H2020 - GV-6 – 2017

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Physical integration of hybrid and electric vehicle batteries at pack level aiming at increased energy density and efficiency Innovation Action (IA)

Grant Agreement — 770019

GHOST

InteGrated and PHysically Optimised Battery System for Plug-in Vehicles Technologies

D 3.3: Prototype & commissioning of the battery system

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Public

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Nature	Document
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1.01	25.11.2020	BU weight addition	Elie Riviere
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1.03	26.11.2020	Assembly instruction document added in annex	Elie Riviere
1.04	26.11.2020	Draft, Non-public contents removed	Patrick Femppel
1.05	02.12.2020	Validation plan update	Elie RIVIERE
2.0	02.12.2020	Introduction added, Official Release	Patrick Femppel, Andreas Könekamp

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3 Acronyms

BCI	Bulk current injection
BEV	Battery electric vehicle
BJB	Battery junction box
BoL	Beginning of life
BOM	Bill of materials
BS	Battery system
BU	Base unit
CAN	Controller area network
CF	Carbon fibre
CFRP	Continuous fibre reinforced polymer
COP	Coefficient of Performance
CRC	Cyclic redundancy check
DOF	Depth of field
DSOC	Delta state of charge
DUT	Device under test
EIS	Electrochemical impedance spectroscopy
EMC	Electromagnetic compatibility
EV	Electric vehicle
FEM	Finite element method
FMEA	Failure mode and effects analysis
FRP	Fibre reinforced plastic
GF	Glass fibre
GHOST	Integrated and physically optimised battery system for plug-in vehicles technologies
GND	Ground
HV	High voltage
HVDB	High voltage disconnection board
HVIL	High voltage interlock loop
IBCB	Inter battery communication bus
IC	Integrated circuit
ISO	International organization for standardization

LOI	Loss of isolation
LTO	Lithium Titanate Oxide
LUT	Lookup-table
LV	Low voltage
M	Month
MAST	Multi-axial simulation table
MCU	Module control unit
MOSFET	Metal oxide semiconductor field-effect transistor
MSD	Manual service disconnect
NTC	Negative temperature coefficient thermistor
NVH	Noise vibration harshness
OCV	Open circuit voltage
OEM	Original equipment manufacturer
PCB	Printed circuit board
PDU	Power distribution unit
PHEV	Plug-in hybrid electric vehicle
PSD	Power spectral density
QM	Quality management
SCMBIC	Single-cell monitoring and battery integrated circuit
SLS	Selective Laser Sintering
SNR	Signal-to-noise ratio
SOC	State of charge
SOH	State of health
SPI	Serial peripheral interface
UART	Universal asynchronous receiver/transmitter
VES	Vehicle energy system
WP	Work package

4 Introduction

The scope of this deliverable is to present the realisation and the commissioning of the GHOST Basic Unit. In Figure 4.1 the key data of the Basic Unit are provided.

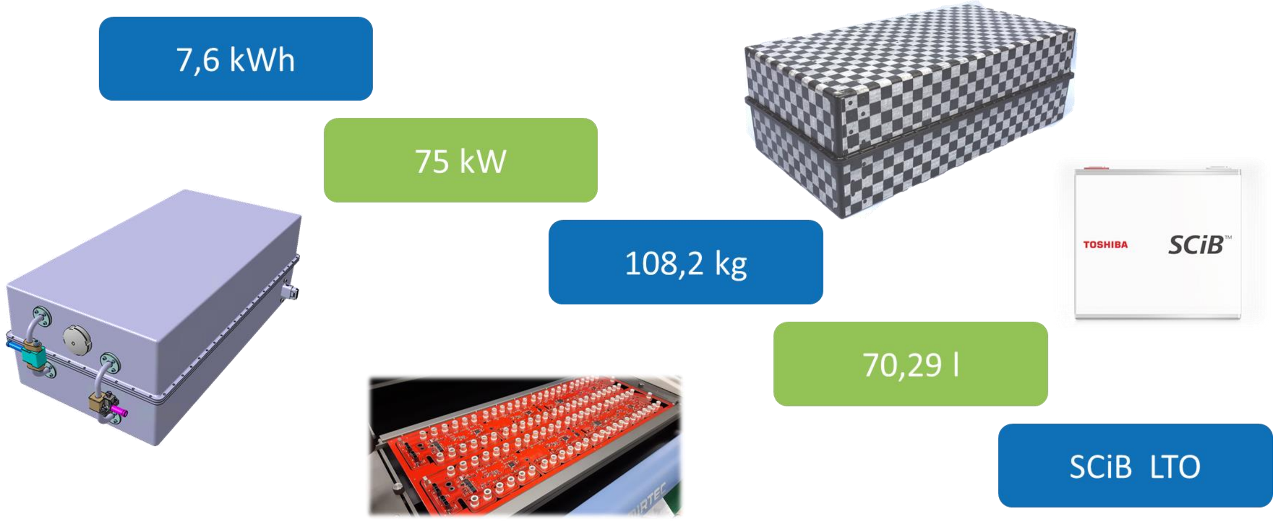


Figure 4.1: The GHOST Basic Unit – Key Data.

In order to address the key targets of the GHOST project, the GHOST team has developed a number of innovative solutions and incorporated them into the Basic Unit. Therefore the Basic Unit provides improved key characteristics, compared to state-of-the-art batteries:

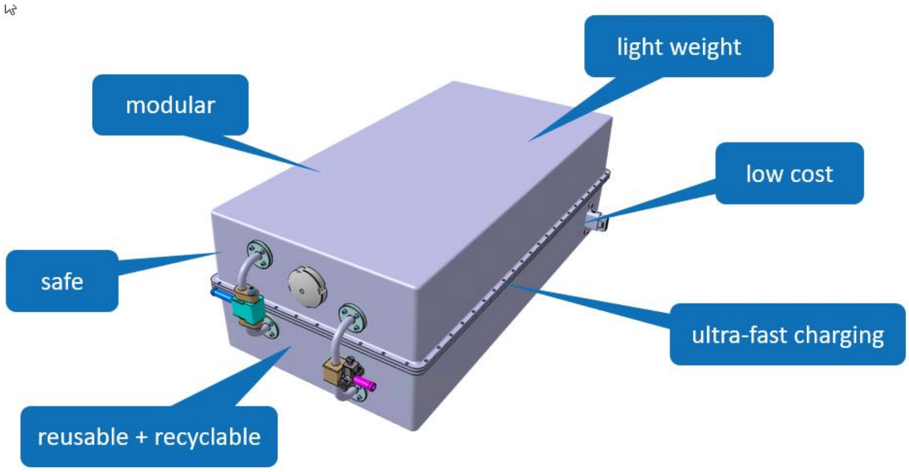


Figure 4.2: Key characteristics of the GHOST Basic Unit

The achieved key characteristic improvements shall now be described in detail.

4.1 Modular

In order to demonstrate the modularity and flexibility of the Ghost Basic Unit, it will be integrated into two different applications (see Figure 4.3):

1.) Fiat 500X PHEV

2.) IVECO EV Bus

Identical, exchangeable basic units are applied with different cooling systems and different system voltages, demonstrating the scalability of this solution.

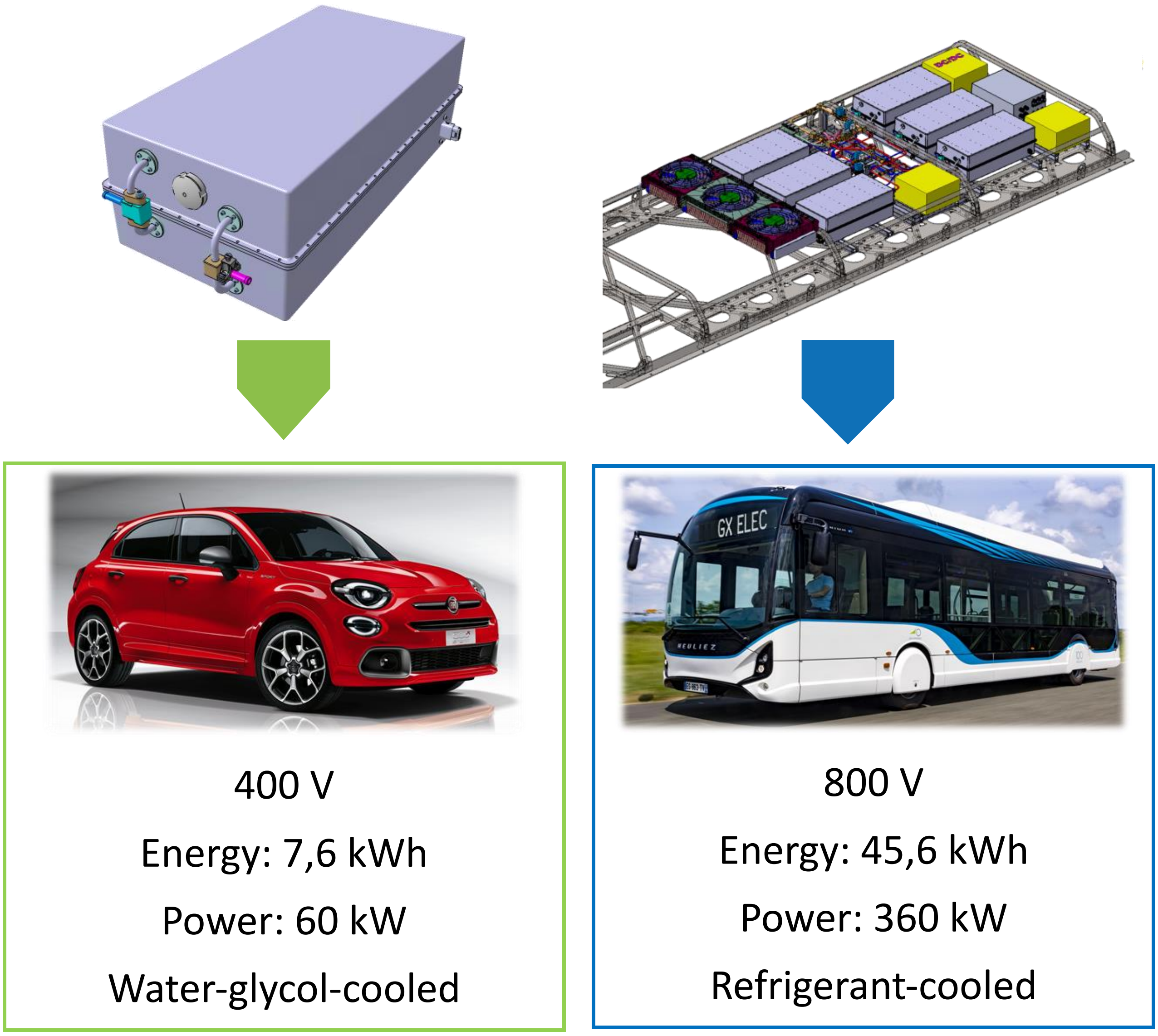


Figure 4.3: The two applications of the modular Ghost Basic Unit

4.2 Light weight

For the Ghost Basic Unit mainly two light weight technologies have been applied (see Figure 4.4):

1.) The housing is manufactured as a sandwich of glass-fiber reinforced shells combined with a molded polymer foam core.
2.) The cell retaining structure is also manufactured as glass-fiber reinforced, light-weight structure, avoiding separate weight from additional module structures.

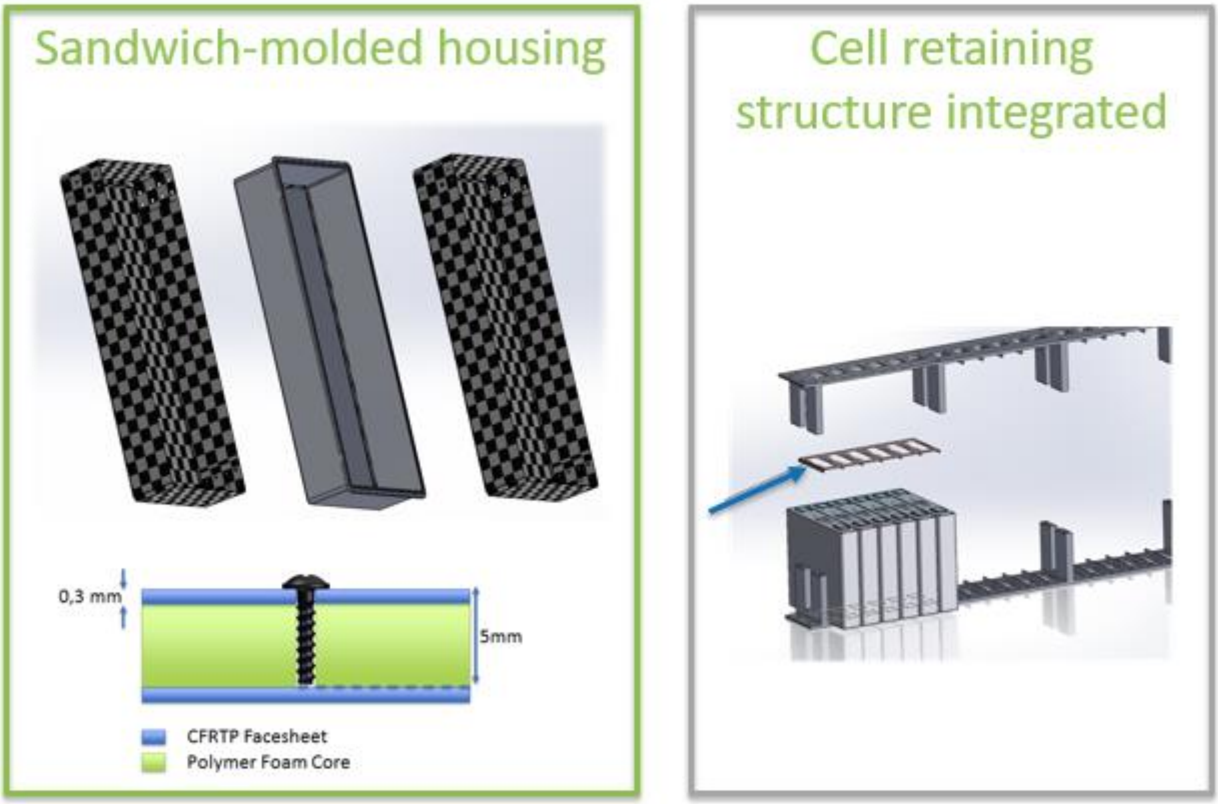


Figure 4.4: Light-weight technologies of the GHOST Basic Unit

By application of these innovative technologies, a significant improvement of the package efficiency – the ratio between cell weight and pack weight respective volume – has been achieved:

	Cell weight / Pack weight	Cell volume / Pack volume
GHOST Basic Unit	73%	54%
Benchmark		
Tesla Model 3	64%	33%
Mitsubishi Outlander	61%	41%
Jaguar I-PACE	55%	35%

4.3 Low cost

In order to significantly reduce battery integration cost, several innovative approaches have been applied for the GHOST basic unit:

1. The foam injection molding into glass-fiber reinforced shells is highly cost efficient for large production quantities. (Figure 4.5)

Figure 4.5: Glass-fibre, foam injection moulding

2. The cell retaining structure has been integrated to the pack (Figure 4.6)

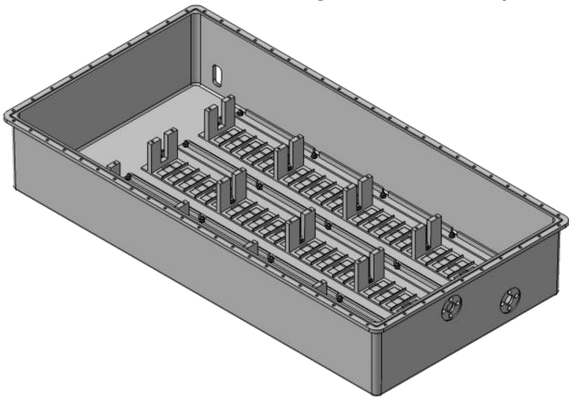


Figure 4.6: Integrate cell retaining structure

3. The electrical integration is based on Power PCBs, highly integrated with module electronics and cell-to-cell bus bars (Figure 4.7)

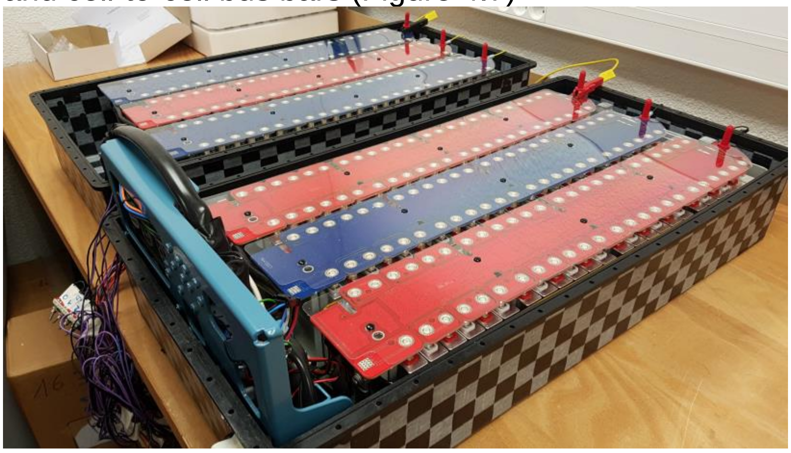


Figure 4.7: Electrical integration with Power PCBs

4.4 Ultra-fast charging

For the IVECO E-bus application, the GHOST Basic Unit will be operated with an innovative direct refrigerant cooling system. Together with the optimized cell-to-cooling plate connection an excellent thermal performance is achieved:

4. 3,6 kW cooling performance (per Basic Unit)
5. ΔT 3K cell2cell @ 3,6 kW

Figure 4.8: 250 kW opportunity charging of an E-bus

4.5 Reusable + recyclable

GHOST batteries are supporting reuse in multiple ways:

- all components are serviceable + reusable (modular)
- the cells are exchangeable
- an easy and full disassembly is supported

Furthermore, the GHOST Basic Unit fully enables recycling:

- all components are recyclable
- Especially a material recycling of the housing feasible:
  - only thermoplastics used, enabling pure fractions for recovery
  - in future with reasonably high production volume, high level specific recycling process feasible

4.6 Safe

Of course, a series production intent battery technology has to fulfill all safety standards of current and upcoming automotive applications. But also a demonstrator needs to fulfill comprehensive safety requirements. A number of measures have been performed in GHOST in order to ensure this:

1. Comprehensive multi-concern safety analysis has been performed, covering all battery related potential hazards
2. battery isolation is tested in multiple steps
3. Vibration and shock tested (Figure 4.9)

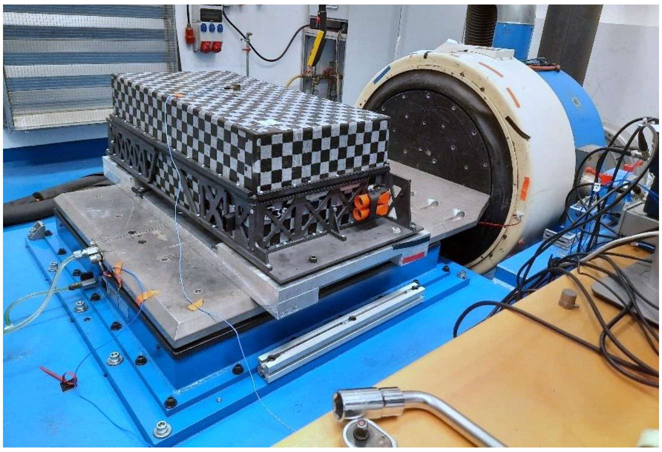


Figure 4.9: GHOST Basic Unit on vibration test bed

4. Sensorless temperature estimation of every single cell (Figure 4.10)

Figure 4.10: Sensorless temp measurement tested with GHOST cell

5. The selected housing material can resist external or internal fire

The following chapters of the report include:

- Electrical manufacture of all harness and sub-assemblies
- Mechanical assembly documentation and prototype realization

- Functional tests and validation plan, at module and at Basic Unit (BU) level.

