Getting started with the STEVAL-L99615C evaluation kit based on the L9961 device for battery management system

Introduction

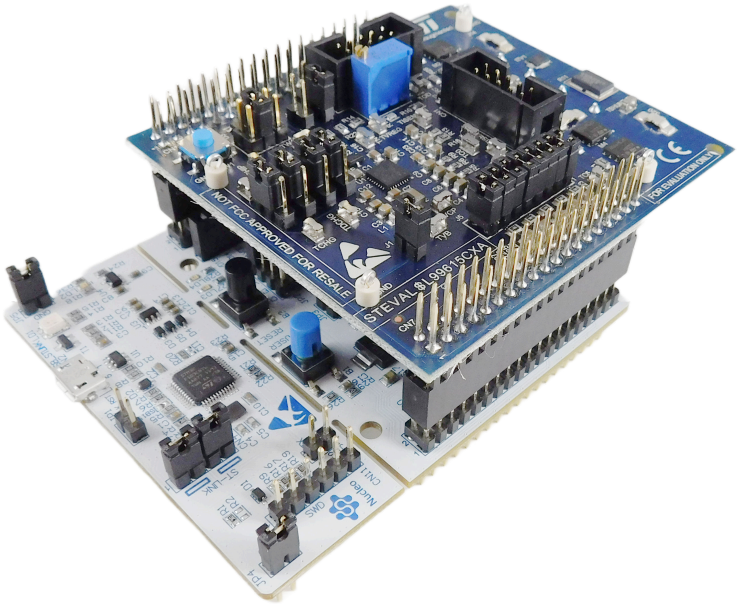
The STEVAL-L99615C is an evaluation kit composed of an expansion board containing the L9961 IC for battery pack monitoring solutions, and the NUCLEO-G071RB STM32 Nucleo-64 development board, aiming to demonstrate the performance and the ease of integration with STMicroelectronics technology for BMS applications.

The kit exploits the characteristics of the L9961, able to monitor up to five Li-Ion battery cells in series configuration, communicating with the STM32G071RB microcontroller, through the I²C interface.

The expansion board has been specifically developed to be stacked on the NUCLEO-G071RB development board through the ST morpho connectors, and embeds a power connector able to connect it to a 5-cell battery pack, or alternatively to an external power supply to emulate the battery pack.

A software package containing a dedicated firmware program for the STM32G071RB microcontroller and a GUI for the PC, has been released to permit users to benefit from the demonstration, looking at the major significant characteristics described by BMS application: cell voltage and stack voltage monitoring, stack current monitoring, temperature conversion via external NTC, OV, and UV thresholds management, etc..

Figure 1. STEVAL-L99615C evaluation kit



1 Getting started

1.1 Overview

The STEVAL-L99615C features:

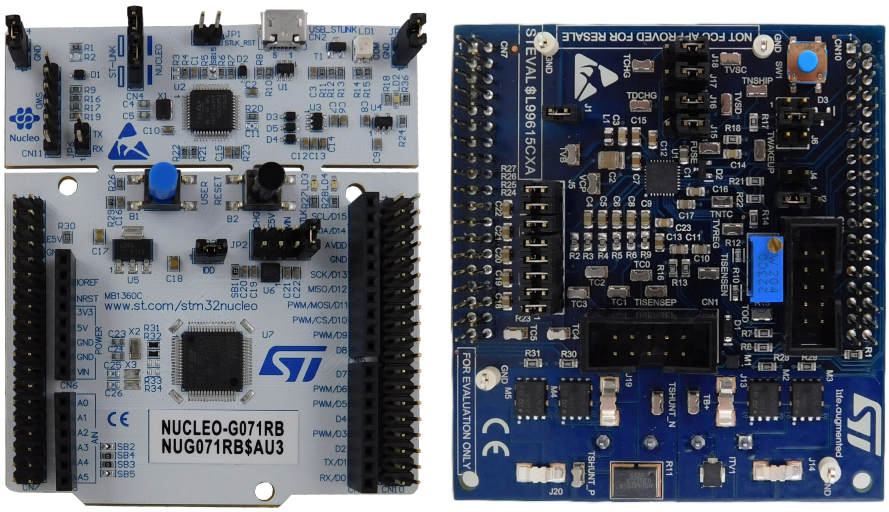
- measurement of cell voltages (3 to 5 cells), with over/undervoltage detection
- measurement of stack voltage, with over/undervoltage detection and plausibility check vs. sum of cells
- measurement of battery pack temperature through an external NTC (emulated by an on-board trimmer) with over/undertemperature detection
- measurement of battery current, with Coulomb counting, overcurrent, and short-circuit in discharge protection
- battery cell balancing supporting up to 70 mA per cell
- dual configurable HS/LS pre-driver for pack relay management
- pack fuse management
- high hot plug robustness

1.2 System architecture

The STEVAL-L99615C evaluation kit consists of two subsystems:

- the NUCLEO-G071RB STM32 Nucleo-64 development board embedding the STM32G071RBT6
- the expansion board embedding the L9961 that monitors the battery pack and physically protects the battery-packed application, contributing also to maintain the expected voltages

Figure 2. NUCLEO-G071RB - L9961 expansion board



1.2.1 NUCLEO-G071RB development board

The NUCLEO-G071RB STM32 Nucleo-64 development board is based on the high-performance Arm Cortex®-M0+ 32-bit RISC core operating at up to 64 MHz frequency, with 128 KB flash memory and 16 KB SRAM.

The ST morpho headers allow expanding the functionality of the STM32 Nucleo open development platform with a wide choice of specific shields.

The STM32 Nucleo-64 boards do not require any separate probe as they integrate the ST-LINK/V2-1 debugger/programmer. They embed comprehensive, free STM32 software libraries and examples available with the STM32CubeG0 MCU package.

Related links

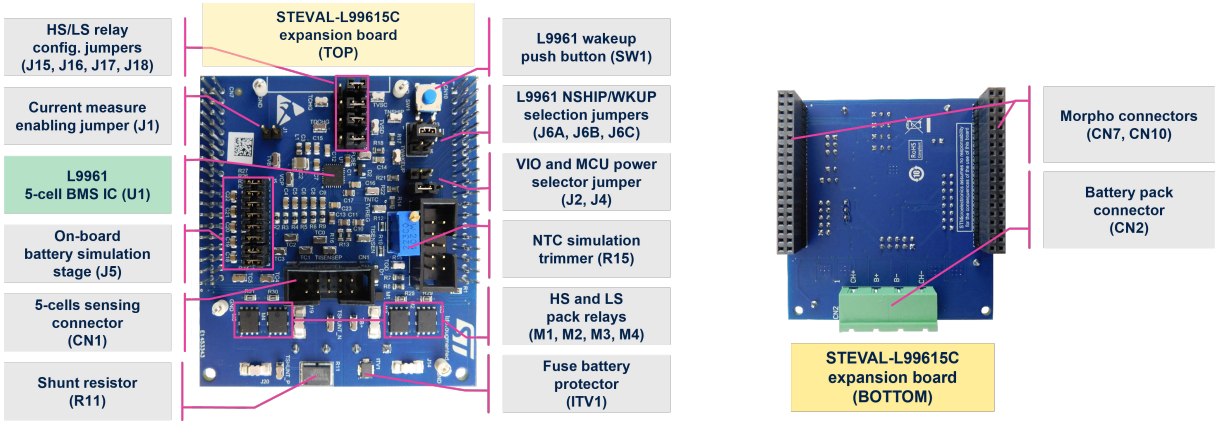
Refer to the related ST web page NUCLEO-G071RB bill of materials and schematic diagrams

1.2.2 Expansion board

The expansion board hosts the L9961 BMS device, a complete battery pack monitoring, balancing, and protection system for Li-Ion and Li-Polymer cells in 3, 4, or 5 series configurations. The device uses a high precision ADC to provide cell voltage, stack voltage, and temperature conversion via external NTC. Voltage monitoring functions are cyclically performed with a programmable loop time. Stack current is also monitored via a high accuracy CSA, continuously running and also performing Coulomb counting. Cell balancing is available and can be simultaneously activated on all cells. IC configuration and information exchange for SOC/SOH estimation are performed via the I²C peripheral.

