TEST REPORT
IEC 62509
Battery charge controllers for photovoltaic systems – Performance and functioning

Report:	
Report Reference No. ..... :	6046293.50
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Applicant's name ..... :	SRNE Solar Co., Ltd
Address ..... :	4-5F,13A Wutong Island, Neihuan Rd, Xixiang, Bao'an, Shenzhen, Guangdong, China
Test specification:	
Standard ..... :	IEC 62509:2010 (Edition 1.0)
Test procedure ..... :	Type test
Non-standard test method ..... :	N/A
Test Report Form No ..... :	IEC 62509_V1.0
TRF Originator ..... :	DEKRA Testing and Certification (Shanghai) Ltd.
Master TRF ..... :	2016-03
Test item description ..... :	Solar Charge Controller
Trade Mark ..... :	SRNE 硕日
Manufacturer ..... :	SRNE Solar Co., Ltd 4-5F,13A Wutong Island, Neihuan Rd, Xixiang, Bao'an, Shenzhen, Guangdong, China
Model/Type reference ..... :	ML2420, ML2430, ML2440, ML4830

Rating..... :	ML2420: Max PV input: 100 Vdc (25°C), 90 Vdc (-25°C), 260 W / 12Vdc, 520 W / 24Vdc; Battery: 12 / 24 Vdc, max charging current: 20 A; Load output: 12 / 24 Vdc, 20 A max ML2430: Max PV input: 100 Vdc (25°C), 90 Vdc (-25°C), 400 W / 12Vdc, 800 W / 24Vdc; Battery: 12 / 24 Vdc, max charging current: 30 A; Load output: 12 / 24 Vdc, 20 A max ML2440: Max PV input: 100 Vdc (25°C), 90 Vdc (-25°C), 550 W / 12Vdc, 1100 W / 24Vdc; Battery: 12 / 24 Vdc, max charging current: 40 A; Load output: 12 / 24 Vdc, 20 A max ML4830: Max PV input: 150 Vdc, 400 W / 12Vdc, 800 W / 24Vdc, 1200 W / 36Vdc, 1600 W / 48Vdc; Battery: 12 / 24 / 36 / 48 Vdc, max charging current: 30 A; Load output: 12 / 24 / 36 / 48 Vdc, 20 A max

Test item particulars:	
Equipment mobility:	☐ movable ☐ hand-held ☐ stationary ☒ fixed ☐ transportable ☐ for building-in
Connection to the mains:	☐ pluggable equipment ☐ direct plug-in ☐ permanent connection ☐ for building-in ☒ Not connected to mains
Enviromental category:	☐ outdoor ☒ indoor unconditional ☐ indoor conditional
Over voltage category Mains:	☐ OVC I ☐ OVC II ☐ OVC III ☐ OVC IV ☒ Not connected to mains
Over voltage category PV:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Over voltage category Battery:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Mains supply tolerance (%):	--
Tested for power systems:	--
IT testing, phase-phase voltage (V):	--
Class of equipment:	☐ Class I ☐ Class II ☐ Class III ☒ Not classified
Mass of equipment (kg):	1.4 kg for ML2420; 2.0 kg for ML2430, ML2440; 2.3 kg for ML4830
Pollution degree:	PD2
IP protection class:	IP32
Possible test case verdicts:	
- test case does not apply to the test object :	N/A
- test object does meet the requirement:	P(Pass)
- test object does not meet the requirement:	F(Fail)
Testing:	
Date of receipt of test item:	2018-11-29
Date (s) of performance of tests:	2018-11-29 to 2018-12-21

General remarks:

The test results presented in this report relate only to the object tested.

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"(see Appendix #)" refers to additional information appended to the report.

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

The test results presented in this report relate only to the item tested.

This report is not used for social proof function in China market

The measurement result is considered in conformance with the requirement if it is within the prescribed limit, It is not necessary to account the uncertainty associated with the measurement result.

Name and address of factory (ies):

SRNE Solar Co., Ltd

4F, Xinju Road No.10, Shangjiao Village, Chang'an Town, Dongguan City, Guangdong, China

General product information:

This solar charge controller can keep monitoring the solar panel's generating power and tracking the highest voltage and current values (V-I) in real time, enabling the system to charge the battery in maximum power. It's designed to be used in off-grid solar photovoltaic systems to coordinate operation of the solar panel, battery and load, functioning as the core control unit in off-grid photovoltaic systems.

