# 1 Document Information

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# 2 Battery Information

Here is the information about the battery used in our robots. This Samsung model is used in all our robots and is arranged in a 4s2p fashion (8 batteries total).

| INR18650-**35E** | |
|---|---|
| Parameter | Value |
| Nominal Voltage | 3.6 V |
| Capacity | 3.350 Ah |
| Maximum continuous discharge current | 8 A |
| Maximum burst discharge current | 13 A |
| Maximal authorized charge current | 1.7 A |
| Maximal charge current | 1.020 A |
| Maximal voltage | 4.2 V |
| Minimum voltage | 2.65 V |
| Weight | 2 044 g |

# 3 Test Descriptions

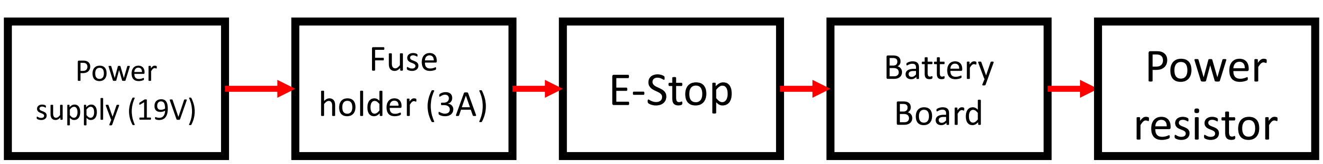
## 3.1 Context and List of Devices

<u>Test objectives and goals:</u> Test the capabilities and functionality of the battery board
<u>Sub-system(s):</u> BMS, Battery Charger, Micro-controller, batteries

<u>Component(s) (devices and test equipment):</u> Voltmeter, E-Stop button, Power supply(19V), PCB guard, Variable Power supply, computer, ESP32, Logic Analyzer, Oscilloscope, Power resistor, temperature sensor.

<u>Environment (location, conditions):</u> Clean non-conductive workspace with an access to PCB guard and variable power supply. Establish perimeter if other persons are around
The location chosen will be the Battery Test Room in the Studio de création.

<u>Setup block diagram:</u>



## 3.2 Risk Table

| #REF | Description | Situation | Probability & Gravity | R.I. | Security measure | Procedure for emergency |
|---|---|---|---|---|---|---|
| R1 | Short circuit and Exploding component | Powering the PCB causing a component failure. A short occur with cells and they deliver a burst of current. | F1 & G2 | 4 | Put guard over PCB when powering up a section. Wearing safety glasses. | Stop the test. Treat the victim. Call medical assistance if lesions occur. |
| R2 | Burning with hot component | Adjusting the power resistor after testing | G1 & F2 | 4 | Test will include a small fan to cool the power resistor. The tester will wear gloves when manipulating the power resistor. | Stop the test. Apply first aid on burn. If the burn is severe, call medical assistance. |
| R3 | Shock | A bad manipulation causes a shock to one of the operators | G1 & F1 | 2 | Operators' vigilance. | Stop the test. Treat the victim. If the shock is severe, call medical assistance. |

Gravity :
G1 : light lesion, normally reversible
G2 : severe lesion, normally irreversible

Probability
F1 : Very rare to much frequent
F2 : Frequent and very probable

R.I (Risk indicator)
Equals to 2 for G1 & F1 or F2
Equals to 4 for G2 & F1
Equals to 6 for G2 & F2

## 3.3 Security Measures

Some risk and dangers are omnipresent and cannot be put in the risk table, as testers are always exposed. Procedures if these incidents were to happen will be described.

### 3.3.1 Bad PCB Assembly

It is possible the board assembly is problematic resulting in a short or a short can be produce after a certain use. In order to reduce the risk, the board will be tested electrically before being powered. The PCB board will also be covered every first power up in order to make sure if something goes wrong the tester are protected.

