15S Battery Cell Monitor & Balancer

PRODUCT MANUAL

1 General Description

The 15S Battery Cell Monitor & Balancer is a precision device that ensures multi-cell batteries are maintained in an optimal state, improving system reliability and prolonging battery life.

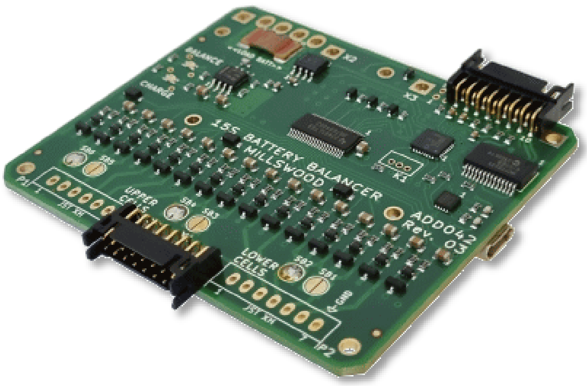

Figure 1 – 15S Battery Cell Monitor & Balancer

The 15S Battery Cell Monitor & Balancer does exactly as its name suggests: it monitors cells within a battery, and it balances those cells if and when they require it. Comprehensive data detailing the battery's internal state is sent via the CAN interface.

2 Features

- Transforms a "dumb" battery into a smart (self-balancing) battery.
- Supports multiple battery chemistries – LiPo, LiS and LiFe.
- Supports 9 to 15S batteries.
- Bidirectional 80 Amp current sensor.
- CAN interface provides control and monitoring of voltages, currents, temperatures.
- Battery temperature monitoring with up to 3 external sensors.
- Heating and cooling outputs to control battery temperature.
- JST connector option for direct connection of 6S batteries.
- User-friendly configuration software.
- Rich variety of balancing control options.
- Weight: 23g.
- PCB dimensions: 62 x 72mm

3 Usage

The Battery Balancer is intended to be connected to a battery, installed into a UAV and interfaced to the vehicle's CAN bus. A pair of indicator lights on the front panel give a "go / no go" indication of the battery's state of balance and state of charge. More detailed battery information is available via the CAN bus.

Use of the battery balancer confers a number of operational advantages:

- Batteries do not need to be removed periodically to check for balance.
- Battery status is available instantly, either directly from the front-panel LEDs, or remotely from the telemetry data sent on the CAN bus.
- Batteries are maintained in a state of balance, improving flight-readiness.

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4 Contents

5 Quick Start Guide

- Download the configuration utility from www.millswoodeng.com.au/resources.html and run it.
- Connect the balancer to your PC with a micro-USB cable.
- Click on the "Connect" menu item to establish a connection with the balancer.
- Click on the "Device" menu and check that reading the balancer's configuration settings works.
- Disconnect the balancer from your PC.
- Using the wiring diagram (given in section 12) corresponding to the number of cells in the battery, bridge the appropriate solder bridges on the balancer with a blob of solder.
- Using the same wiring diagram, wire up the cell balance connections between balancer and battery. Check your solder bridges and balance connections carefully before connecting the battery – a mistake here may damage the balancer.
- Reconnect the balancer to your PC.
- Click on the "Voltages" tab and check that cell voltages are being measured correctly.
- Click on the "Current and Temperature" tab and check that these are also being measured correctly.
- If desired, adjust the configuration settings and write these to the balancer.
- If desired, save your settings to a file.

6 Visual indicators

There are 2 LED indicators on the front panel, one for balance and one for charge. The LED colours have the following meanings:

6.1 Balance LED

● GREEN	The battery is balanced.
● RED	The battery is not balanced.
● OFF	No battery connected (or the Battery Balancer is sleeping).

Table 1 – Balance LED states

The balancing LED flashes when balancing is occurring.

6.2 Charge LED

● GREEN	The battery is fully charged.
● ● RED & GREEN	The battery is fully charged, but one (or more) cells are over or under voltage.
● RED	The battery is not fully charged.
● OFF	No battery connected (or the Battery Balancer is sleeping).

Table 2 – Charge LED states

The charge LED is only valid when the battery current is zero (i.e. not being charged and not under load).

The thresholds for both the charge and balance LEDs are user-configurable.

7 Connectors

7.1 Micro-USB connector

Used to connect the Battery Balancer to a PC. This connection is only required when configuring the Battery Balancer, although it may also be useful for displaying a battery's cell voltages, currents and temperatures in real-time.

7.2 X1 – Battery balance connector

X1 connects to the battery's cell balance connections. There are 3 possible connector arrangements:

1. Harwin 16-way right-angle, M80-5401642
2. Hirose 16-way right-angle, DF11-16DP-2DS(52)
3. JST 7-way right-angle (x 2), S7B-XH-A(LF)(SN)

The 16-way Hirose DF11 is the preferred connector. The mating connector's part number is DF11-16DS-2C.

Mating connectors for the Harwin M80 include M80-4611605, M80-4611642, M80-4811605 and M80-4811642.

Wiring for the cell balance connections is dependent on the battery's cell count (see section 12, Appendix 2 – Wiring diagrams). Unfortunately the Harwin and Hirose connectors have different pin numbering arrangements. For this particular application the Harwin pin numbers map to cell numbers more naturally than the Hirose, and so the wiring diagrams in section 12 use the Harwin pin numbers.

