TEST REPORT

IEC 60730-1

Automatic electrical controls
– Part 1: General requirements

Report reference number..... :	**IC200709N001-3**
Date of issue.....:	2021-03-08
Total number of pages.....:	21
Testing laboratory name..... :	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address.....:	No. 96, Guantai Road (Houjie Section), Houjie Town, Dongguan City, Guangdong Province, 523942, People's Republic of China
Accreditation .....:	ilac-MRA A2LA ACCREDITED Certificate # 2951.01
Applicant's name ..... :	**Shenzhen SOFARSOLAR Co., Ltd.**
Address.....:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China.
Test specification	
Test item. .....:	FUNCTIONAL SAFETY
Standard .....:	IEC 60730-1+AMD1:2015+AMD2:2020 Automatic electrical controls –Part 1: General requirements
Test result. .....:	The product(s) were found in compliance with the Class B parameters
Test Report Form No. .....:	IEC 60730-1
TRF Originator .....:	Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch
Master TRF .....:	Dated 2020-05-12
Test item description.....:	Battery pack with software version V2.00
Trademark .....:	AMASSTORE
Model/Type reference..... :	GTX3000-H4, GTX3000-H5, GTX3000-H6, GTX3000-H7, GTX3000-H8, GTX3000-H9, GTX3000-H10

Ratings..... :	GTX3000-H4: 204.8V, 50Ah, 10kWh
	GTX3000-H5: 256V, 50Ah, 12.5kWh
	GTX3000-H6: 307.2V, 50Ah, 15kWh
	GTX3000-H7: 358.4V, 50Ah, 17.5kWh
	GTX3000-H8: 409.6V, 50Ah, 20kWh
	GTX3000-H9: 460.8V, 50Ah, 22.5kWh
	GTX3000-H10: 512V, 50Ah, 25kWh

Testing Location ..... :	**Bureau Veritas Shenzhen Co., Ltd. Dongguan Branch**
Address.....:	No. 96, Guantai Road (Houjie Section), Houjie Town, Dongguan City, Guangdong Province, 523942, People's Republic of China
Tested by (name and signature) .....:	Lukes Lin 
Approved by (name and signature) .....:	James Huang 
Manufacturer's name ..... :	Shenzhen SOFAR SOLAR Co., Ltd.
Manufacturer address..... **:**	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China.
BMS Manufacturer.....:	Shenzhen Peicheng Intelligent Control Technology Co., Ltd.

Document History			
Date	**Internal reference**	**Modification / Change / Status**	**Revision**
2020-12-17	Lukes Lin	Initial report was written	0
Supplementary information:			

Test items particulars

Equipment mobility .....:	Use for household energy storage
Operating condition .....:	Continuous
Class of equipment.....:	IP 65
Mass of equipment [kg] .....:	Approx.: 138kg for GTX3000-H4 Approx.: 168kg for GTX3000-H5 Approx.: 198kg for GTX3000-H6 Approx.: 228kg for GTX3000-H7 Approx.: 258kg for GTX3000-H8 Approx.: 288kg for GTX3000-H9 Approx.: 318kg for GTX3000-H10

Test case verdicts

Test case does not apply to the test object .....:	N/A
Test item does meet the requirement .....:	P(ass)
Test item does not meet the requirement .....:	F(ail)

Testing

Date of receipt of test item.....:	2020-07-09
Date(s) of performance of test.....:	2020-07-09 to 2020-12-01

General remarks:

The test result presented in this report relate only to the object(s) tested. This report shall not be reproduced in part or in full without the written approval of the issuing testing laboratory.

”(see Annex #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

Throughout this report a comma is used as the decimal separator.

1. Scope of the Investigation

1.1 Applicable Standard(s)

Standard	Edition/Revision Date
IEC 60730-1+AMD1, Automatic electrical controls - Part 1: General requirements	2015

1.2 Product Overview

The GTX3000-H series is a household energy storage product for solar applications. It is made up of a Battery Control Module Unit (BCMU), the Battery module and a Base, and the Battery module consists of a Battery Manager Unit (BMU) and 16 cells in series. The system allows 4~10 Battery modules in series. Figure 1 shows the composition diagram. The evaluation focused on the BCMU and BMU, which are used for managing and monitoring the status of battery. The safety functions include voltage, current and temperature management during charging and discharging mode.

Figure 1 Composition Diagram for the product

1.3 Safety Function(s) Investigated

Safety Function	Investigation Parameters
Cell Overvoltage Protection : Maximum cell voltage ≥ 3.7± 0.01V for 1.5± 0.5 sec	Class B
Cell Undervoltage Protection : Minimum voltage ≤ 2.8 ± 0.01V for 1.5 ± 0.5 sec	Class B
Cell Overtemperature Protection under Charging Condition : Maximum temperature ≥ 55±3°C	Class B
Cell Overtemperature Protection under Discharging Condition : Maximum temperature ≥ 60±3°C	Class B
Cell Overcurrent Protection under Discharging Condition : Maximum current ≥ 35± 2A for 5.0± 0.5 sec	Class B
Passive Overcurrent Protection (POCP): Max. current for input/output ≥ 50 A	Class B
Cell Overcurrent Protection under Charging Condition : Maximum current ≥35 ± 2A for 5.0± 0.5 sec	Class B

1.4 Considerations

The protection thresholds are based on customer's risk analysis and declaration, which shall be evaluated in the end product assessment, including voltage, current and temperature protections.

The software can be remotely updated by PC application in end use. To meet the requirements of IEC 60730-1, the software pack intended to be updated shall be submitted for evaluation before it is published.