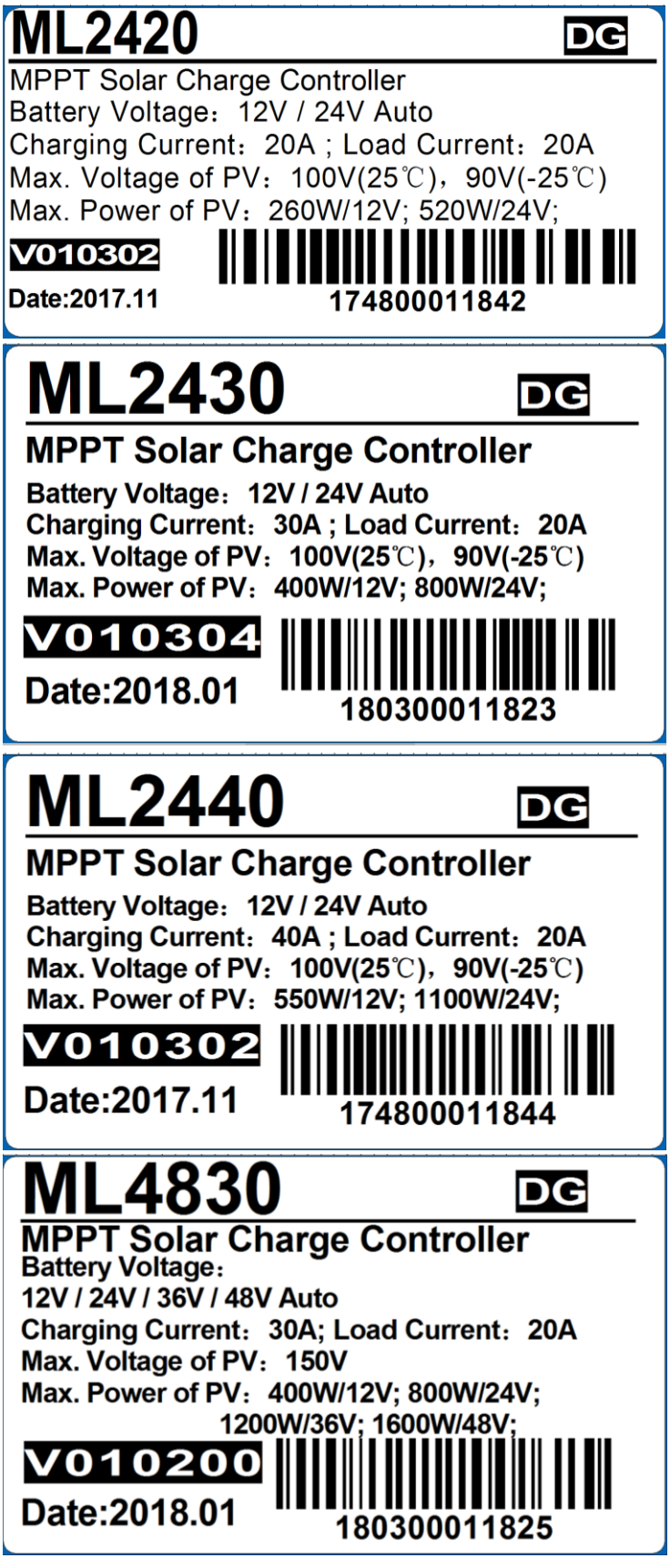
This solar charge controller have below protection function:
- Input power limiting protection
- Battery reverse connection protection
- Photovoltaic input side too high voltage protection
- Photovoltaic input side short-circuit protection
- Photovoltaic input reverse-connection protection
- Load overpower protection
- Load short-circuit protection
- Reverse charging protection at night
- TVS lighting protection
- Over-temperature protection.

The operation temperature range is specified as: - 35°C to 45°C.

The product was tested on:

ML2420 Hardware Version: V0.3	Software Version: V1.3.5
ML2430 Hardware Version: V0.5	Software Version: V1.3.0
ML2440 Hardware Version: V0.5	Software Version: V1.4.8
ML4830 Hardware Version: V0.7.1	Software Version: V2.0.1

Copy of marking plate:



IEC 62509			
Clause	Requirement - Test	Result - Remark	Verdict
4	Functionality and performance requirements of a PV BCC		P
4.1	General		P
	This Clause describes the performance and functionality requirements for PV battery charge controllers (BCC). These requirements are divided in 5 main categories:		P
	• Battery lifetime protection.	Considered.	P
	• Efficiency.	Considered.	P
	• User interface.	Considered.	P
	• Fail safe functions.	Considered.	P
	• Marking and documentation.	Considered.	P
	The provisions in this standard are not intended to preclude or rule out innovative control techniques aimed at providing effective battery charging. These however shall be verifiable by testing.		P
4.2	Applicability of requirements		P
	Required provisions ensure reliable operation and essential protection functions, and are generally easily achievable on even inexpensive BCCs intended for small installations (e.g. single module installations at extra low voltage).		P
	Recommended provisions ensure more effective battery charging, better efficiencies, longer battery lifetime and additional user interface functions. They are intended to provide and/or facilitate more advanced battery charging and load management.		P
4.3	Battery lifetime protection requirements		P
4.3.1	Prevent leakage current from battery to PV generator	See appended table.	P
	The BCC shall limit leakage current flowing from the battery to the PV generator in order to prevent battery discharging at night. The allowable reverse current on the PV side shall be ≤ 0,1 % of the BCC rated input current when the battery voltage is equal to the rated voltage.		P
	Compliance shall be verified by test according to 5.2.1.		P
4.3.2	Basic battery charging functions		P
4.3.2.1	General		P
	The BCC shall provide appropriate charging set-points and load disconnect set-points for the specific battery technology or technologies it is intended to be used for.		P