The mapping of cell balance connections to pin numbers is as follows:

Name	Harwin M80 pin number	Hirose DF11 pin number
Cell 15+	16	2
Cell 14+	15	4
Cell 13+	14	6
Cell 12+	13	8
Cell 11+	12	10
Cell 10+	11	12
Cell 9+	10	14
Cell 8+	9	16
Cell 7+	8	1
Cell 6+	7	3
Cell 5+	6	5
Cell 4+	5	7
Cell 3+	4	9
Cell 2+	3	11
Cell 1+	2	13
Cell 1- (Ground)	1	15

Table 3 – Balance connector pin numbering

JST connectors mate directly with the standard cell balance cables fitted to 6S batteries. If using the JST connectors remember to bridge solderbridges SB2, SB4 and SB6.

7.3 X2 – Internal current sense connector

The internal current sensor operates independently from the rest of the battery balancer, and use of the internal current sensor is entirely optional. Because of the wide common-mode range of the current sensor it may be wired in series with either the positive or negative battery lead.

The PCB footprint is designed to take a Harwin M80-5000000M5-04-PM3-00-000. The mating connector is a Harwin M80-4000000F1-04-PF5-00-000.

Pins on this type of connector are only rated for 40 Amps, and so pairs of pins wired in parallel must be used if the current exceeds this value.

If wired in series with the positive battery lead, pins A and B should be connected to the battery's positive terminal, and the load connected to pins C and D. This results in charging current being reported as positive.

Reverse the connections if sensing current in the battery's negative lead.

7.4 X3 – Interface connector

There are 2 possible connector arrangements:

1. Harwin 20-way right-angle, M80-5402042
2. Hirose 20-way right-angle, DF11-20DP-2DS(52)

The 20-way Hirose DF11 is the preferred connector. The mating connector's part number is DF11-20DS-2C.

Mating connectors for the Harwin M80 include M80-4612005, M80-4612042, M80-4812005 and M80-4812042.

Unlike the cell balance connections, the Hirose connector pin numbers are more logical here, as so Table 4 is ordered using the DF11 pin numbers.

Name	Hirose DF11 pin number	Harwin M80 pin number	Type	Description
CAN L	1	10	I/O	CAN data, low side
CAN H	2	20	I/O	CAN data, high side
I_EXT-	3	9	Input	External current sense, negative input
I_EXT+	4	19	Input	External current sense, positive input
Ground	5	8	Ground	
3.3VDC power	6	18	Output	Power source for external current sensor
Ground	7	7	Ground	
Analog voltage	8	17	Input	Analog voltage input
Ground	9	6	Ground	
Master shutdown	10	16	Input	Active low master shutdown input
TS1-	11	5	Input	Temperature sensor 1, negative input
TS1+	12	15	Input	Temperature sensor 1, positive input
TS2-	13	4	Input	Temperature sensor 2, negative input
TS2+	14	14	Input	Temperature sensor 2, positive input
TS3-	15	3	Input	Temperature sensor 3, negative input
TS3+	16	13	Input	Temperature sensor 3, positive input
Ground	17	2	Ground	Ground reference for cool output
Cool	18	12	Open-drain	Connection for battery cooling device
Ground	19	1	Ground	Ground reference for warm output
Warm	20	11	Open-drain	Connection for battery warming device

Table 4 – Interface connector pin allocations

7.4.1 CAN interface

The CAN interface is not terminated internally. The CAN protocol is described in detail in the CAN protocol document.

7.4.2 Analog voltage

The analog voltage input is used to turn balancing on and off, if configured to do so. It may be driven by a logic-level signal if its switching threshold is configured appropriately.

7.4.3 Master shutdown

Pull low to shut down the battery balancer. This input has an internal pull-up resistor, and so connection to this pin is optional.

7.4.4 External temperature sensors

The battery balancer supports up to 3 external temperature sensors. Connection of temperature sensors is optional. The temperature sensor inputs are designed for 10k NTC thermistors. Devices with a beta of 3950K will give the most accurate results (typically within +/-1 degree from -20 to +65C), but any 10k NTC thermistors will work acceptably well.

Connect thermistors between TSx+ and TSx- pins. Although these pins are designated plus and minus, 10k NTC thermistors are not polarised and may be connected with either polarity.

The temperature sensor inputs are not referenced to ground; do not allow these connections to come into contact with any externally applied voltages or damage to the battery balancer may occur.

7.4.5 External current sensor

An external current sensor with a differential voltage output may be connected across the I_EXT+ and I_EXT- pins. The 3.3VDC power output is provided to power this sensor. To conserve power the 3.3VDC power output is turned off whenever the battery balancer is asleep or shut down.

External current sensing may be used at the same time as internal current sensing. Measured currents are reported separately in the CAN data streams.

7.4.6 Warm output

This open-drain output switches low when the battery temperature is below 25% of the configured normal operating range. There is 5°C of hysteresis applied to the switching threshold.

This output is intended to turn a battery heater on.

7.4.7 Cool output

This open drain output switches low when the battery temperature is above 75% of the configured normal operating range. There is 5°C of hysteresis applied to the switching threshold.

As this output may be used to drive a fan, a recirculation diode is included.

8 Configuration Software

The configuration utility is a Windows application that allows configurable settings to be read from and written to the Battery Balancer. Settings can also be saved to file and retrieved for later use. The file format is XML, and so Battery Balancer settings files can be inspected using any browser or text editor.

The configuration utility may be downloaded from www.millswoodeng.com.au/resources.html

To configure the Battery Balancer, simply connect it to a PC with a micro-USB cable and run the configuration utility. Be aware that some micro-USB cables intended for charging do not have the data lines connected. These cables do not work.

The Battery Balancer will power itself from the USB connection.

The main page of the configuration utility consists of tabbed pages, and there is a menu across the top. The "Connection" menu allows selection of the serial port to which the Battery Balancer is connected. Once connected successfully, the "Device" menu will become accessible. This menu allows reading and writing to the Battery Balancer, as well as viewing its serial number and upgrading its firmware.

