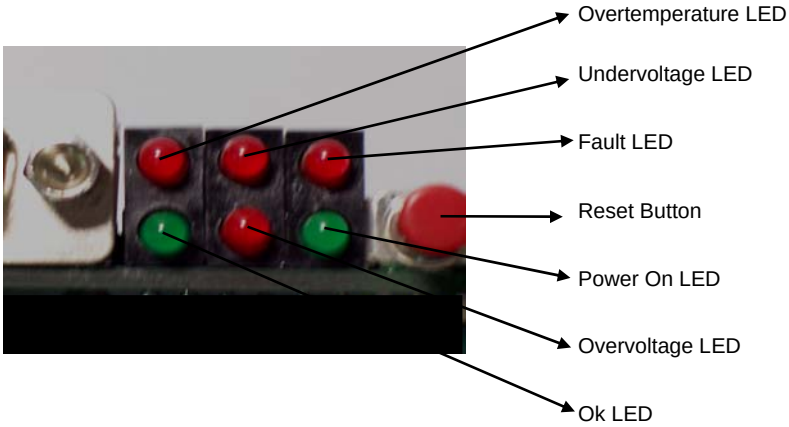
#Undervoltage at Module X, Battery Shut Down!

Where X is the number of the measurement module that transmitted the error message. To find the cell that caused the error message, you must examine the last data set transmitted to the computer. You must check the voltages of the 7 cells connected to the measurement module X. The voltage that is nearest to 2.7V belongs to that cell that caused the battery shut down. You will not be able to restart the safety unit (by pressing the RESET button), until all cell voltages at the battery are over 2.7V.

The OT LED (red color): This LED indicates OVERTEMPERATURE. In this case one of the temperature sensors measured a temperature of more than 60 degrees centigrade. The battery is shut down and all measurement modules are powered down to reduce current consumption. The following error message will also be transmitted to the computer:

#Overtemperature at Module X, Battery Shut Down!

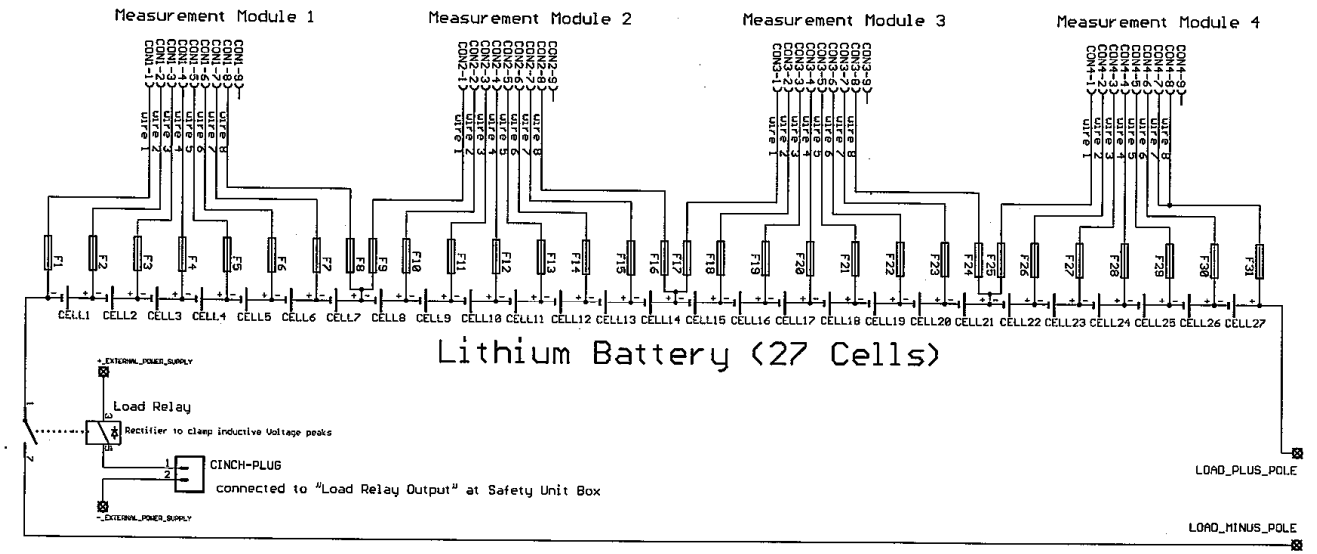
Where X is the number of the measurement module that transmitted the error message. To find the number of the sensor, that caused the error message, you must examine the last data set transmitted to the computer. The temperature that is nearest to 60°C is that one, that caused the battery shut down. You will not be able to restart the safety unit (by pressing the RESET button), until all temperatures at the battery are below 60°C.



4. TECHNICAL DATA

Cell voltage inputs (7 per module)	• Resolution 12 bits • Voltage range full scale +5V
Temperature (2 per module)	• Resolution 12 bits • Temperature range 5°C to 75°C
Overvoltage	• Cell voltage >4.2V
Under-voltage	• Cell voltage < 2.7V
Over-temperature	• Temperature at sensor > 60°C
Power supply	• From battery, 2.7V min. per module 30V max. per module
Current on/off output	• Plug for coil of external relay, current over plug. 100mA max
Current consumption	• 25mA max. with 7 cells @ 3.7V per cell
Operating temperature Range	• 0°C - 70°C

5. APPENDIX A



Connection Scheme for Battery Safety Unit