

Evaluation board for the SLB series for Series-Parallel Connection

EVSLB-SCTR02

User Guide

Description

Nichicon "SLB" series are "Small Lithium Titanate Rechargeable Batteries" ideal for powering IoT systems. The EVSLB-SCTR02 is an evaluation board allows you to connect up to 6 SLB12400L151 units in any combination of series or parallel for evaluation. Each evaluation board is equipped with a cell balance circuit with overcharge/over discharge sensing and indicator for each cell. A product that can be configured with an output terminal that can be connected to a daughter board on the EVSLB-BUTI03.

Note: This board has been prepared for the purpose of easy evaluation of the SLB series' characteristics at the research and development stage and its quality cannot be guaranteed. This board is not intended to be used in products or any part thereof.

For product information on the SLB series, please refer to the following web page.

<https://www.nichicon.com/en-us/products/lithium-titanate-rechargeable-batteries/>

Features

- Nichicon LTO battery: SLB12400L151 can be installed onto this board
The SLBs can be mounted easily without soldering; thanks to the on-board socket
- Up to six SLBs can be connected in series or parallel by appropriate wiring the main terminal
- Overcharge / over-discharge detection circuit for each cell
The control threshold voltage (detection start/release) can be set arbitrarily by changing resistors
(The detection signals of each cell are output by OR synthesis)
- Cell balancing circuit
The control threshold voltage (cell balancing start/release) can be set arbitrarily by changing resistors
The cell balance current can be set arbitrarily by changing resistors
Includes LED indicators for visual confirmation of circuit operation
- OV/CB signal terminals allow checking the overcharge and cell balance flags of each cell
- Daughter connection to EVSLB-BUTI03/EVSLB-BUAD04 is available
A backup power supply system using SLB as a storage element can be constructed without wiring

Applications

Power circuits that require higher voltages or larger storage capacity than single cell SLBs.

Standalone energy harvesting power supply system with large intermittent load current,
5V/12V backup power supply, Disaster prevention infrastructure, Smart home, Wireless power receiving system etc.

1. Specifications

- Main Terminal (Input/Output): 14P / 1" pitch Pin header
[Terminals connected to each cell: 3pin (V1N) to 14pin (V6P)]
Allowable voltage and current specifications conform to SLB series specifications per cell:
Charge/discharge current : DC up to 20C (SLB12400L151: 3.0A)
Voltage range : 2.8V to 1.8V
[Overcharge/over-discharge flag terminal: 1pin (OVF) / 2pin (UVF)]
MOSFET open drain output (Active L, reference level = V1N (3pin))
Set the external circuit so as not to exceed the MOSFET specifications (RE1J002YN: ROHM) (*)
- OV/CB Terminal (Output): 13P / 1" pitch Pin header
Outputs overcharge and cell balance flags for each cell
Overcharge flag : Active L
L level = - voltage of the corresponding cell
H level = Pulled up to + voltage of the corresponding cell with 1MΩ
Cell balance flag : Active L
L level = - voltage of the corresponding cell
H level = Pulled up to + voltage of the corresponding cell with cell balancing resistor
When using these signals, refer to the circuit diagram and handle with care for differences in voltage levels.
- Overcharge/over-discharge detection circuit (Initial settings) (*)
Overcharge:
detection voltage: 2.78V; release voltage: 2.71V
Over-discharge:
detection voltage: 1.80V; release voltage: 2.19V
- Cell balancing circuit (Initial settings) (*)
Cell balancing start voltage : 2.66V
Cell balancing release voltage : 2.60V
Cell balancing current : User-settable using Rx13 (x=A to F)
(An additional current of about 2mA flows to light the LED indicator during cell balancing)
- Dimensions: 45mm×56mm×12mm

(*) Please refer to individual datasheets for details.

Small Lithium Titanate Rechargeable Battery "SLB" series (Nichicon)

<https://nichiconbattery.com/>

Voltage detector: XC6135 (TOREX)

<https://product.torexsemi.com/system/files/series/xc6135.pdf>

MOSFET for cell balancing: DMN1019UFDE (Diodes)

<https://www.diodes.com/assets/Datasheets/DMN1019UFDE.pdf>

Small signal MOSFET: RE1J002YN (ROHM)

<https://fscdn.rohm.com/en/products/databook/datasheet/discrete/transistor/mosfet/re1j002yntcl-e.pdf>