8.1 Configure tab

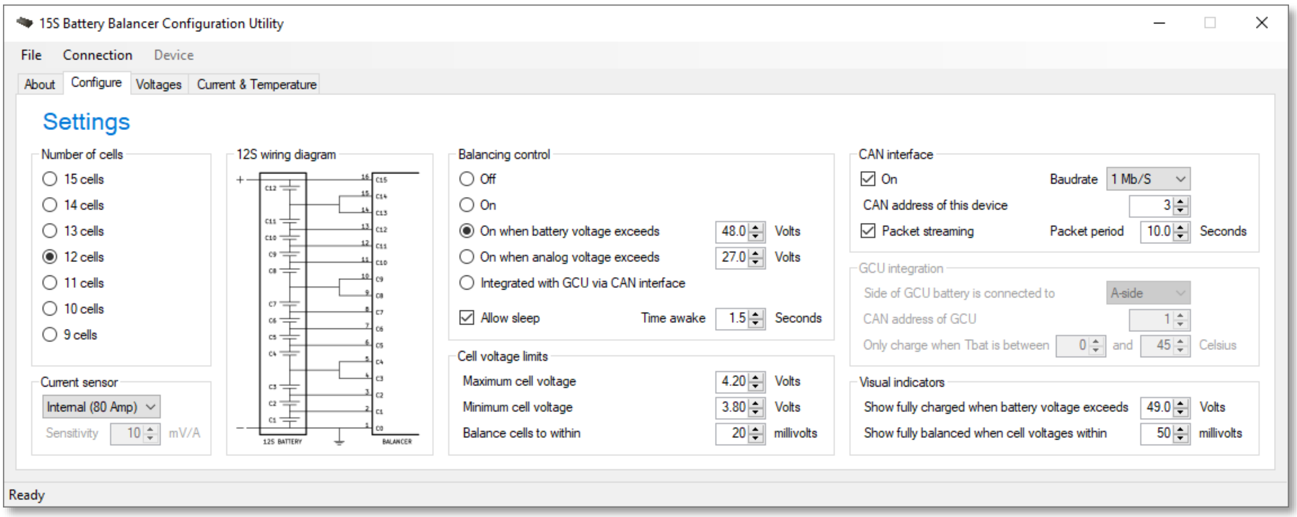


Figure 2 – Configure tab

When written to the Battery Balancer, settings are stored in non-volatile memory and are retained after power is removed.

8.1.1 Number of cells

Select the number of cells in the battery.

8.1.2 External current sensor

Select the gain of the external current sensor.

8.1.3 Wiring diagrams

Click on the diagram to display a larger version of the wiring diagram corresponding to the number of cells selected. Appendix 2 – Wiring diagrams are also given in section 12 of this document.

8.1.4 Balancing control

Select one of the 4 control options:

- **Off:** Balancing is disabled.
- **On:** Balancing is enabled and occurs whenever:
  - the cell voltage spread (max – min) exceeds the cell balancing target, or
  - a cell's voltage exceeds the maximum permitted cell voltage.
- **On when battery voltage exceeds:** Balancing is enabled whenever the battery voltage is above the threshold specified.
- **On when analog voltage exceeds:** Balancing is enabled whenever the analog input voltage is above the threshold specified.

8.1.5 Power management

If "**Allow sleep**" is checked, the Battery Balancer will go to sleep if no activity is detected for the length of time specified in the "Sleep after" box. This time can range from 2 seconds to over an hour. Activity is defined as any of: balancing, CAN bus activity, being connected to a PC. The Balancer will wake from sleep automatically if any of these activities recommence.

When sleeping occurs the balancer will turn off both the "Warm" and "Cool" outputs. If the battery absolutely must maintain its temperature at all times and there is a risk that it may go to sleep, do not allow sleeping to occur.

When the Battery Balancer goes to sleep, the 2 LEDs will glow green very faintly. This is normal and does not draw any appreciable current.

8.1.6 Cell voltage limits

- **Maximum cell voltage:** The maximum safe voltage for cells to be charged up to. Cells with voltage exceeding this limit will be discharged until they reach this limit.
- **Minimum cell voltage:** Cells will never be discharged below this voltage.
- **Balance cells to within:** The target cell voltage spread that the Battery Balancer will attempt to reach by discharging cells with higher voltages. There is 10mV of hysteresis, so that once the target is reached balancing will not resume until the spread between cells exceeds the target plus 10mV.

8.1.7 CAN interface

- **Bit rate:** Select the same bit rate for all devices sharing the CAN bus.
- **CAN address of this device:** Choose a unique 16-bit address for the Battery Balancer. The Battery Balancer will respond to this address and also to the global address of 65535 (FFFF Hex).
- **Packet streaming:** Enables the regular transmission of measured data. Data may also be requested (polled) from the Battery Balancer.
- **Packet period:** Sets how often measured data is transmitted, if packet streaming is enabled.

The CAN protocol is described in detail in the CAN protocol document.

8.1.8 Battery temperature limits

8.1.8.1 Temperature qualification

From firmware version 2.04, balancing can be "qualified" by battery temperature. This means that balancing can be restricted to only occur when the battery temperature is within safe limits. One or more external temperature sensors must be fitted for temperature qualification to occur, and the worse-case values from all external sensors are used in making the balancing decision.

If no external temperatures sensors are fitted then balancing occurs regardless of battery temperature (the internal temperature sensor is not used to qualify balancing).