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Clause	Requirement - Test	Result - Remark	Verdict
4.3.2.2	Protect battery from over-charge		P
	The BCC shall cut out or regulate the charging current to avoid over-charging of the battery according to battery manufacturer recommended end of charge set point.	Considered.	P
	Compliance shall be determined by test according to 5.2.2.		P
4.3.2.3	Protect battery from over-discharge		P
	The BCC shall have a provision to prevent the battery from over-discharging either by directly interrupting the current to the load, or by a trip signal to enable an external piece of equipment to stop the current to the load, or an alarm.	Considered.	P
	If battery over-discharge protection is achieved by means of audible or visible alarms that prompt the system user to disconnect all or non-essential load, this shall be clearly stated in the operation manual.		P
	If over-discharge protection is reliant on the installation of an external device that provides over-discharge protection (such as an inverter), this fact shall be clearly stated in the installation manual.	Not rely on the installation of an external device.	N/A
	Battery over-discharge protection can be triggered by a battery voltage measurement, a state of charge calculation, a combination of both or other algorithms. The protection set-points may be current compensated. Battery over-discharge protection set-point shall be verifiable by testing. The BCC documentation and/or interface shall clearly specify the algorithms and criteria used to establish the load disconnect and reconnect set-points.		P
	Compliance shall be determined by test according to 5.2.3.		P
4.3.2.4	Set-point accuracy		P
	The BCC measurement accuracy for voltage set-points for charge control shall be ±1 % or better. For load disconnect it shall be ±2 % or better.	Considered.	P
	Compliance shall be determined by test according to 5.2.2 and 5.2.3.		P
4.3.3	Charging regime		P
4.3.3.1	General		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The BCC shall be matched to the specific battery technology for its intended use to ensure that correct charging set-points are implemented. The PV BCC can use a variety of methods to ensure correct charging of batteries, the requirements in this clause include some of the possible solutions and do not limit other solutions.		P
4.3.3.2	Required charging stages		P
	As a minimum, PV battery charge controllers shall have bulk and float charging stages.	Considered.	P
4.3.3.3	Recommended charging stages		P
	In addition to the requirements of 4.3.3.2, battery charge controllers should provide equalize charge periodically to the battery. The periodicity of equalise charge should be more than 7 days.	Considered.	P
4.3.3.4	Adjustable charging set-points		P
	Self-adaptive set-points based on advanced algorithms shall be able to be verified using information provided by the user interface and the BCC documentation. No specific test procedure has been developed for devices employing these advanced techniques.	Automatic recognition of battery voltage is supported.	P
4.3.3.5	Temperature compensated charging set-points		P
	Bulk, float, and other high voltage or end of charge set-points should be temperature compensated. Temperature compensation if provided should be in accordance with battery manufacturer recommendations for the particular type of battery. Temperature compensated set-points shall be identifiable from the charge controller documentation.	Considered.	P
4.3.3.6	Voltage drop compensation for set-point measurement		P
	The BCC should provide a means to compensate for voltage drop in battery cables, or provide installation instructions to minimise voltage drop.	Provide installation instructions to minimise voltage drop.	P
	If the battery charge controller has the provision for battery sense cables, it shall be able to operate with or without these. This is to protect the unit against unintended disconnection of the battery sense cables. This requirement is tested according to 5.2.2 and 5.2.3 by performing the test with and without the sense wires connected at 25 °C test conditions.		N/A
4.3.4	Set-point security		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Charging set-points shall be secured against change other than by a deliberate and qualified action.		P
	Compliance shall be determined by inspection of the unit and accompanying operating instructions.		P
4.3.5	Load disconnect capability		P
	Where over-discharge protection is provided by means of load disconnect functionality the load disconnect and reconnect set-points shall be verified by testing according 5.2.3.	Disconnect set-point: 11.1 V, reconnect set-point: 12.6 V for each 12 V battery voltage.	P
	The load could be either a load directly switched or a load controlled by the BCC by other means. In the case of a BCC directly switching the load this should be provided by means of an integrated load breaking switching device.		P
	If a BCC has multiple load disconnect set-points, these shall be verifiable by testing and able to be determined from the BCC user interface and/or clearly written in documentation.		N/A
4.4	Energy performance requirements		P
4.4.1	Stand by self-consumption		P
	With no PV input or load the self-consumption of a PV BCC shall be as detailed in Table 1, when the battery voltage is equivalent to 2,1 V/Cell ± 2 %, and the ambient temperature is 25 °C±2 °C.	See appended table.	P
	Compliance shall be determined by test according to 5.3.1. **Table 1 – Requirements for self-consumption** Nominal charging current: Maximum self-consumption < 5 A: 5 mA 5 A ≤ I ≤ 50 A: 0,1 % of nominal charging current > 50 A: 50 mA		P
4.4.2	BCC efficiency		P
	Power efficiency of the BCC shall be evaluated from 10 % to 100 % of the rated charging current, at a battery voltage equivalent to 2,2 V/Cell±2 % and at ambient temperature of 25 °C±2 °C.	See appended table.	P
	The efficiency shall be determined by test according to 5.3.2		P
4.5	Protection and fail safe requirements		P
4.5.1	Thermal performance		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The BCC shall be capable of handling rated input current/power from the generator and, simultaneously, rated load current to load terminals (if provided) for at least 1 h at the manufacturer's specified maximum rated ambient operating temperature ± 2 °C. Battery voltage shall be 2,2 V/Cell ± 2 %.	Considered.	P
	Compliance shall be determined by test according to 5.4.1.		P
4.5.2	Overcurrent operation		P
4.5.2.1	PV side		P
	The BCC shall not be damaged by excessive current from the PV generator up to 125 % of the full rated current. The BCC shall continue to operate normally after such an event and shall not require manual resetting.	See appended table.	P
	Compliance shall be determined by test according to 5.4.2.		P
4.5.2.2	Load side		P
	If the BCC has a load terminal, this terminal shall be current protected to prevent over loads from causing damage to the operation of the essential PV BCC functions.	Considered.	P
	The rating of the load terminals should match the requirement of the intended application/s.		P
4.5.3	PV generator and battery reverse polarity		P
	The BCC shall be protected from reverse polarity connection of the PV generator or the battery by hardware or by documented procedure and markings.		P
4.5.4	Open circuit on battery terminals (no battery connection)		P
	BCC with load terminals shall be protected from damage to itself and protect the load from the open circuit voltage of the PV generator in the case of battery disconnection.	Considered.	P
4.6	User interface requirements		P
4.6.1	General		P
	The user interface of a BCC should include any of the following types; LCD screen, LED indicators, audible alarms, relay contacts, other computer interface or other analogue or digital interface. The interface can provide the user with valuable information about the system operation if implemented properly.	LCD screen provided.	P

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Clause	Requirement - Test	Result - Remark	Verdict
	The user interface may be integrated into another system component separate from the BCC such as an additional control/logging/interface unit that can be physically connected to the BCC or operate via wireless communication.		P
4.6.2	Operational information		P
4.6.2.1	General		P
	The level of information provided to the user is determined by the intended application and its specific requirements.		P
	The user interface of the charge controller should provide information such as detailed in 4.6.2.2.		P
4.6.2.2	Recommended operation information	Considered.	P
	• An indication of charging status (i.e. charging or not charging).		P
	• An indication of load-disconnect state (or over discharge protection status).		P
	• An indication of the state-of-charge of the connected battery.		P
	Other additional operational information displayed by the unit may include but is not limited to:	Considered.	P
	• Charging set-points.		P
	• Battery voltage.		P
	• Charging current.		P
	• Energy input/output.	Input/output power provided.	N/A
4.6.3	User adjustable set-points and parameters		N/A
	If user-adjustable set-points or parameters are provided, the user interface shall provide a facility to modify and display those adjustments as specified in 4.3.3.4.	No user-adjustable set-points or parameters are provided.	N/A
	Compliance shall be determined by inspection of the unit and accompanying user/installation manual.		N/A
4.6.4	Alarms		P
	The following conditions should be signalled by the user interface:		P
	• Low battery state of charge / Low battery voltage / Low availability.		P
	• Load disconnect.		P
	• BCC trip (e.g. by over temperature).		P