The model has only one protection channel to be evaluated, and the other protection channel which realized by communication with end use device was not investigated in this report, this should be evaluated on end product system.

Functions listed in Item 1.3 are relied on firmware and redundant hardware, critical components of safety-related circuit shall be controlled in end-product, refer to item 4.1 hardware and item 5 referenced documents for detail.

2. Product Description

2.1 Functional Safety-Related Hardware

Architectural Design

The GTX3000-H series energy storage product is managed by the BMU module and BCMU module.
The BMU module is mainly for detecting voltage / temperature of battery cells, and the BCMU module is for current detecting and charge / discharge relay controlling according to the detecting result. Figure 2 is the structure diagram of the GTX3000-H series energy storage product.

The BMU has one analog front-end (AFE MAX14921) and one MCU (STM8L051F3). AFE is intended to measure cells' voltage /temperature parameters and battery module voltage as well. The MCU with 8-KB Flash and 256-byte data EEPROM. It supports many communication interfaces, such as USART, I2C and Ethernet, etc.

The main control chip of BCMU module is the SST19-727A-REV_1 core board,. It has 16KB SRAM and 128KB FLASH. It supports many communication interfaces, such as UART, I2C and Ethernet, etc.

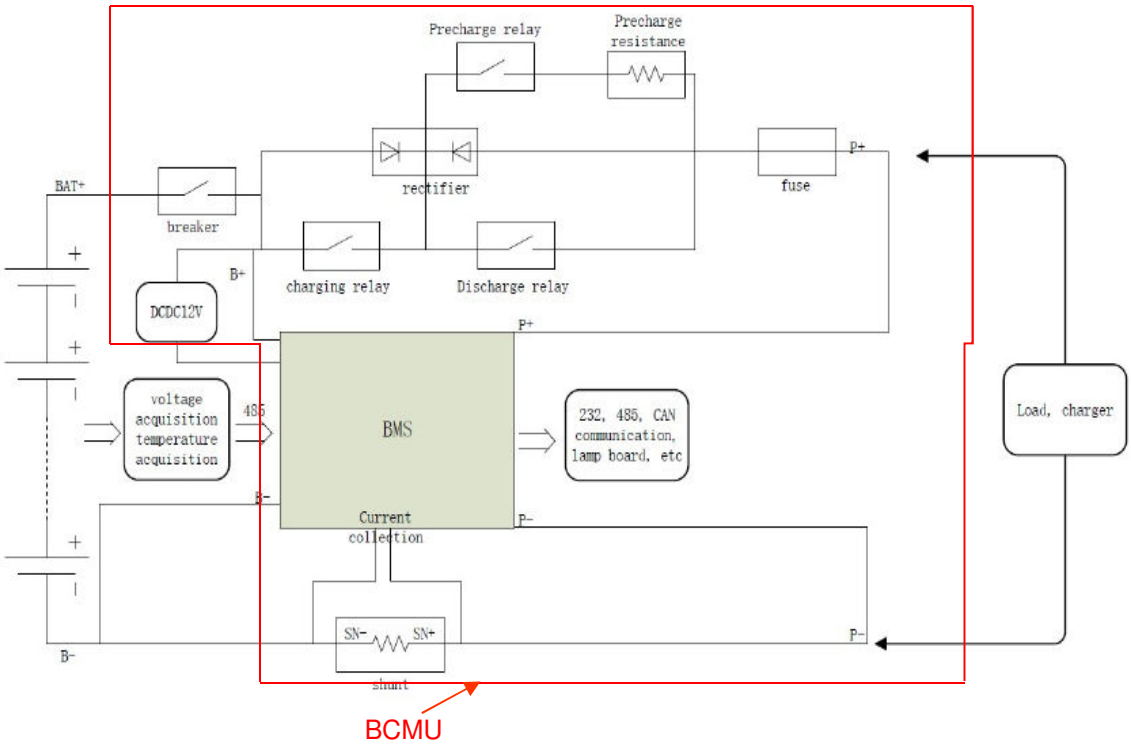
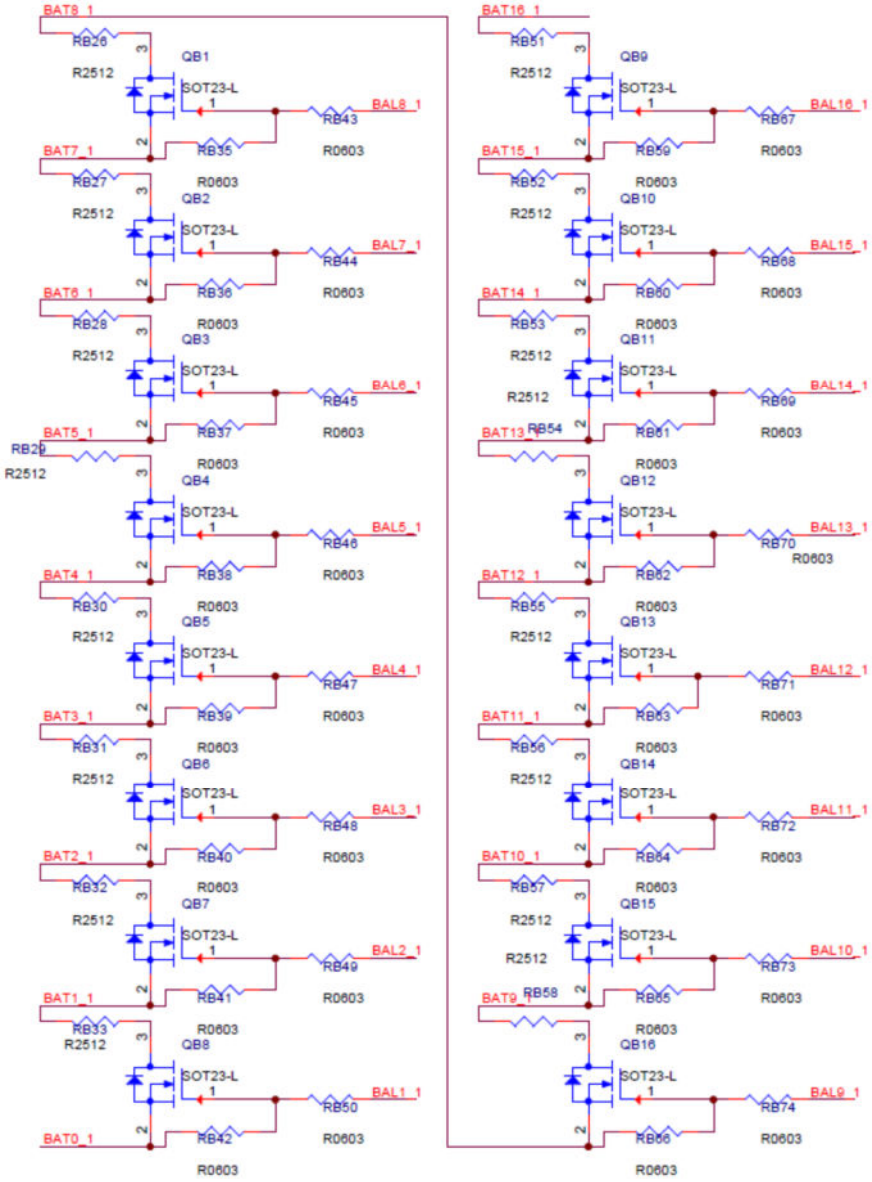