8.1.8.2 Warm and cool outputs

The warm and cool outputs (for driving a heater and/or fan respectively) also use the battery temperature limits to determine when to switch on and off.

The warm output is active (switches low) when the temperature is below 25% of the range specified (i.e. the battery is getting cold and needs warming). The cool output is active (low) when the temperature is above 75% of the range specified (i.e. the battery is getting hot and needs cooling). 5 degrees of hysteresis is applied to each of these switching thresholds.

It does not matter which input the external temperature sensor is connected to – all 3 inputs are processed and the worse-case values used. If no external temperature sensors are detected then the internal temperature sensor is used instead. This is approximate at best – it is only intended as a last resort to cater for the case when all 3 sensors have failed or become disconnected.

8.1.9 Visual indicators

- **Show fully balanced when cell voltages within:** This is the threshold for determining the colour of the balance LED. If the cell voltage spread is less than this threshold, the balance LED will be green.
- **Show fully charged when battery voltage exceeds:** This is the threshold for determining the colour of the charge LED. If the battery voltage is above this threshold, the charge LED will be green.

These thresholds apply only to the visual indicators; they do not affect operation of the Battery Balancer in any way.

Note that with default configuration settings, the charge LED is only valid at zero current. When under any significant load the charge LED will be red, but this does not mean that the battery is flat.

8.2 Voltages tab

The configuration utility is able to display a battery's cell voltages in real-time.

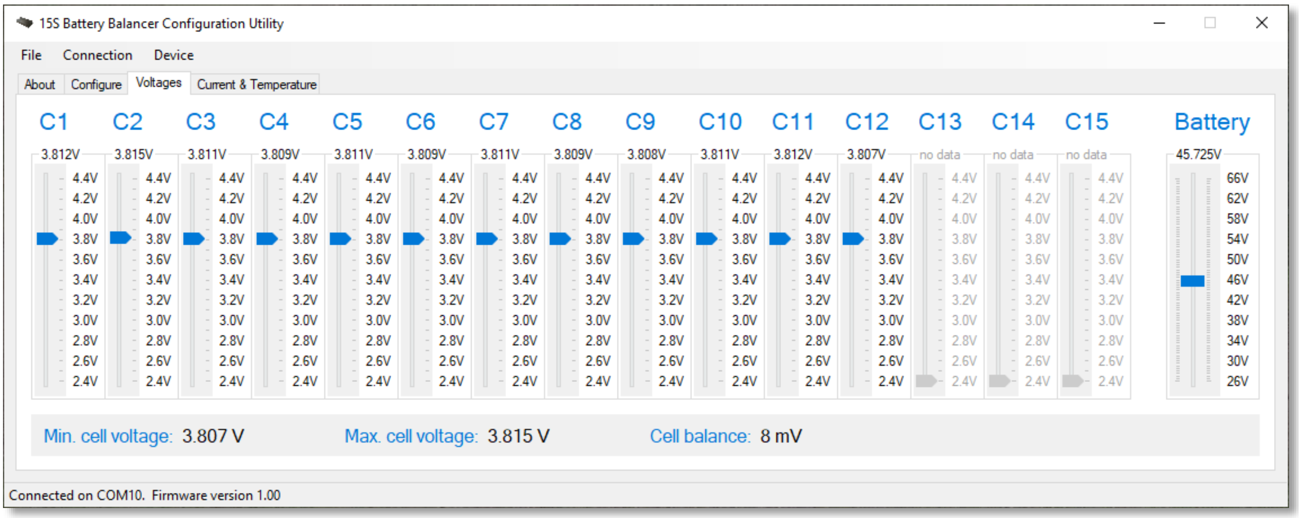


Figure 3 – Voltages tab

All of this data is also available via the CAN interface. The CAN protocol is described in detail in the CAN protocol document.

8.3 Current and Temperature tab

The configuration utility is able to display measured currents and temperatures in real-time.

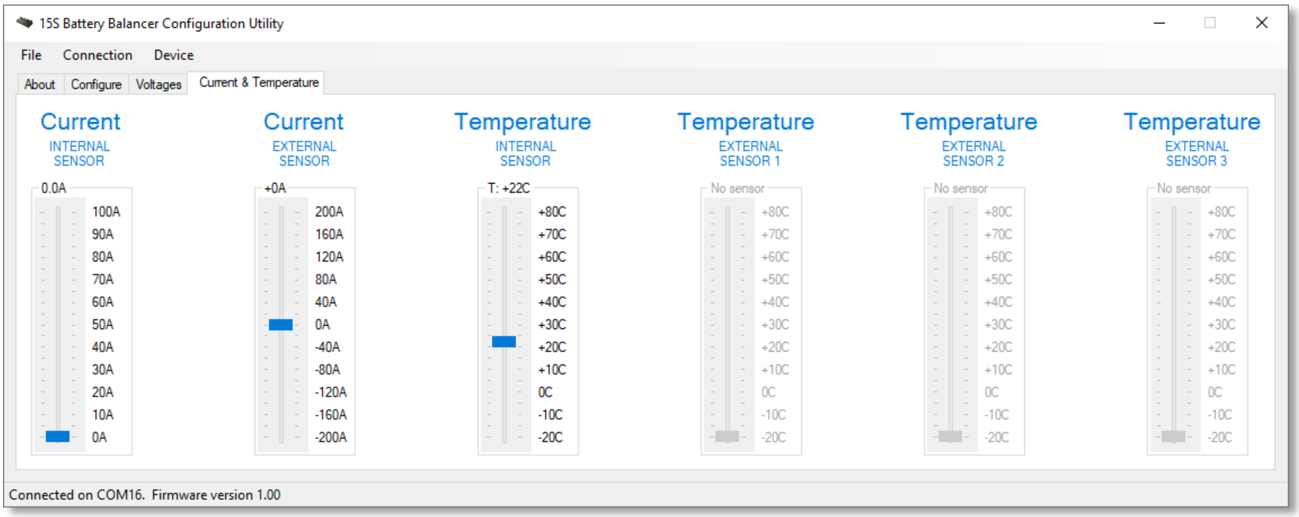


Figure 4 – Current and Temperature tab

All of this data is also available via the CAN interface. The CAN protocol is described in detail in the CAN protocol document.