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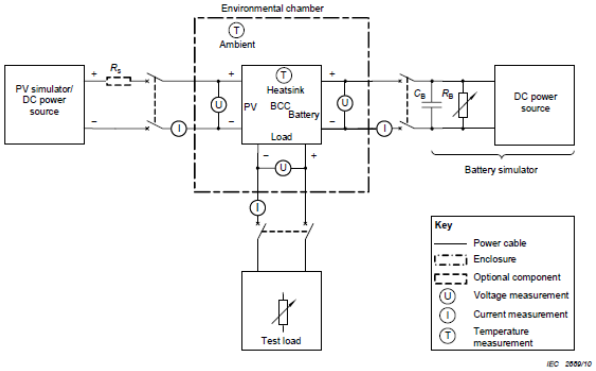
Clause	Requirement - Test	Result - Remark	Verdict
	Visible and/or audible alarms, clearly identifiable by the system user, shall be triggered within the unit in case of any of the above conditions occurring. Audible alarms shall be time limited and revert to a visible alarm or be pulsed.	LED fault indicators and LCD screen which can display abnormal information help users to identify system faults.	P
	Compliance shall be determined by test according to 5.2.2 and 5.2.3.		P
5	Tests		P
5.1	General conditions for tests		P
5.1.1	Setup and preconditioning for tests		P
	The BCC shall be mounted and installed according to the instructions supplied with the unit. Where the BCC is intended to be installed in a particular manner or configuration (e.g. wallmounting), the installation shall mimic such conditions.		P
	The BCC shall be installed in a temperature-controlled chamber for all tests. The test procedure shall not commence until the chamber and BCC temperatures have reached thermal stability.		P
5.1.2	DC power sources for testing		P
5.1.2.1	PV input		P
	The power source used as the PV input should be a PV generator simulator, however, a voltage and current controlled power source in combination with a series resistor (RS in the test diagrams) can be used.	PV simulator used.	P
5.1.2.2	Battery simulator		P
5.1.3	General test setup		P
	The general test setup shall be as specified in Figure 1. Any variations or modifications to the basic setup for a particular test are specified in 5.1.4, 5.1.5 and 5.1.6 and in the corresponding test clauses.  Figure 1 – General test setup		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Voltage measurements shall be made at the BCC terminals.		P
5.1.4	Reverse current test setup		P
	The test setup shall be as specified in Figure 2.		P
5.1.5	Charging cycle test setup		P
5.1.5.1	General		P
	The test setup shall be as specified in Figure 1, with the considerations described below.		P
5.1.5.2	PV input		P
	A PV generator simulator is the preferred option. If a PV generator simulator of the required voltage and/or current ratings is not available, use a power supply with a series resistor (R_S).		P
5.1.5.3	Battery simulator		P
	The battery side PSU is required as a back up for those BCCs that scan the PV IV curve and therefore disconnect the PV current for a few seconds to perform this operation. It is intended to prevent the battery voltage from dipping too much during such IV curve scans.		P
5.1.6	Efficiency, thermal performance and PV overcurrent test setup		P
5.1.6.1	General		P
	The test setup shall be as specified in Figure 1, with the considerations described in 5.1.5.2 and 5.1.6.2.		P
5.1.6.2	Battery simulator		P
5.2	Battery lifetime protection tests		P
5.2.1	Battery to PV generator leakage current test	See appended table.	P
5.2.1.1	Objective/scope		P
	This test is intended to measure the reverse current through the BCC from the battery to the PV generator, when the PV generator is connected but not producing any current. The test verifies compliance with the requirements of 4.3.1. Measurements are to be made at 25 °C ± 2 °C.		P
5.2.1.2	Test setup		P
5.2.1.3	Test procedure		P
	• Connect test setup as specified in Figure 2.		P
	• Ensure the conditions specified in 5.1.1 are met.		P
	• Adjust the battery voltage to 2,1 V/Cell ± 2 %.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	• Measure the current in the R_{PV} loop.		P
	• Compare result to requirement of 4.3.1.		P
5.2.2	Charging cycle tests	See appended table.	P
5.2.2.1	Objective/scope		P
	These tests are intended to measure the charging set-points of the BCC at 25 °C and 40 °C. Measurement at both temperatures allows for verification of set-point temperature compensation when the BCC has this capability.		P
5.2.2.2	Test setup		P
	As specified in 5.1.5.		P
5.2.2.3	Test procedure		P
5.2.3	Load disconnect / load reconnect test		P
5.2.3.1	Objective/scope		P
	This test is intended to verify the low voltage set-points used for load disconnect (LVD) and load reconnect (LVR). Measurements are required at 25 °C.		P
5.2.3.2	Test setup		P
	As specified in 5.1.3.		P
5.2.3.3	Test procedure		P
5.3	Energy performance tests		P
5.3.1	Standby self-consumption test	See appended table.	P
5.3.1.1	Objective/scope		P
	The aim of this test is to determine the self-consumption of the battery charge controller in standby mode (no PV input or load).		P
5.3.1.2	Test setup		P
	As specified in 5.1.3.		P
5.3.1.3	Test procedure		P
5.3.2	Efficiency test	See appended table.	P
5.3.2.1	Objective/scope		P
	The aim of this test is to determine the efficiency curves of the battery charge controller over the range 10 % to 100 % charging current at an ambient temperature of 25 °C.		P
5.3.2.2	Test setup		P
	As specified in 5.1.6.		P
5.3.2.3	Test procedure		P