Figure 2 Structure Diagram of product

Safety Functions - Hardware

For voltage protection, the AFE is connected to the battery cell directly and all cells' voltage information can be easily detected and processed into digital voltage by the 16-bit ADC of AFE. All voltage values are sent to MCU via a 8-bit SPI interface. If any cell voltage exceeds the reference threshold of the system, the cell voltage detected in BMU module will be returned to SST19-727A-REV_1 core board in the BCMU module via UART, then the core board will control the charge / discharge relay directly by pin RELAY if needed. Detailed schematic see figure 3 and figure 4.



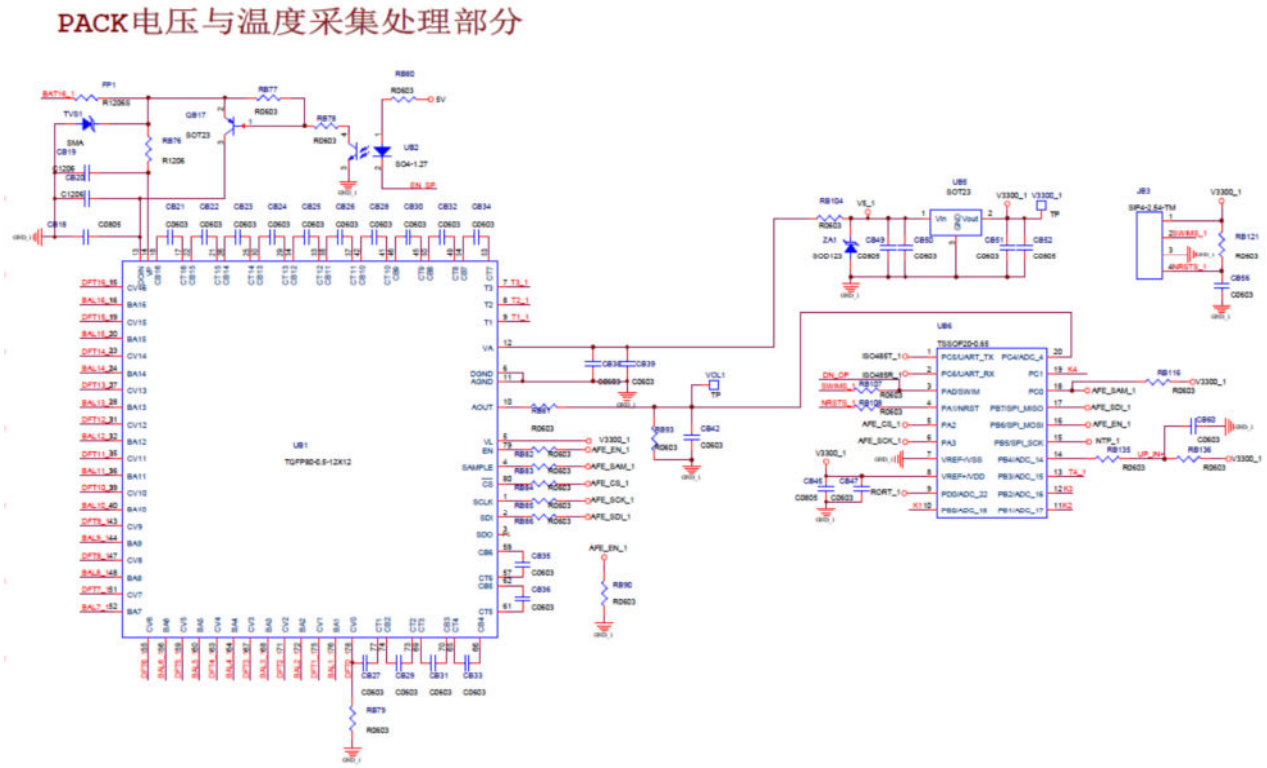


figure 3 Voltage and temperature protection circuit

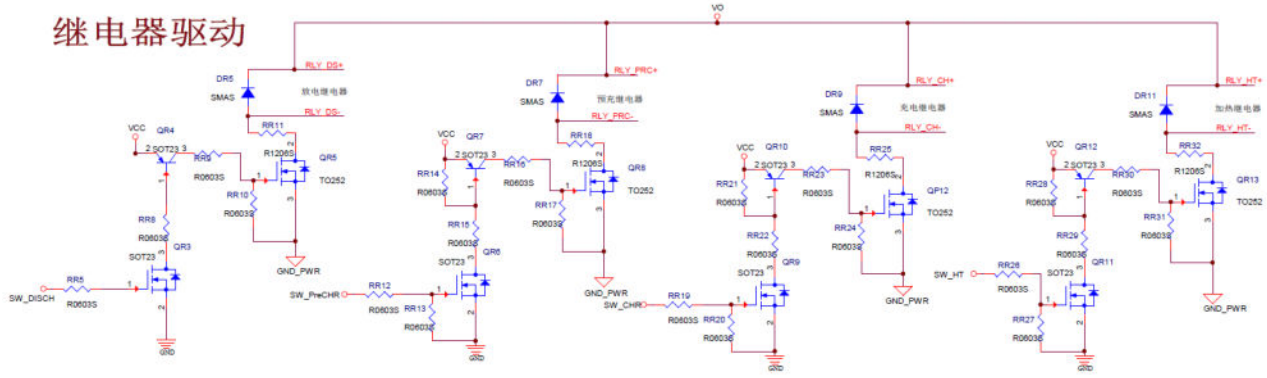


figure 4 Relay Control for Protection

For temperature protection, product is provided with four temperature sensors on battery cell to detect the cell temperature, them are sampled by AFE, also, they are sampled by MCU. if any cell's temperature is higher than the temperature protection limit, the cell temperature detected in BMU module will be returned to SST19-727A-REV_1 core board in the BCMU module via UART, then the core board will control the charge / discharge relay directly by pin RELAY if needed. Detailed schematic see figure 3, figure 4 and figure 5.

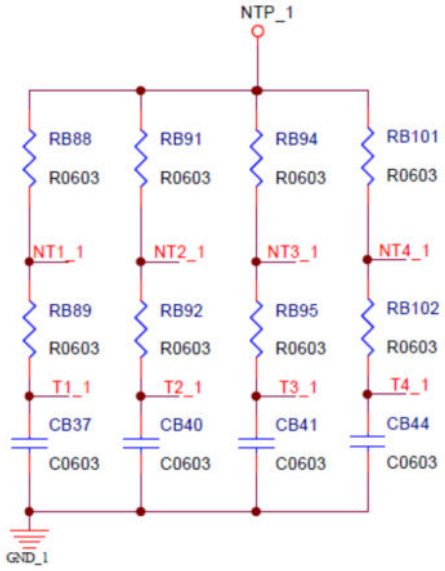


figure 5 temperature detection circuit

For current protection, the BCMU module monitors the current in the main circuit by the shunt resistor J71, and the current information will be returned to SST19-727A-REV_1 core board with pins PC0 / PC1, then the charge / discharge relay will be shut down in the same way with voltage protection if the current is out of the limit. Figure 6 shows the current detection schematic. In addition, there is an air switch in the main circuit to take active current protection.