9 Specifications

9.1 Absolute Maximum Ratings

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Symbol	Parameter	Min	Max	Unit
V_{BAT}	Battery voltage	-0.3	+100	V_{DC}
V_{CELL}	Cell voltage	-0.3	+9	V_{DC}
V_{ANALOG}	Analog input voltage range	-100	+100	V_{DC}
I_{SENSE}	Internal current sensor current	-100	+100	A_{DC}
V_{ISENSE}	Internal current sensor voltage range	-14	+80	V_{DC}
V_{CAN_L}, V_{CAN_H}	CAN L and H voltage range	-58	+58	V_{DC}
V_{WARM}, V_{COOL}	Warm and Cool voltage range	-0.3	+68	V_{DC}
T_{INT}	Internal temperature	-55	+105	°C

Table 5 – Absolute Maximum Ratings

9.2 Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V_{BAT}	Battery voltage	18	65	V_{PP}
V_{CELL}	Cell voltage	2	5	V_{DC}
I_{SENSE}	Internal current sensor current	-80	+80	A_{DC}
V_{ISENSE}	Internal current sensor voltage range	-14	+80	V_{DC}
V_{ANALOG}	Analog input voltage range	0	50	V_{DC}
V_{CAN_L}, V_{CAN_H}	CAN L and H voltage range	-12	+12	V_{DC}
V_{CAN_L}, V_{CAN_H}	CAN L and H voltage range	-12	+12	V_{DC}
V_{WARM}, V_{COOL}	Warm and Cool voltage range	0	63	V_{DC}
T_{INT}	Internal temperature	-40	+85	°C

Table 6 – Recommended Operating Conditions

9.3 Electrical Specifications

Minimum and maximum limits apply across the range of values given in the recommended operating conditions. Typical values are measured with T_{INT} = +25°C.

	Min	Typ	Max	Unit
Cell parameters				
Discharge resistance		10		Ω
Measurement accuracy (V_{CELL} = 3.6 – 4.3 V)	-40	±10	+40	mV
Measurement accuracy (V_{CELL} = 3.2 – 4.6 V)	-40	±15	+40	mV
Measurement accuracy (V_{CELL} = 2.0 – 5.0 V)	-50	±25	+50	mV
Balancing hysteresis		+10		mV
Internal current sensor				
Measurement accuracy		±1		A
Series resistance		250		μΩ
3.3VDC power output				
Voltage	3.1	3.3	3.5	V
Current	50		100	mA
Analog input				
Measurement accuracy		±250	±500	mV
Input impedance	220			kΩ
Warm and Cool outputs				
Voltage (active low)			50	mV
Current (active low, sinking current)			1	A
Quiescent battery current				
12S Lipo, awake, LEDs on		5		mA
12S LiPo, asleep		60		μA
Temperature sensing (using 3950K 10k NTC)				
Measurement accuracy (-20 to +65°C)		±1	±2	°C

Table 7 – Electrical Specifications

10 Document version history

10.1 0.9 -> 1.0

- Initial release.

10.2 1.0 -> 2.0

- Internal current sensor changed to bi-directional.
- Analog input voltage range increased (section 9).
- External power output voltage changed.
- Wiring diagrams updated to reflect new solderbridges (section 12).
- CAN common-mode voltage range updated (section 9).
- Mating connector part numbers added (section 7).