2. Appearance and user interfaces

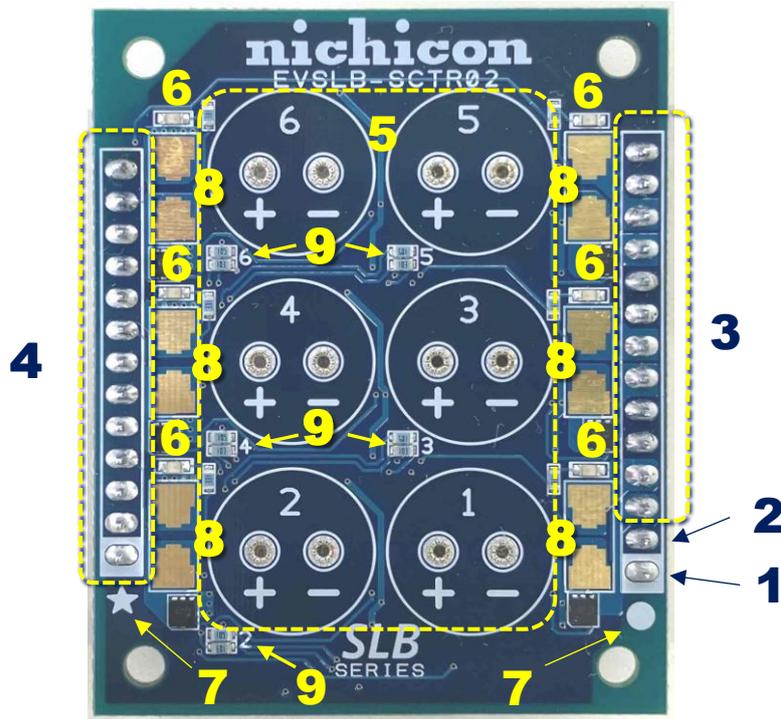


Fig 2-1 Front Side

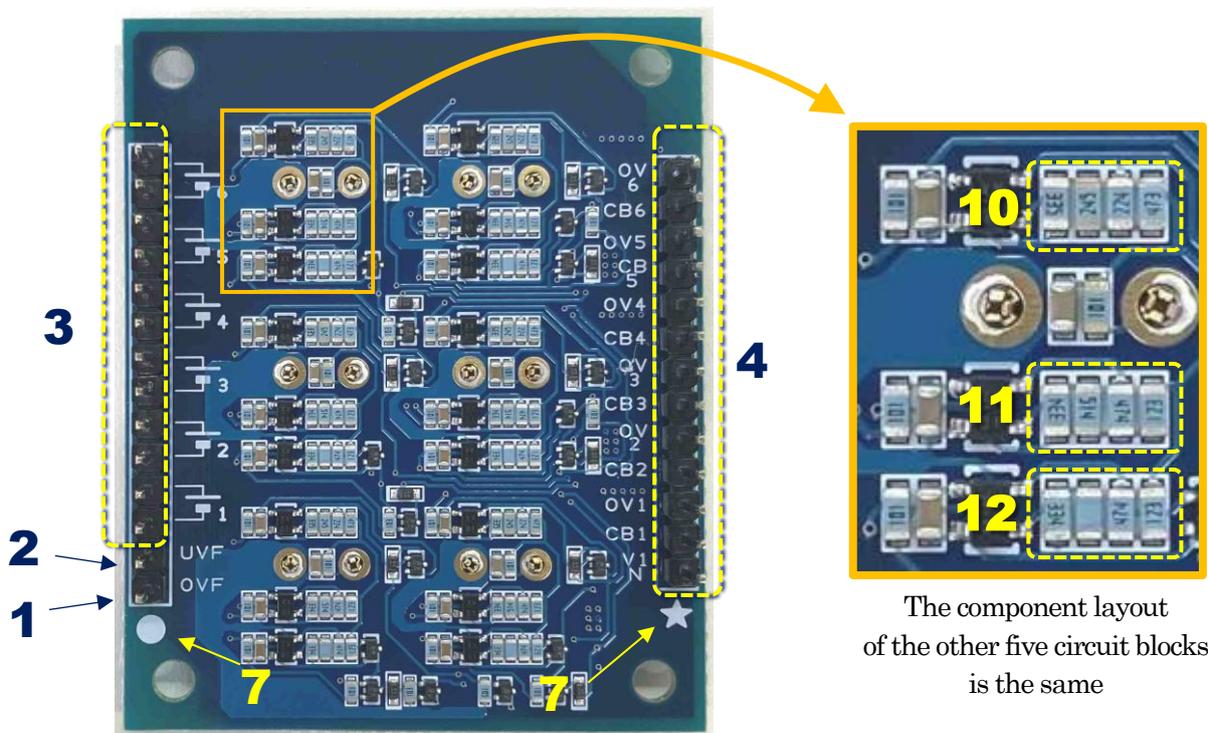


Fig 2-2 Back Side

Table2-1 Functions of each part

No.	Name	Ref.No.	Description
1	Main terminal 1pin	PA1 OVF	Overcharge flag output (n-ch MOSFET open drain, V1N reference, Active L) If overcharge is detected in any of the cells used, this pin outputs Low (V1N). If overcharge is not detected, this pin becomes open. Use by pulling up to any voltage. Leave it open if not used. *Please set the external circuit so that it is within the rating of the output MOSFET.
2	Main terminal 2pin	PA1 UVF	Over-discharge flag output (n-ch MOSFET open drain, V1N reference, Active L) If over-discharge is detected in any of the cells used, this pin outputs Low (V1N). If over-discharge is not detected, this pin becomes open. Use by pulling up to any voltage. Leave it open if not used. *Please set the external circuit so that it is within the rating of the output MOSFET.
3	Main terminal 3pin to 14pin	PA1 VnN/VnP (n=1 to 6)	Terminals are connected to the negative (VnN) and positive (VnP) sides of each cell (n=1 to 6), where n corresponds to the mounting location number of the SLB silk-screened on the board. By connecting these terminals appropriately, any series-parallel connection can be configured for up to six SLBs. Pull out the wiring to the load circuit and charging circuit from the appropriate points of these terminals. For instructions on configuring a series-parallel circuit, see 4.2 Board Setup and Usage Instructions .
4	OV/CB terminal	PA2	Output terminal can monitor the overcharge flag and cell balance flag of each cell. Do not apply voltage or signals from outside. If the SLB is configured in series connection, the H/L levels output from each cell will differ, you need to handle this with care. Leave this terminal open if not using these signals.
5	SLB mounting position	Sx1/Sx2 (x=A to F)	Install SLB12400L151 in this location. Insert the lead wires into the socket holes, paying close attention to the polarity. No soldering is required. When removing the SLB, pull it straight up so as not to put stress on the leads. If you are using less than six SLBs, using them in order from lowest to highest silk screen number simplifies the work required to optimize the protection circuit. For details, see 4.2 Board Setup and Usage Instructions .