The IC also integrates a dual pre-driver programmable in both HS/LS configurations for driving pack relays. The L9961 also implements battery pack fuse protection to prevent fire and explosion hazards. A 3.3 V regulator with a high current capability is available for supplying a pack controller and other external circuitry in both standby and normal operation modes. The IC protects the battery pack against over/undervoltage conditions and monitors for over/undertemperature. It also features protection against overcurrent (both directions) and short-circuit in discharge events. Safety relevant configurations can be stored in the internal NVM to avoid reprogramming the device at each wake-up.

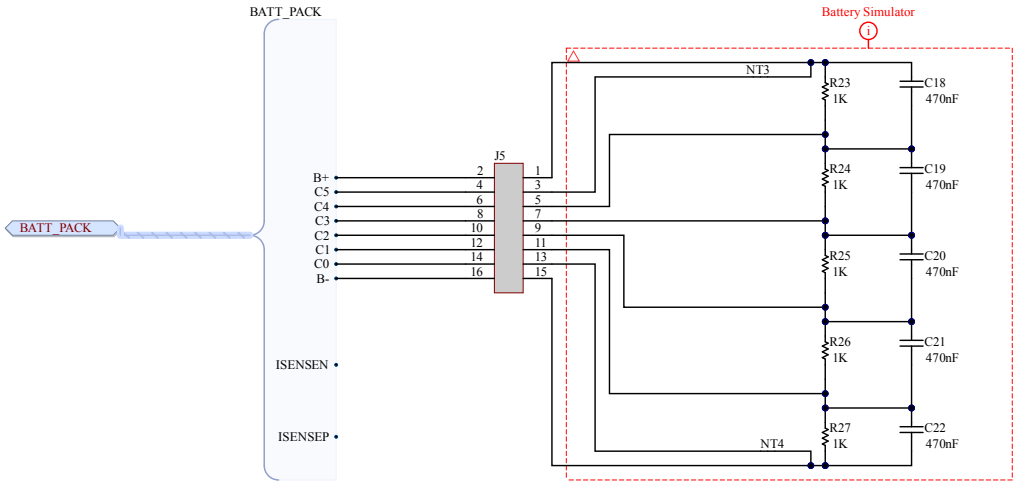
Figure 3. STEVAL-L99615C expansion board - top and bottom



1.2.3 Power supply section

In case a real battery is not available, it is possible to use the battery simulator embedded on the L9961 demo board by installing a J5 jumper and by feeding the L9961 demo board through the CN2 connector (B+ and B-).

Figure 4. Power supply connector and battery simulator

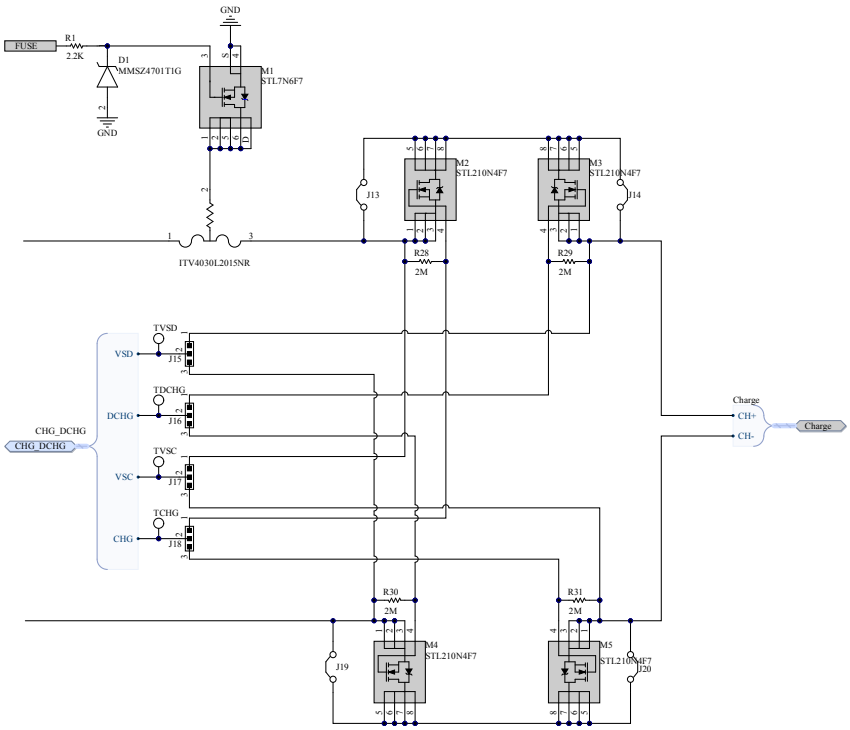


1.2.4 Pack relays stage

The L9961 uses a dual pre-driver stage to manage the external Charge (CHG) and Discharge (DCHG) switches. The pre-driver stage can be configured as high-side or low-side by programming the CHG_HS_LS and DCHG_HS_LS field.

To set the DCHG MOSFET to **high-side** operation, remove the J13 and J14 jumpers and install a jumper in J15 and J16 position 1-2 or for **low-side** operation, remove the J19 and J20 jumpers and install a jumper in position 2-3. To set the CHG MOSFET to **high-side** operation, install a jumper in J17 and J18 position 1-2 or for **low-side** operation, install a jumper in position 2-3.

Figure 5. Pack relays schematic

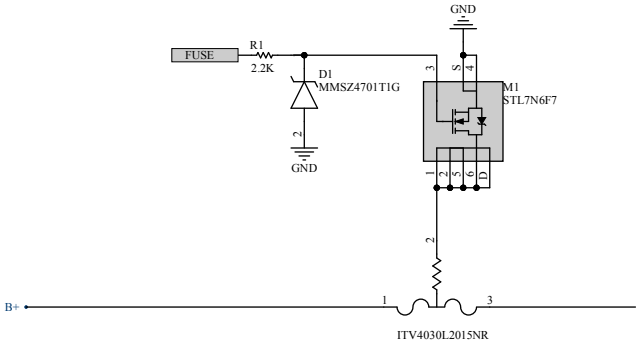


Note: See L9961 datasheet for further details.

1.2.5 Fuse stage

Under certain conditions classified as permanent failures, the L9961 can be programmed to activate the FUSE pre-driver. An external NMOS can be driven to blow up a fuse connected in series to the battery pack positive terminal.

Figure 6. Fuse stage schematic



Note: See L9961 datasheet for further details.