### 3.3.2 Fire

In the case of a fire, the fire must be contained and limit the chances of getting burns. It is also primordial to call the proper security depending on your environment. If the fire spreads out of control, here is a table of the proper actions to take in case of a fire for different situations.

| | In the Battery Test Room | Outside the Battery Test Room |
|---|---|---|
| In the Lipo bag | Try to extinguish the fire with an extinguisher and use sand if necessary, and make sure the ventilation is still working and not damaged. If the fire can't be contained, start the alarm and leave the perimeter. | Try to extinguish the fire with an extinguisher and use sand if necessary, and make sure the ventilation is still working and not damaged. If the fire can't be contained, start the alarm and leave the perimeter. |
| Out of the bag | Try to extinguish the fire with an extinguisher and use sand if necessary, and make sure the ventilation is still working and not damaged. If the fire can't be contained, start the alarm and leave the perimeter. | Try to extinguish the fire with an extinguisher and use sand if necessary, and make sure the ventilation is still working and not damaged. If the fire can't be contained, start the alarm and leave the perimeter. |

### 3.3.3 Release of Toxic Gas

Lipo Batteries can release toxic gas if damaged or heated. Some are highly toxic gas and are invisible to the eye. Since most of them are hard to detect, good ventilation must be operational in the room when charging the batteries in order to make sure no gas is accumulating in the room. If the testers observe any kind of gas release from the batteries, the test should be stopped, and the security needs to be informed. The room needs to be evacuated and the doors must be left closed.

### 3.3.4 Electrolyte Spilling

If the batteries were to spill electrolyte after an impact the inert sand should be used to soak the electrolyte and to prevent the liquid to react to anything else. Before using the sand, security gloves should be worn to manipulate the sand. Once you have the gloves take the batteries and place them in the sand box. Once the spilling has been controlled, contact the proper emergency line. The remains should be sent for recycling and not thrown in trash.

# 4 Test Procedures

**Note : Batteries must remain disconnected until 4.6**

## 4.1 Initial Connections

1. Set un the adjustable Power Supply to 14.8V 2A **R3**
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the +Batt Net
4. Place the negative of the adjustable power supply to the -Batt Net
5. Put PCB guard over PCB
6. Power the adjustable Power Supply **R3**
7. Wait 30 sec and remove the guard if nothing failed **R1**
8. Measure Voltage at the end of 5V Regulator U6 (should be 5V) **R3**
9. Measure Voltage at pin 1 and 2 of the BMS(U1) (should be 14.8V) **R3**
10. Measure Voltage at pin 8 of ADC(U3) (should be 5V) **R3**
11. Connect the ESP32 to a computer with the usb port on the ESP32
12. With the ESP32 send a request to read the chip ID of BMS
13. Read Chip ID (Should be 0x10)
14. Adjust BMS parameter to appropriate settings
15. With the ESP32, send a request to read the Config Register of ADC (address 1001001)
16. Read Config Register (should be 0x8583)
17. Adjust ADC parameter to appropriate settings
18. With the ESP32, send a request to read the Config Register of ADC (address 1001000)
19. Read Config Register (should be 0x8583)
20. Adjust ADC parameter to appropriate settings
21. With the ESP32 send a request to read the chip ID of Charger
22. Read Chip ID (Should be 0x000BH)

## 4.2 Initial Test BMS Cell Voltage

1. Set un the adjustable Power Supply to 14.8V 2A **R3**
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the VC6
4. Place the negative of the adjustable power supply to the VC0
5. Put PCB guard over PCB
6. Power the adjustable Power Supply **R3**
7. Wait 30 sec and remove the guard if nothing failed **R1**
8. Set another adjustable power supply to 3.3V 5mA **R3**
9. Connect the positive of the second adjustable power supply to the VC1 pin 8 of the BMS **R1** **R3**
10. Connect the negative of the second adjustable power supply to the VC0 pin 9 of the BMS **R1** **R3**
11. Make sure the VCOUT outputs the cell voltage of VC1 (VCOUT_SEL 0b01 CELL_SEL 0b000)
12. Measure voltage out of VCOUT (Should be 3.3*0.6V) **R1**