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Clause	Requirement - Test	Result - Remark	Verdict
5.4	Protection and fail safe tests		P
5.4.1	Thermal performance test	See appended table.	P
5.4.1.1	Objective/scope		P
	This test is carried out to evaluate the performance of the charge controller at the maximum rated temperature and rated charging current in bulk mode. Where no manufacturer's maximum rated ambient operating condition is specified then this test is to be done at 40 °C. The effect of a load connected via integrated load switching device should be included in this test.		P
5.4.1.2	Test setup		P
	As specified in 5.1.6.		P
5.4.1.3	Test procedure		P
5.4.2	PV overcurrent protection test	See appended table.	P
5.4.2.1	Test setup		P
	As specified in 5.1.6.		P
5.4.2.2	Objective/scope		P
	This test is carried out to evaluate the performance of the charge controller under over load conditions at 25 °C and 125 % of the rated charging current in bulk mode.		P
5.4.2.3	Test procedure		P
5.4.3	Load over current protection test	See appended table.	P
5.4.3.1	Objective/scope		P
	This test is carried out to evaluate the performance of the charge controller at 25 °C and 125 % of the rated load current.		P
5.4.3.2	Test setup		P
	As specified in 5.1.3.		P
5.4.3.3	Test procedure		P
5.4.4	Battery reverse polarity test	See appended table.	P
5.4.4.1	Objective/scope		P
	This test is intended to verify the BCC tolerance to the connection of the battery in reverse polarity and also to verify the protection of the load from being supplied with negative voltage.		P
5.4.4.2	Test Setup		P
	As specified in 5.1.3, with the observations specified in the test procedure.		P
5.4.4.3	Test procedure		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Review the BCC documentation and the unit itself to verify whether it is capable of withstanding a reverse polarity connection on the battery terminals, or if there is a specific warning not to do so. If a warning is given in the unit or its documentation do not go ahead with the test.		P
5.4.5	PV generator reverse polarity test	See appended table.	P
5.4.5.1	Objective/scope		P
	This test is intended to verify the BCC tolerance to the connection of the PV generator in reverse polarity and also to verify the protection of the load from being supplied with negative voltage.		P
5.4.5.2	Test setup		P
	As specified in 5.1.3 with the observations specified in the test procedure.		P
5.4.5.3	Test procedure		P
	Revise the BCC documentation and the unit itself to verify whether it is capable of withstanding a reverse polarity connection on PV terminals, or if there is a specific warning not to do so. If a warning is given in the unit or its documentation do not go ahead with the test.		P
5.4.6	Battery open circuit test		P
5.4.6.1	Objective/scope		P
	This test is intended to verify the BCC tolerance to the occurrence of an open circuit on the battery terminals, and the protection of the load from being connected directly to the PV generator voltage.		P
5.4.6.2	Test setup		P
	As specified in 5.1.6 with the modifications indicated in the test procedure.		P
5.4.6.3	Test procedure	After test the BCC can reconnect the battery and is operating normally.	P
5.5	User interface tests	Considered.	P
	User interface requirements are verified mainly by inspection of the BCC and the accompanying instruction and installation manuals. Alarms are verified during other tests such as:		P
	Load disconnect / load reconnect test (5.2.3)		P
	Reverse polarity tests (5.4.4 and 5.4.5)		P
	Thermal performance test (5.4.1)		P
	Overcurrent protection test (5.4.2 and 5.4.3)		P