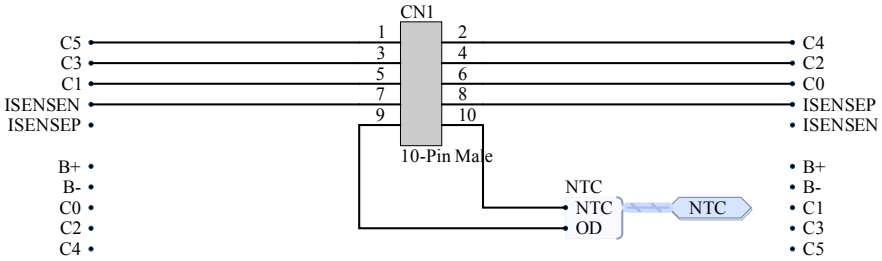
1.2.6 L9961 demo board connectors

The CN1 is a 10-pin IDC style connector used to route sense signals from the remote 5-cell battery board to the L9961 demo board. The connector contains the Kelvin connections for C0 through C5, the current sense resistors differential voltage, and the NTC voltage, which can be used to route an external NTC and shunt resistor.

If the external Rshunt is used, R11 should be uninstalled and replaced with the new one.

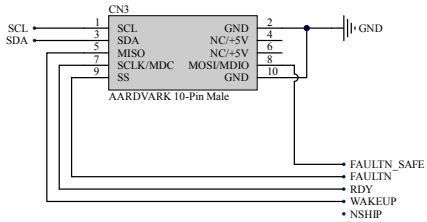
If the external NTC is used, R12 should be removed. Once it has been removed, the user can connect the external resistor between the NTC and OD pins. It is important to polarize the NTC with an external pull-up resistor biased to VREG. For further details regarding the application circuit, please refer to the "Application Information" section in the L9961 datasheet.

Figure 7. CN1 connector



This is a 10-pin IDC style connector, which allows to either connect an Aardvark I^2C/SPI Host Adapter or a Beagle I^2C/SPI Protocol Analyzer to the L9961 demo board.

Figure 8. CN3 connector



2 Jumpers and connectors

2.1 L9961 demo board jumpers and connectors

Table 1. L9961 demo board jumpers and connectors description

Name	Description	Configuration	Type
CN1	Remote sense: used to route sense signals from the 5-cell battery board to the L9961 demo board	-	10-pin IDC style
CN2	Battery pack: used to route the power signals from the 5-cell battery board to the L9961 demo board	-	4-pin Phoenix header
CN3	Total phase: used to connect an Aardvark I²C/SPI Host Adapter or a Beagle I²C/SPI Protocol Analyzer	-	10-pin IDC style
CN7, CN10	ST morpho connector: used to place L9961 demo board on top of the NUCLEO-G071RB micro board	-	-
J1	Used to measure current flowing into VB pin	-	-
J2	VIO voltage selector	1-2: 3.3 V from micro 2-3: 3.3 V from L9961 (VREG)	-
J4	Used to select micro power source	OPEN: micro is fed from the NUCLEO-G071RB micro board USB CLOSE: micro is fed from VREG. *Note: If µC is fed from VREG, JP3 jumper must be open on the NUCLEO-G071RB micro board*	-
J5	Battery simulator: used to simulate battery pack	OPEN: battery simulator circuit is disconnected. *Note: This configuration is used when the 5-cell battery board is connected* CLOSED: battery simulator circuit is connected	Multiple position jumper
J6A	Used to connect NSHIP pin to B+	-	-
J6B	Used to drive NSHIP pin from micro	-	-
J6C	Used to drive WAKEUP pin from SW1 push button	-	-
J13, J14	Used to bypass the HS relay MOSFETs	OPEN: when HS relay MOSFETs is used CLOSED: when LS relay MOSFETs is used	Soldered jumper
J19, J20	Used to bypass the LS relay MOSFETs	OPEN: when LS relay MOSFETs is used CLOSED: when HS relay MOSFETs is used	Soldered jumper
J15, J16, J17, J18	Used to configure the relay MOSFETs to either high or low-side usage	1-2: HS configuration is selected 2-3: LS configuration is used	-
SW1	Push button: used to take the device out of SHIPMENT state *Note: If J6C jumper is closed, the SW1 is also used to take the device out of STADNBY state.*	-	-

2.2 NUCLEO-G071RB micro board jumpers and connectors

Table 2. NUCLEO-G071RB micro board jumpers and connectors description

Name	Description	Configuration	Type
CN2	STLINK USB connector	-	USB micro-B
CN7, CN10	ST morpho connector: used to pace L9961 demo board on top of the NUCLEO-G071RB micro board	-	-
JP2	5 V jumper selection(1)	OPEN: no 5 V power 1-2 CLOSED: 5 V from STLINK 3-4 CLOSED: 5 V from VIN 7 V to 12 V 5-6 CLOSED: 5 V from E5V 7-8 CLOSED: 5 V from USB_CHG	-
JP3	STM32 VDD current measurement	Opened when micro is powered from VREG	-

1. *See UM2324 for further details.*

2.3 5-cell battery board connectors

Table 3. 5-cell battery board connectors description

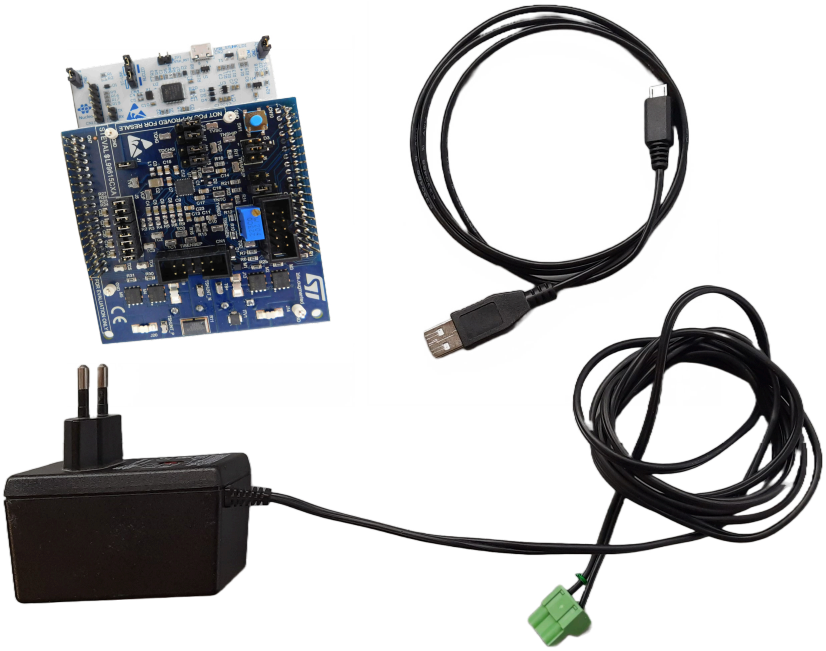
Name	Description	Configuration	Type
CN1	Remote sense: used to route sense signals from the 5-cell battery board to the L9961 demo board	-	10-pin IDC style
CN2	Battery pack: used to route the power signals from the 5-cell battery board to the L9961 demo board	-	4-pin Phoenix header
CN3	Charge/Discharge: used to connect a load or charger to the battery pack	-	2-pin Phoenix header

3 Application setup

3.1 System requirements

To set up the demo and run the application with the evaluation kit, the following items are required:

Figure 9. Demo setup: STEVAL-L9961 kit, power supply and USB Type-A to Micro-B cable



- STEVAL-L99615C kit
- USB Type-A to Micro-B cable
- a portable power supply (up to 20 V, 1 A) to feed the STEVAL-L99615C kit (in case a real battery is not available), possibly equipped with a two or four position plug 7.62MM connector as the Wurth 691351400002 or 691351400004, like the one shown in Figure 9.
- the evaluation GUI contained in the STSW-L99615C
- a laptop to install the evaluation GUI contained in the STSW-L99615C

3.2 How to run the application demo

To run the application demo, in voltage and NTC temperature acquisition mode, follow the procedure below:

Step 1. Verify that the setting of the STEVAL-L99615C jumpers respects the configuration reported in Table 4.