*Please refer to the attached parts layout board for reference numbers.

- Table 2-1 Continued -

No.	Name	Ref.No.	Description
6	Cell balancing indicator	Dx1 (x=A to F)	When the SLB cell voltage is within the cell balancing voltage range (2.66V or higher when the voltage is rising, and 2.60V or higher when the voltage is falling), the LED indicator (red) located next to the SLB mounting position will light up. When the SLB cell voltage is outside the cell balancing voltage range, the LED indicator will turn off. For details, see 4.2 Board Setup and Usage Instructions .
7	Alignment marks	★ / ●	When used in combination with EVSLB-BUTI03/EVSLB-BUAD04, you can configure a backup power supply without external wiring by inserting the pin header of this board into the header socket of those boards so that the ★/● marks silk-screened near the connectors on both sides of those boards are in the same position.
8	Cell balancing resistor	Rx13 (x=A to F)	The location to implement the resistor that controls the cell balancing current. Mount an appropriate resistor that can limit the desired cell balancing current. For details on the settings, refer to 4.2 Board Setup and Usage Instructions .
9	Overcharge / over-discharge signal transmission resistor	Rx20/Rx21 (x=A to F)	These resistors are used to level-shift the overcharge and over-discharge flags detected in each cell to form an OR circuit. The resistor connection needs to be optimized so that the detection signal is transmitted correctly according to the SLB connection configuration. For details on the settings, see 4.2 Board Setup and Usage Instructions .
10	Resistor for setting the over-discharge detection threshold	Rx16 to Rx19 (x=A to F)	This resistor sets the operating threshold of the over-discharge detection circuit. You can set any operating threshold by changing the resistance. For details, see 4.2 Board Setup and Usage Instructions .
11	Resistor for setting the cell balancing threshold	Rx9 to Rx12 (x=A to F)	This resistor sets the operating threshold of the cell balancing circuit. You can set any operating threshold by changing the resistance. For details, see 4.2 Board Setup and Usage Instructions .
12	Resistor for setting the overcharge detection threshold	Rx3 to Rx6 (x=A to F)	This resistor sets the operating threshold of the overcharge detection circuit. You can set any operating threshold by changing the resistance. For details, see 4.2 Board Setup and Usage Instructions .