10.3 2.0 -> 2.1

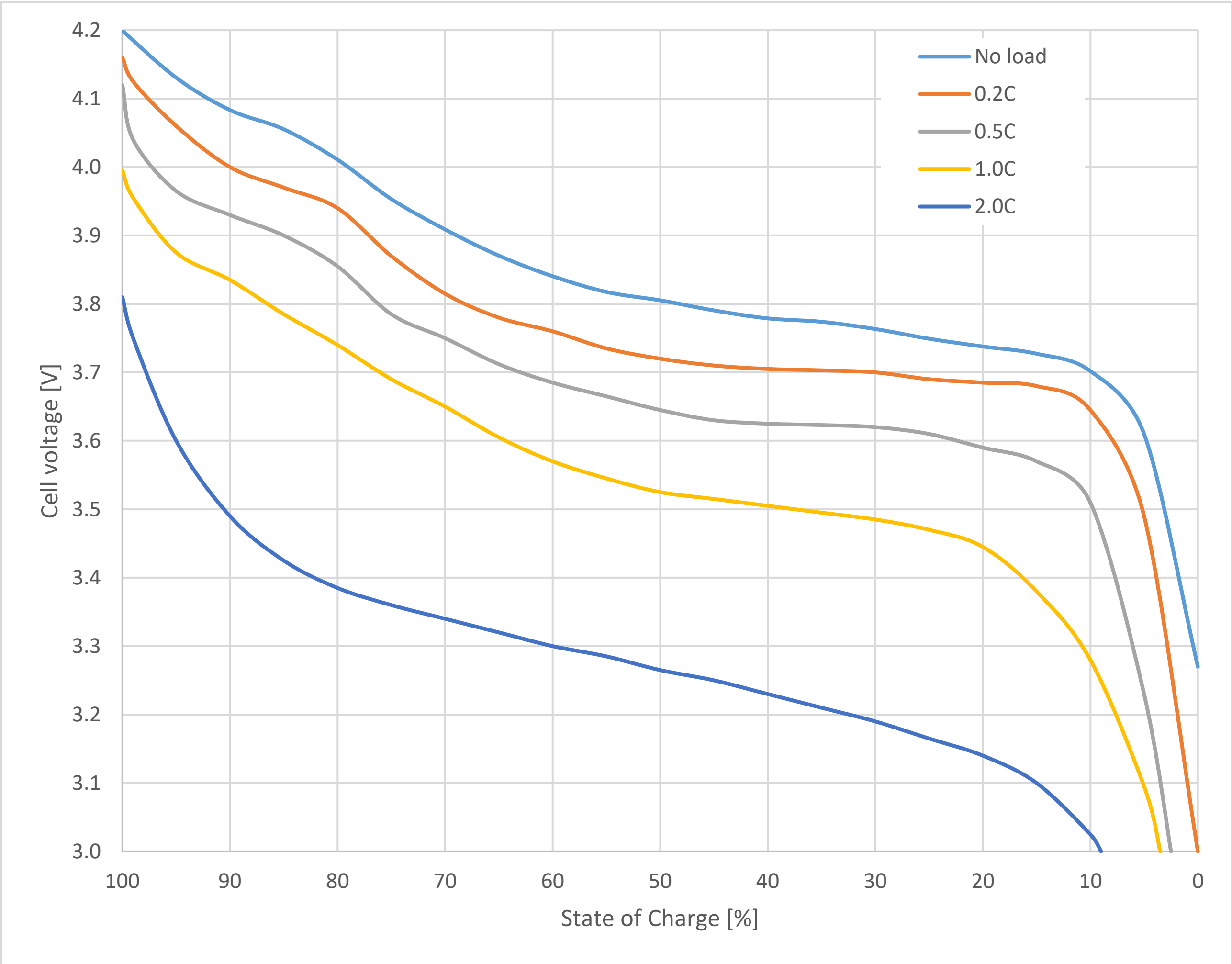
- Description of X1 (cell balance connector) updated to include Hirose DF11 and JST XH connectors.
- Description of X3 (interface connector) updated to include Hirose DF11 connector.
- Description of X3 (interface connector) updated to include warm and cool outputs (added at hardware rev. 3).

10.4 2.1 -> 2.2

- GCU integration section changed to Battery temperature limits. Description of temperature qualification added. Description of warm and cool output behaviour added.
- Electrical specifications for Warm and Cool outputs added.
- Electrical specifications for Quiescent current added.
- Power management section added describing the changed sleep behaviour of firmware version 2.04 and later.