Figure 10. STEVAL-L99615C jumpers setting

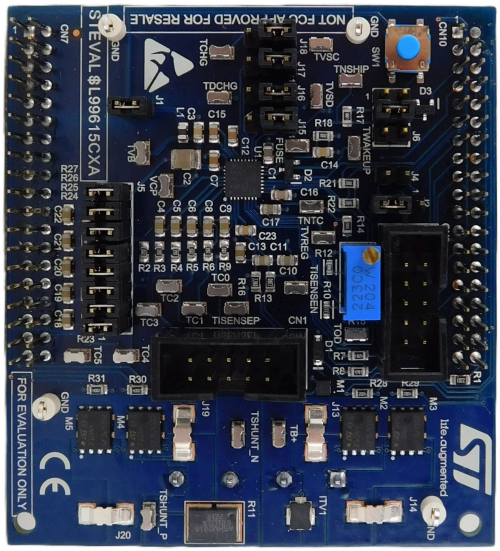


Table 4. Jumper settings

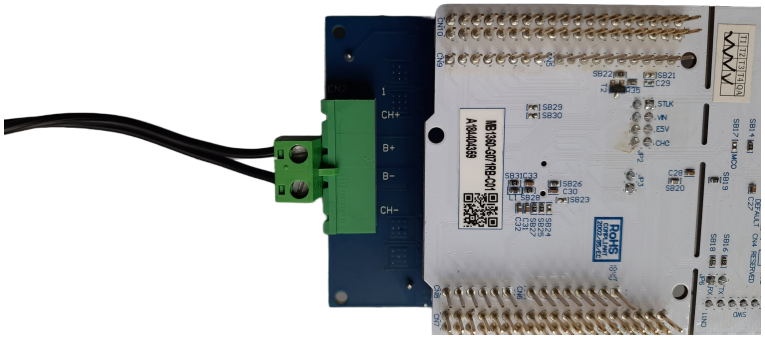
Name	Board	Description	Configuration
J1	EXP. BOARD	Used to measure current flowing into VB pin	Closed
J2	EXP. BOARD	VIO voltage selector	2-3: 3.3 V from L9961 (VREG)
J4	EXP. BOARD	Used to select micro power source	Closed
J5	EXP. BOARD	Battery simulator – used to simulate battery pack	Closed *Note: It is assumed that 5-cell battery board is not used.*
J6B	EXP. BOARD	Used to drive NSHIP pin from micro	Closed
J15, J16, J17, J18	EXP. BOARD	Used to configure the relay MOSFETs to either high or low-side usage	1-2: HS configuration is selected
J13, J14	EXP. BOARD	Used to bypass the HS relay MOSFETs	Closed
J19, J20	EXP. BOARD	Used to bypass the LS relay MOSFETs.	Closed
JP3	NUCLEO	STM32 VDD current measurement	Open
JP2	NUCLEO	STM32 5 V jumper selection	1-2: 5 V from STLINK
CN4	NUCLEO	STM32 SWD interface	Closed

Step 2. After installing the GUI from the STSW-L99615C SW package to the laptop, and confirming that the kit Nucleo board is programmed with the firmware binary contained in the same SW package (refer to the UM3141), connect the STEVAL-L99615C to the laptop through the USB cable.

Note: In the case of NUCLEO programming, refer to the STM32CubeProgrammer user manual for firmware uploading.

Step 3. Connect the power supply terminals to the B+ and B- pins of the battery pack connector (CN2), and power on the appliance (suggested setting 7.5 V, 1 A as test rating).

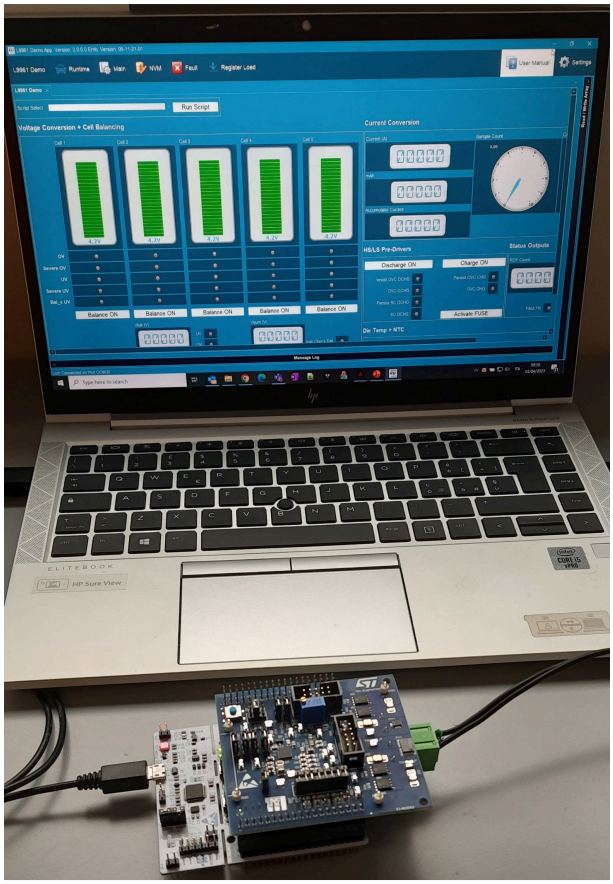
Figure 11. How to connect the power terminals to the battery



Step 4. Launch the GUI on the laptop and verify the COM used by the evaluation board is recognized by laptop Operative System (WINDOWS in the described case) device manager. If recognized, the GUI releases a message on the left part of the bottom side of its template, referring to the connected COM number used.

Figure 12. GUI view and focus on connected COM

Figure 13. **STEVAL-L99615C connected to a laptop (panoramic view)**



Step 5. Clicking on the GUI tab "Register Load", upload the example CSV file "Voltage Acquisition Init - 5Cell+VB+NTC.csv" also embedded in the SW package file, and then click the "Play" button. This operation presets an instruction set that permits the GUI to demonstrate the acquisitions of voltage cells and battery pack, and also NTC acquisition. After completing the register loading operation, press OK to begin voltage acquisition.