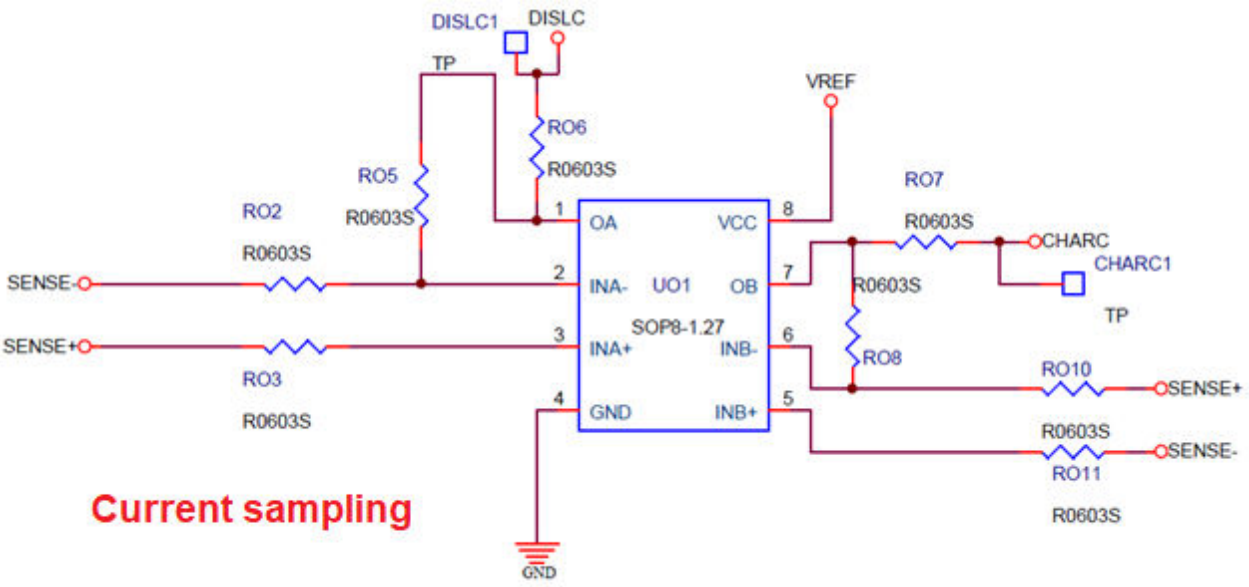
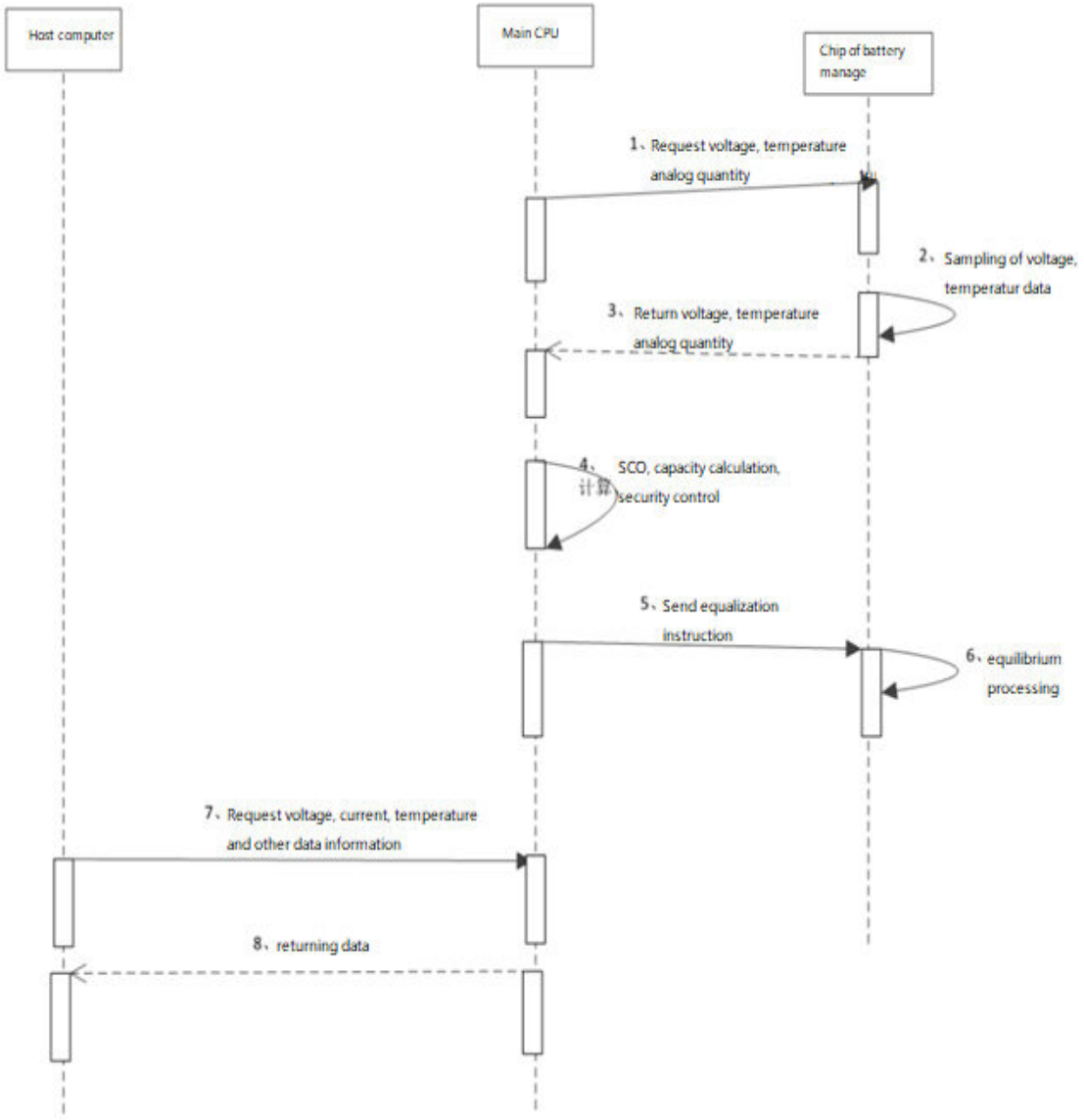