Most of this material has been presented during the online Public Demonstration (17.11.2020), and is available on the GHOST internet pages for download:

https://h2020-ghost.eu/library/eventsmaterials/public-demonstration/

This document covers the final assembly at EVE System , after housing and cooling system are already installed.

5 Housing and Stackframe production

The housing is made of two components. A glass fibre reinforced Facesheet (composite-Preform) is produced by overmolding. Two of these Facesheets are then inserted into an injection moulding machine, where the Polymer foam is injected between the Facesheets (see Figure 5.1 and Figure 5.2). This results in a housing which has high mechanical properties at low weight and low cost due to a manufacturing time of under two minutes (see Figure 5.3) . The material can be re-used by the end-of-life of the battery housing. Two thirds of the material can be implemented into new, re-granulated housings.

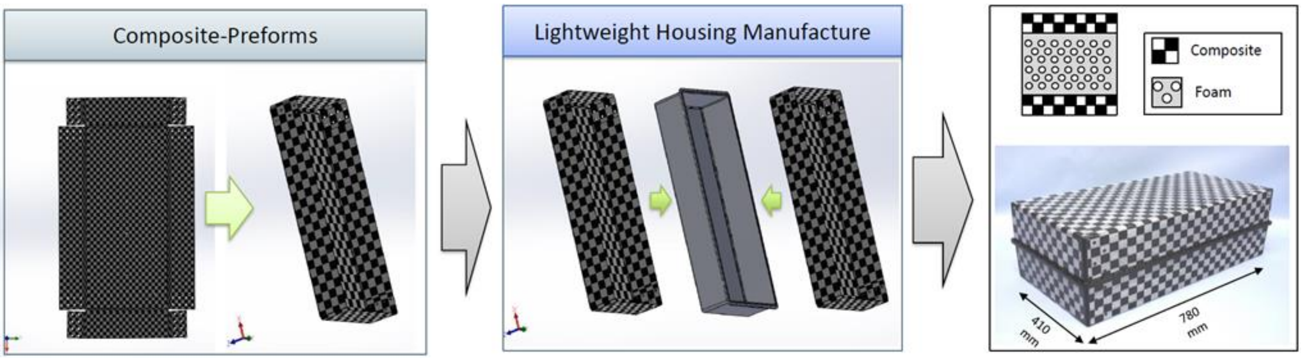


Figure 5.1: Production process of the housing.

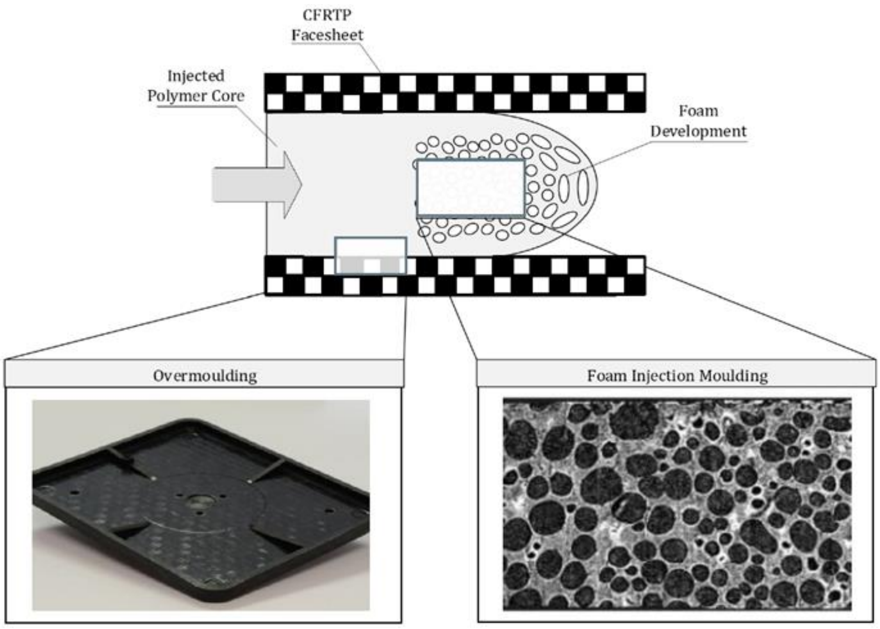


Figure 5.2: Three layers of the housing.

Figure 5.3: Injection moulding machine of Fraunhofer

The Stackframes are made of a non-conductive thermoset matrix polymer and a fibre reinforcement. For the manufacturing, a pultrusion profile was chosen. Due to the complex and filigree structure of the Stackframe, a 3D Print Insert had to be implemented into the pultrusion profile (see Figure 5.4). The Stackframe is then mechanically fixed into the housing with glew and screws.

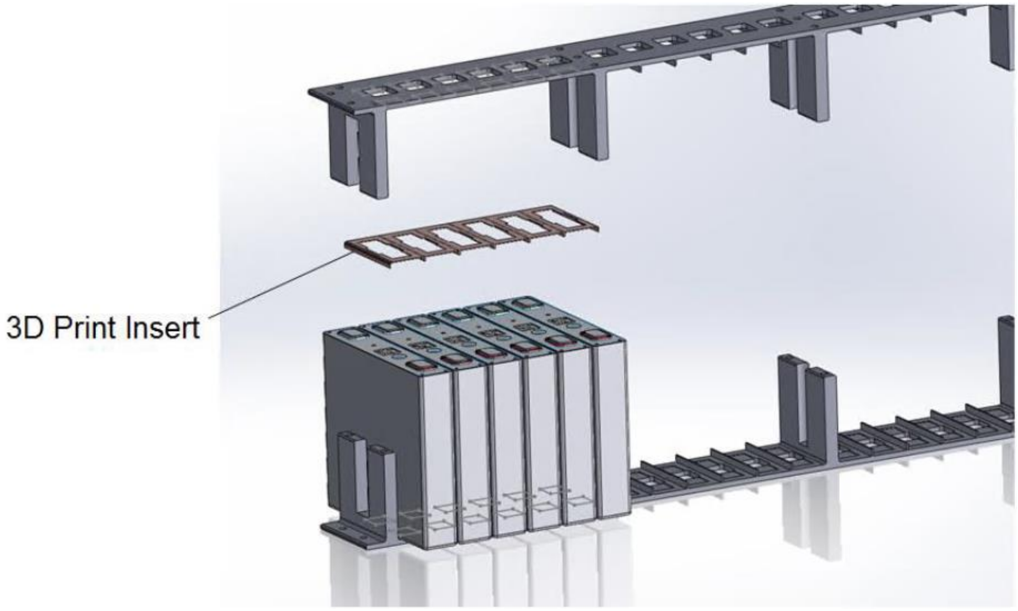


Figure 5.4: Setup of the Stackframe with cells and 3D print insert.

6 Production and assembly of the cooling profile

Valeo is in charge of the manufacturing of the cooling profile and the assembly process of the cooling profile itself. The cooling profile is made of an aluminium extrusion profile with a width of around two millimetres and a height of around 100 millimetres. The cooling profile is inserted into the housing of the BU. Holes for the in-/outlet of the cooling profile need to be drilled into the housing during the insertion of the profile.

When the cooling profile is inserted, sets of six cells are assembled into the stack frames. The blue gapfiller is the thermal interface between the cells and the cooling profile. Due to its relatively high viscosity, the remaining gaps of six cells must be sealed by using a gapfiller with a low viscosity (beige colour). Then, the blue gapfiller is inserted between the gap of the cells and the cooling profile by using a syringe (see Figure 6.1).

Figure 6.1: Stack of six cells with applied gapfiller

7 Mechanical assembly of first Basic Unit

The first prototype has been completely assembled. This try-out was used to tune the pre-series process. Based on this experience, a detailed procedure has been written.

Main process is based on:

1. Separate assembly of the 2 BU halves, including cells and cooling profile;
2. Installation of Power PCB & power braids;
3. Installation of the Battery Junction Box in the lower half;
4. Two halves assembly and BU closing.

Step 1 is out of the scope of this document.

7.1 Cell installation

This process is done during the cooling system installation procedure. Nevertheless Figure 7.1 shows the overall cells and the cooling profile installation.

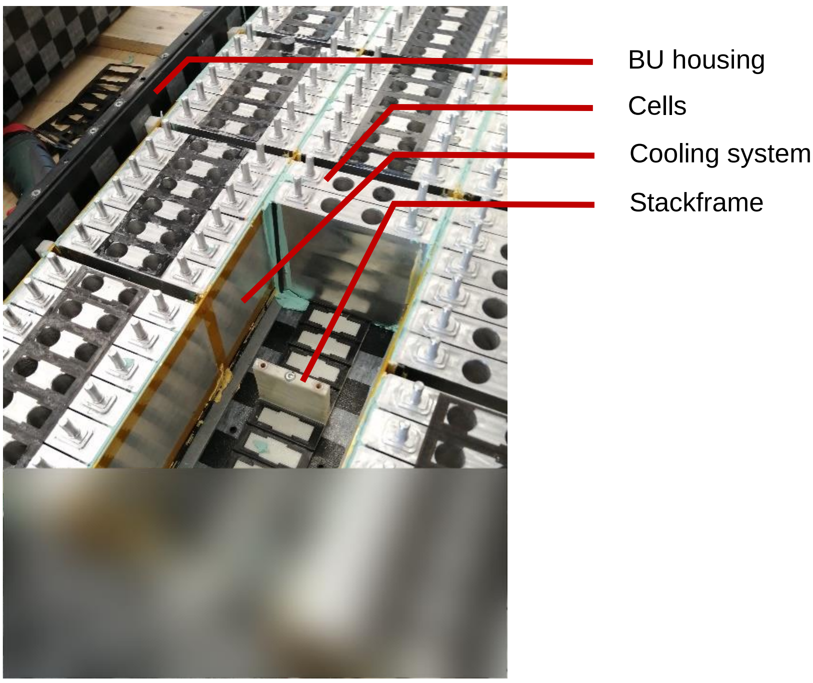


Figure 7.1 : Cell and cooling system installation in half basic unit housing

7.2 Power PCB and Power braids installation

This is the first step in EVE System scope. When all cells are installed, BU is ready for power PCB plug. This step connects simultaneously all cells together (power path) and slave BMS measurements. The connection is based on two connectors per cell. No tool, no screws are needed (see Figure 7.2).

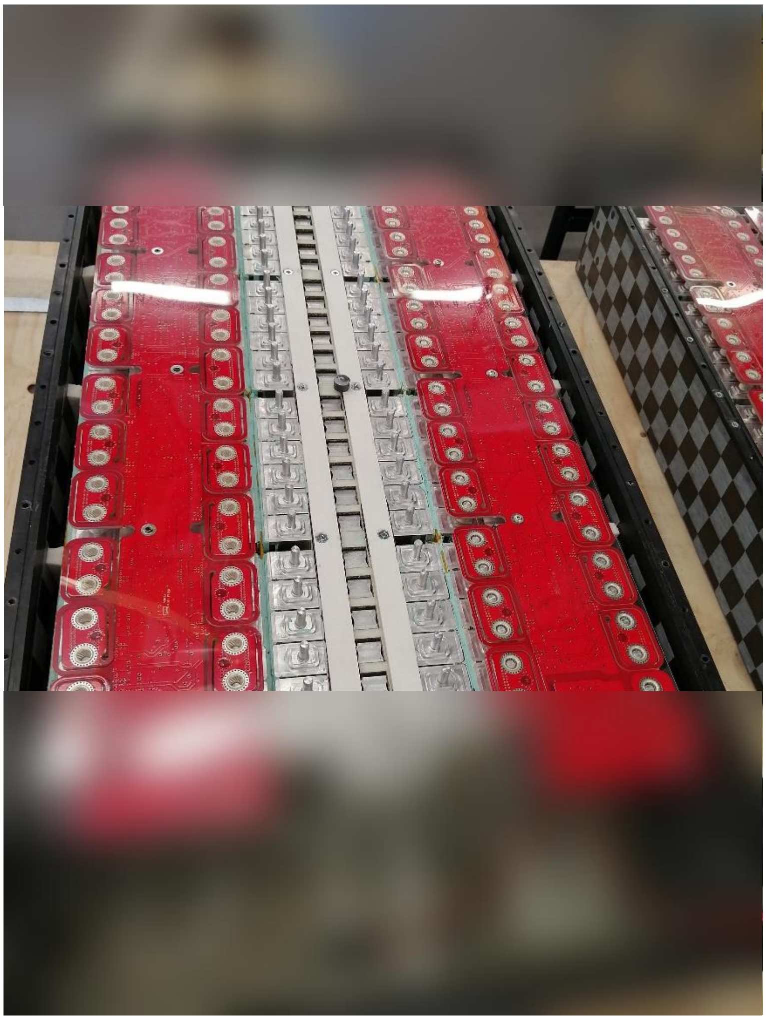


Figure 7.2 : Power PCB being installed (2/3)

When all power PCB`s are installed, the power braids can be connected (see Figure 7.3).

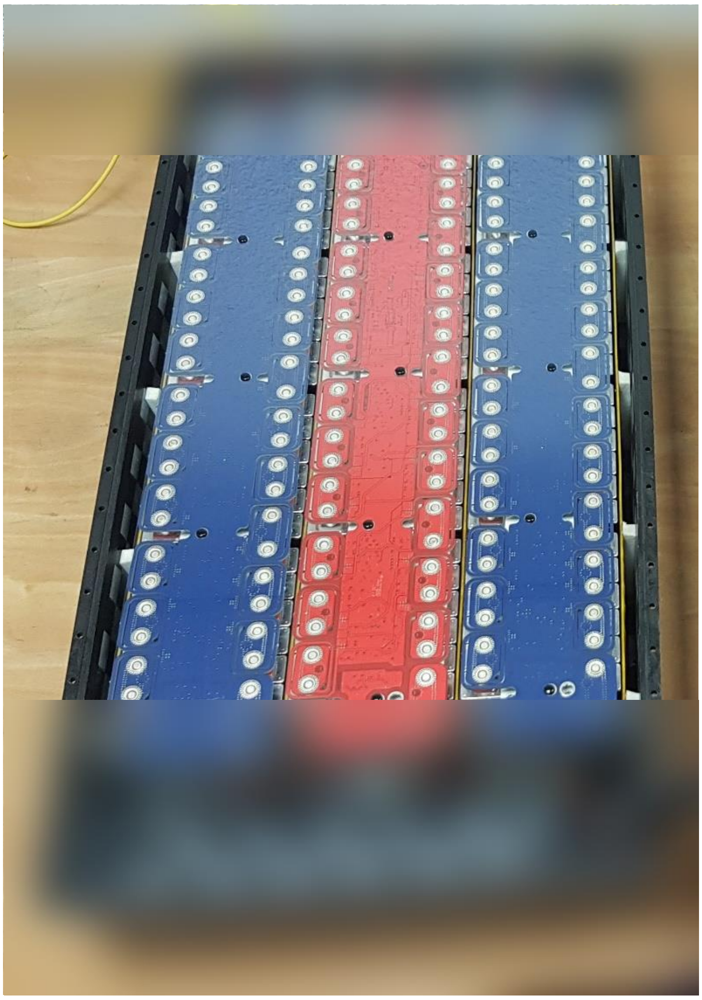


Figure 7.3 : Power braids are installed after the Power PCB`s

7.3 BJB installation

Last preparation step before BU closing is the installation of the Battery Junction Box (see Figure 7.4), including fuses, contactors, power connectors and Master BMS.

This step was switched during the first assembly to be easily and safely done. It includes connectors fixing, some power connections between power PCBs and contactors and BJB fixing to the housing. As the space is very limited, some process adjustments were done.