Figure 14. GUI tab "Register Load" - open

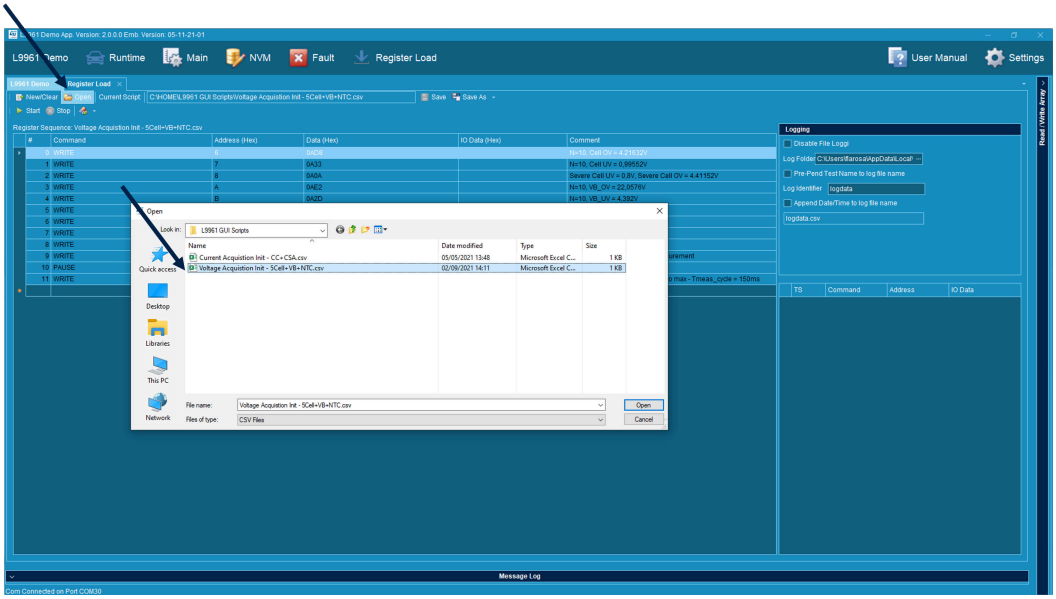


Figure 15. GUI tab "Register Load" - register loading operation

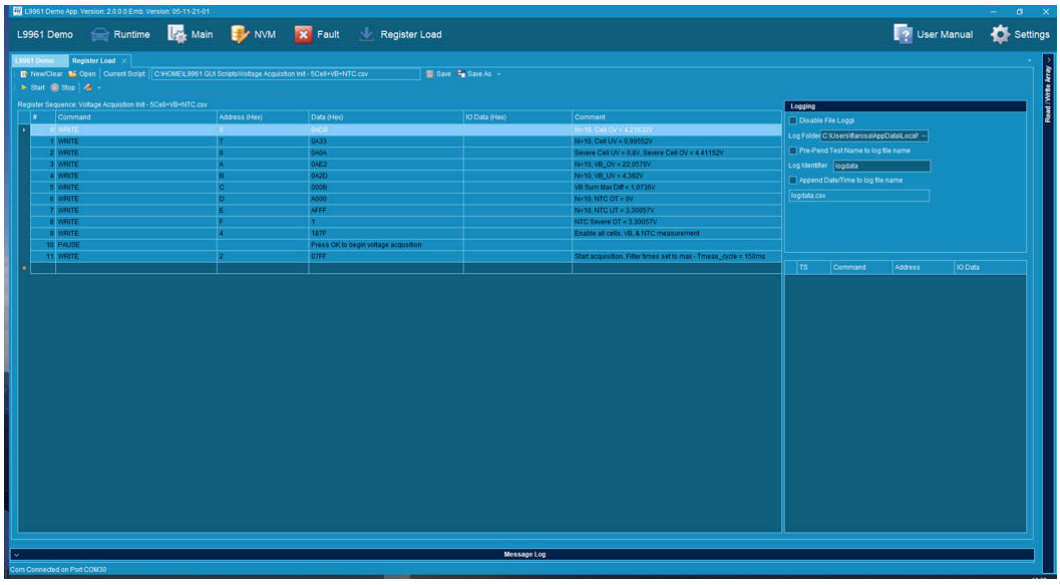
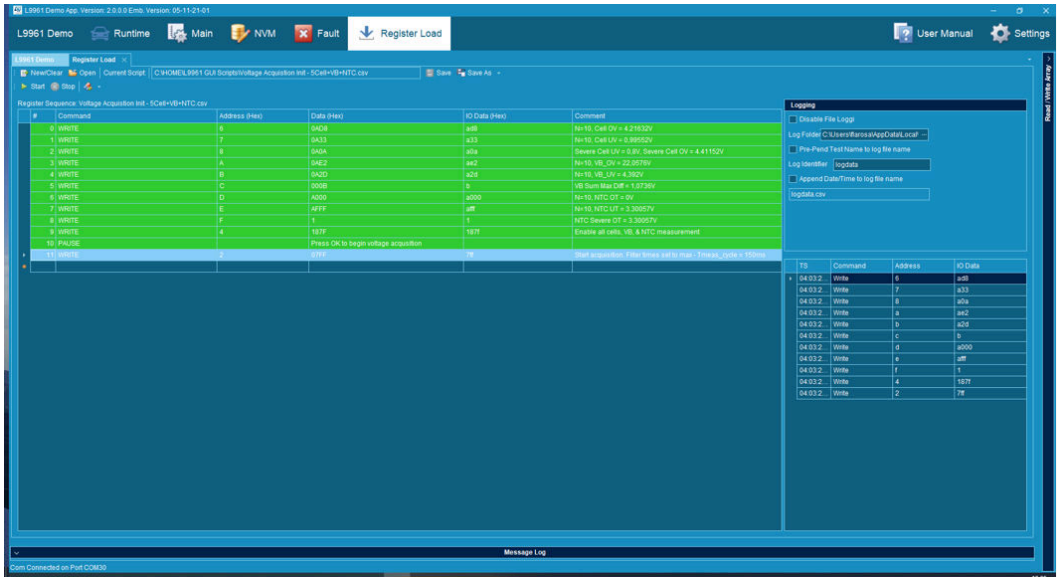


Figure 16. **Register Load: csv commands loaded**



Step 6. Then, opening the "L9961 Demo" tab and setting the Periodic Timer (for example to 250 ms), it is possible to observe the direct acquisition of the voltages on each cell: in fact, applying 7.5 V to the CN2 connector (on VB+ and VB+ pins), the five resistive dividers integrated in the STEVAL-L99615C expansion board and emulating the battery pack circuit, return 1.5 V for each cell.

Figure 17. **L9961 Demo tab**

4 Board schematics

Note: The schematic diagrams below refer to the expansion board included in the STEVAL-L99615C evaluation kit. For the schematic diagrams of the NUCLEO-G071RB development board, see the related web page.

Figure 18. STEVAL-L99615C expansion board schematic (1/5)