3. Circuit configuration

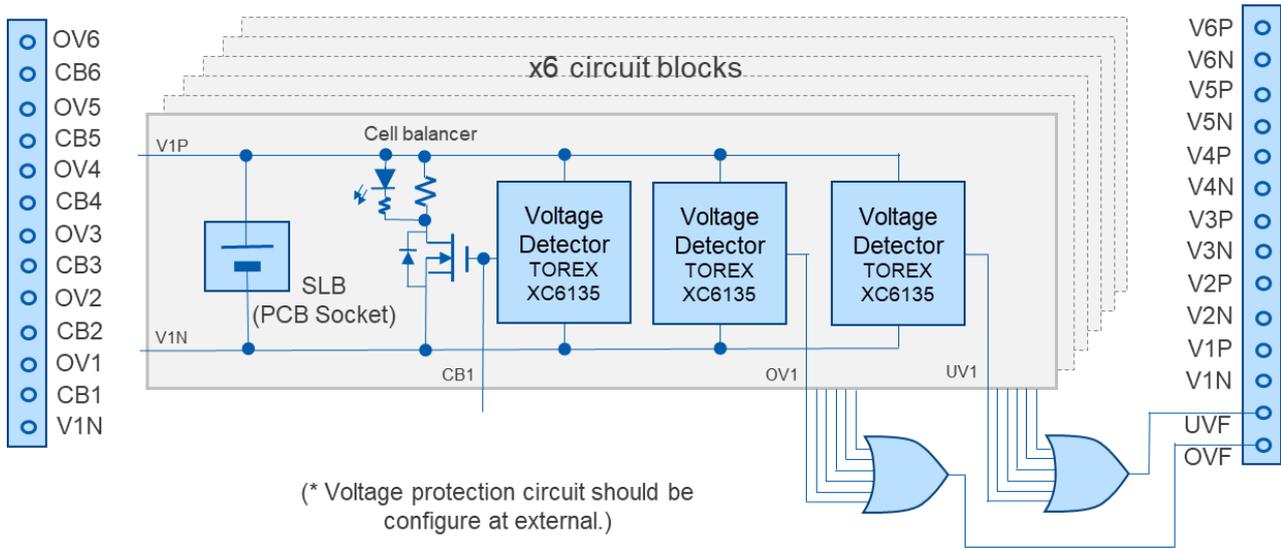


Fig 3-1 Circuit configuration and functional block diagram

4. Usage guidance

4.1 Precautions for use

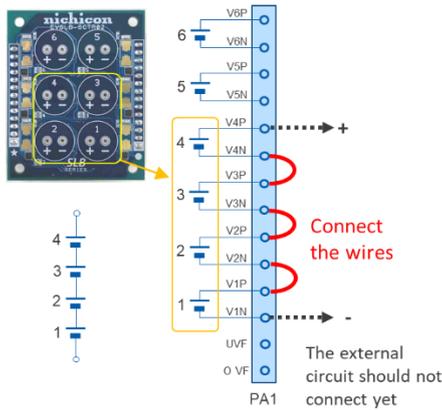
- Before installing the SLB, complete the necessary component mounting and wiring (wiring the main connection terminals, installing cell balance resistors, optimizing the overcharge/over-discharge signal transmission circuit, etc.). If you do it with the SLB installed, there is a risk of electric shock, or damage to circuit components due to unintentional short circuits, etc.
- When installing the SLB, pay close attention to the polarity. This board does not have a protection function against reverse polarity insertion of SLB, so installing it with the wrong polarity will damage the circuit.
- Do not short-circuit the load/charging circuit connection wires or the +/- terminals of each SLB cell. This may not only damage or deteriorate the SLB performance, but may also damage the board and surrounding circuits and cause smoke.
- This board does not have a current cutoff function, so basically an external switch circuit or similar is required to stop overcharging and over-discharging. If overcharging and over-discharging can be avoided by the operating specifications of the external circuit, those protection devices are not necessarily required, but please consider carefully before deciding whether or not to include a protection circuit.
- Do not input an external voltage or signal to the OV/CB terminal, as this may cause the circuit to malfunction or be damaged.
- Pay attention to the GND potential of all connected circuits and measuring instruments. When multiple SLBs are connected in series, the reference voltages of each cell and the control circuits connected to each cell are not all the same, so you need to pay attention to the differences in voltage levels when observing and using input and output signals.

4.2 Board Setup and Usage Instructions

Step1. Wiring of SLB series/parallel connection

Connect the corresponding terminals of connector Pg1 according to the configuration of the SLB series you want to connect (for example, 5 in series (=5S1P), 2 in series, 2 in parallel (=2S2P), etc.). If you use the SLB series inserted into block 1 of circuit blocks 1 to 6 in ascending order of number as the bottom cell, you can easily customize the required protection circuit (step2 on the next).

[Example 1] In the case of 4 series (4S1P)



[Example 2] In the case of 2 series 3 parallels (2S3P)

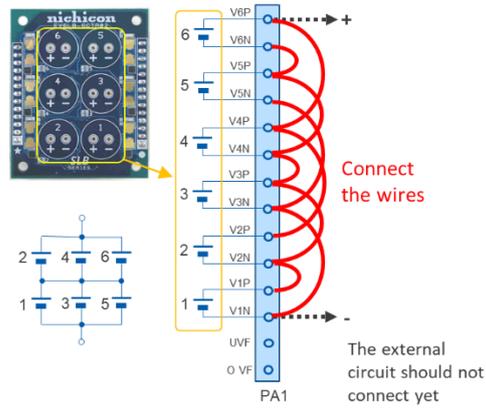
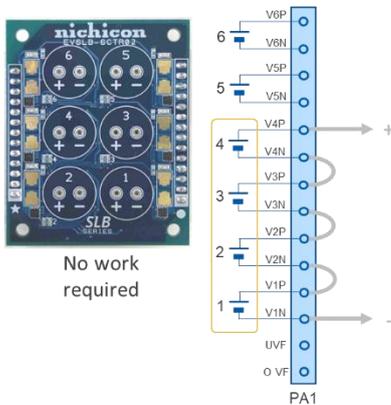


Fig 4-2-1 Example of wiring PA1

Step2. Optimization of overcharge/over-discharge detection circuit

The circuit configuration is needed to be optimized so that the overcharge/over-discharge signal circuit operates properly according to the connection configuration of the SLB series. This is done by removing the appropriate resistors (Rx20/Rx21, x=B to F), but this is not necessary if it is a simple series connection (2S1P to 6S1P) without parallel connection.

[Example 1] In the case of 4 series (4S1P)



[Example 2] In the case of 2 series 3 parallels (2S3P)

