# Testing and test results: Modular tether less baby simulator

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# Verification of equipment/instrumentation list

|  |  |  |
| --- | --- | --- |
| **Description:** | | |
| Verification of the test setup of the modular tether less baby patient simulator. Verify the installation of all components and equipment. | | |
| **Acceptance Criteria:** | | |
| The specifications of the installed equipment/instrumentation should correspond with the tabled data. | | |
| **Result / Deviations:** | | |
| Charger was not delivered on time so instead a power supply is used. | | |
| **Conclusion:** | **PASS ✓** | FAIL |
| Comments: - | | |

| **Name / Description** | **Brand /**  **Draw. No** | **Specifications** | **Pass / Fail** |
| --- | --- | --- | --- |
| Charger | - | 12V DC adapter  4A | **Fail X** |
| Batteries | Panasonic NCR18650B ZLF | Technology: Li-ion  Voltage: 3.7V  Capacity: 3400 mAh | **PASS ✓** |
| BMS | Texas Instruments BQ779915EVM-014 | 3-series to 5-series stackable ultra-low power primary protector evaluation module | **PASS ✓** |
| Buck converter | Texas Instruments  LM2596 | Input: 1.2V – 37V  Output: 3.3V, 5V or 12V | **PASS ✓** |
| Fuel Gauge | Texas Instruments BQ34Z100EVM | 1s to 16s Impedance Track Fuel Gauge Battery Evaluation Module | Gas Gauge Battery | **PASS ✓** |

# Testing of Equipment/Instrumentation

## Test 01.01: BMS Cell balancing

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Multimeter | | |
| **Extra information** | | |
| Since 3 cells are used, terminals 3, 4 and 5 are shorted. The batteries are connected between terminal bat – and 1, 1 and 2, 2 and 3. | | |
| **Step 1** | | |
| Make sure the batteries are charged through the BMS. | | |
| **Step 2** | | |
| Set the multimeter to voltage measuring range. | | |
| **Step 3** | | |
| Connect the positive terminal of the multimeter to the positive terminal of battery 1. | | |
| **Step 4** | | |
| Connect the negative terminal of the multimeter to the negative terminal of battery 1. | | |
| **Step 5** | | |
| Read the voltage of battery 1 on the display of the multimeter. | | |
| **Step 6** | | |
| Read the voltage of battery 1 on the display of the multimeter. | | |
| **Step 7** | | |
| Repeat step 1 till 6 for battery 2 and 3. | | |
| **Step 8** | | |
| Compare the measured voltages and see if they are approximately equal. | | |
| **Expected test result:** | **Measured test result** | |
| Approximately equal voltages | Approximately equal voltages | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 1: BMS cell balancing cell 1, Figure 2: BMS cell balancing cell 2, Figure 3: BMS cell balancing cell 3.*    Figure 1: BMS cell balancing cell 1    Figure 2: BMS cell balancing cell 2    Figure 3: BMS cell balancing cell 3 | | |

## Test 01.02: Output voltage of BMS

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter | | |
| **Extra information** | | |
| For this test use the BQ77915EVM-014 user guide section 2.4 steps 1 till 8:  <https://www.ti.com/lit/ug/sluubu2b/sluubu2b.pdf?ts=1654166305192&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ77915EVM-014> | | |
| **Expected test result:** | **Measured test result** | |
| Output voltage should meet input voltage of about 18V | Output voltage meets the input voltage of about 18V. | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 4: Output voltage of BMS*    Figure 4: Output voltage of BMS | | |

## Test 01.03: Simulation of overvoltage condition of BMS

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter | | |
| **Extra information** | | |
| For this test use the BQ77915EVM-014 user guide section 2.4 steps 9 till 11:  <https://www.ti.com/lit/ug/sluubu2b/sluubu2b.pdf?ts=1654166305192&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ77915EVM-014> | | |
| **Expected test result:** | **Measured test result** | |
| When a supply voltage of 22V is adjusted the voltage over the pack terminals is approximately 600mV below the supply voltage. | The output is approximately 600mV below the supply voltage | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 5: Simulation of overvoltage condition of BMS.*    Figure 5: Simulation of overvoltage condition of BMS | | |

## Test 01.04: Simulation of a hot and cold condition of BMS

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter | | |
| **Extra information** | | |
| For this test use the BQ77915EVM-014 user guide here section 2.4 steps 12 and 13:  <https://www.ti.com/lit/ug/sluubu2b/sluubu2b.pdf?ts=1654166305192&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ77915EVM-014> | | |
| **Expected test result:** | **Measured test result** | |
| When the shunt on pins 1-2 of J4 are removed, the pack voltage drops to approximately 0V.  When the shunt on pins 3-4 of J4 are removed, the pack voltage drops to approximately 0V. | The pack voltage dropped during both measurements to approximately 0V. | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 6: Simulation of a hot and cold condition of BMS.*    Figure 6: Simulation of a hot and cold condition of BMS | | |