11 Appendix 1 – Reference data

11.1 Typical Lithium polymer characteristics at 23 °C

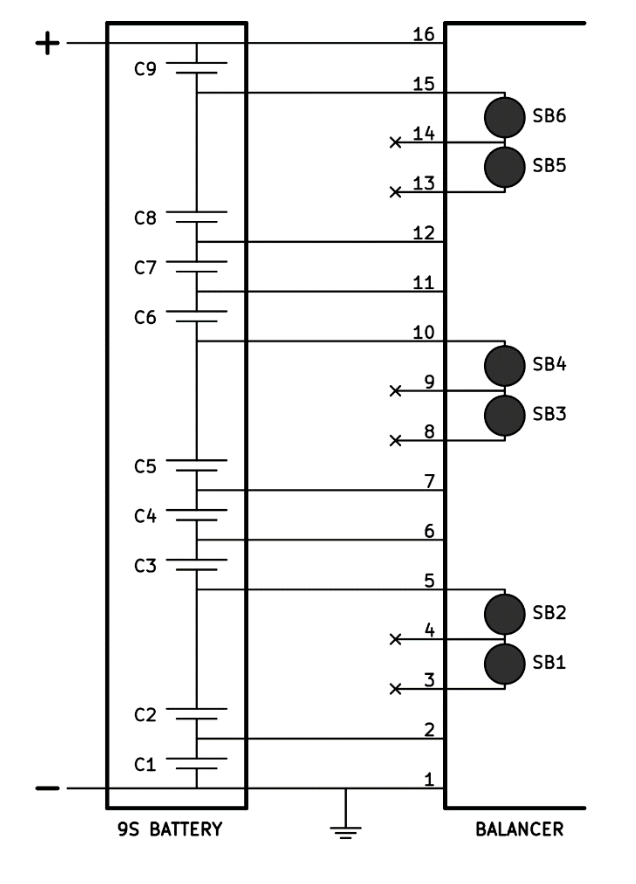


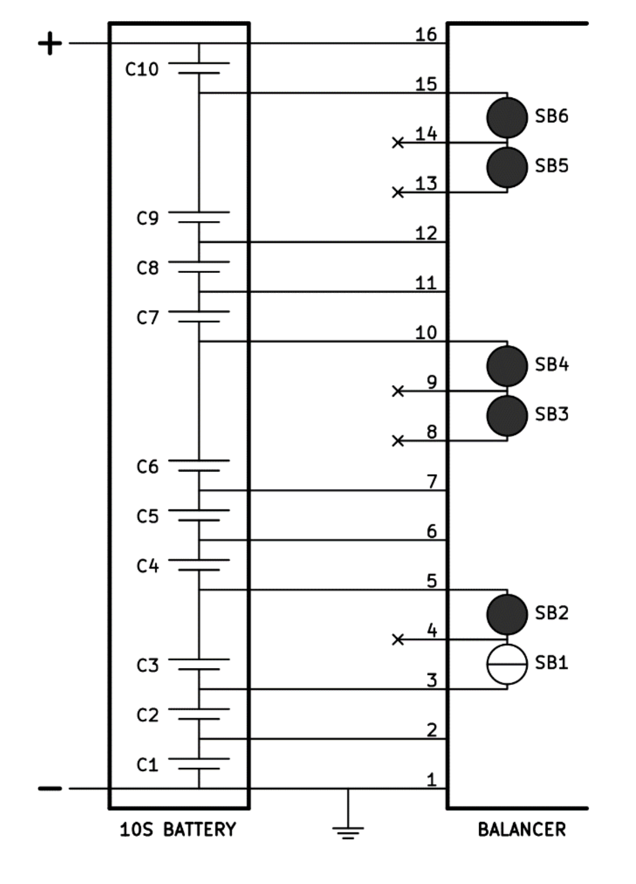
Graph 1 – LiPo cell voltage versus state of charge at 23 °C

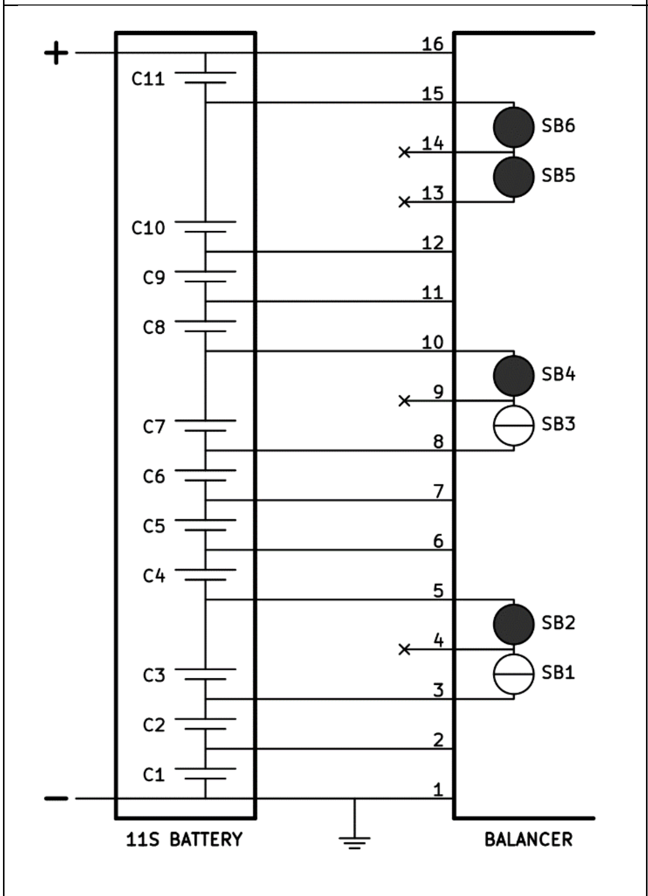
With regard to Graph 1, the no load curve is the average of a large number of datasets. It is the only curve that applies to LiPo cells in general. The loaded curves vary significantly between batteries because manufacturers use different criteria to determine their C ratings.