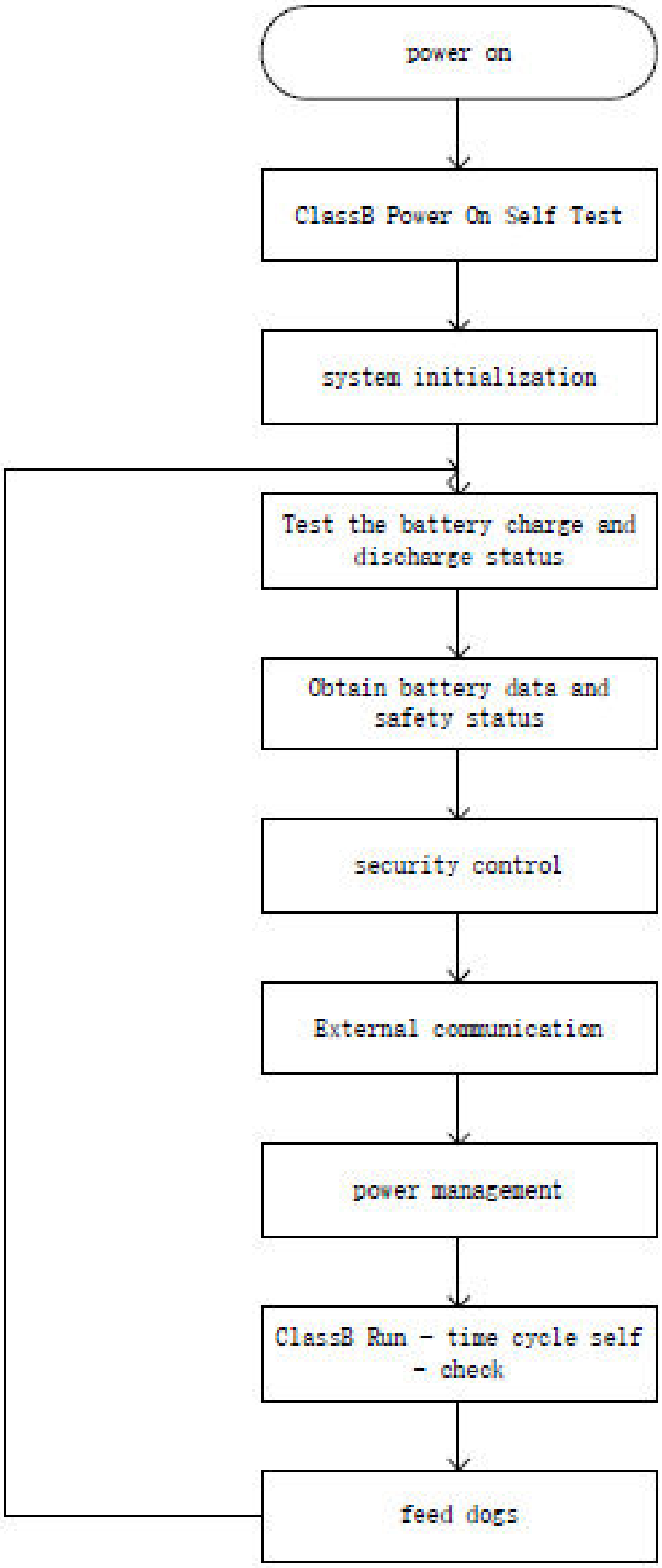
figure 6 Current detection circuit

2.2 Functional Safety-Related Software

The firmware of the product is developed by “IAR Embedded Workbench for STMicroelectronics STM8”, which is provided by MCU manufacturer.

The program is initialized to set internal configuration, such as clock, timer, Watch Dog, GPIO, ADC, UART, CAN and Flash, and then voltage/current/temperature limit and delay configuration in AFE is loaded by MCU during startup, product is initialized to a safe state. MCU circularly samples voltage/current/temperature data returned from AFE until protection is required. In addition, the code of addressing microelectronic hardware failure modes is circularly called in the main loop. Figure 7 shows the main flowchart of the program.




power on
ClassB Power On Self Test
system initialization
Test the battery charge and discharge status
Obtain battery data and safety status
security control
External communication
power management
ClassB Run - time cycle self - check
feed dogs