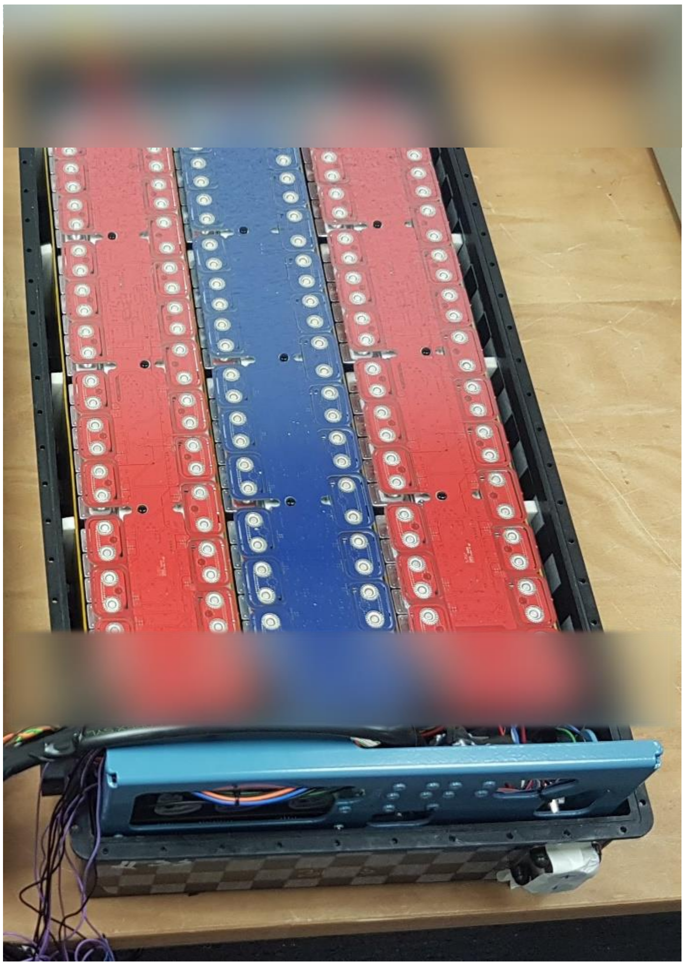


Figure 7.4 : BJB installed and power connector fixed

7.4 2 halves assembly and BU closing

After finishing all halves pre-assembly, the BU closing process can start. A detailed video has been done and is available here:

https://emdesk.eu/cms/?p=334&hash=6F0ZXN0OzI5Nzg3NQnnZG93bmxvYWQ7bGb

Main steps are described below.

7.4.1 Upper half handling

First step is to handle the upper half using straps and lifting equipment. Once straps are installed and one half is lifted, it is flipped by 180 degrees (see Figure 7.5).

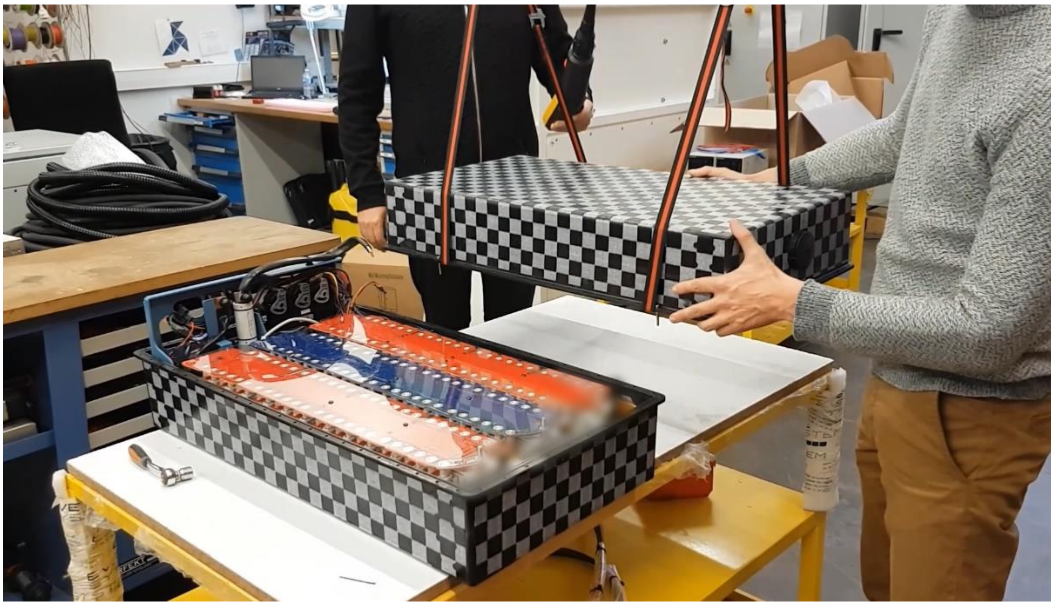


Figure 7.5 : Upper half lift using straps

7.4.2 Upper and lower halves approach

Next step is to approach and align the two halves (see Figure 7.6). Once in place, electrical connections can be done.

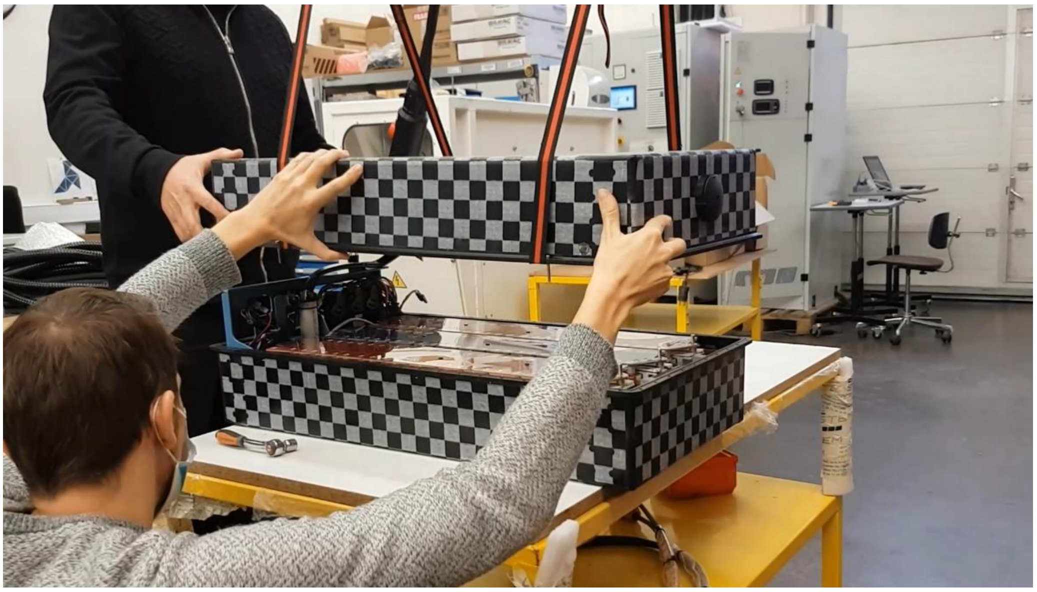


Figure 7.6 : Two halves in place, BU ready for electrical connections

7.4.3 Electrical connections

Before closing the BU, some remaining power and control connections must be done between the two halves. They have been optimized to be easily done while the upper half is maintained some centimetres over the lower half (see Figure 7.7 and Figure 7.8)

Figure 7.7 : Power connection between 2 BU halves

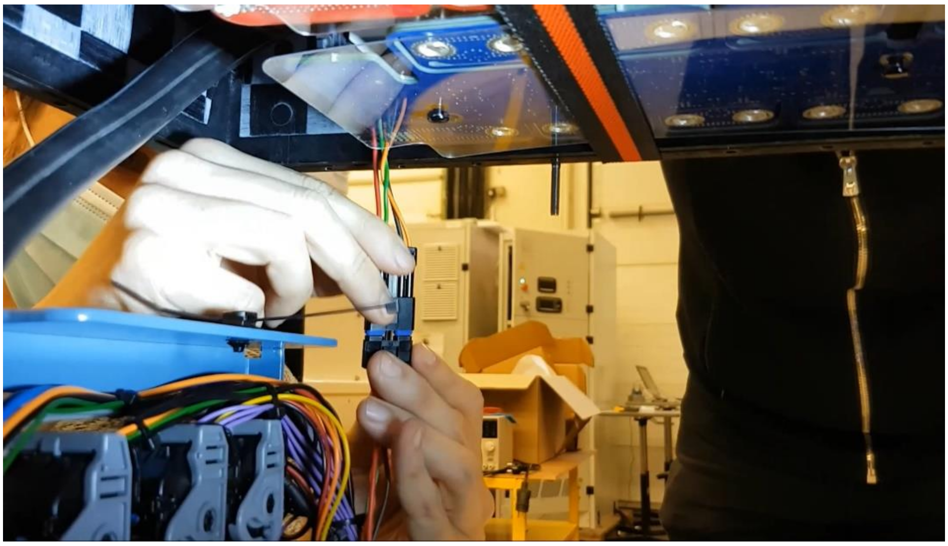


Figure 7.8 : Signal connection between two BU halves

7.4.4 Basic unit closing

The last step is to close basic unit by putting upper and lower halves in contact. Three power connections will be done automatically, closing the power path of the whole BU. This automatic contact is very interesting from a safety point of view: total BU voltage is not present until the box is fully closed (see Figure 7.9)

Figure 7.9 : BU nearly closed with three power connection about to be connected

Then, the straps can be removed (see Figure 7.10).

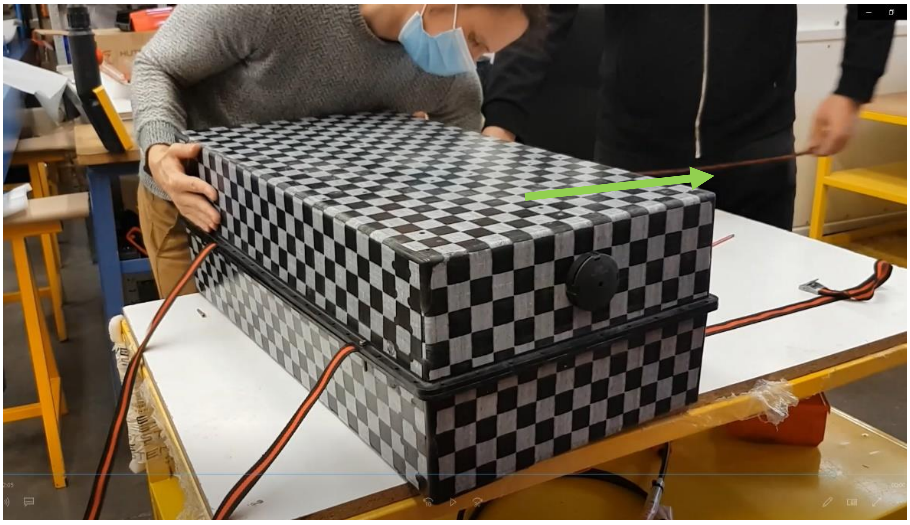


Figure 7.10 : Straps removal

7.5 Weight verification

This first BU was used to check parts weight. Results are:

- Basic unit full, except gap filler: 106.5 kg
- Cells: 79.2 kg
- E/E components: 8.6 kg
- Housing and flat tube: 18.7 kg

8 Assembly procedure of pre-series Basic Unit

Once the first BU is assembled, a detailed assembly procedure has been written, considering all feedback from first assembly.

A very detailed 3D video has been extracted from the CAD and is shared within the assembly presentation of the public demonstration:

https://h2020-ghost.eu/library/eventsmaterials/public-demonstration/

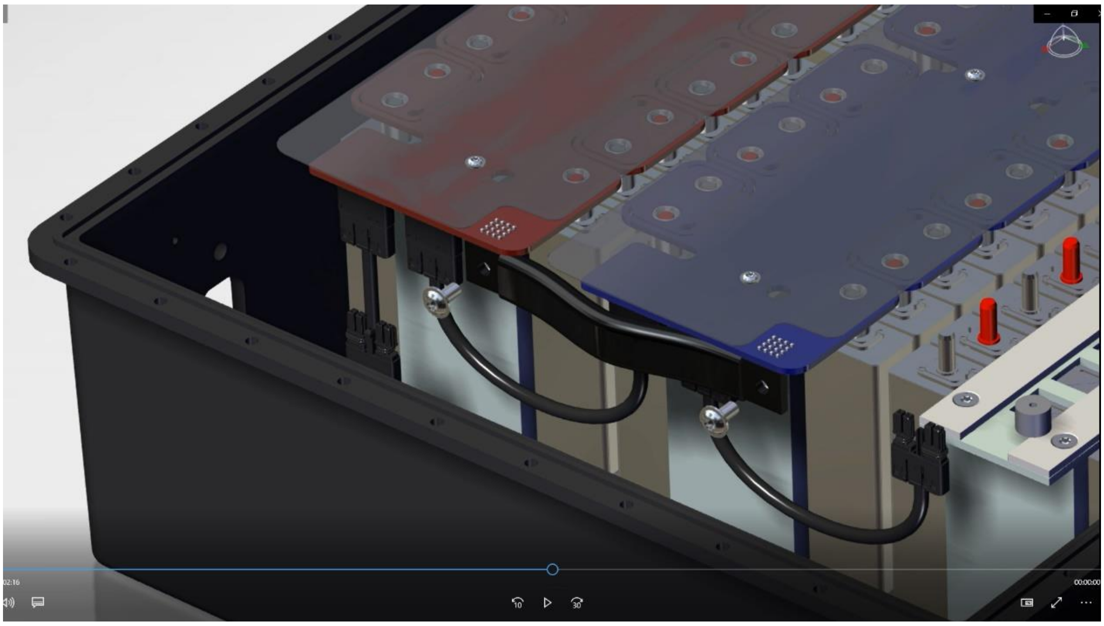


Figure 8.1 : Extract from the 3D assembly video

To complete this video, an exhaustive assembly instructions sheet is available.

This document contains all necessary BOM and step by step assembly instructions. It is available in annex 1.

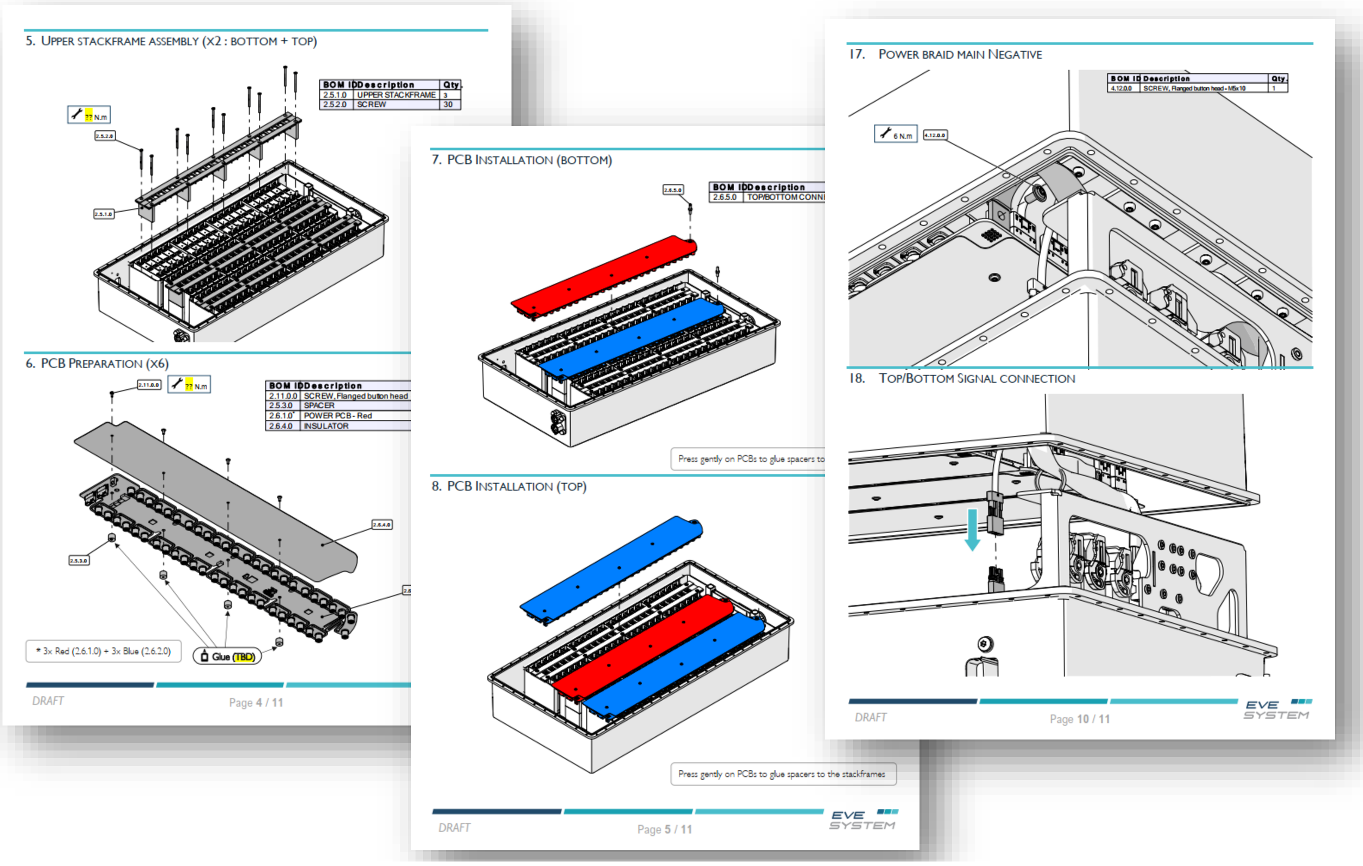


Figure 8.2 : Assembly instructions extract

9 Functional validation plan

In parallel to mechanical & electrical assembly, functional validation of power PCB has been done. Once BU assembly is completed, functional validation of the full BU has also been done.

9.1 Power PCB

Individual power PCB validation was done using a test module. It covers power, thermal and functional aspects.