5.2.1	TABLE: Battery to PV generator leakage current test		P
Model	ML2420		
Parameter	Test condition	Measured value	Limits
$I_{Leakage}$	24 V battery system	<1 mA	20 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	12 V battery system	<1 mA	20 mA (≤ 0,1 %*I_{rated})

5.2.1	TABLE: Battery to PV generator leakage current test		P
Model	ML2430		
Parameter	Test condition	Measured value	Limits
$I_{Leakage}$	24 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	12 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})

5.2.1	TABLE: Battery to PV generator leakage current test		P
Model	ML2440		
Parameter	Test condition	Measured value	Limits
$I_{Leakage}$	24 V battery system	<1 mA	40 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	12 V battery system	<1 mA	40 mA (≤ 0,1 %*I_{rated})

5.2.1	TABLE: Battery to PV generator leakage current test		P
Model	ML4830		
Parameter	Test condition	Measured value	Limits
$I_{Leakage}$	48 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	36 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	24 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})
$I_{Leakage}$	12 V battery system	<1 mA	30 mA (≤ 0,1 %*I_{rated})
Supplementary information: The BCC shall limit leakage current flowing from the battery to the PV generator in order to prevent battery discharging at night. The allowable reverse current on the PV side shall be ≤ 0,1 % of the BCC rated input current when the battery voltage is equal to the rated voltage.			

5.2.2	TABLE: Charging cycle test						P
Model	ML2420						
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	27.822	10.193	13.11	20.04	N/A	N/A	N/A
End of bulk charge	29.299	0.075	14.438	0.085	14.4	14.438	0.26
Float charge	30.106	0.069	13.87	0.081	13.8	13.87	0.51
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Bulk charge	24.723	12.429	13.129	21.57	N/A	N/A	N/A
End of bulk charge	24.989	0.083	14.162	0.079	14.13	14.162	0.23
Float charge	24.878	0.075	13.56	0.077	13.53	13.56	0.22
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.07mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	42.781	12.990	25.929	20.487	N/A	N/A	N/A
End of bulk charge	44.304	0.0827	28.831	0.0899	28.8	28.831	0.11
Float charge	44.705	0.0786	27.57	0.0787	27.6	27.57	0.11
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Bulk charge	39.670	14.928	26.129	21.639	N/A	N/A	N/A
End of bulk charge	39.991	0.091	28.294	0.088	28.26	28.294	0.12
Float charge	39.898	0.087	26.93	0.076	27.06	26.93	0.48
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-2.98mV/°C / 2V		

Supplementary information:

The temperature compensation function provided, the controller can automatically adjust charging set-point parameters according to temperature change.

The BCC measurement accuracy for voltage set-points for charge control shall be ± 1 % or better.

5.2.2	TABLE: Charging cycle test						P
Model	ML2430						
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	28.333	14.359	13.359	28.376	N/A	N/A	N/A
End of bulk charge	29.298	0.0826	14.328	0.0865	14.4	14.328	0.50
Float charge	29.385	0.0798	13.732	0.0803	13.8	13.732	0.49
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Bulk charge	24.633	16.604	13.331	28.52	N/A	N/A	N/A
End of bulk charge	24.986	0.097	14.063	0	14.13	14.063	0.47
Float charge	24.989	0.078	13.474	0	13.53	13.474	0.41
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-2.94mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	43.148	18.011	26.132	28.559	N/A	N/A	N/A
End of bulk charge	44.297	0.0867	28.675	0.0899	28.8	28.675	0.43
Float charge	44.538	0.0795	27.486	0.0856	27.6	27.486	0.41
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Bulk charge	44.615	17.585	26.328	28.593	N/A	N/A	N/A
End of bulk charge	44.992	0	28.118	0	28.26	28.118	0.50
Float charge	44.895	0	26.932	0	27.06	26.932	0.47
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.09mV/°C / 2V		

Supplementary information:

The temperature compensation function provided, the controller can automatically adjust charging set-point parameters according to temperature change.
The BCC measurement accuracy for voltage set-points for charge control shall be ± 1 % or better.