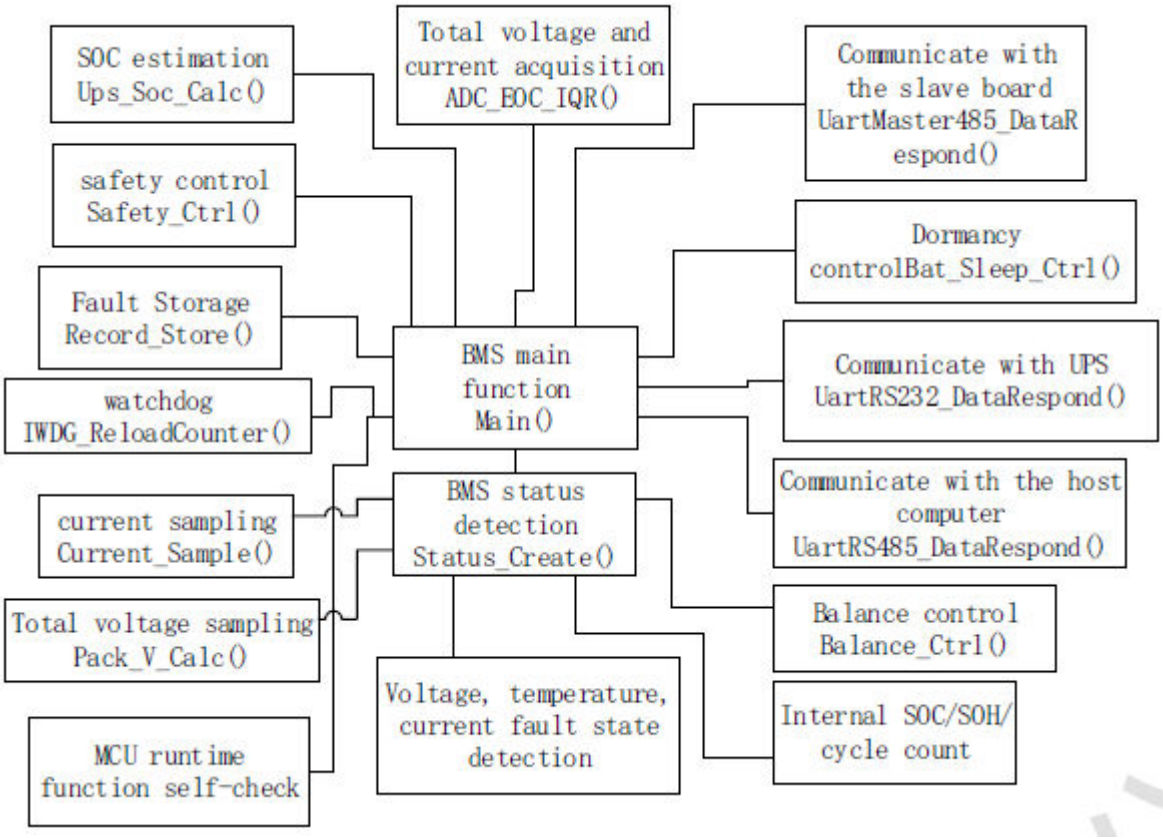


Figure 7 Main flowchart of the program

Safety Functions - Software

The safety functions contain voltage protection, current protection and temperature protection, they have the same protective logic in the software when implemented. If any cell's voltage/current/temperature exceeds the protective limit, the corresponding protective flag will be set and charge/discharge will be disabled within specific delay time.

Take voltage protection for example, the Periodic 100 milli-second Interrupt triggers the cell voltage read function (Void Status_Create (void)) as well as the function for determining max and min cell voltage (void Over_Cell_V_Det(void), void Under_Cell_V_Det(void)), the max and min cell voltage in the pack are determined and their value are stored for comparation with the threshold of overvoltage and undervoltage protection. If the max or min cell voltage exceeds the corresponding limit within the fault limit time (Gmin), the corresponding protection level flag will be set according to the fault severity, and the charge/discharge will be disabled if the flag is BIT1.

The voltage ADC faults in AFE can be detected by comparison between measured whole pack voltage and total voltage of calculating all single cells, the current ADC and temperature ADC fault in AFE can be detected by plausibility check.

Risk Analysis for Microelectronics

Risk Analysis for Microelectronics

TABLE: Microelectronic Hardware Failure Modes			
Software Class			Class 1
Component	Fault/Error	Declared Mitigation Mechanism	Comments
1.0 CPU	-	-	-
1.1 Registers	Stuck-at	Periodic self-test Static Memory Test	Load 0xAAA in all RAM address
1.2 Instruction Decoding and Execution	Overflow	-	-
1.3 Program Counter	Stuck-at	Logical monitoring of the program sequence	Lock-step check
1.4 Addressing	NA	-	-
1.5 Data paths Instruction Decoding	NA	-	-
2. Interrupt Handling and Execution	No interrupt or too frequent interrupt	Time-slot monitoring	Compares counter value of PIT3 with PIT1 and PIT2
3. Clock	Wrong frequency (for quartz synchronized clock: harmonics / subharmonics only)	Frequency monitoring	A reciprocal method of comparing two independent clock sources is used while clocking two timers.
4. Memory	-	-	-
4.1 Invariable Memory	All single-bit faults	Multiple checksum	CRC Check