13. Verify voltage by reading the ADC registers with ESP32
14. Close adjustable 3.3V Power Supply
15. Repeat steps 8 to 14 but adjusting the power supply to 2.5V, 3.5V, 4V and 5V, the value measured should be the voltage*0.6
16. Set another adjustable power supply to 11.5V 5mA R3
17. Connect the positive of the second adjustable power supply to the VC5 pin of the BMS R1 R3
18. Connect the negative of the second adjustable power supply to the VC0 pin of the BMS R1 R3
19. Make sure the VCOUT outputs the cell voltage of VC6 (VCOUT_SEL 0b01 CELL_SEL 0b101)
20. Measure voltage out of VCOUT (Should be 3.3*0.6V) R1
21. Verify voltage by reading the ADC registers with ESP32
22. Close adjustable 11.5V Power Supply
23. Repeat steps 16 to 23 but adjusting the power supply to 12.3, 11.3V, 10.8V and 9.8V, the value measured should be the (14.8-voltage) *0.6
24. Close all adjustable Power Supply
25. Set un the adjustable Power Supply to 14.8V 2A R3
26. Close adjustable Power Supply
27. Place the positive of the adjustable power supply to the VC6 and to the VC3
28. Place the negative of the adjustable power supply to the VC0
29. Set another adjustable power supply to 11.5V 5mA R3
30. Connect the positive of the second adjustable power supply to the VC2 pin of the BMS R1 R3
31. Connect the negative of the second adjustable power supply to the VC0 pin of the BMS R1 R3
32. Make sure the VCOUT outputs the cell voltage of VC3 (VCOUT_SEL 0b01 CELL_SEL 0b010)
33. Measure voltage out of VCOUT (Should be 3.3*0.6V) R1 R3
34. Verify voltage by reading the ADC registers with ESP32
35. Close adjustable 11.5V Power Supply
36. Repeat steps 29 to 35 but adjusting the power supply to 12.3, 11.3V, 10.8V and 9.8V, the value measured should be the (14.8-voltage) *0.6
37. Close all adjustable Power Supply
38. Set un the adjustable Power Supply to 14.8V 2A R3
39. Close adjustable Power Supply
40. Place the positive of the adjustable power supply to the VC6 and to the VC2
41. Place the negative of the adjustable power supply to the VC0
42. Set another adjustable power supply to 11.5V 5mA R3
43. Connect the positive of the second adjustable power supply to the VC1 pin of the BMS R1 R3
44. Connect the negative of the second adjustable power supply to the VC0 pin of the BMS R1 R3
45. Make sure the VCOUT outputs the cell voltage of VC2 (VCOUT_SEL 0b01 CELL_SEL 0b001)
46. Measure voltage out of VCOUT (Should be 3.3*0.6V) R1 R3
47. Verify voltage by reading the ADC registers with ESP32
48. Close adjustable 11.5V Power Supply
49. Repeat steps 42 to 48 but adjusting the power supply to 12.3, 11.3V, 10.8V and 9.8V, the value measured should be the (14.8-voltage) *0.6
50. Close all adjustable Power Supply

## 4.3 Temperature

1. Set un the adjustable Power Supply to 14.8V 2A R3
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the VC6
4. Place the negative of the adjustable power supply to the VC0
5. Put PCB guard over PCB
6. Power the adjustable Power Supply R3
7. Wait 30 sec and remove the guard if nothing failed R1
8. Measure ambient temperature.
9. Measure voltage at ADC U3 PIN 6 and 7 (Should be around 2.02V) R1 R3
10. Verify voltage by reading the ADC registers with ESP32
11. Simulate a temperature of 40C on packs with the help of a heat gun R2
12. Measure voltage at ADC U3 PIN 6 and 7 (Should be around 1.8V) R1 R3
13. Verify voltage by reading the ADC registers with ESP32
14. Repeat step 1 to 3 but with 45C and 50C
15. Close adjustable Power Supply