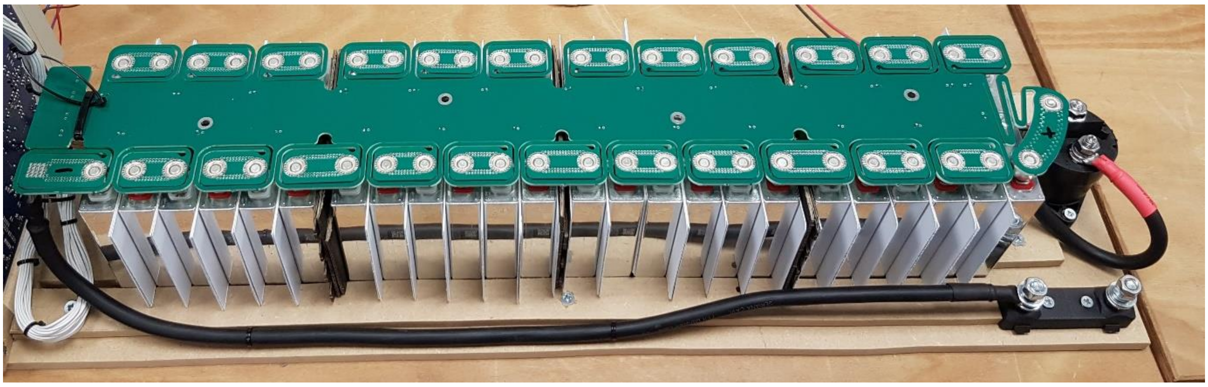
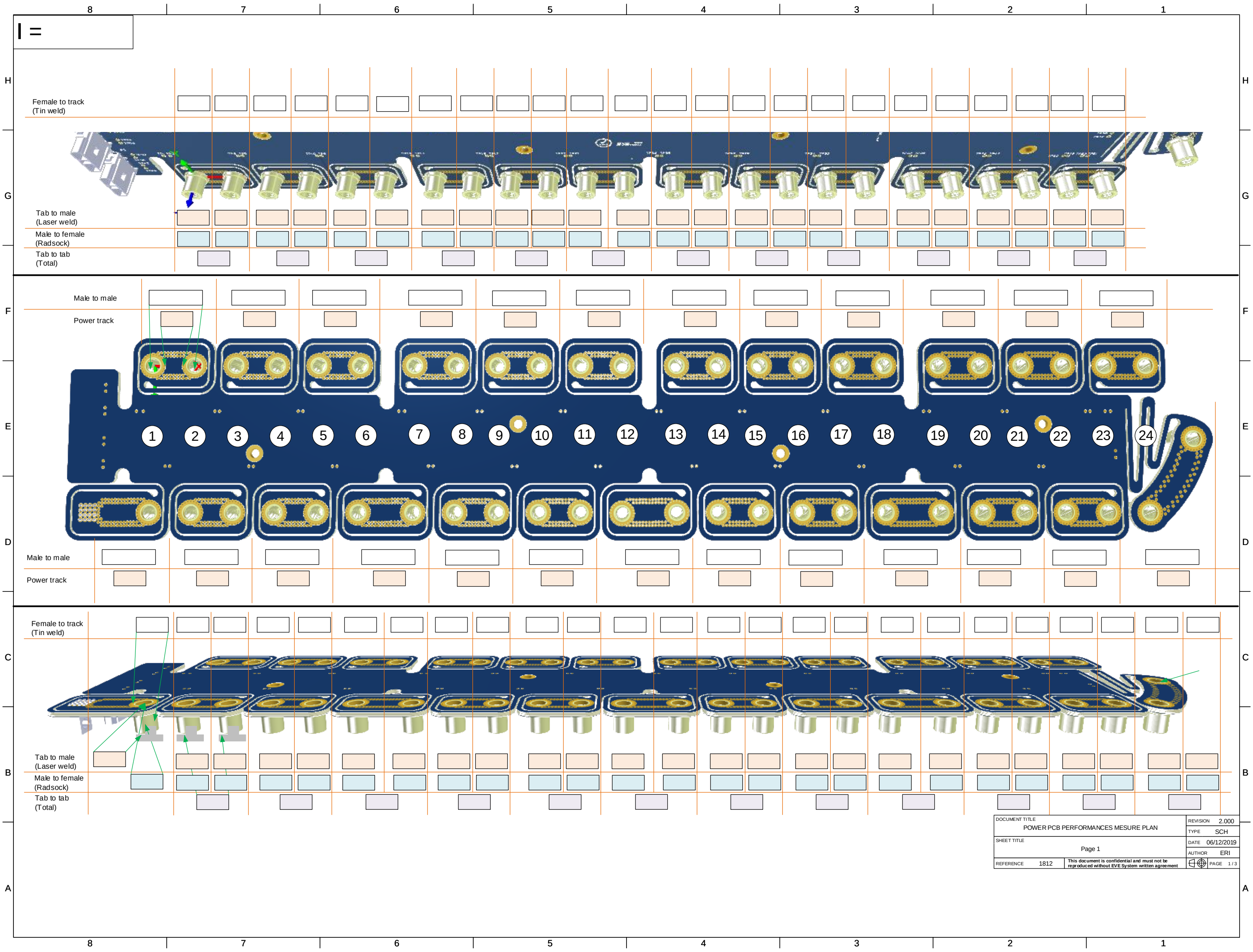


Figure 9.1 : test module used to work on power PCB validation before full BU availability

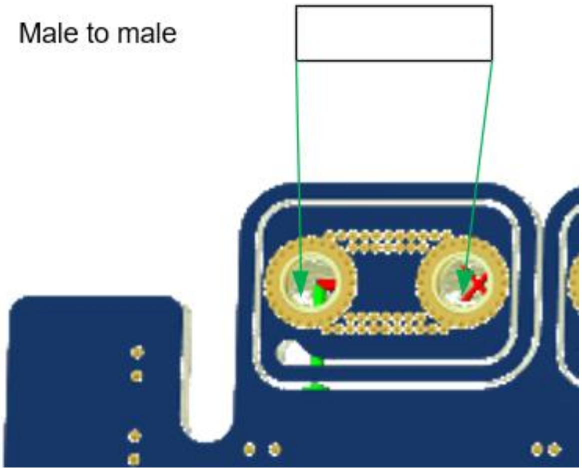
9.1.1 Resistance aspects

A detailed power qualification has been done to measure welds, contact and PCB resistances. The Voltage drops are measured @20A with a high precision multimeter.

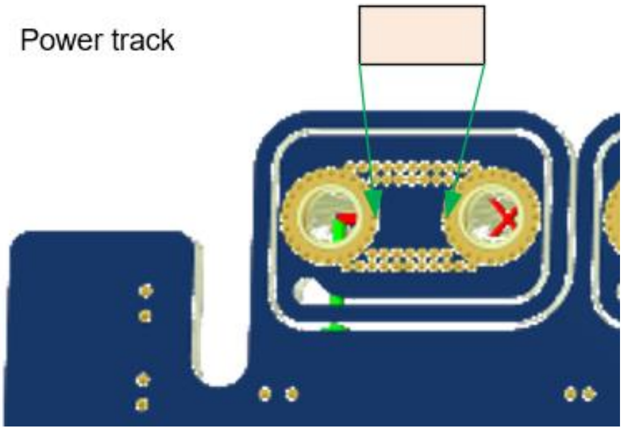
9.1.1.1 Measurement sheet



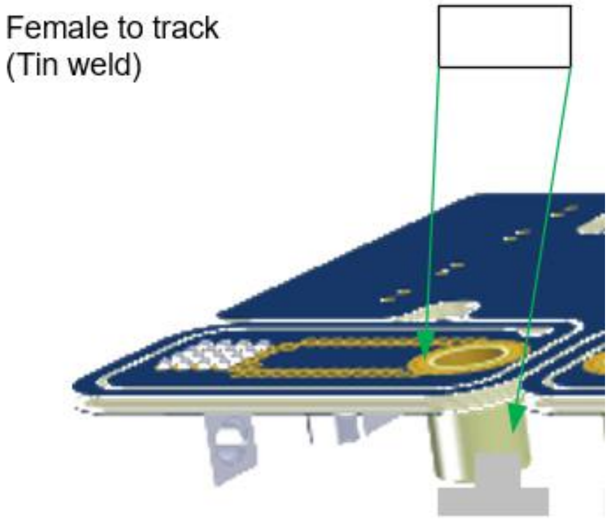
9.1.1.1.1 Male pin to male pin



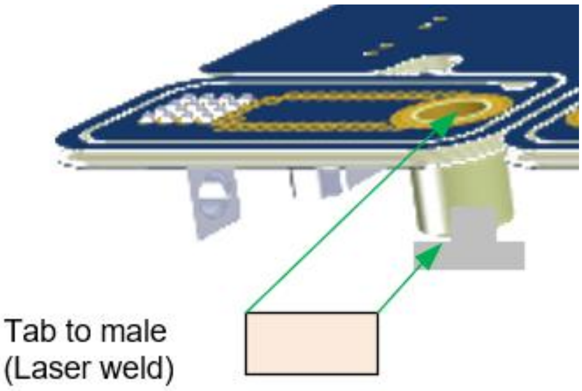
9.1.1.1.2 Power track (Power PCB copper)



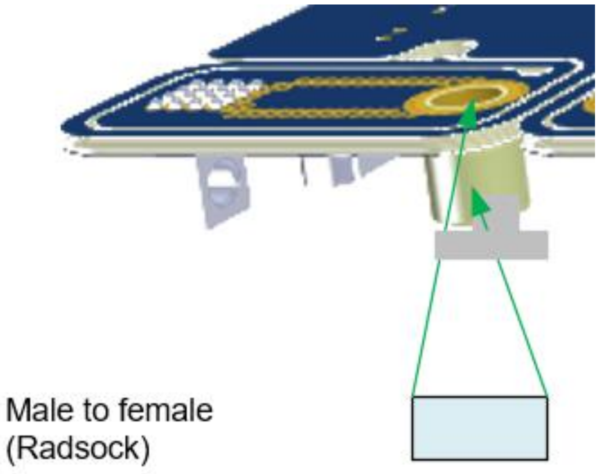
9.1.1.1.3 Female radsock to power track (Tin weld)



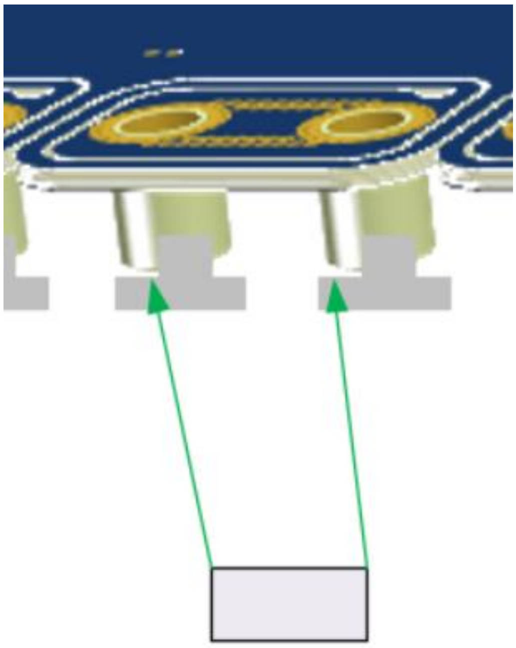
9.1.1.1.4 Cell tab to male radsock (pin laser weld)



9.1.1.1.5 Male radsock to female radsock (Contact qualification)



9.1.1.1.6 Cell tab to cell tab (total resistance of the solution)



9.1.1.2 Measurement results

All details in 1812-ED-PowerPCB resistances measurement-2.000.xlsx.

Sum-up:

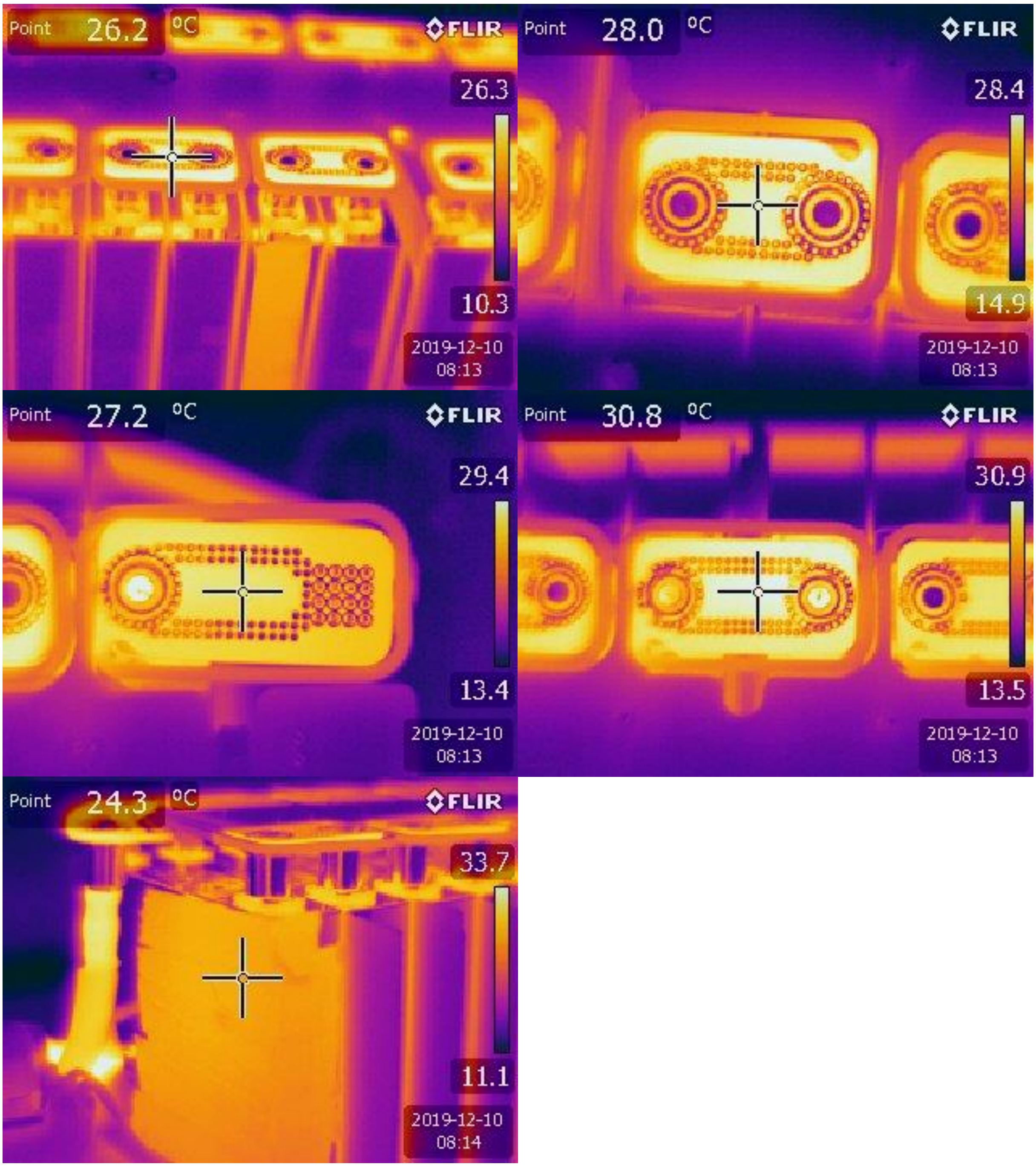
		mOhm					
Cellule	Plot	Power track	Male to male	Female to track (Tin weld)	Tab to male (Laser weld)	Male to female (Radsock contact)	Tab to tab (Total)
Total		**0.46**	**2.2735**	**0.3435**	**0.9995**	**1.4175**	**3.175**
Total [%]		**14%**		**11%**	**31%**	**45%**	**100%**
Total BU							**19.05**
Moyenne		0.0160	0.0888	0.0070	0.0208	0.0289	0.1309
Min		0.0130	0.0830	0.0055	0.0195	0.0260	0.1245
Max		0.0240	0.1050	0.0090	0.0220	0.0475	0.1465

- ➔ Low disparity on laser welds
- ➔ Total solution around 0.13 mΩ / cell
- ➔ Power PCB track impact is low

9.1.2 Thermal aspects

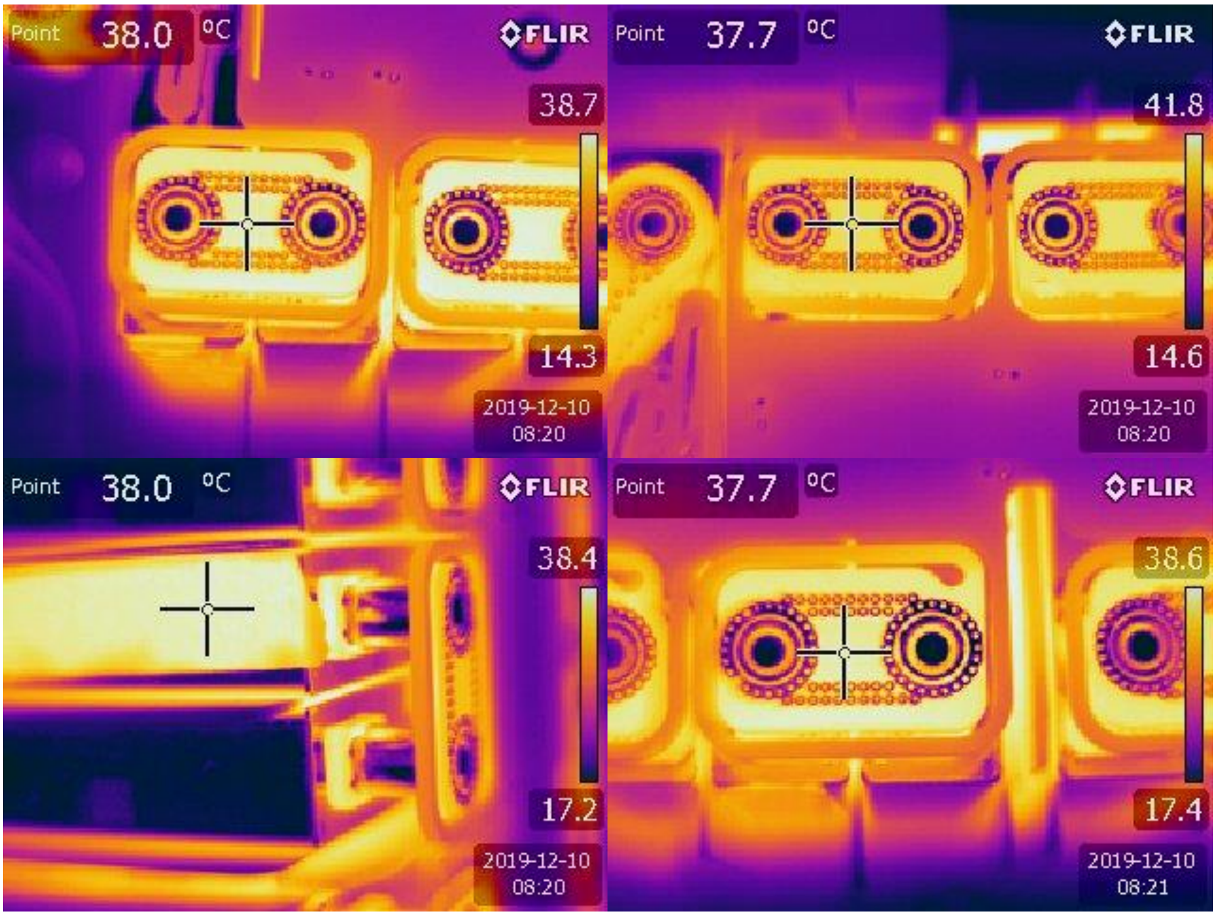
Thermal pictures have been done to check temperature rise and homogeneity between PCB and cells.