## Test 01.05: Simulation of undervoltage of BMS

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter | | |
| **Extra information** | | |
| For this test use the BQ77915EVM-014 user guide section 2.4 steps 14 till 16:  <https://www.ti.com/lit/ug/sluubu2b/sluubu2b.pdf?ts=1654166305192&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ77915EVM-014> | | |
| **Expected test result:** | **Measured test result** | |
| When a supply voltage of 12V is adjusted the voltage over the pack terminals drops to approximately 0V. | The voltage over the pack terminals is approximately 0V. | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 7: Simulation of undervoltage of BMS.*    Figure 7: Simulation of undervoltage of BMS | | |

## 

## Test 02.01: 3.3V and 5V output buck converter

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter | | |
| **Extra information** | | |
| The potentiometer of the buck converters are adjusted to achieve 3.3V and 5V output. | | |
| **Step 1** | | |
| Connect the positive terminal of the power supply to the positive terminal of the buck converter. | | |
| **Step 2** | | |
| Connect the negative terminal of the power supply to the negative terminal of the buck converter. | | |
| **Step 3** | | |
| Connect the positive terminal of the multimeter to the positive terminal of the buck converter. | | |
| **Step 4** | | |
| Connect the negative terminal of the multimeter to the negative terminal of the buck converter. | | |
| **Step 5** | | |
| Set the multimeter to voltage measuring range. | | |
| **Step 6** | | |
| Set the power supply to 12V and turn it on. | | |
| **Expected test result:** | **Measured test result** | |
| Measurement of about 3.3V and 5 V at the multimeter. | Output voltage measurement meets the voltages 3.3V and 5V. | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The measured results matched the expected results as can be seen in *Figure 8: 3.3V and 5V output buck converter*    Figure 8: 3.3V and 5V output buck converter | | |

## Test 03.01: Reading the state of charge using the fuel gauge

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| BQ34Z100 Fuel Gauge Evaluation Board from Texas Instruments (fuel gauge EVM)  EV2400 Analog Evaluation Model from Texas Instruments (Fuel gauge adapter)  Bq Battery Management Software from Texas Instruments | | |
| **Extra information** | | |
| The steps on conducting the test and experimentation can be followed from these datasheets:  The guide for connection between laptop with the analog evaluation model can be found here (section 3, Page 2)  [Quickstart Guide for the bq34z100-G1 (ti.com)](https://www.ti.com/lit/ug/sluubv2/sluubv2.pdf?ts=1654075592984&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ34Z100EVM)  The steps to configure the fuel gauge EVM can be found here ( Section 2.3, Page 5)  [bq34z100EVM Wide Range Impedance Track Enabled Battery Fuel Gauge (Rev. B) (ti.com)](https://www.ti.com/lit/ug/sluu904b/sluu904b.pdf?ts=1654075593856&ref_url=https%253A%252F%252Fwww.ti.com%252Ftool%252FBQ34Z100EVM)  The bq Battery Management Software can be found here  [BQSTUDIO Application software & framework | TI.com](https://www.ti.com/tool/BQSTUDIO) | | |
| **Expected test result:** | **Measured test result** | |
| State of charge of the battery should be read by the software while the battery is connected to the fuel gauge. | The system can properly read the state of charge, state of health, temperature, etc…, of the battery with a single cell. | |
| **Test conclusion** | **PASS ✓** | FAIL |
| The state of health value is read as expected when one cell is connected to the BMS; however, with multi-cell batteries, some calibration is required on the software side.  The measured results matched the expected results as can be seen in *Figure 9: Reading the state of charge using the fuel gauge test setup, Figure 10: Reading the state of charge using the fuel gauge software.*    Figure 9: Reading the state of charge using the fuel gauge test setup    Figure 10: Reading the state of charge using the fuel gauge software | | |

# Testing of the complete system

## Test 05.01: Complete system

|  |  |  |
| --- | --- | --- |
| **Step – by – step plan** | | |
| **Equipment / Instrumentation reference:** | | |
| Power supply, Multimeter, 2x 100 Ohm load | | |
| **Extra information** | | |
| Connect the system as shown in *Figure 11: Complete system*    Figure 11: Complete system | | |
| **Step 1** | | |
| Measure the voltage over the 3.3V load and 5V load without charger connected. | | |
| **Step 2** | | |
| Measure the voltage over the 3.3V load and 5V load with charger connected. | | |
| **Step 3** | | |
| Read the state of charge using the fuel Gauge. | | |
| **Expected test result:** | **Measured test result** | |
| Output of the 3.3V buck converter without charger connected is approximately 3.3V | Measured value is 3.33V | |
| Output of the 5V buck converter without charger connected is approximately 5V. | Measured value is 5.009V | |
| Output of the 3.3V buck converter with charger connected is approximately 3.3V | Measured value is 3.33V. | |
| Output of the 5V buck converter with charger connected is approximately 5V. | Measured value is 5.009V. | |
| The state of charge should be measured by the fuel gauge reading one cell. | The software couldn’t communicate to the fuel gauge. | |
| **Test conclusion** | PASS | **FAIL X** |
| The measured results matched the expected results as can be seen in *Figure 12: Complete system without charger, Figure 13: Complete system with charger.*    Figure 12: Complete system without charger    Figure 13: Complete system with charger | | |