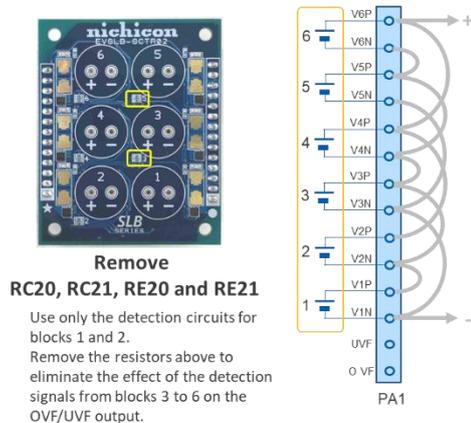


Fig 4-2-2 Overcharge/over-discharge signal circuit setting example

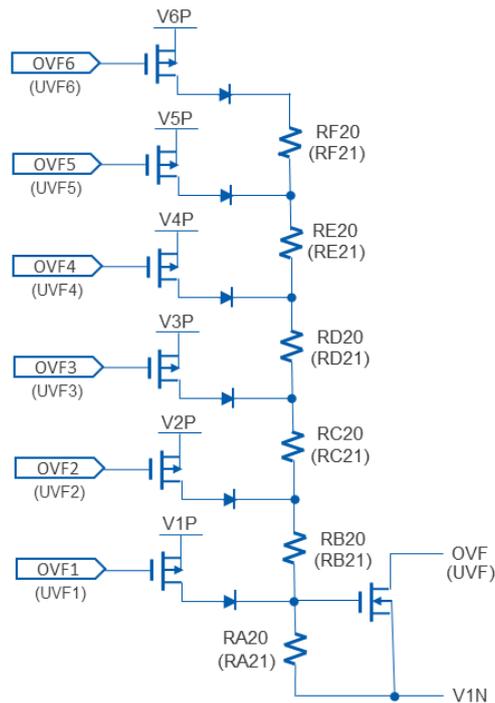
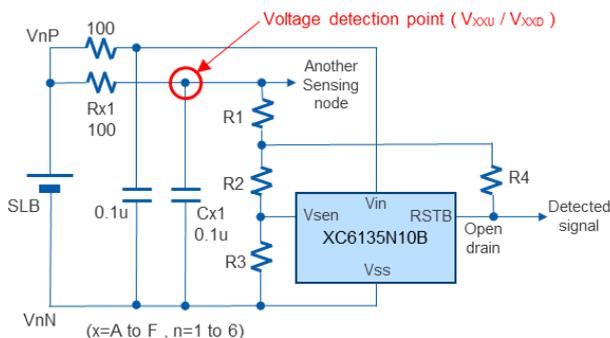


Fig 4-2-3 Configuration of overcharge/over-discharge signal transmission circuit

Step3. Setting of voltage detection threshold

Calculate the desired overcharge/over-discharge and cell balancing detection/release voltages using the information below as a reference, and replace the resistors as necessary.

If there is no need to change the default settings (listed in **1. Specifications**), you can skip this step.



Circuit Number	R1	R2	R3	R4
Cell Balancing	Rx9	Rx10	Rx11	Rx12
	12k	510k	330k	470k
Overcharge Detection	Rx3	Rx4	Rx5	Rx6
	12k	549k	330k	470k
Over-discharge detection	Rx16	Rx17	Rx18	Rx19
	47k	2.4M	3.3M	220k

(Upper row x=A to F , lower row is initial setting resistance value)

Fig 4-2-4 Configuration of overcharge, over-discharge and cell balancing voltage detection circuit

TOREX XC6135 datasheet:

<https://product.torexsemi.com/system/files/series/xc6135.pdf>

The XC6135N10B is an active low type voltage detection IC with a detection voltage of 1.0V, recovery hysteresis of 2mV (typ), N-ch open drain output. To simplify the following calculations, the effects of the IC's detection voltage accuracy and temperature characteristics will be omitted, but please consider these factors when deciding on the constants. Also, please select resistors with an accuracy of ±1% or less.

If the Vsen pin input resistance is Ri (=39MΩ typ) in the configuration in Figure 4.2.4, the detection voltage V_{XXD} [V] and release voltage V_{XXU} [V] can be calculated using the following formula.

(α: The magnification of the detection release voltage to the detection voltage of the voltage detection IC alone. In the case of the XC6135N10B, the IC detection voltage = 1V, and the IC detection release voltage = 1V + 2mV = 1.002V, so α = 1.002.)

$$V_{XXD} = 1 + \frac{(R1 + R2)(R3 + Ri)}{R3 \cdot Ri} \qquad V_{XXU} = \alpha \cdot \left\{ V_{XXD} + \frac{R1}{R4} \left(1 + \frac{R2(R3 + Ri)}{R3 \cdot Ri} \right) \right\}$$

- ◇ It is preferable to select each constant of R1 to R4 so that the combined resistance value is within the range of approximately 10kΩ to 10MΩ. Since the battery energy is constantly consumed through this resistor network, the larger the resistance value, the less current is consumed but noise resistance will decrease. Also, if the value of R4 is small, the circuit current that flows when low voltage is detected will be large, so setting this is preferable in terms of current consumption but the hysteresis width obtained will be smaller.
If the combined resistance of R1 to R4 is extremely low, the decoupling resistor of 100 Ω may affect the detection threshold.
- ◇ Due to the effect of R1, the IC output level during non-detection will be lower than VnP.
Do not select an extremely large value to avoid problems with driving the subsequent circuit (100kΩ or less is recommended).
- ◇ The XC6135 is a device that detects when the voltage drops below a threshold, and when the voltage rises above the hysteresis setting after detection, the detection is released. On this board, the inverted logic signal of XC6135 output is used for cell balance and overcharge detection circuits that start operating (or output a signal) when the voltage rises. In these two detection circuits, the XC6135 is always in a ?? state (the output FET is ON) where it is detecting a low voltage except when the cell balancing circuit is operating or the overcharge signal is being output. Therefore, current flows through R4, which increases the operating current compared to when cell balancing is in operation or when overcharge is detected.