9.1.2.1 At +120A - 3-4 minutes



9.1.2.2 > 8 minutes (current stopped)

- Power track T° very closed to cell side T°



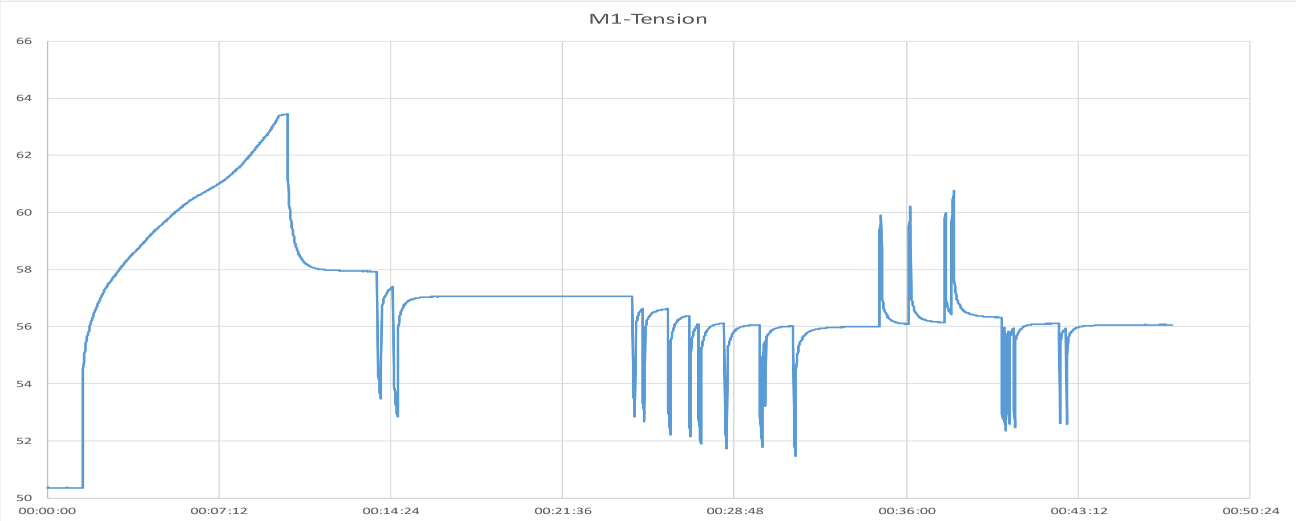
9.1.3 Module ESR qualification

Module ESR estimation has been done using the dU/dI method. Methods and results are below.

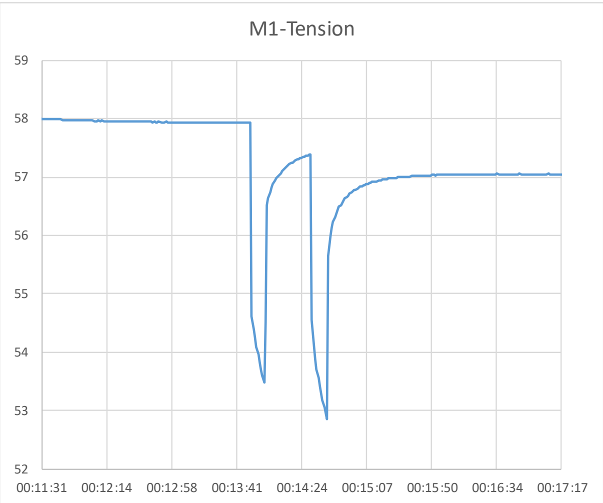
9.1.3.1 At 40°C

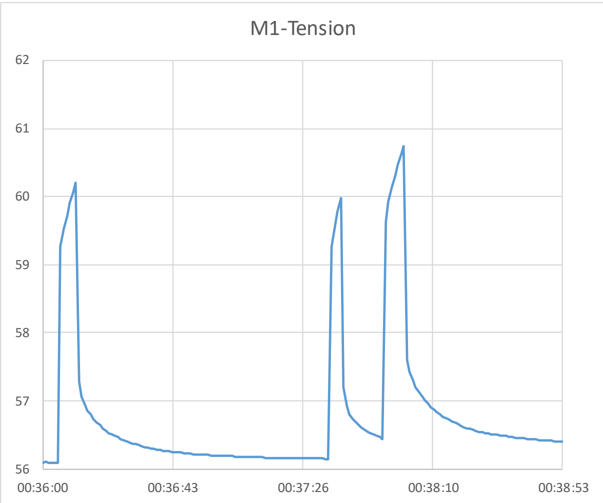
Cells between 35°C and 40°C for all measurement

9.1.3.1.1 From BMS measurements



Zooms:





ESR calculation from BMS measurements (= cell + radsock + power tracks + all welds)

	V_{start}	V_{end}	R[mΩ]
	57.92	54.39	17.65
	57.39	54.56	14.15
	53.48	56.51	15.15
	52.85	55.64	13.95
	56.09	59.26	15.85
	60.2	57.28	14.6
	56.14	59.27	15.65
	59.98	57.14	14.2
	56.42	59.63	16.05
	60.75	57.61	15.7
	52.6	55.48	14.4
	55.9	52.9	15
	52.57	55.5	14.65
Average value			**15.1538462**

9.1.3.1.2 From external measurements

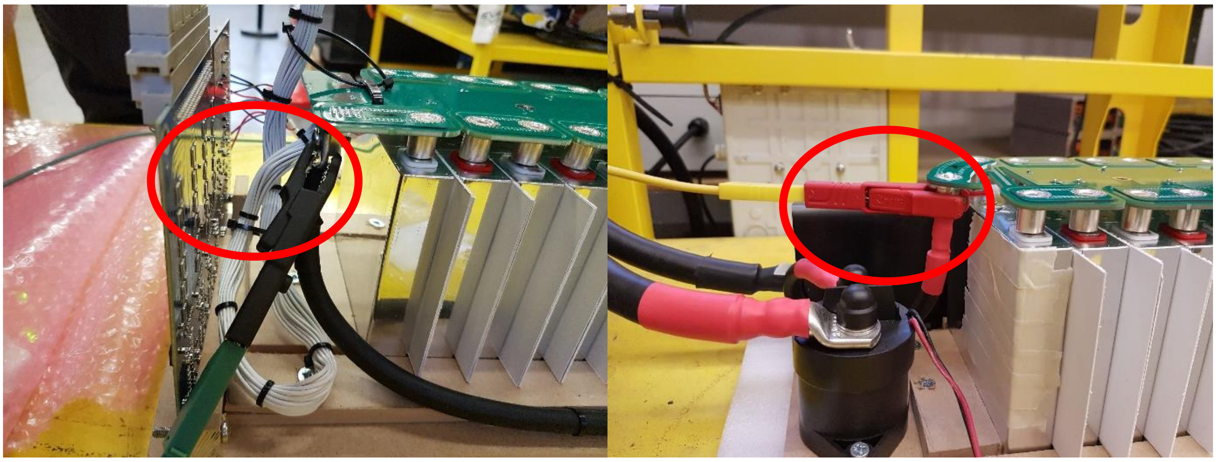
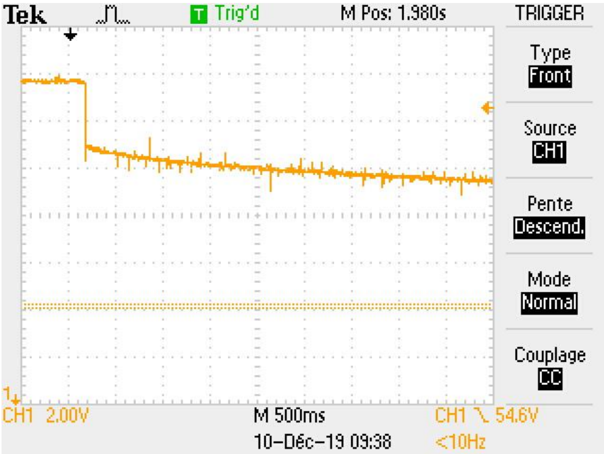
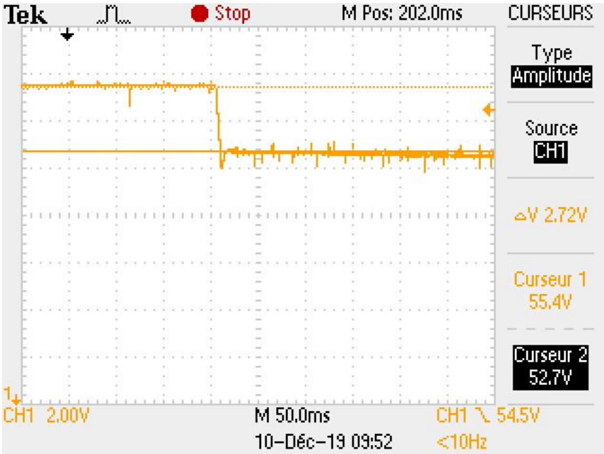