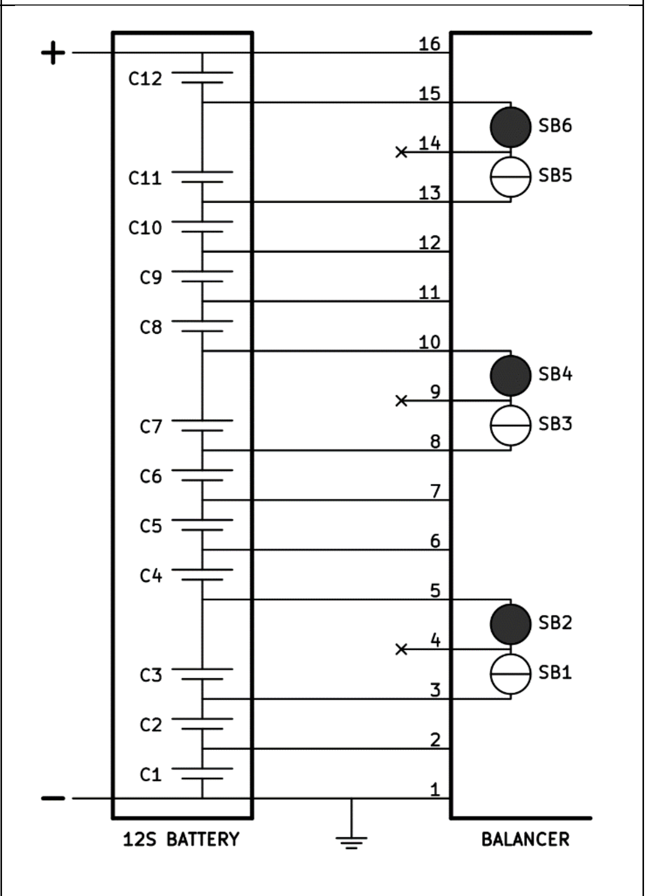
12 Appendix 2 – Wiring diagrams

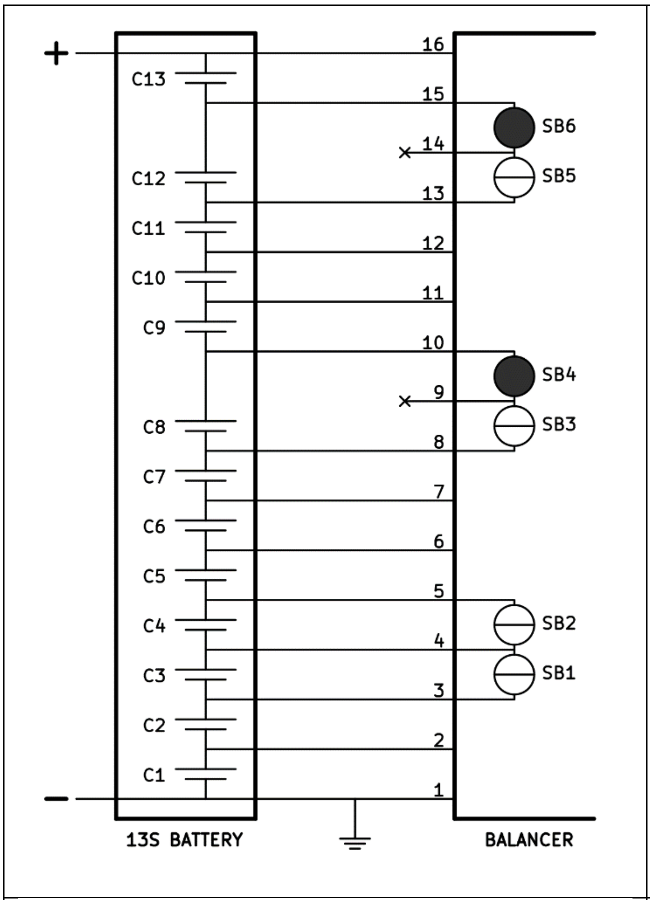
Note that pin numbers are Harwin M80, not Hirose DF11.







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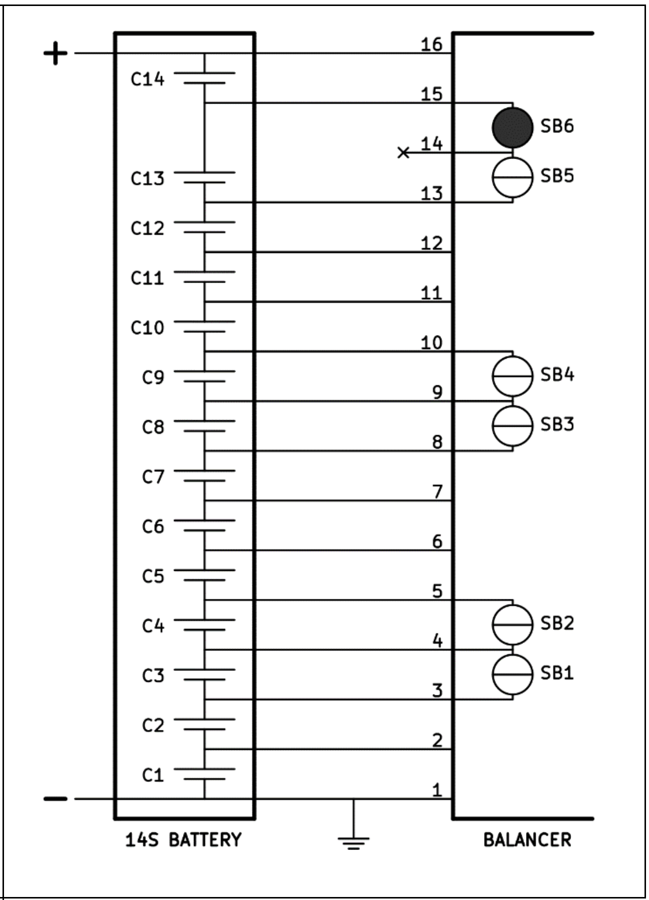
13S BATTERY
BALANCER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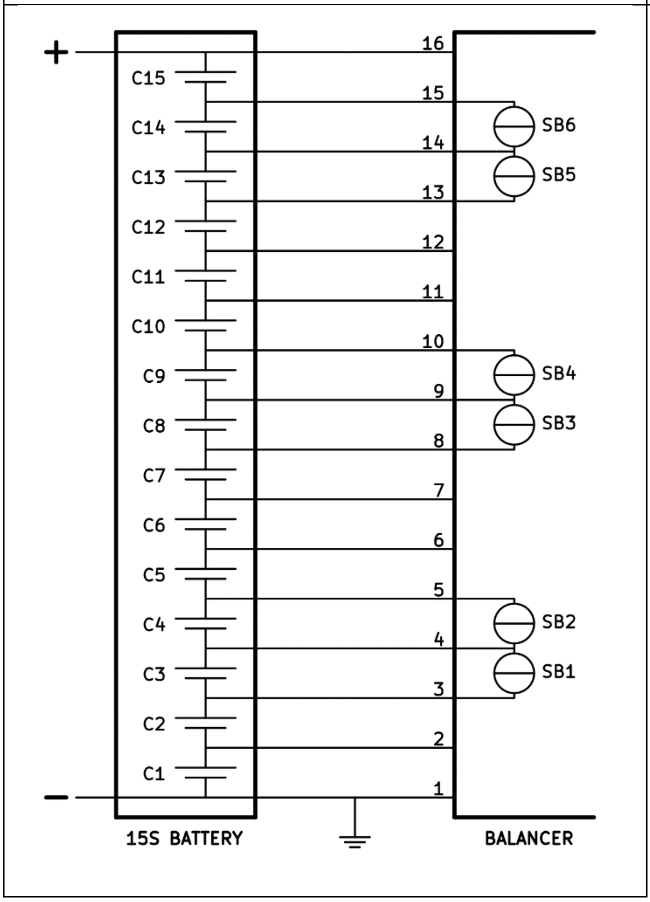
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