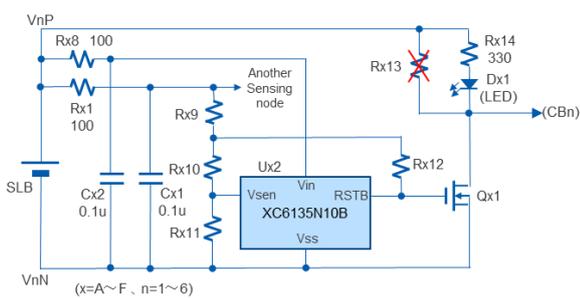


Fig 4-2-5 Cell balancing circuit

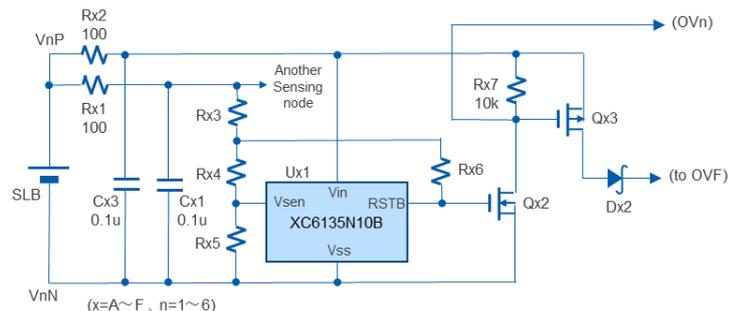


Fig 4-2-6 Overcharge detection circuit

Step4. Setting of cell balancing current

Calculate the resistance value to get the desired cell balancing current to flow by using the formula below, and mount it on Rx9 (x=g to L) of the circuit block to be used. The mounting pads are compatible with sizes 0805 to 2512 (in inches).

$$R_{x13} [\Omega] = V_{CB} / I_{CB(start)} [mA]$$

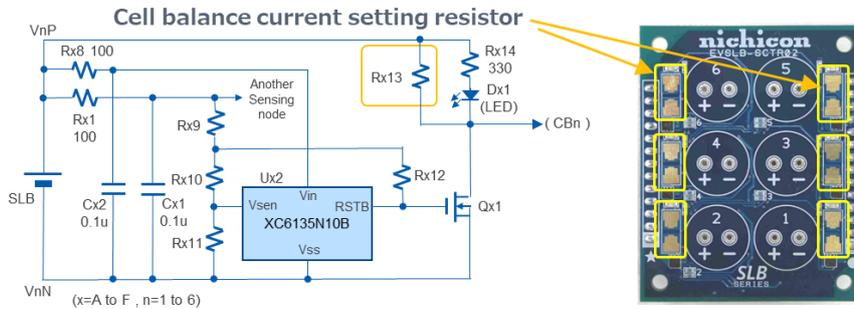


Fig 4-2-7 Cell balancing circuit

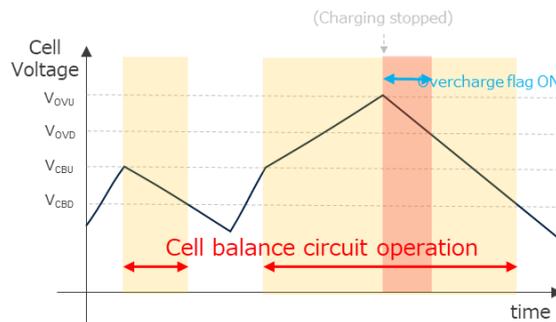


Fig 4-2-8 Cell balancing operation

- ◇ The cell balancing current varies depending on the voltage of the corresponding cell. To be precise, the cell balancing current value is set including the on-resistance of Qx3, but since the on-resistance of the MOSFET used in this circuit is 50mΩ or less, it will be no problem if you ignore the on-resistance when the cell balancing current is within the range of the commonly used value.
- ◇ During cell balancing, power consumption at Rx13 corresponds to the square of the cell balancing current value multiplied by the resistance value, so care should be taken to prevent heat generation, etc., especially when the cell balancing current value is large. When parallel connections are involved, it will work with only one cell balancing resistor among the parallel elements, but the temperature gradient will be smaller if all resistors are used to distribute the power consumption.
- ◇ If cell balancing is not required, Rx13 does not need to be mounted with a resistor. However, in the default state, a few mA of current flows to drive the LED when the cell balance voltage level is detected, and this plays a small role in adjusting the cell balance. If you do not need this current, remove Rx14 (330 ohm). (in this case the cell balance indicator will not function)

Step5. External circuit configuration

This board has an overcharge/over-discharge detection function, but does not have a current cutoff function, so an external switch circuit or similar is required to stop overcharge or over-discharge. Please configure an appropriate circuit and insert it into the charge path (and/or) discharge path.

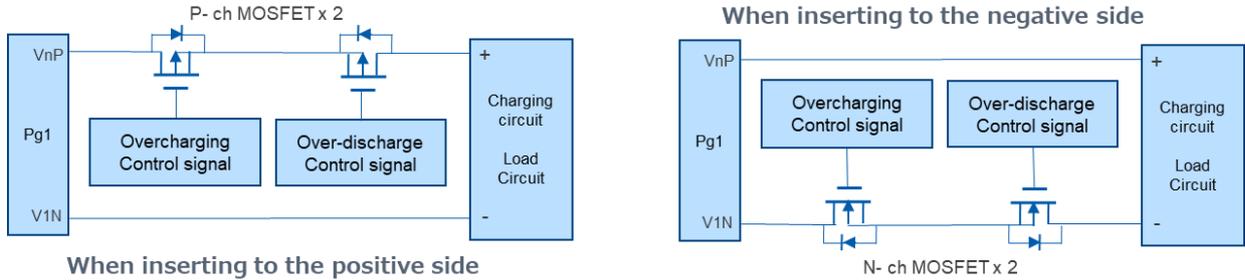


Fig 4-2-9 Example of the external switch circuit

- ◇ To prevent power being unexpectedly supplied when inserting the SLB series into the board, it is preferable to:
 - Either keep the overcharge/over-discharge protection switch device OFF until the device is in use (for example, in the circuit shown above, short out the gate and source of each MOSFET)
 - or
 - Install a separate switch between the charging circuit and load circuit.
- ◇ When using a circuit like the one shown above, be careful not to impair the protection function by the wiring of the device that controls the current cut-off MOSFET. In particular, if you insert a protection device on the negative side, you may need to devise a way to exchange signals between this board and the connected circuit, since the current is cut off by cutting the GND between this board and the connected circuit when the protection function is on.
- ◇ OVF/UVF signal (open drain output with a reference level V1N, ON when detected / Hi-Z when not detected) output from this board can also be used as the overcharge/over-discharge control signal. Please take the above into consideration when configuring a circuit that will allow the current cutoff switch to operate properly.
- ◇ If overcharging and over-discharging can be avoided by the operating specifications of the external circuit, a protection device is not necessarily required, but please consider carefully before deciding whether or not to include a protection circuit.