Figure 9.2 : external measurement setup

9.1.3.1.2.10A -> -200A

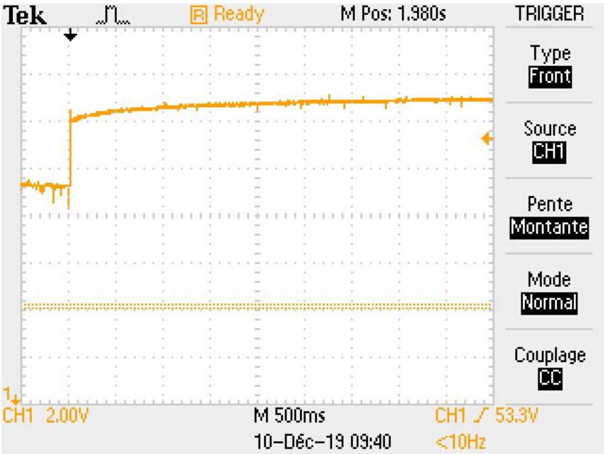


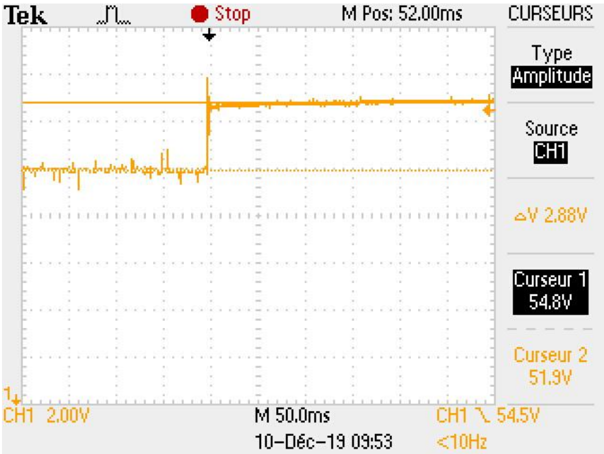


ESR = 3V/200A = 15mΩ

ESR = 3.4V/200A = 17mΩ

9.1.3.1.2.2-200A -> 0A

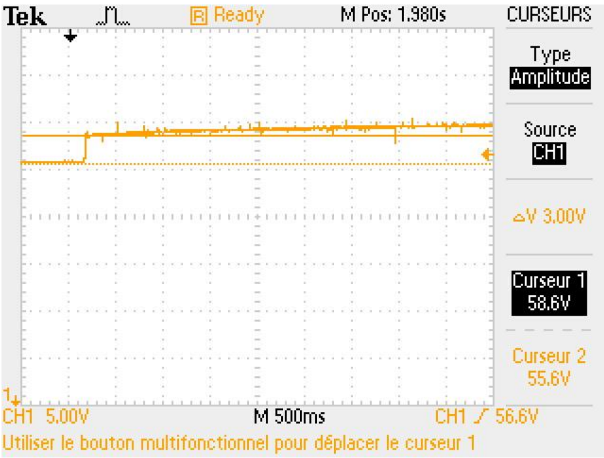




ESR = 3V/200A = 15mΩ

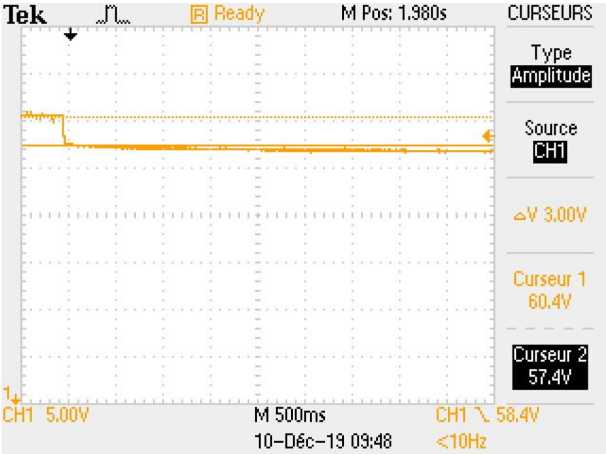
ESR = 2.9V/200A = 14.5mΩ

9.1.3.1.2.30 -> +200A



ESR = 3V/200A = 15mΩ

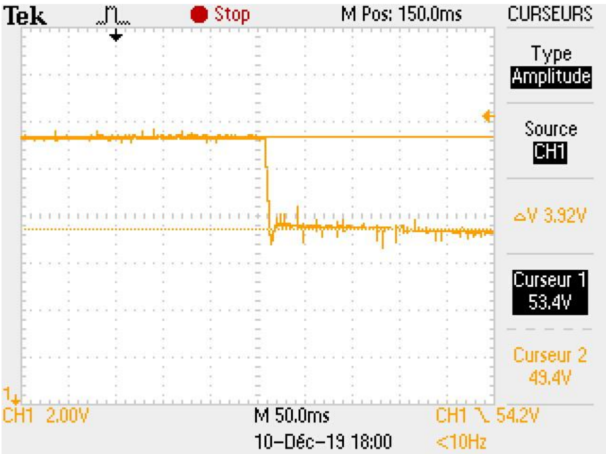
9.1.3.1.2.4+200A -> 0A



ESR = 3V/200A = 15mΩ

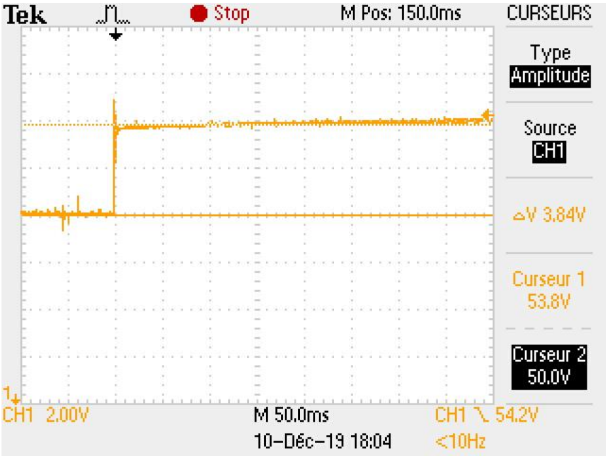
9.1.3.2 At 20°C

9.1.3.2.1 0A -> -200A



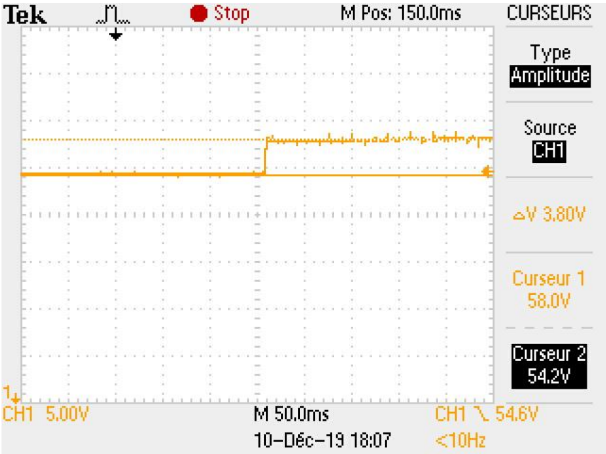
ESR = 3.92V/200A = 19.6 mΩ

9.1.3.2.2 -200A -> 0A



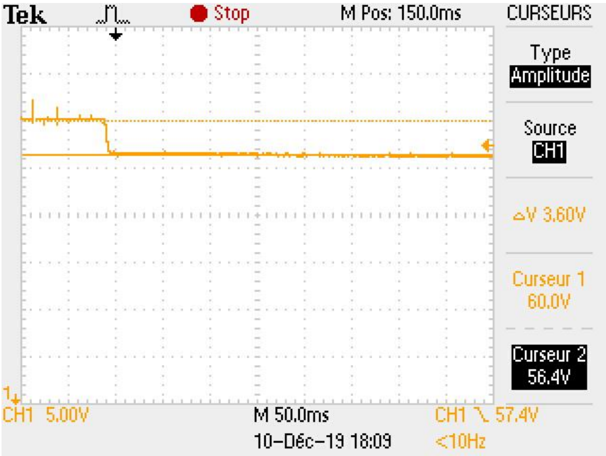
ESR = 3.84V/200A = 19.2 mΩ

9.1.3.2.3 0A -> +200A



ESR = 3.80V/200A = 19 mΩ

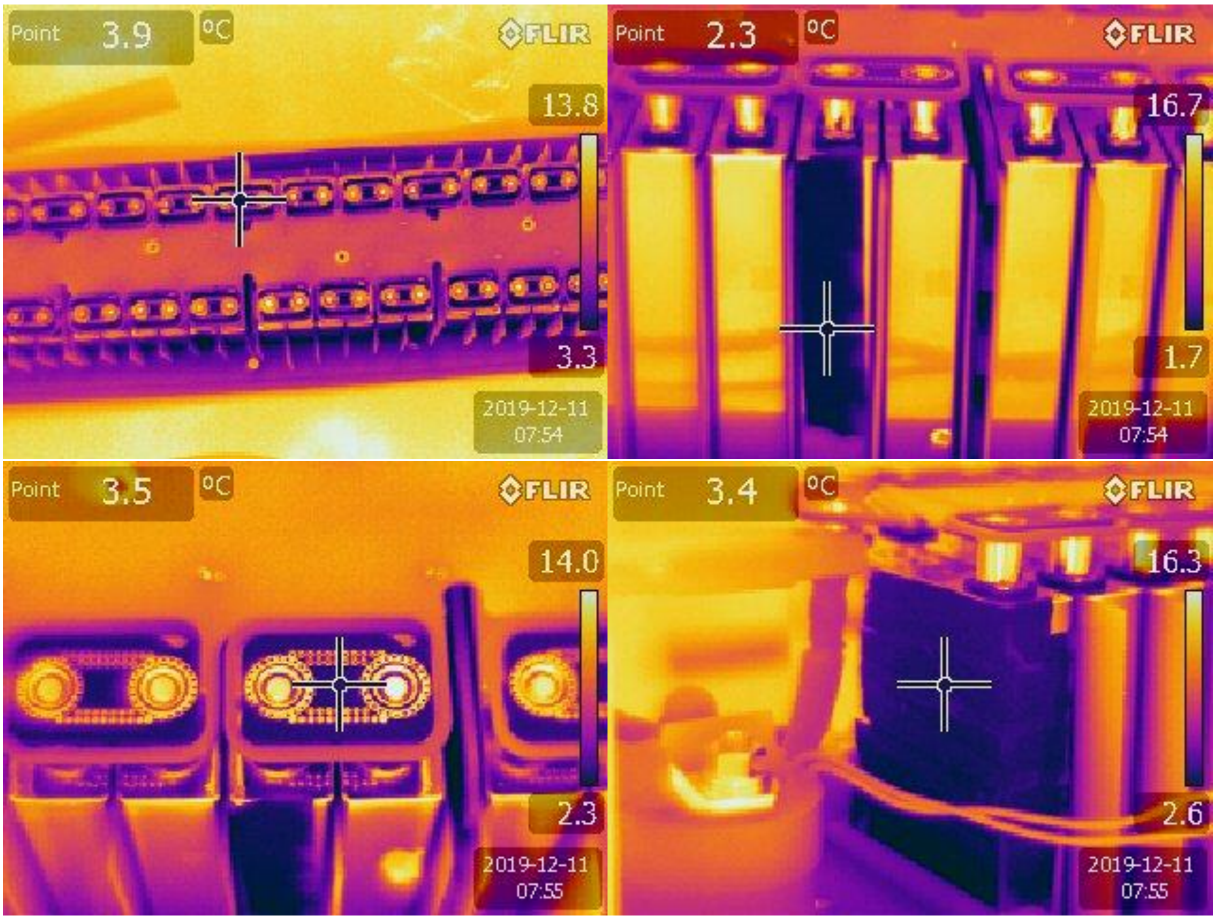
9.1.3.2.4 +200A -> 0A



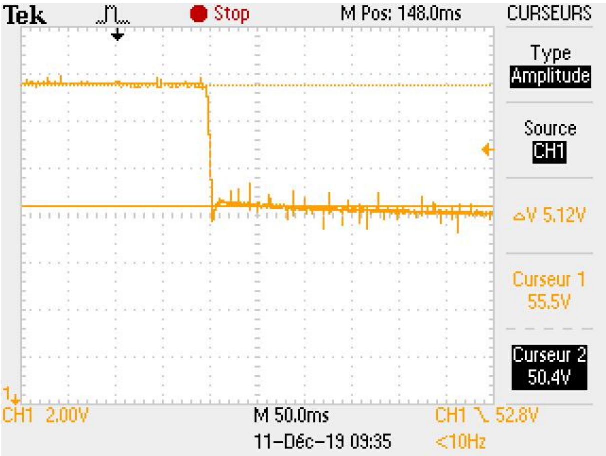
ESR = 3.60V/200A = 18 mΩ

9.1.3.3 At 3°C

PCB track really close to cell side T°.

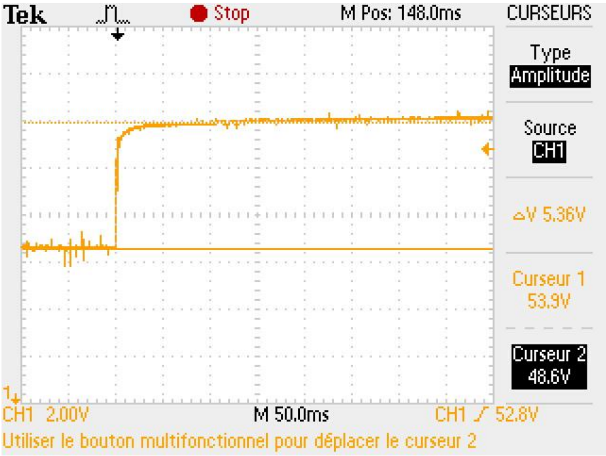


9.1.3.3.1 0A -> -200A



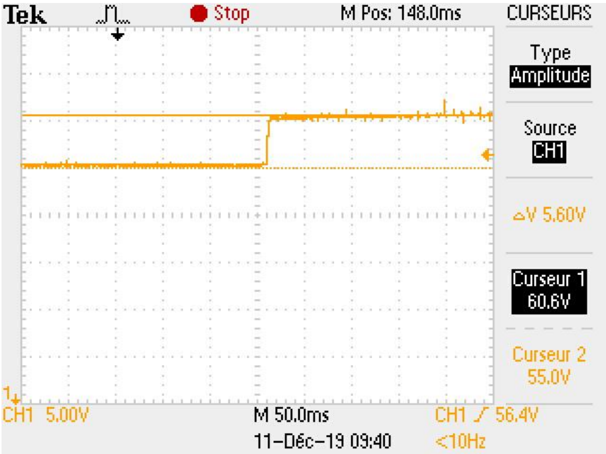
ESR = 5.12V/200A = 25.6 mΩ

9.1.3.3.2 -200A -> 0A



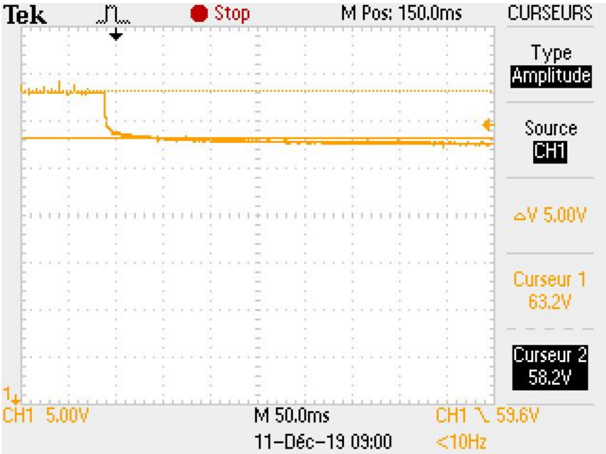
ESR = 5.36V/200A = 26.8 mΩ

9.1.3.3.3 0A -> +200A



ESR = 5.60V/200A = 28 mΩ

9.1.3.3.4 +200A -> 0A



ESR = 5.00V/200A = 25 mΩ

9.1.3.4 Sum-up

	0A -> -200A	-200A -> 0A	0A -> +200A	+200A -> 0A	Average (Total)	Average /cell *
3 °C	25.6 mΩ	26.8 mΩ	28 mΩ	25 mΩ	**26.4 mΩ**	**0.96 mΩ**
20 °C	19.6 mΩ	19.2 mΩ	19 mΩ	18 mΩ	**19.0 mΩ**	**0.66 mΩ**
40 °C	16 mΩ	14.8 mΩ	15 mΩ	15 mΩ	**15.2 mΩ**	**0.50 mΩ**

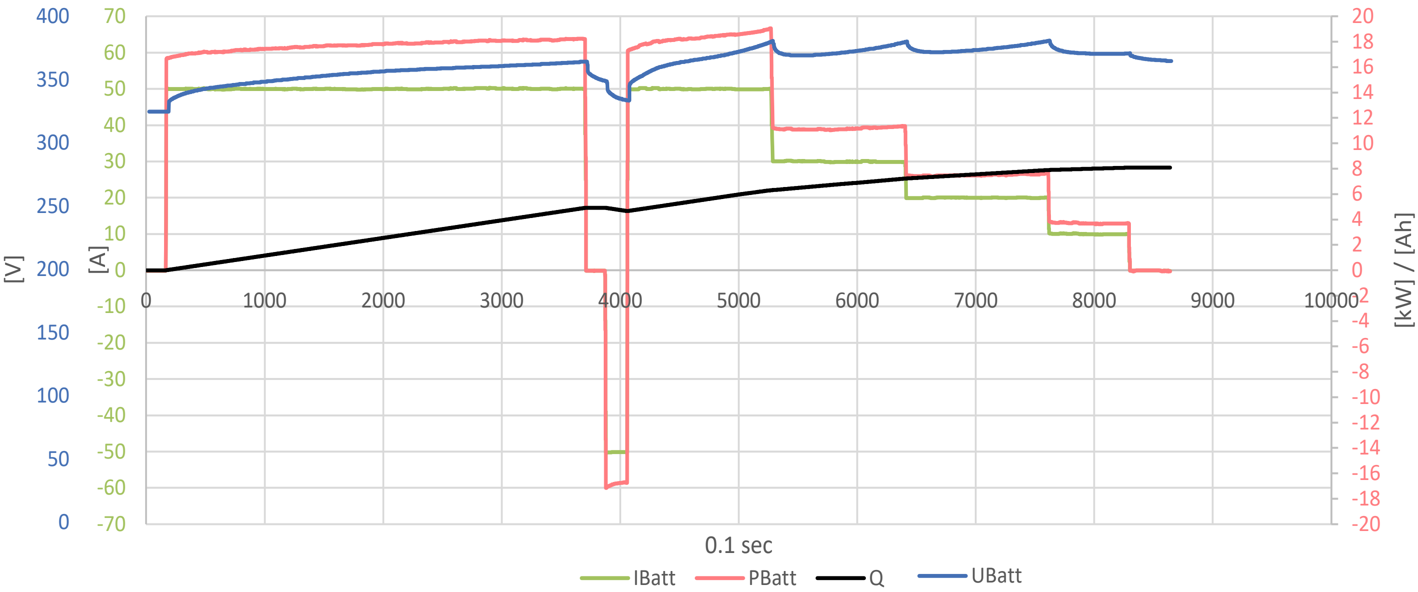
* Power PCB part is 3.175 mΩ/ module, so:

Average /cell = (Average (Total) – 3.175) / 24

9.2 Full BU

After unitary tests on power PCB, integration tests have been conducted on fully assembled basic unit.

9.2.1 Power tests (w/o cooling)



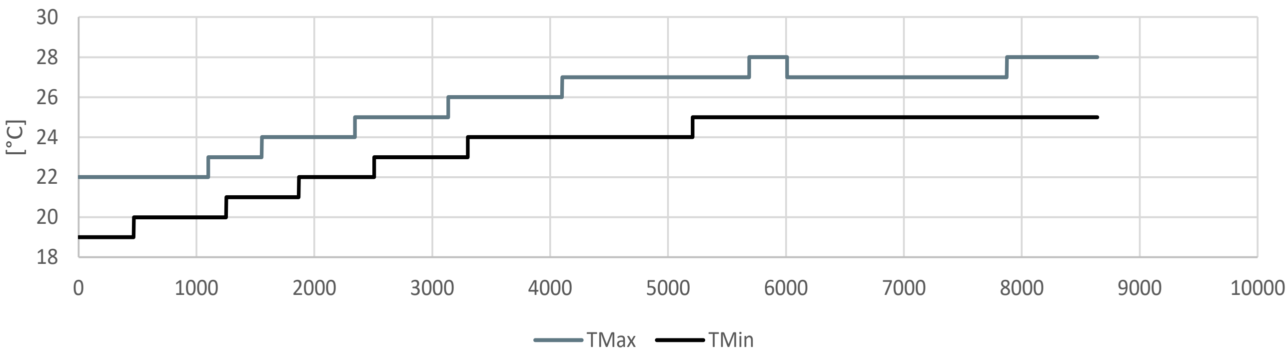


Figure 9.3 : 2C charging + ESR test

- No cooling
- Adiabatic conditions
- 35% capacity / 14 min test
- +6 °C temperature rise

9.2.2 ESR qualification at BU level

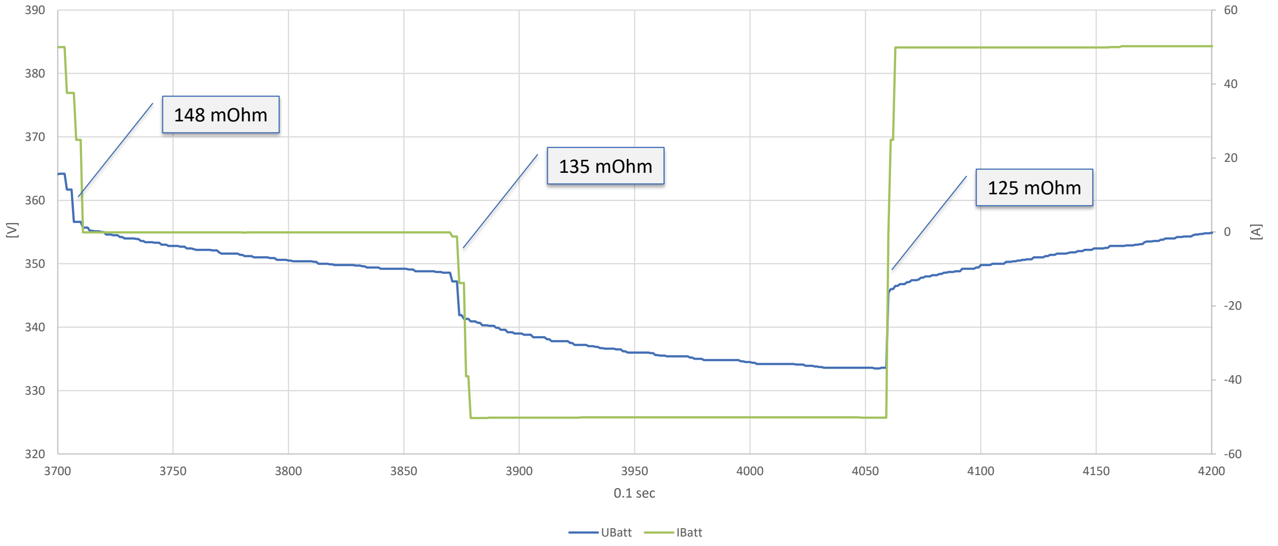


Figure 9.4 : ESR measurement on full BU

Full BU ESR measurements are in the same range than estimation done from module ESR qualification.

9.2.3 Functional validation

Functional unitary validation of the basic unit is done, starting from the master BMS architecture.