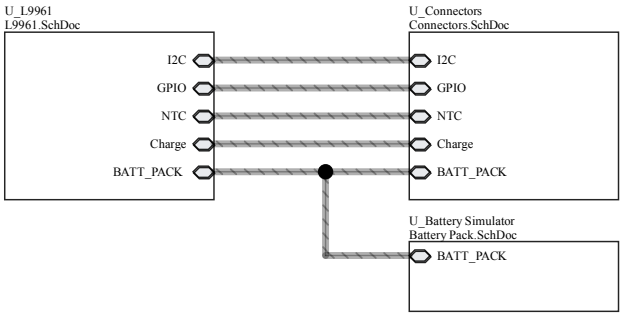


Figure 19. **STEVAL-L99615C expansion board schematic (2/5)**

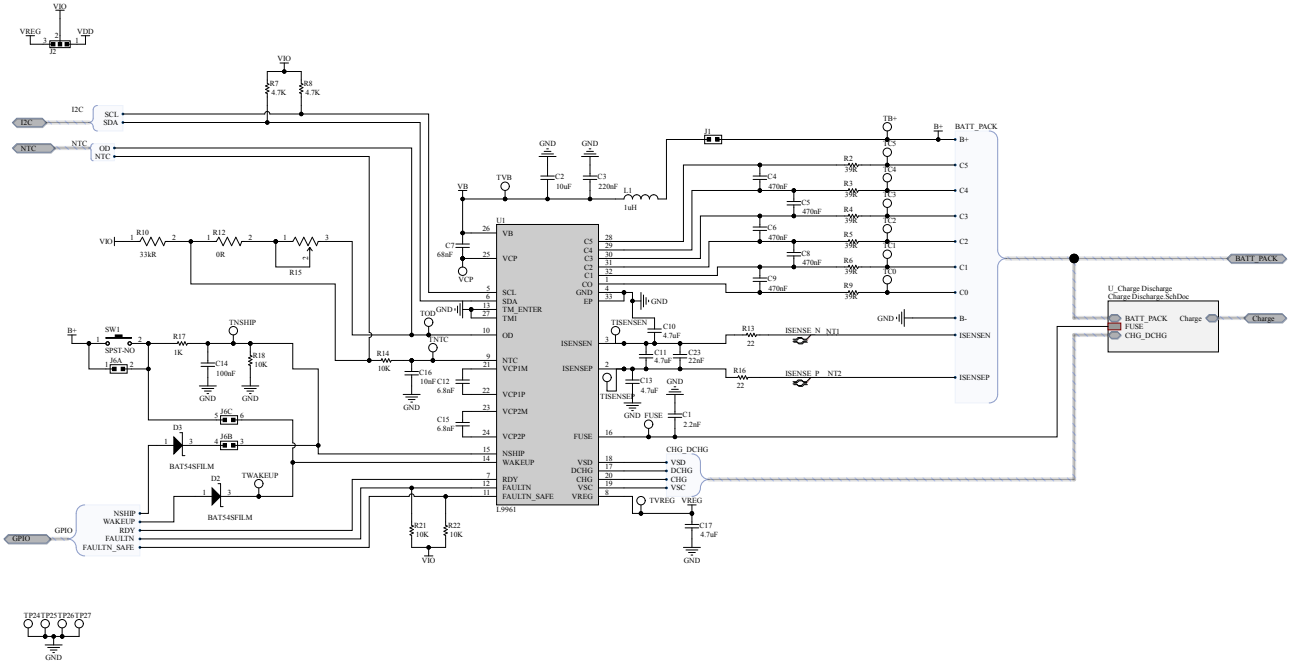


Figure 20. **STEVAL-L99615C expansion board schematic (3/5)**

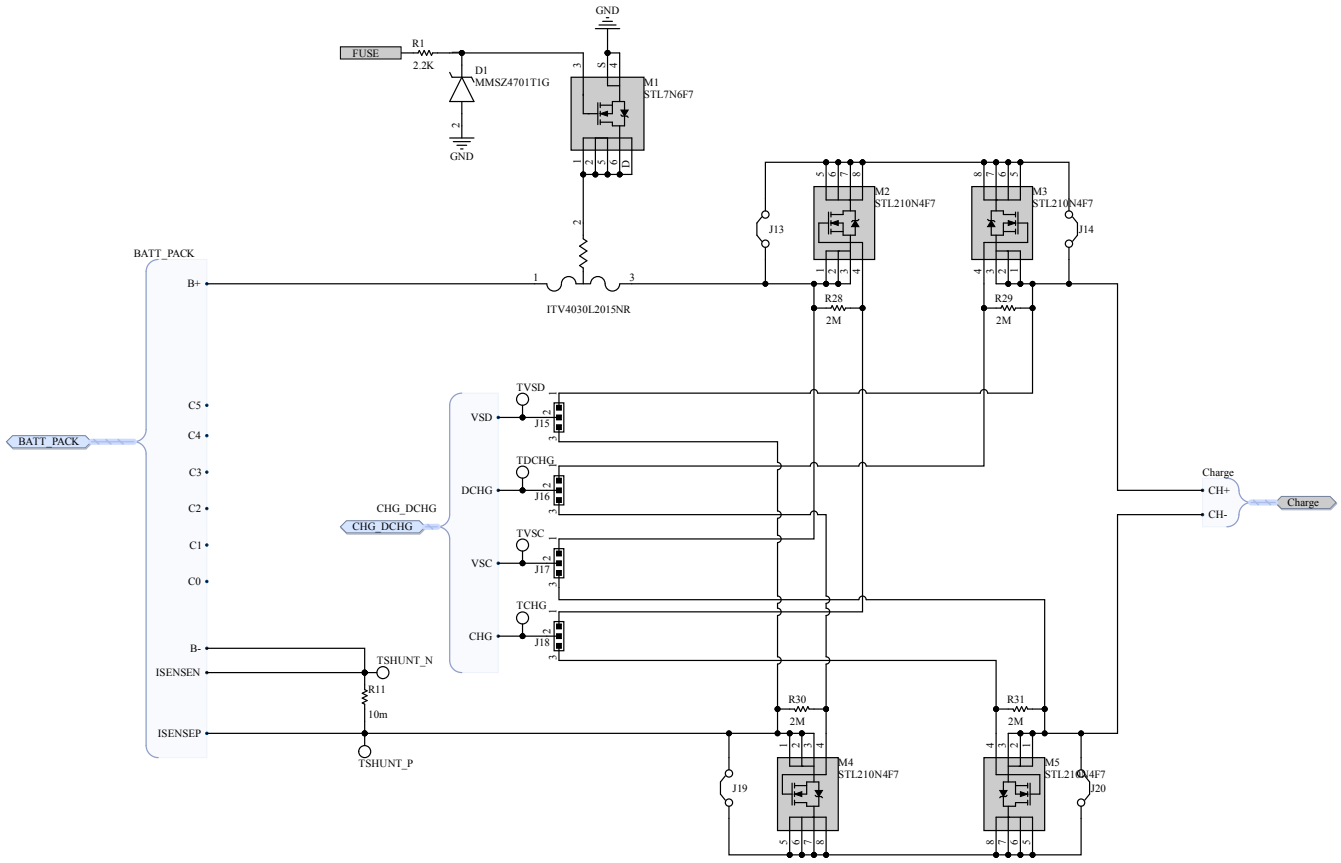


Figure 21. **STEVAL-L99615C expansion board schematic (4/5)**

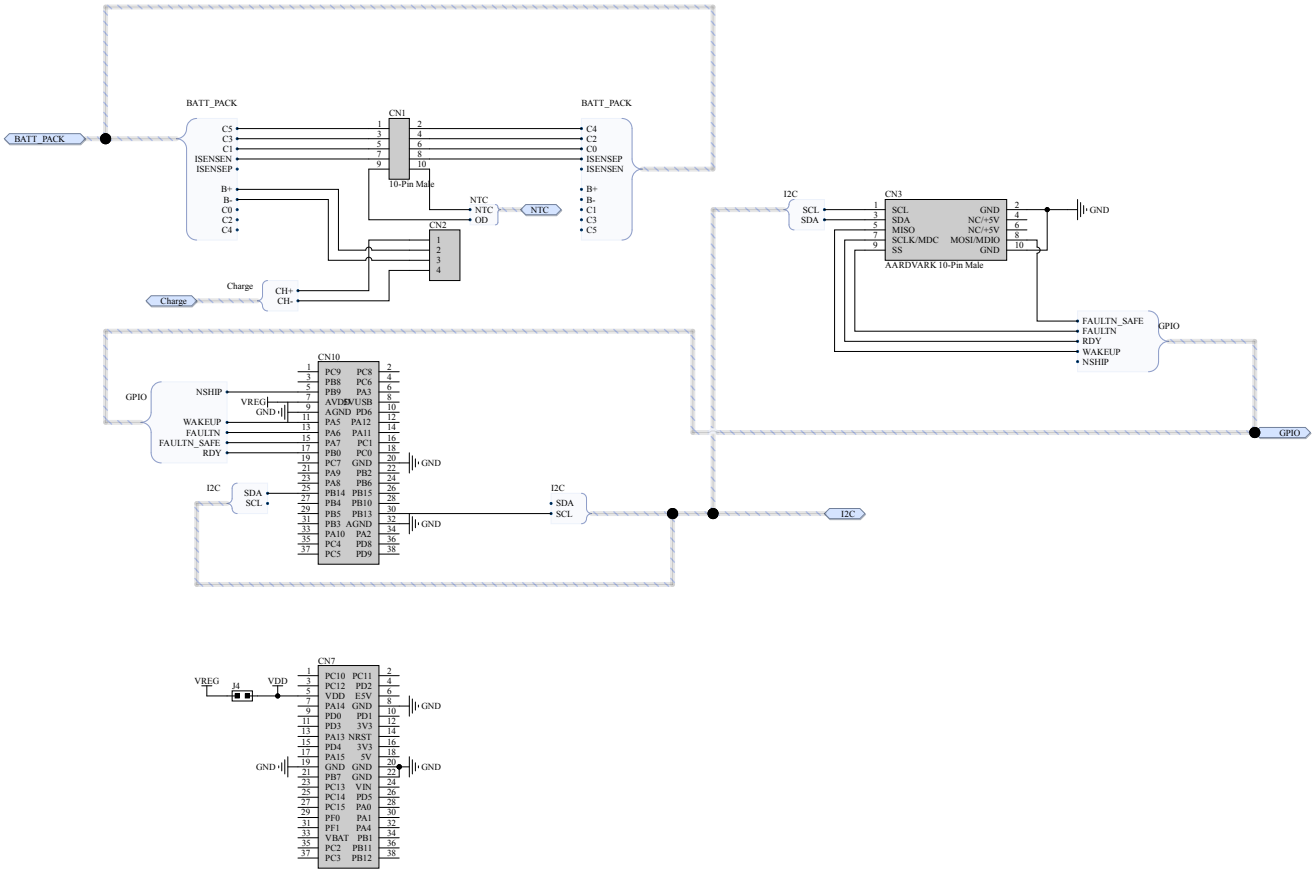
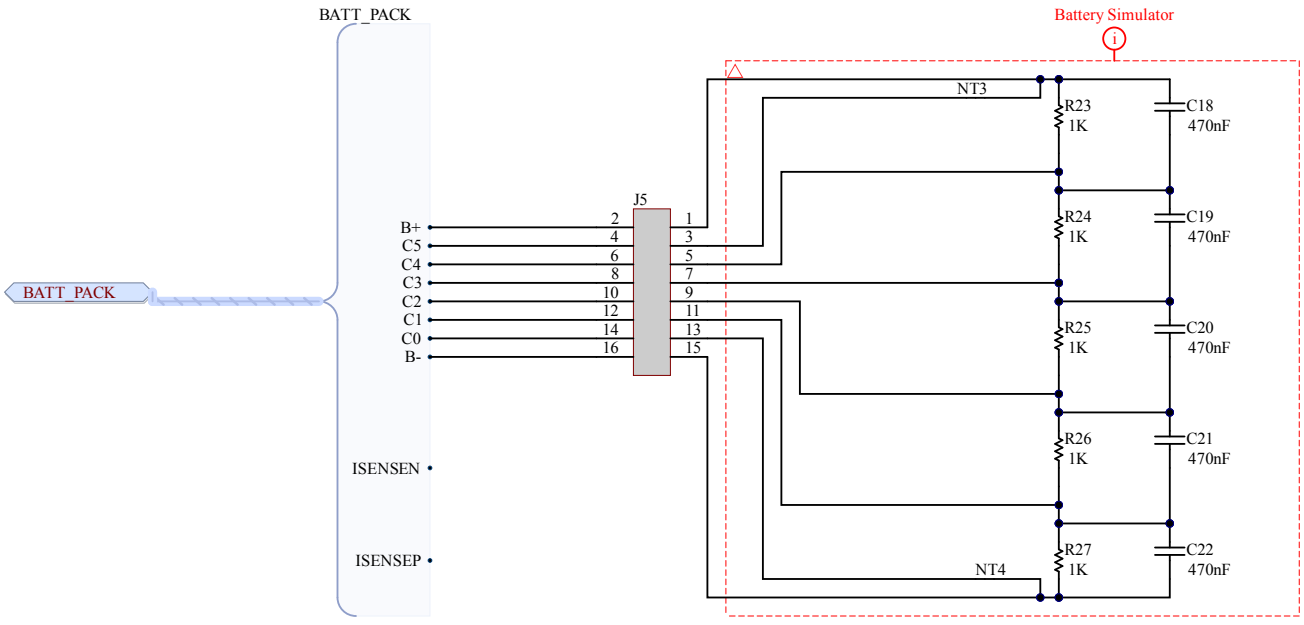


Figure 22. **STEVAL-L99615C expansion board schematic (5/5)**



5 Bill of materials

Note: The BOM below refers to the expansion board included in the STEVAL-L99615C evaluation kit. For the BOM of the NUCLEO-G071RB development board, see the related web page.

Table 5. Expansion board bill of materials

Item	Quantity	Reference	Value	Description	Manufacturer	Order code
1	2	D2, D3	BAT54FILM, SOT23	Small signal Schottky diode	STMicroelectronics	BAT54FILM
2	1	C1	2.2nF	CAP CER 2.2UF 50V X7R 0805	KEMET	C0805C222K5RAC7800
3	1	C2	10uF	CAP CER 10UF 50V X7R 1210	KEMET	C1210C106K5RAC7800
4	1	C3	220nF	CAP CER SMD 0805 2.2UF 10% X7R 5	KEMET	C0805C224K5RAC7025
5	1	C7	68nF	CAP CER 0.068UF 50V X7R 0805	KEMET	C0805C683K5RAC7800
6	1	C14	100nF	CAP CER 0.1UF 50V X7R 0805	KEMET	C0805C104K5RAC7800