4.2 Variable Memory	DC fault	Periodic static memory test	Read/write 0x9876 and 0x3456 in all RAM address
4.3 Addressing (relevant to variable and invariable memory)	Stuck-at	Word protection with single bit redundancy including the ddress	See 4.1 & 4.2 above

5. Internal data path	-	-	-
5.1 Data	Stuck-at	Word protection with single bit redundancy	See 4.1 & 4.2 above
5.2 Addressing	Wrong address	Word protection with single bit redundancy including the ddress	See 4.1 & 4.2 above
6. External Communication	-	-	-
6.1 Data	Hamming distance 3	CRC – Single word	CRC check for UART
6.2 Addressing	Wrong address	CRC – Single word	CRC check for UART
6.3 Timing	Wrong point in time; wrong sequence	Time-slot monitoring	-
7. Input/Output periphery	Fault condition as specified in end product standard	Plausibility check	-Read back the output state to check
7.1 Digital I/O	N/A	-	-
7.2 Analog I/O	-	-	-
7.2.1 A/D- and D/A-Converter	Fault condition as specified in end product standard	Plausibility check	-
7.2.2 Analog multiplexer	Wrong addressing	Plausibility check	-
8. Monitoring devices comparators	NA	N/A	-
9.0 Custom chips eg. ASIC, GAL, Gate Array	Any output outside the static and dynamic functional specification	Periodic self-test	-

3. Requirements Checklist(s)

Sec.	Requirement	Comments	Verdict
H.11.12.3.1	General-Process definition	There is a standardized process of the firmware development. Detailed information can be found in document “General-Process definition” and “Software configuration plan”.	**P**
H.11.12.3.2.1	software safety requirements	All safety related functions have been described, and most protections have redundant solution. All risks have been analyzed, including failure of safety circuit and internal faults of the microelectronics. Detailed information can be found in documents “Software Requirements Specification” and ”Software design summary”. Document “The Detailed System Diagram Descreption” shows the description of interfaces between software and hardware.	**P**
H.11.12.3.2.2	software architecture	Detailed information can be found in”Software design summary”.	**P**
H.11.12.3.2.3	model design and coding	Software is refined into modules based on the architecture design and software requirements, and software code is structured. Detailed information can be found in “Software design” and “PRQA Rule Compliance Report ”	**P**