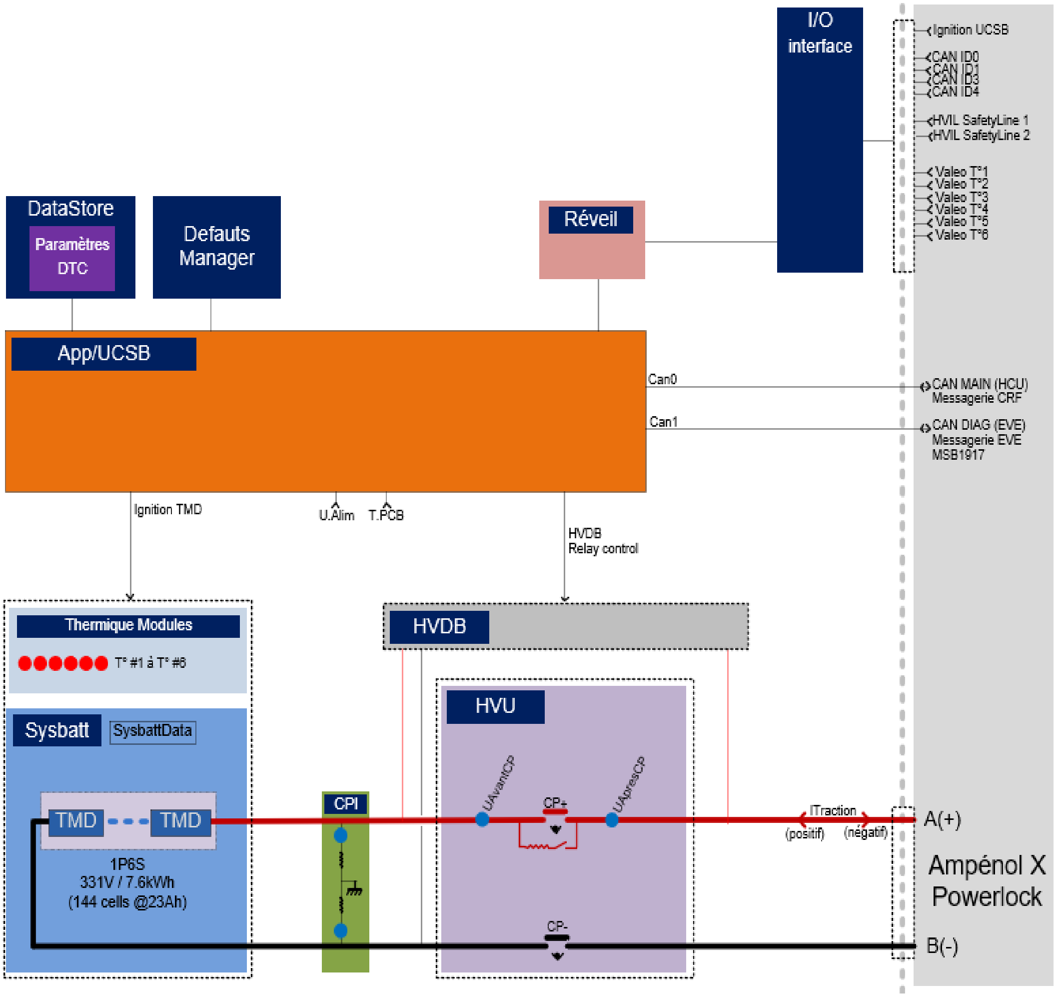


Figure 9.5 : Master BMS functional software architecture

A detailed validation plan has been conducted:

Item	Test description	Who	When	Result	Justification (recording, curve, screenshot…)
Initial unitary tests of master BMS I/O	Individual BMS & rack I/O test	GBO	02/12/2020	OK	
Communication between master BMS and slave BMS	CAN line monitoring / simulation	GBO	02/12/2020	OK	
Insulation measurment function	Test w/ external insulation faults	GBO	11/20/20	Ok	R+=∞ / R-=220MΩ
High voltage measurement	Test w/ external voltmeter	GBO	02/12/2020	OK	
Current measurement	Test w/ external ampermeter	GBO	02/12/2020	OK	
Temperature monitoring	Test w/ external thermometer	GBO	02/12/2020	OK	
HVIL lines	HW & SW influence of HVIL line	GBO	11/20/20	OK	cf. Justification 6
Precharge function	Recording of AVCP & APCP during CP closing	GBO	11/20/20	Ok	cf. Justification 5
Contactors monitoring	All contactor failures detection test	GBO	11/20/20	Ok	cf. Justification 2
SoC calculation	To be checked during charge & discharge tests	GBO	02/12/2020	OK	
Overdischarge cut off	Discharge until OVD	GBO	02/12/2020	OK	cf. Justification 4
Overcharge protection	Charge until OVC	GBO	02/12/2020	OK	
Overtemperature protection	Heat until OVT	GBO	02/12/2020	OK	
Undertemperature protection	Cool until UDT	GBO	02/12/2020	OK	
Operating temperature range check	BU functionnal in temperature range	GBO	02/12/2020	OK	
Overcurrent protection (fuse test)	External short circuit				
Full SOC range functional check	Full charge / discharge	GBO	02/12/2020	OK	
Real time max current limitation computation + protection	IMD/IMR/IMC computation function of U/SoC/T	GBO	02/12/2020	OK	cf. Justification 1
Charge current calculation	IMC computation	GBO	02/12/2020	OK	
Balancing function	Unbalance one cell using bypass + full charge w/ recording	GBO	02/12/2020	OK	

Cooling / heating system interface function test	6 T° probes monitoring / comparison w/ external thermometer	GBO	02/12/2020	OK	
Communication with Vehicle Control Unit (VCU) in both discharge and charge mode	CAN line monitoring / simulation	GBO	11/20/20	Ok	Ghost_BS_CAN_A_v2.dbc + Justification 3
Serial assembly of two battery systems					
Parallel assembly of two battery systems					
Mix of serial and parallel assembly of battery systems					
HVDB management	Closed on car, opened on bus + economizer (voltmeter or sw record)	GBO	11/20/20	8V	Closing=12V , Economizer=8V
Multiple BU management based on HW id	CAN bank selection based on HW ID	GBO	11/20/20	Ok	
Fault management	N1-N2 : CAN messages, N3 : safety	GBO	11/20/20	Ok	
Use mode based on master request	CAN & HV monitoring	GBO	11/20/20	Ok	Connectors_req: 1=Use mode / 0=Standby mode
LV power consumption (ON & OFF)	Measurement w/ external ampermeter	GBO	02/12/2020	OK	
LV voltage monitoring & adaptation to 12 or 24V network	Change LV voltage and monitore faults Repeat for car & bus modes	GBO	02/12/2020	OK	

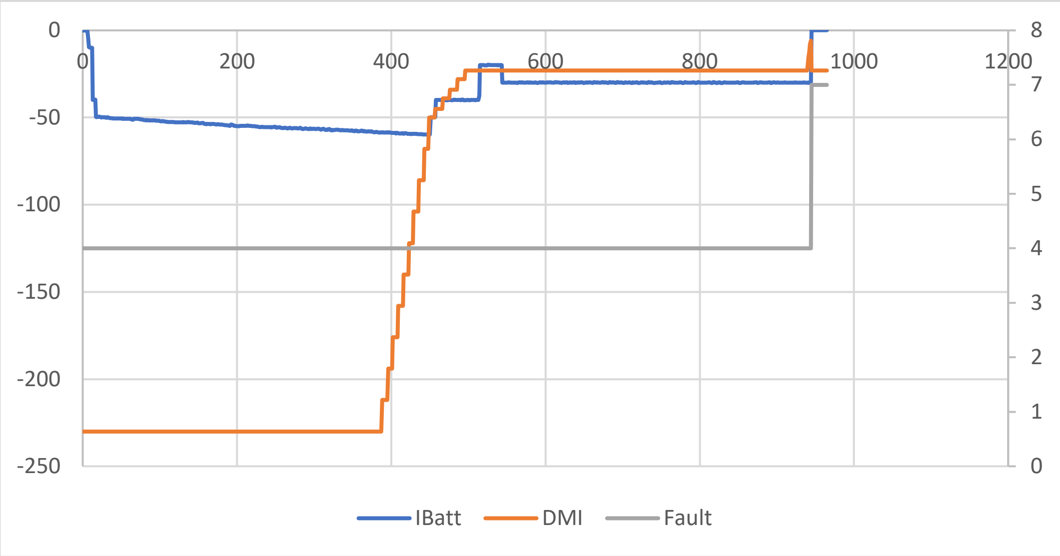


Figure 9.6 : Justification1 – IMD computation + protection

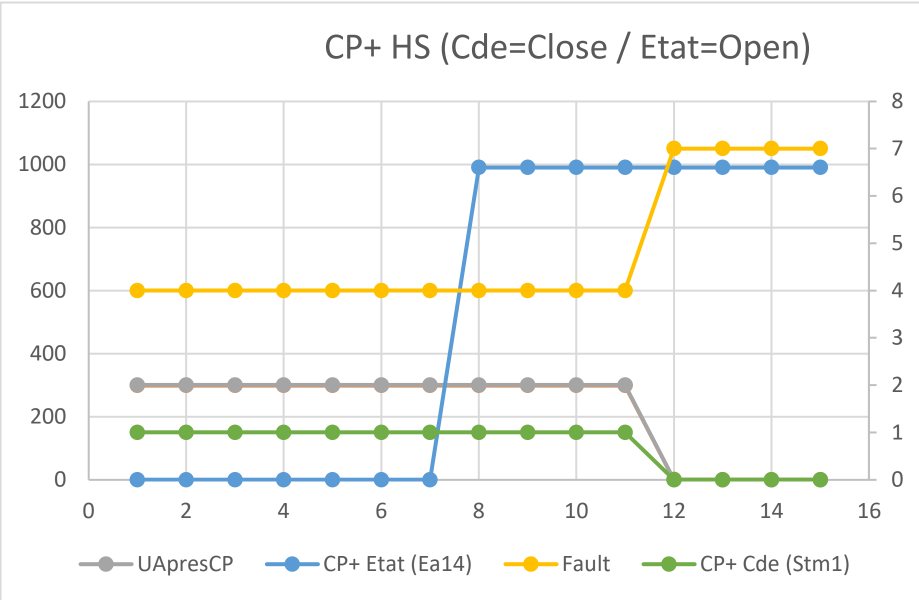


Figure 9.7 : Justification 2 – Contactors monitoring

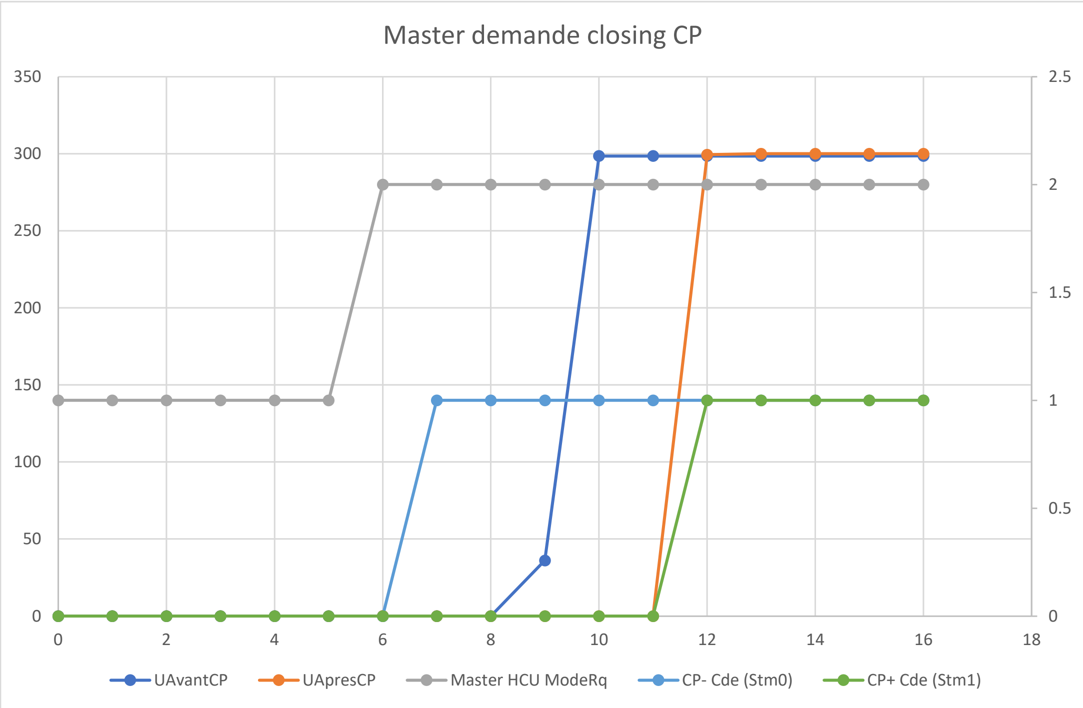


Figure 9.8 : Justification 3 - Contactors closing on master demand

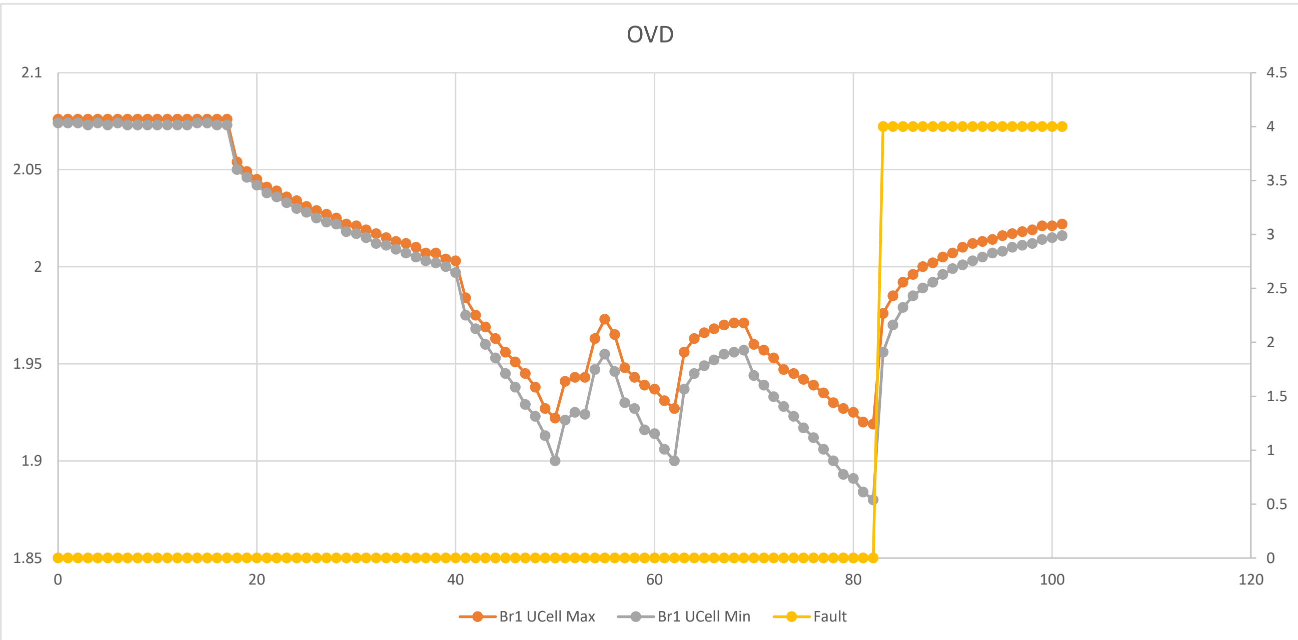


Figure 9.9 : Justification 4 – Fault on cell over discharge

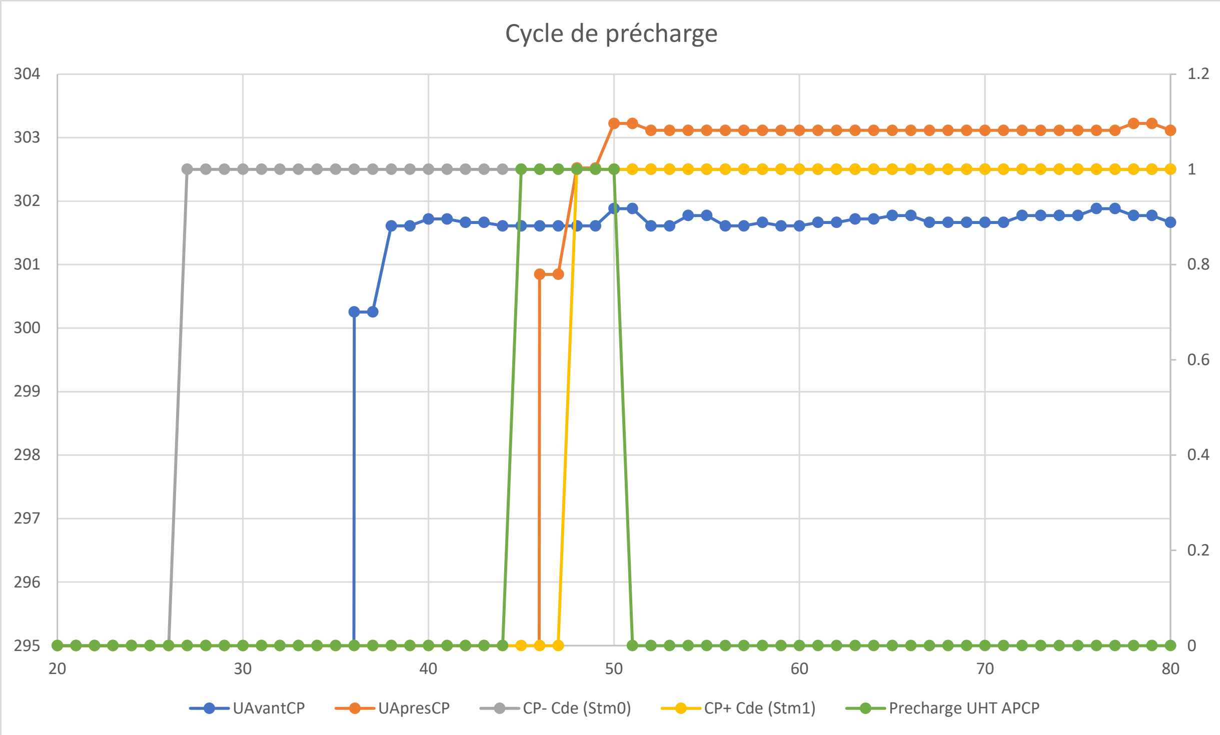


Figure 9.10 :Justification 5 – Precharge function

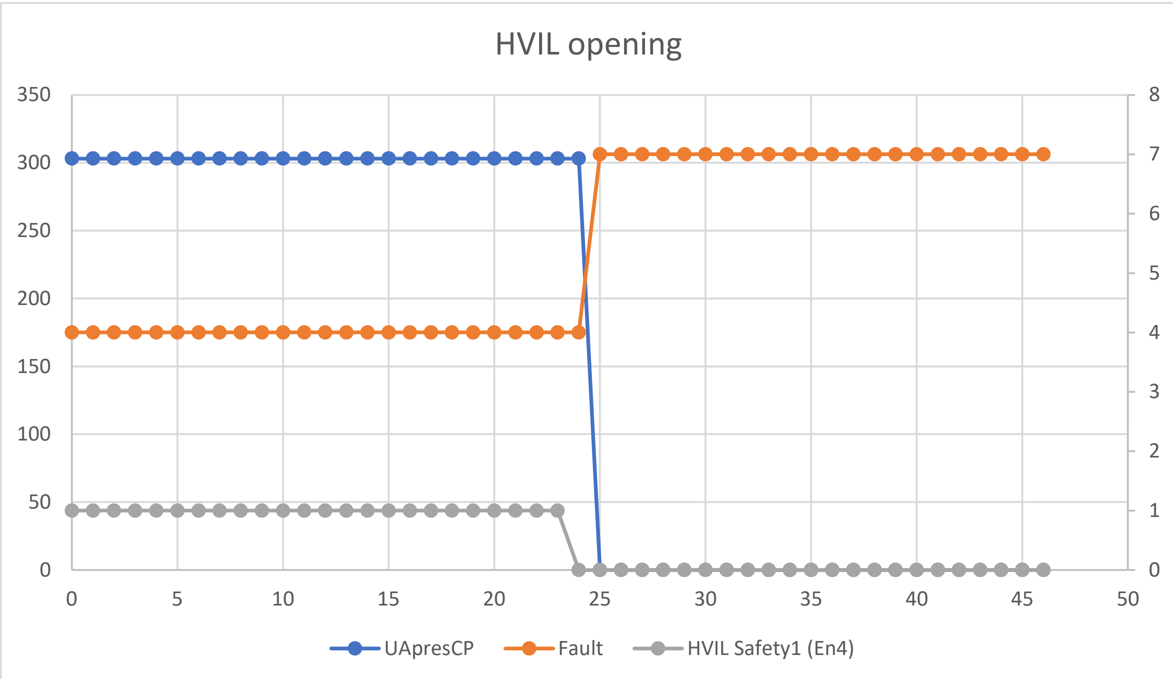


Figure 9.11 : Justification 6 - HVIL monitoring

10 Pre-series production

10.1 BU components

All BU components are ready to be integrated:

1. BJB with HVDB, including low voltage harness:

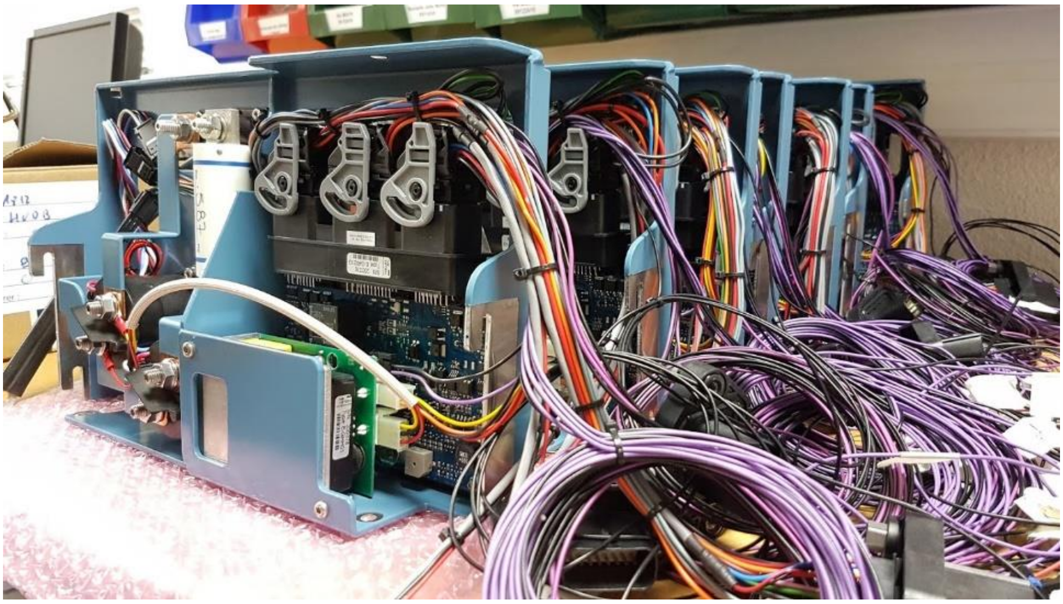


Figure 10.1 : BJB including master BMS, HVDB and LV harness ready to be integrated.

2. Slave BMS:

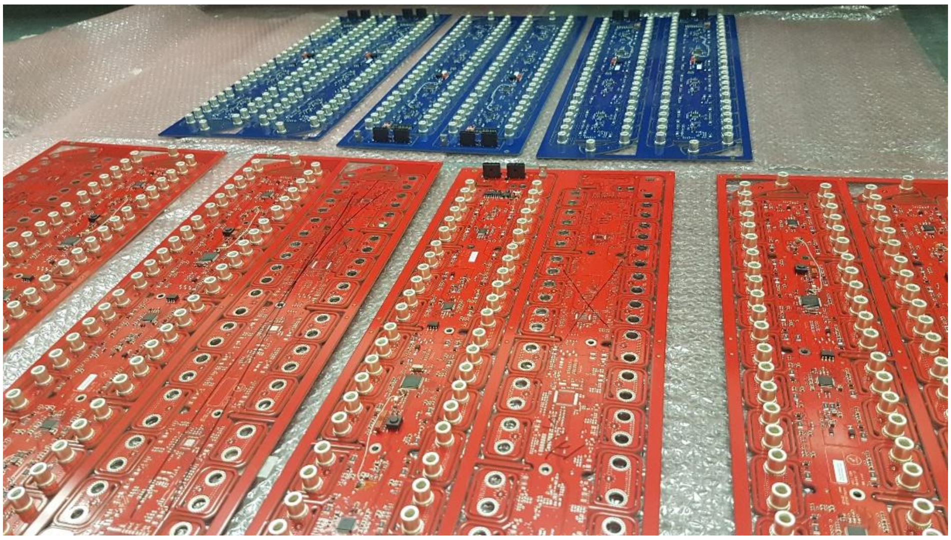


Figure 10.2 : Slaves BMS ready to be integrated.

3. LTO cells with male pins:

Figure 10.3 : More than 1000 cells are ready to be integrated, with dedicated pins laser welded.

10.2 BU production testing

Master and slave BMS are unitary tested before being integrated in BU.

Here is an example of slave BMS test process:

			200192
	TMD montée à l'envers pour accès LED et bypass		E-GHB02
1	**Préparation**		
1.1	Flasher le bios		x
1.2	Ressouder le watchdog		x
1.1	Monter la TMD sur un module		x
1.2	Flasher l'applicatif (teste aussi le CAN)		x
2	**Tests HW**	***scanProfiles tous prêts***	
2.1	Tester le réveil par J1		x
2.2	Tester la sortie réveil J2	multimètre ou autre TMD en série	x
2.3	Tester le réveil par J2		x
2.4	Tester la sortie réveil J1	multimètre ou autre TMD en série	x
2.5	Tester les 24 mesures de tension	eveAL + multimètre keysight, moins de 2mV d'erreur	x
2.6	Vérifier le fonctionnement des mesures primaires et secondaires	Aucun défaut actif, pts convertisseurs dispo pour les 2 ADC	x
2.7	Tester les 24 bypass	DiagBypassMask = 0xFFFFFF = 16777215 + valider à la caméra thermique 24 résistances 2512 près des oreilles doivent s'allumer Attention les 2*2 résistances 2512 au centre ne sont pas des bypass	x
2.8	Valider les 24 mesures de T° cellules + du shunt		x
2.9	Tester le pilotage 5VCC CAN	eveAL + vérifier perte de com CAN (Can0.Sdby + reset après)	x
2.10	Tester le pilotage 4VCC CTN	eveAL + perte points convertisseurs T° cell1-8 ~~TP65 (voir onglet "TP65")~~ ('Vt' / 'VT')	x
2.11	Tester les enables AD (Vdrive + EN étages 2 et 3)	eveAL + leds AD ou perte tensions cellules ('#z'/'#Z')	x
2.12	Vérifier la config HW lue	'?'	x
2.13	Tester l'enable shunt	eveAL + regarder les pts convertisseurs ('Vi' / 'VI') / TMD ROUGE SEULEMENT	-
2.14	Vérifier que les 5 leds fonctionnent		x
2.15	Vérifier les pts shunt	6714 pts @ 0 A / TMD ROUGE SEULEMENT	-
2.16	Absence de défaut injustifié	'! ' 2.11, 2.13 (TMD BLEUE SEULEMENT), 2.18, 1.12 sont OK	x
3	**Calibration (TMD ROUGE SEULEMENT)**	(faisable aussi au niveau de la BU une fois toutes les TMD en série)	
3.1	offset	'mo'	-
3.2	gain	injecter 50A + 'mg'	-
3.3	Sauvegarder	PS + PB	-
4	**Finalisation**		
4.1	Inscrire le SN en mémoire (%B1)		x
4.2	Inscrire le pltID en mémoire (%B3=147)		x
4.3	Inscrire le appID en mémoire (%B5=174)		x
4.4	Sauvegarder (DW)		x
4.5	Coller l'étiquette		x
		RESULT	**OK**

Figure 10.4 : slave BMS test procedure

All Basic Units will be tested according an end of line test procedure.

11 Conclusion and Outlook

With the GHOST Basic Unit major improvements of key characteristics have been demonstrated:

- **increased energy density**
- **modularity**
- **ultra fast charging**
- Integrated mass-production design for **manufacturing**, **recycling** and **second use.**
- **safety**

Nevertheless, the GHOST project is facing some delay, and some activities linked to production and commissioning of BU are still pending:

- Definition of water tightness test
- Series / parallel connection of multiples basic units (Bus application)
- Complete production of eight remaining BU
- Cooling system integration in production procedure

Finally, the demonstration of GHOST solutions in **two demonstrators** (**BEV** bus with ultra-fast partial charge capability and **P-HEV** car) and one lab demonstrator (module level) for the **post Lithium-Ion technology** will complete the project.

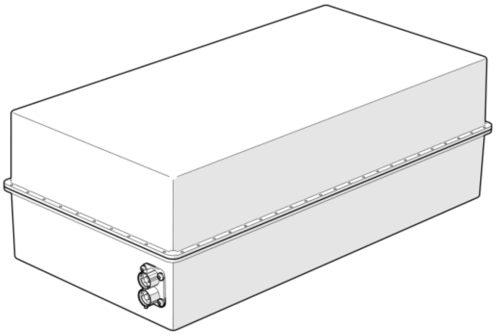
12 Annex

12.1 Annex 1: Basic unit assembly procedure

EVE SYSTEM

GHOST

BASIC UNIT
ASSEMBLY INSTRUCTIONS

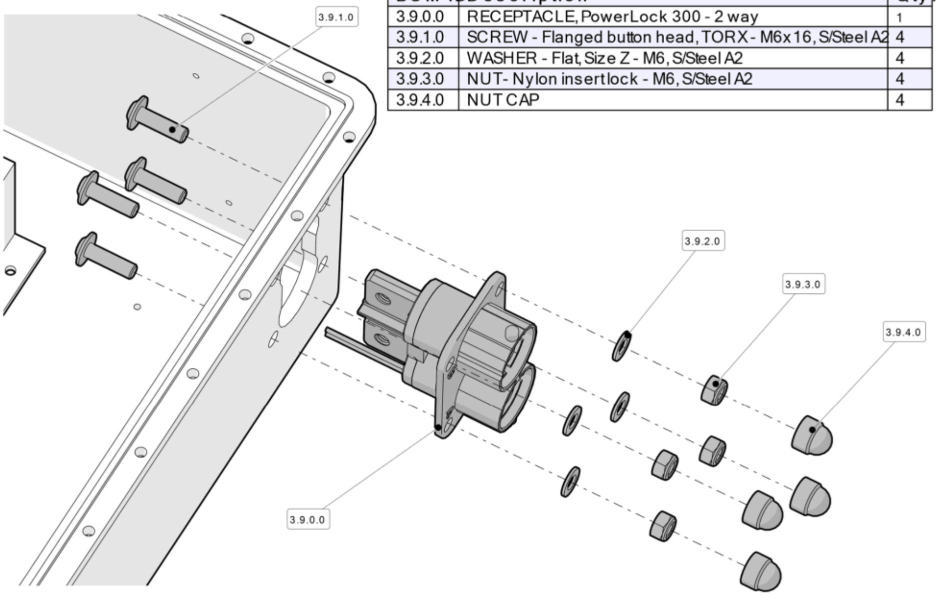


History			
Author	Version	Date	Information
M. LE GARREC	1.000	23/07/2020	Creation
M. LE GARREC	2.001	23/09/2020	Assembly order changed following 1st assembly

Version 1.000 (DRAFT)

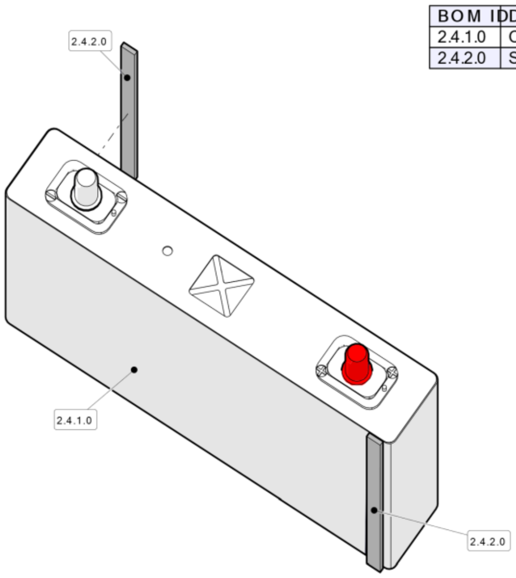
1. HV Connector (Bottom)

BOM ID	Description	Qty
3.9.0.0	RECEPTACLE, PowerLock 300 - 2 way	1
3.9.1.0	SCREW - Flanged button head, TORX - M6x16, S/Steel A2	4
3.9.2.0	WASHER - Flat, Size Z - M6, S/Steel A2	4
3.9.3.0	NUT- Nylon insertlock - M6, S/Steel A2	4
3.9.4.0	NUT CAP	4



2. Cell Preparation (x144)

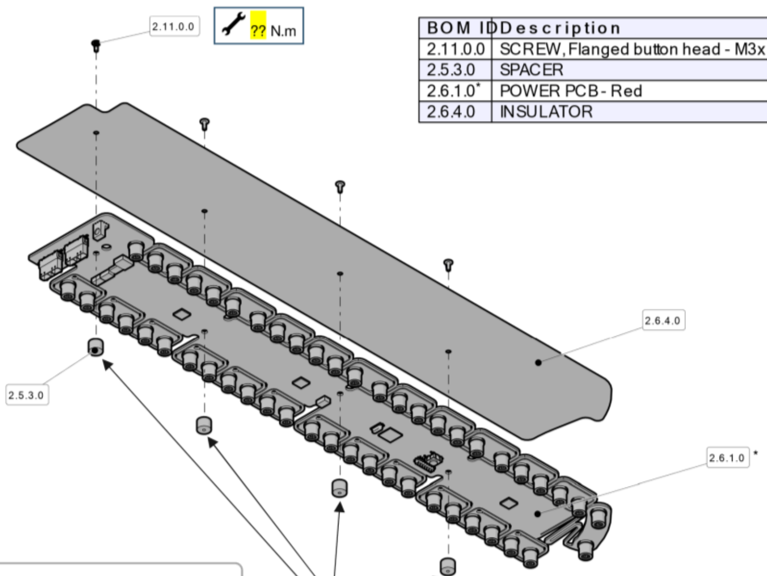
BOM ID	Description	Qty
2.4.1.0	CELL	1
2.4.2.0	SEALING STRIP	2



DRAFT Page 2 / 11 EVE SYSTEM

6. PCB PREPARATION (X6)

BOM ID	Description	Qty
2.11.0.0	SCREW, Flanged button head - M3x8	4
2.5.3.0	SPACER	4
2.6.1.0*	POWER PCB - Red	1
2.6.4.0	INSULATOR	1



* 3x Red (2.6.1.0) + 3x Blue (2.6.2.0)

Glue (TBD)

DRAFT

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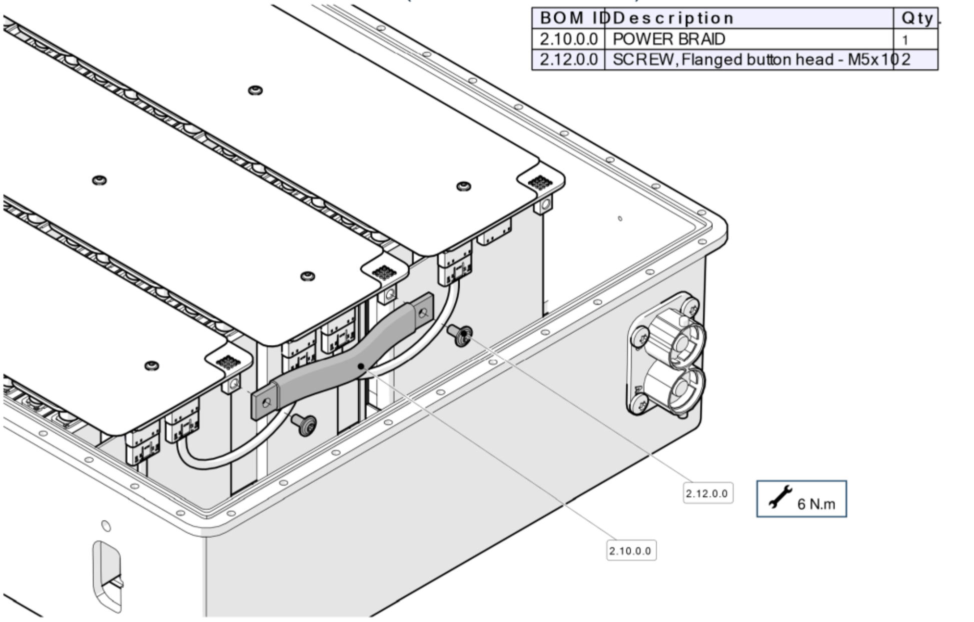
EVE SYSTEM

11. POWER BRAID INSTALLATION (X2 : BOTTOM + TOP)

BOM ID	Description	Qty
2.10.0.0	POWER BRAID	1
2.12.0.0	SCREW, Flanged button head - M5x10	2



16. TOP HALF ABOVE BOTTOM HALF