7	1	C16	10nF	CAP CER 10000PF 50V X7R 0805	KEMET	C0805C103K5RAC7210
8	1	C23	22nF	CAP CER 0.022UF 50V X7R 0805	KEMET	C0805C223K5RAC7800
9	2	C12, C15	6.8nF	CAP CER 6800PF 50V X7R 0805	KEMET	C0805C682K5RAC7800
10	4	C10, C11, C13, C17	4.7uF	CAP CER 4.7UF 25V X7R 0805	KEMET	C0805C475M3RAC7800
11	10	C4, C5, C6, C8, C9, C18, C19, C20, C21, C22	470nF	CAP CER 0.47UF 50V X7R 0805	KEMET	C0805C474M5RAC7800
12	2	CN7, CN10	ESQ-119-24-T-D	CONN SOCKET 38POS 0.1 TIN PCB	Samtec Inc.	ESQ-119-24-T-D
13	1	J6	TSW-103-07-F-D	CONN HEADER VERT 6POS 2.54MM	Samtec Inc.	TSW-103-07-F-D
14	1	J5	TSW-108-07-F-D	CONN HEADER VERT 16POS 2.54MM	Samtec Inc.	TSW-108-07-F-D
15	1	R10	33K	RES SMD 33KΩ 5% 1/10W 0603	Bourns Inc.	CR0603-JW-333ELF
16	1	R12	0	RES SMD 0 Ω JUMPER 1/10W 0603	Panasonic Electronic Components	ERJ-3GEY0R00V
17	1	R15	3296W-1-204LF	TRIMMER 200KΩ 0.5W PC PIN TOP	Bourns Inc.	3296W-1-204LF
18	2	CN1, CN3	30310-6002HB	CONN HEADER VERT 10POS 2.54MM	3M	30310-6002HB
19	1	CN2	1728879	TERM BLOCK HDR 4POS 90DEG 7.62MM	Phoenix Contact	1728879
20	1	L1	1uH	FIXED IND 1UH 300MA 150 MΩ SMD	KEMET	L0805C1R0MPWST
21	1	ITV1	ITV4030L2015NR	FUSE BATTERY PROTECTOR 20V 15A	Littelfuse Inc.	ITV4030L2015NR