Step6. Installing the SLB

Insert the SLB12400L151 into the onboard socket of the circuit block to be used. When inserting, be sure to pay close attention to the polarity. (There is no protection against incorrect polarity insertion.)

This completes the preparation.

If you remove the measure to prevent unintended power supply in step 4, the connected circuit will start operating.

5. Other information

- ◇ The current consumption (per cell block) during operations in the initial state is as shown in the table below.

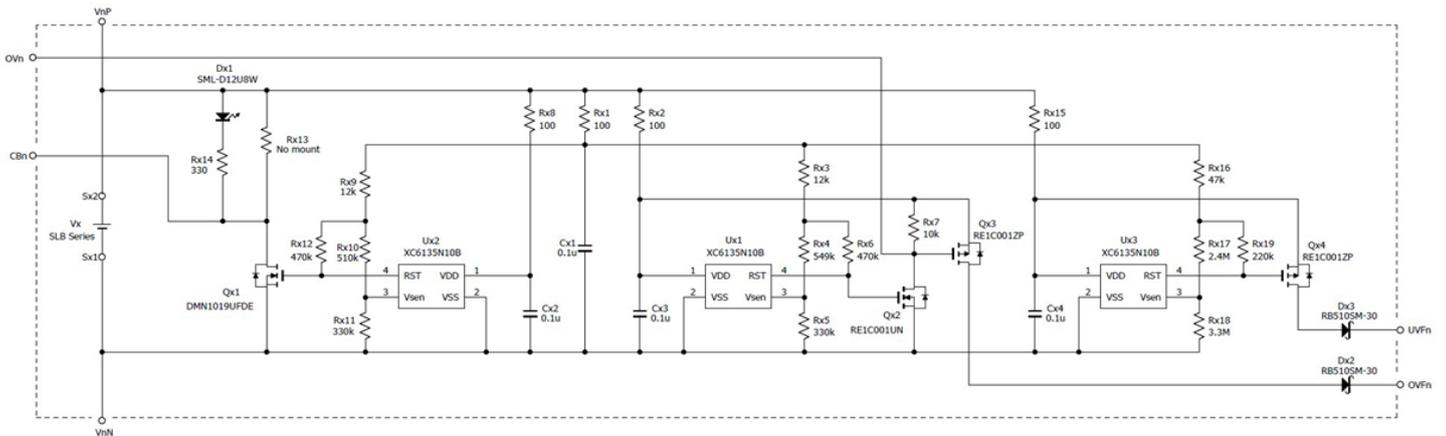
Table 5-1 Current consumptions on the initial setting

Item	Consumption	Measurement voltage
During normal operation (overcharge/over-discharge not detected, cell balance circuit not operating)	Approx. 18.5μA	2.50V
When the cell balance circuit is operating (overcharge not detected) *	Approx. 2.5mA	2.65V
When overcharge is detected (cell balancing circuit also operates) *	Approx. 3.4mA	2.75V
When over-discharge is detected	Approx. 35μA	1.80V

* If a cell balance current is set in Rx13, that current is added

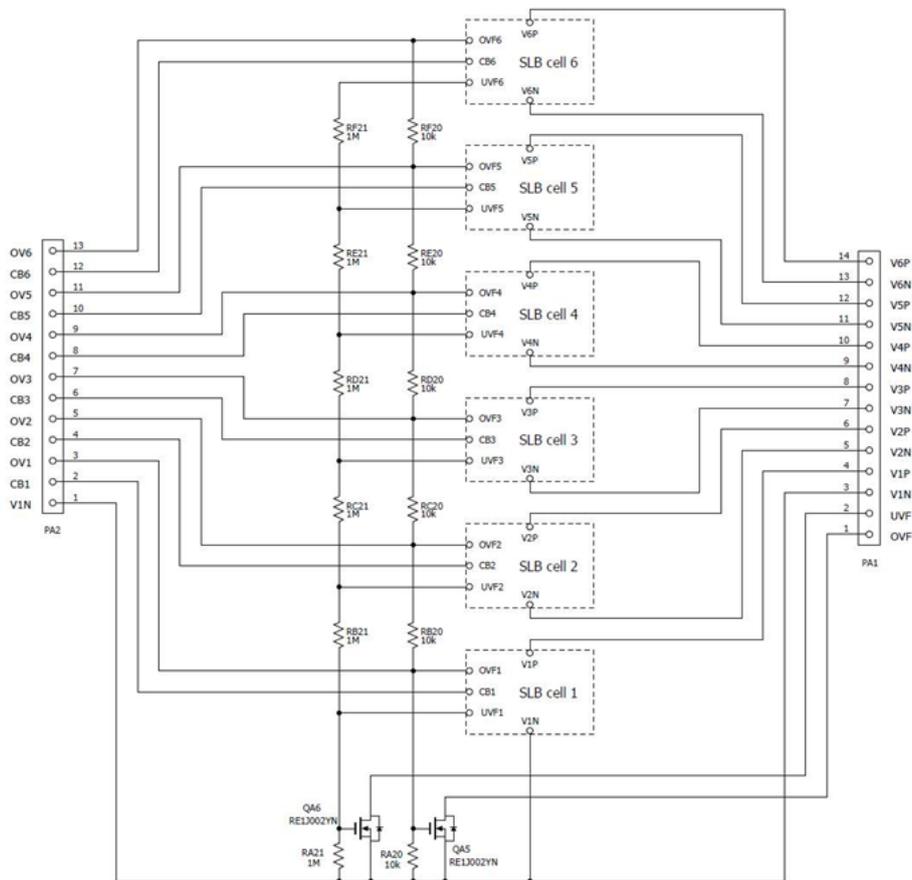
- ◇ Part numbers are not printed on the board, so if you need to match the parts on the board with the circuit numbers, please refer to the included parts layout board.
- ◇ Please treat the component constants used on this board as reference values only (including threshold settings that may deviate from the SLB rating when the accuracy of all circuit components and characteristic temperature fluctuations are accumulated in the worst case). Carefully examine the circuit constants, taking into consideration various conditions such as the materials used and the expected usage environment.