Sec.	Requirement	Comments	Verdict
H.11.12.3.2.4	Design and coding standard	This part was inspected during on-site audit by partly code review. The software code was well meet the coding standard. Detailed information can be found in “Rules of software coding”.	**P**
H.11.12.3.3	Testing	The firmware was tested by multiple measures, code review, module test and integrating test are conducted, and test cases, test data and test results are documented. Detailed information can be found in “BMS Software test report”.	**P**
H.11.12.3.4.1	Tools, programming languages	Detailed information can be found in “Software development tools”.	**P**
H.11.12.3.4.2	Manage of software versions	According to the document “Software version management”, all versions are uniquely identified for traceability. Detailed information can be found in and “Software version update lists”.	**P**
H.11.12.3.4.3	Software modification	It’s the first version to be evaluated.	**N/A**
H.11.12.4	Remotely actuated control functions	The software can be remotely updated in the end use, and CRC is used for checking. Detailed information can be found in “Software version management”.	**P**
H.26.4	Harmonics and Interharmonics Including Mains Signalling at A.C. Power Port, Low Frequency Immunity Tests		**N/A**
H.26.5. 1	Voltage dips, voltage interruptions		**N/A**
H.26.5.2	Voltage Variation Test		**N/A**
H.26.6	Test of Influence of Voltage Imbalance		**N/A**
H.26.8	Surge Immunity Test		**P**
H.26.9	Electrical Fast Transient/Burst Test		**P**
H.26.10	Ring Wave Immunity Test		**P**
H.26.11	Electrostatic Discharge Test		**P**
H.26.12	Radio-frequency Electromagnetic Field Immunity		**P**
H.26.12.2	Immunity to Conducted Disturbances		**P**
H.26.12.3	Immunity to Radiated Disturbances		**P**

Sec.	Requirement	Comments	Verdict
H.26.13	Test of Influence of Supply Frequency Variations		**N/A**
H.26.14	Power Frequency Magnetic Field Immunity Test		**P**
H.26.15	Evaluation of Compliance		**P**

Test after which Evaluation of Compliance is conducted	Safety Function (Class B or C)	Results/observations
RADIO-FREQUENCY ELECTROMAGNETIC FIELD IMMUNITY – IMMUNITY TO CONDUCTED DISTURBANCES IMMUNITY TO RADIATED ELECTROMAGNETIC FIELDS POWER FREQUENCY MAGNETIC FIELD IMMUNITY TEST ELECTRICAL FAST TRANSIENT/BURST IMMUNITY TEST SURGE IMMUNITY TEST RING WAVE TEST ELECTROSTATIC DISCHARGE TEST	Class B	Declared Values: OVP ≥ 3.7 ± 0.01V for 1.5 ± 0.5 sec Measured Values: 3.707V, 1.72 sec Declared Values: UVP ≤ 2.8 ± 0.01V for 1.5 ± 0.5 sec Measured Values: 2.801 V, 1.48 sec Declared Values: OTP/C ≥ 55± 3℃ Measured Values: 56.7℃ Declared Values: OTP/DC ≥ 60 ± 3℃ Measured Values: 61.2℃ OCP/DC ≥35± 2A for 5.0± 0.5 sec Measured Values: 35A, 5.38 sec SCP/DC: 50A fuse, Measured Values: waved because of the fuse was certified. OCP/C ≥35± 2A for 5.0± 0.5 sec Measured Values: 35A, 5.47 sec
COMPOSITE OPERATIONAL AND THERMAL CYCLING TEST EFFECTS OF SHIPPING AND STORAGE TEST	Class B	Declared Values: OVP ≥ 3.7 ± 0.01V for 1.5 ± 0.5 sec Measured Values: 3.709V, 1.71 sec Declared Values: UVP ≤ 2.8 ± 0.01V for 1.5 ± 0.5 sec Measured Values: 2.804 V, 1.59 sec Declared Values: OTP/C ≥ 55± 3℃ Measured Values: 56.1℃ Declared Values: OTP/DC ≥ 60 ± 3℃ Measured Values: 60.8℃ OCP/DC ≥35± 2A for 5.0± 0.5 sec Measured Values: 35A, 5.41sec

		SCP/DC: 50A fuse, Measured Values: waved because of the fuse was certified. OCP/C ≥35± 2A for 5.0± 0.5 sec Measured Values: 35A, 5.30 sec
Supplementary information: N/A		

4. Functional Safety-Related Components

4.1 Hardware

Schematic Ref. No.	Function	Manufacturer	Model
SST19-727B-1.0-SCH	AFE	Panasonic	MAX14921
	MCU	ST	STM8L051F3
SST19-727-V1.1-SCH	MCU	ST	STM32F072VBT6

4.2 Software

Model/Module Ref.	Version/Revision	Unique Identifier #
STM32F072VBT6	2.00	P128S50A-SH0163-2.00

5. Referenced Documents

Doc. Name	Doc. #	Ver./Rev./Date
MCU failure analysis	/	A1.0/ 2020/05/19
Component single fault analysis	/	A0/ 2020/09/20
Hardware FMEA analysis for BMS	/	A0/ 2020/09/20
General-Process definition	/	V1.0/2020/08/28
BMS Software Requirements Specification	/	V1.0/2020/06/11
Software design summary	/	V1.0/2020/08/05
Software Design	/	V1.0/2020/08/28
Software test report	/	V1.0/2020/9/27
Software development tools	/	V1.0/ 2020-08-02
Software version update lists	/	/
Software version management	/	V1.0/ 2020/04/11
Rules of software coding	/	V1.0/ 2020/04/13
SST19-727B-1.0-SCH	Schematic for SST19-727B-REV-1.0	/
SST19-727A-V1.1-SCH	Schematic for SST19-727A-REV_1.1	/