## 4.4 Initial Test Charger

### 4.4.1 Connections to charger

1. Verify the 19V charger and connect the charger to the board R3
2. Put PCB guard over PCB
3. Power the 19V charger R3
4. Wait 30 sec and remove the guard if nothing failed R1
5. Read Voltage between R24 and R28 pin 6 U5(should be 2.545V) R1 R3
6. With the ESP32, send a request to read the Charge Options register of charger (address 0x12H)
7. Read Charge Options register (AC Adapter Indication should be at 1)
8. Unplug the 19V charger

### 4.4.2 Charger Current and Voltage

1. Set un the adjustable Power Supply to 14.8V 2A R3
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the +Batt Net
4. Place the negative of the adjustable power supply to the -Batt Net
5. Put PCB guard over PCB
6. Power the adjustable Power Supply R3
7. Make sure the VIOUT (pin 14 U1) outputs is at 1V (0A) R1 R3
8. Set the Max current Charge to 15V 1A on the Charger R3
9. Close adjustable Power Supply
10. Remove adjustable Power Supply
11. Put the Power resistance (15 Ω) between +Batt Net and -Batt Net
12. Put PCB guard over PCB
13. Verify the 19V charger and connect the charger to the board
14. Put PCB guard over PCB
15. Power the 19V charger R3
16. Wait 30 sec and remove the guard if nothing failed R1
17. Measure current across R27 (Should be 1A) R1 R3
18. Measure current across R16 (pin 11-12 U1)(Should be 1A) R1 R3
19. Measure voltage at VIOUT should be 0.898V R1 R3
    Current across R16 should be 1A so the tension should be 17mV with respect to VSS
    For inputs from -62.5 to 187.5 = 250mV of delta p17
    For outputs 0.25 to 1.25 = 1.5 of delta
    1.5/250 = 1V + 0.006*R16 = 1.102
20. Measure Voltage across the power resistor (Should be 15V) R2 R1 R3
21. Unplug the 19V charger
22. Repeat steps 1 to19 but adjusting the charging current and voltage at (15.5 V,2.5 A,6.2 Ω) (16 V, 3 A, 5.3 Ω) and (16.8 V, 3.4 A, 4.94 Ω)

## 4.5 Test ILIM

### 4.5.1 Charger Current Limit

1. Set un the adjustable Power Supply to 14.8V 2A
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the +Batt Net
4. Place the negative of the adjustable power supply to the -Batt Net
5. Put PCB guard over PCB
6. Power the adjustable Power Supply R3
7. Set the Max current Charge to 15V 0.5A on the Charger
8. Close adjustable Power Supply
9. Remove adjustable Power Supply
10. Put the Power resistance (14 Ω) between +Batt Net and -Batt Net R2
11. Put PCB guard over PCB
12. Verify the 19V charger and connect the charger to the board
13. Put PCB guard over PCB

14. Power the 19V charger R3
15. Wait 30 sec and remove the guard if nothing failed R1
16. Read Voltage across the power resistor (Should be 7V) R1 R2 R3
17. Unplug the 19V charger

### 4.5.2 Charger Voltage Limit

1. Set un the adjustable Power Supply to 14.8V 2A R3
2. Close adjustable Power Supply
3. Place the positive of the adjustable power supply to the +Batt Net
4. Place the negative of the adjustable power supply to the -Batt Net
5. Put PCB guard over PCB
6. Power the adjustable Power Supply R3
7. Set the Max current Charge to 15V 2A on the Charger
8. Close adjustable Power Supply
9. Remove adjustable Power Supply
10. Put the Power resistance (15 Ω) between +Batt Net and -Batt Net R2
11. Put PCB guard over PCB
12. Verify the 19V charger and connect the charger to the board
13. Put PCB guard over PCB
14. Power the 19V charger R3
15. Wait 30 sec and remove the guard if nothing failed R1
16. Read Voltage across the power resistor (Should be 15V) R1 R2 R3
17. Unplug the 19V charger