Item	Quantity	Reference	Value	Description	Manufacturer	Order code
22	4	J13, J14, J19, J20	5102	MICRO-MINI 6.9MM SMT JMPR	Keystone Electronics	5102
23	2	J1, J4	TSW-102-07-F-S	CONN HEADER VERT 2POS 2.54MM	Samtec Inc.	TSW-102-07-F-S
24	5	J2, J15, J16, J17, J18	TSW-103-07-G-S	CONN HEADER VERT 3POS 2.54MM	Samtec Inc.	TSW-103-07-G-S
25	1	U1	L9961, VFQFPN 5X5X1 32L P0.5	Chip for consumer battery management applications up to 5 cells	STMicroelectronics	L9961
26	1	D1	MMSZ4701T1G	DIODE ZENER 14V 500MW SOD123	ON Semiconductor	MMSZ4701T1G
27	1	R1	2.2K	RES SMD 2.2KΩ 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF2201V
28	2	R7, R8	4.7K	RES SMD 4.7KΩ 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF4701V
29	2	R13, R16	22	RES SMD 22 Ω 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF22R0V
30	4	R14, R18, R21, R22	10K	RES SMD 10KΩ 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF1002V
31	4	R28, R29, R30, R31	2M	RES SMD 2MΩ 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF2004V
32	6	R2, R3, R4, R5, R6, R9	39	RES SMD 39 Ω 5% 1/4W 0603	RΩ Semiconductor	ESR03EZPJ390
33	6	R17, R23, R24, R25, R26, R27	1K	RES SMD 1KΩ 1% 1/8W 0805	Panasonic Electronic Components	ERJ-6ENF1001V
34	1	R11	10m	RES 0.01 Ω 1% 7W 2818	Vishay Dale	WSHM2818R0100FEA
35	1	M1	STL7N6F7, PowerFLAT 2x2	N-channel 60V, 21mΩ typ., 7A STripFET F7 Power MOSFET	STMicroelectronics	STL7N6F7
36	4	M2, M3, M4, M5	STL210N4F7, PowerFLAT 5x6	MOSFET (N-Channel)	STMicroelectronics	STL210N4F7
37	1	SW1	KSC701J LFS	SWITCH TACTILE SPST-NO 0.05A 32V	C&K	KSC701J LFS
38	4	TP24, TP25, TP26, TP27	5007	PC TEST POINT COMPACT WHITE	Keystone Electronics	5007
39	23	FUSE, TB+, TC0, TC1, TC2, TC3, TC4, TC5, TCHG, TDCHG, TISENSEN, TISENSEP, TNSHIP, TNTC, TOD, TSHUNT_N, TSHUNT_P, TVB, TVREG, TVSC, TVSD,		PC TEST POINT	KOA Speer Electronics, Inc.	RCWCTE

Item	Quantity	Reference	Value	Description	Manufacturer	Order code
		TWAKEUP, VCP				
40	20	Jumper	Jumper		RSPRO	251-8682
41	1	PCB not reference	PCB 2 LAYER FR4 TG 130-140C°	PCB 2 LAYER - size 77.64x70.52x1.6mm thickness copper 70 microns		

6 Kit versions

Table 6. **STEVAL-L99615C versions**

Finished good	Schematic diagrams	Bill of materials
STEVAL$L99615CA (1)	STEVAL$L99615CA schematic diagrams	STEVAL$L99615CA bill of materials

1. *This code identifies the STEVAL-L99615C evaluation kit first version. The kit consists of a STEVAL-L99615CX whose version is identified by the code STEVAL$L99615CXA and a NUCLEO-G071RB whose version is identified by the code NUG071RB$AU2.*

7 Battery holder

The current chapter contains a reference schematic and relative BOM for developing a 5-cell battery holder. This board, once developed, may be connected to the STEVAL-L99615C kit through the 5-cell battery board connector (CN2), permitting to demonstrate the direct acquisition of the electrical characteristics from the single connected batteries.

Figure 23. Battery board schematic

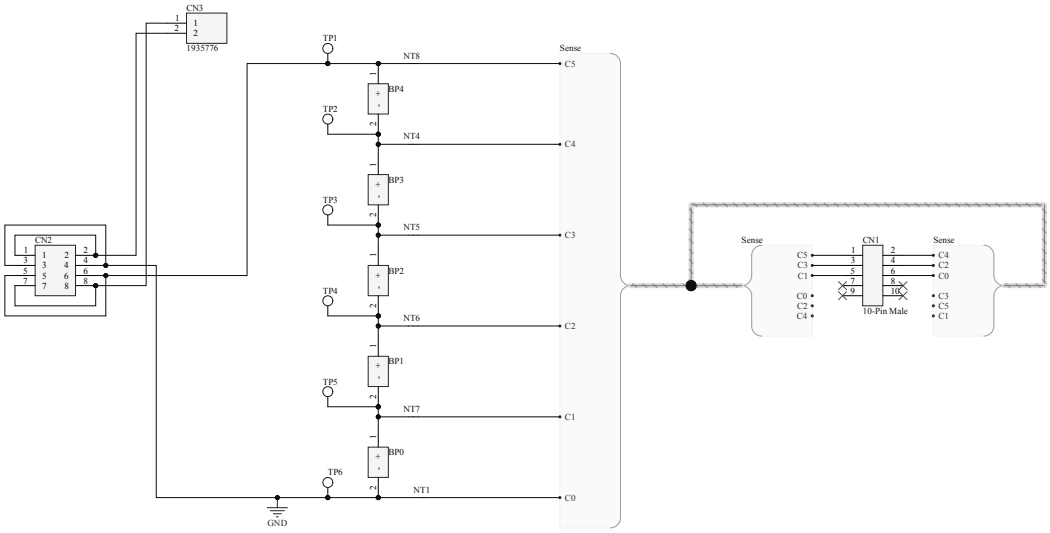


Table 7. Battery holder bill of materials

Designator	LibRef	Quantity	Manufacturer Name	Manufacturer Part Number	Manufacturer P/N	Manufacturer Part Number	Supplier 1
BP0, BP1, BP2, BP3, BP4	LI-ION 18650 1 CELL HOLDER	5			BH-18650-PC		Digi-Key
CN1	CN 2x10 shrouded	1				30310-6002HB	Digi-Key
CN2	1745807	1				1745807	Mouser
CN3	1935776	1	Phoenix Contact	1935776			
TP1, TP2, TP3, TP4, TP5, TP6	Test Point	6			5007		Digi-Key
flat cable 2x5 compatible with CN1 connector		1					
Steel Spacer with skrew 2.5mm		4					

8 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale.

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accepts harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Notice for Innovation, Science and Economic Development Canada (ISED)

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2015/863/EU (RoHS).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032).

Revision history

Table 8. **Document revision history**

Date	Revision	Changes
12-Apr-2023	1	Initial release.

Contents

List of tables

List of figures