6. Schematics



"n" is a number from 1 to 6
"x" is an alphabet from A to F

Battery Cell Circuit
(The EVB contains 6 circuit blocks same as this diagram)



Connection of OVF and UVF signal / EVB Overview

7. Parts list

Table 7 Parts list

Ref No.	Component	Value	Manufacturer	Description
Cx1	Capacitor (0603)	100nF	Murata	GCJ188R71H104KA12D
Cx2	Capacitor (0603)	100nF	Murata	GCJ188R71H104KA12D
Cx3	Capacitor (0603)	100nF	Murata	GCJ188R71H104KA12D
Cx4	Capacitor (0603)	100nF	Murata	GCJ188R71H104KA12D
Dx1	LED	Red	Rohm	SML-D12U8WT86
Dx2	Schottky barrier diode		Rohm	RB510SM-30T2R
Dx3	Schottky barrier diode		Rohm	RB510SM-30T2R
PA1	Pin header	14pin	Adam Tech	PH1-14-UA
PA2	Pin header	13pin	Adam Tech	PH1-13-UA
Qx1	MOSFET	n-ch	Diodes	DMN1019UFDE-7
Qx2	MOSFET	n-ch	Rohm	RE1C001UNTCL
Qx3	MOSFET	p-ch	Rohm	RE1C001ZPTL
Qx4	MOSFET	p-ch	Rohm	RE1C001ZPTL
QA5	MOSFET	n-ch	Rohm	RE1J002YNTCL
QA6	MOSFET	n-ch	Rohm	RE1J002YNTCL
Sx1	Through hole socket	-	Mac8	AF-0.7(H)
Sx2	Through hole socket	-	Mac8	AF-0.7(H)
Ux1	IC (Voltage detector)		TOREX	XC6135N10BNR-G
Ux2	IC (Voltage detector)		TOREX	XC6135N10BNR-G
Ux3	IC (Voltage detector)		TOREX	XC6135N10BNR-G
Rx1	Resistor (0603)	100ohm	KOA	RK73H1JTDD1000F
Rx2	Resistor (0603)	100ohm	KOA	RK73H1JTDD1000F
Rx3	Resistor (0603)	12kohm	KOA	RK73H1JTDD1202F
Rx4	Resistor (0603)	549kohm	KOA	RK73H1JTDD5493F
Rx5	Resistor (0603)	330kohm	KOA	RK73H1JTDD3303F
Rx6	Resistor (0603)	470kohm	KOA	RK73H1JTDD4703F
Rx7	Resistor (0603)	10kohm	KOA	RK73H1JTDD1002F
Rx8	Resistor (0603)	100ohm	KOA	RK73H1JTDD1000F
Rx9	Resistor (0603)	12kohm	KOA	RK73H1JTDD1202F
Rx10	Resistor (0603)	510kohm	KOA	RK73H1JTDD5103F
Rx11	Resistor (0603)	330kohm	KOA	RK73H1JTDD3303F
Rx12	Resistor (0603)	470kohm	KOA	RK73H1JTDD4703F
Rx13	Resistor (2512)	→	→	Need to mount an appropriate value resistor
Rx14	Resistor (0603)	330ohm	KOA	RK73H1JTDD3300F
Rx15	Resistor (0603)	100ohm	KOA	RK73H1JTDD1000F
Rx16	Resistor (0603)	47kohm	KOA	RK73H1JTDD4702F
Rx17	Resistor (0603)	2.4Mohm	KOA	RK73H1JTDD2404F
Rx18	Resistor (0603)	3.3Mohm	KOA	RK73H1JTDD3304F
Rx19	Resistor (0603)	220kohm	KOA	RK73H1JTDD2203F
Rx20	Resistor (0603)	10kohm	KOA	RK73H1JTDD1002F
Rx21	Resistor (0603)	1Mohm	KOA	RK73H1JTDD1004F

"x" can be A, B, C, D, E, or F (all six circuit blocks have the same circuit configuration and constants).

Revision history

Revision No.	Date	Description
0.80	Nov.8 th , 2024	Preliminary version
1.00	Nov.27 th , 2024	Release version