## 4.6 Battery Test

### 4.6.1 Discharge Battery Test – 1 Cell

1. With the help of a voltmeter, verify voltage across each battery (should be around 3.6V) R1
2. Then Connect a single battery with an interrupter to the load resistance without making the connection R1 R3
3. Put PCB guard over Setup
4. Activate contacts
5. Wait 30 sec and remove the guard if nothing failed R1
6. Measure current through resistor (should be 3.6 V /15 Ω = 240mA) R1 R3
7. Measure voltage across the resistor. R1 R3
8. The connection should be stopped if the battery voltage drops under 2.8V
9. Record the voltage each minute when the voltage is changing and every 20 minutes during the plateau

### 4.6.2 Charge Battery Test – 1 Cell

1. Set un the adjustable Power Supply to 4.2V 1.5A R1 R3
2. Then Connect a single battery with an interrupter to the load resistance without making the connection R1 R3
3. Put PCB guard over Setup
4. Activate Power Supply
5. Wait 30 sec and remove the guard if nothing failed R1
6. Measure Voltage across the resistor. R1 R3
7. The connection should be stopped if the battery voltage is over 4.2 V
8. Record the voltage each minute when the voltage id changing and every 20 minutes during the plateau

### 4.6.3 Cycle Discharge – All Cells

1. Put 5 single battery in parallel (1s5p) with an interrupter to the adjustable power supply R1 R3
2. Connect the voltmeter to the batteries R1
3. Put PCB guard over Setup
4. Activate Power Supply
5. Wait 30 sec and remove the guard if nothing failed R1
6. Measure voltage across the resistor. Stop when voltage is under 2.8 V R1 R3
7. Repeat process 1 to 6 with for all batteries to cycle at least 3 times each battery and alternate with test 4.6.4

### 4.6.4 Cycle Charge – All Cells

1. Set un the adjustable Power Supply to 4.2V 1.5A R1 R3
2. Then Connect 4 batteries in parallel (1s4p) with an interrupter to the making the connection R1 R3
3. Connect the voltmeter to the batteries R1
4. Put PCB guard over Setup
5. Activate Power Supply
6. Wait 30 sec and remove the guard if nothing failed R1
7. Measure voltage across the cells. Stop when voltage is 4.2 V and current is less than 600 mA R1 R3
8. Repeat process 1 to 6 with for all batteries to cycle at least 3 times each battery and alternate with test 4.6.3

## 4.7 Battery in Board Test

1. Put protective gear (Goggle, gloves etc)
2. Places batteries on each socket starting with BT8 and going up to BT0 R1
3. Put PCB guard over Setup
4. Wait 30 sec and remove the guard if nothing failed R1
5. Measure Voltage at the end of 5V Regulator U6 (should be 5V) R1 R3
6. Measure Voltage at pin 1 and 2 of the BMS(U1) (should be 14.8V) R1 R3
7. Measure Voltage at pin 8 of ADC(U3) (should be 5V) R1 R3
8. Connect the ESP32 to a computer with the USB port on the ESP32
9. With the ESP32 send a request to read the chip ID of BMS
10. Read Chip ID (Should be 0x10)
11. Adjust BMS parameter to appropriate settings
12. With the ESP32, send a request to read the Config Register of ADC (address 1001001)
13. Read Config Register (should be 0x8583)
14. Adjust ADC parameter to appropriate settings
15. With the ESP32, send a request to read the Config Register of ADC (address 1001000)
16. Read Config Register (should be 0x8583)
17. Adjust ADC parameter to appropriate settings
18. With the ESP32 send a request to read the chip ID of Charger
19. Read Chip ID (Should be 0x000BH)

**Approbation**

Approved by: ______________________
Date: ________________________

Approved by: François Michaud
Date: 10/10/2019

**Test Results**

| Tester | Time & date | Results | Comments |
|---|---|---|---|

**Warning**
For testing, we highly suggest adapting the procedure to your environment. This is only an example and Securbot is not responsible for the procedure written above if used outside of Université de Sherbrooke or without proper knowledge of lithium-ion usage risks.

**Comments**

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