5.2.2	TABLE: Charging cycle test						P
Model	ML2440						
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	28.015	21.174	13.829	39.585	N/A	N/A	N/A
End of bulk charge	29.298	0	14.4	0	14.4	14.4	0
Float charge	29.586	0	13.72	0	13.8	13.72	0.58
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Bulk charge	24.476	24.016	13.652	39.64	N/A	N/A	N/A
End of bulk charge	24.987	0	14.13	0	14.13	14.13	0
Float charge	24.985	0	13.58	0	13.53	13.58	0.37
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.0mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	58.121	19.06	26.933	39.378	N/A	N/A	N/A
End of bulk charge	59.313	0	28.779	0	28.8	28.779	0.003
Float charge	59.417	0	27.63	0	27.6	27.63	0.11
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Bulk charge	44.457	24.941	26.655	39.783	N/A	N/A	N/A
End of bulk charge	44.993	0	28.228	0	28.26	28.228	0.11
Float charge	44.896	0	27.12	0	27.06	27.12	0.22
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.06mV/°C / 2V		

Supplementary information:

The temperature compensation function provided, the controller can automatically adjust charging set-point parameters according to temperature change.
The BCC measurement accuracy for voltage set-points for charge control shall be ± 1 % or better.

5.2.2	TABLE: Charging cycle test						P
Model	ML4830						
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	38.482	11.452	13.558	30.33	N/A	N/A	N/A
End of bulk charge	39.355	0	14.502	0	14.4	14.502	0.71
Float charge	39.595	0	13.889	0	13.8	13.889	0.64
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			12.6V				
Bulk charge	24.610	17.603	13.378	30.28	N/A	N/A	N/A
End of bulk charge	24.987	0.229	14.205	0	14.13	14.205	0.53
Float charge	24.993	0.108	13.602	0	13.53	13.602	0.53
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.3mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	48.150	17.683	26.969	30.37	N/A	N/A	N/A
End of bulk charge	49.346	0	28.924	0	28.8	28.924	0.43
Float charge	49.858	0	27.68	0	27.6	27.68	0.29
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			25.2V				
Bulk charge	44.589	18.841	26.389	30.605	N/A	N/A	N/A
End of bulk charge	44.993	0.233	28.349	0	28.26	28.349	0.31
Float charge	44.996	0.109	27.151	0	27.06	27.151	0.34
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.19mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			37.8V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	66.171	18.519	38.975	30.502	N/A	N/A	N/A
End of bulk charge	67.420	0	43.478	0	43.2	43.478	0.64
Float charge	68.03	0	41.658	0	41.4	41.658	0.62
Chamber temperature			40°C				

Battery voltage:2.1V/Cell±2%			37.8V				
Bulk charge	59.557	20.46	38.885	30.414	N/A	N/A	N/A
End of bulk charge	59.996	0.224	42.593	0	42.39	42.593	0.48
Float charge	59.988	0.218	40.785	0	40.59	40.785	0.48
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.28mV/°C / 2V		
Chamber temperature			25°C				
Battery voltage:2.1V/Cell±2%			50.4V				
Charging stages	Input voltage (V)	Input current (A)	Output voltage (V)	Output current (A)	Set-point Voltage (V)	Measured Voltage (V)	Accuracy (%)
Bulk charge	106.31	16.538	55.983	30.579	N/A	N/A	N/A
End of bulk charge	107.40	0	57.816	0	57.6	57.816	0.38
Float charge	108.1	0	55.428	0	55.2	55.428	0.41
Chamber temperature			40°C				
Battery voltage:2.1V/Cell±2%			50.4V				
Bulk charge	99.64	16.705	52.892	30.646	N/A	N/A	N/A
End of bulk charge	100.00	0.227	56.723	0	56.52	56.723	0.36
Float charge	100	0.118	54.351	0	54.12	54.351	0.43
Temperature compensation		Set value			Measured Value		
		-3mV/°C / 2V			-3.04mV/°C / 2V		

Supplementary information:

The temperature compensation function provided, the controller can automatically adjust charging set-point parameters according to temperature change.
The BCC measurement accuracy for voltage set-points for charge control shall be ± 1 % or better.

5.2.3	TABLE: Load disconnect / load reconnect test	P
Model	ML2420	

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.314	0	0	0	0.51	25°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.040	25.015	19.27	19.06	0.63	25°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.235	0	0	0	1.22	25°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.491	12.465	19.28	18.82	0.87	25°C

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.206	0	0	0	0.03	40°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.084	25.059	19.3	19.1	0.46	40°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.264	0	0	0	1.48	40°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.458	12.432	19.27	18.80	1.13	40°C

Supplementary information:

Disconnect set-point: 11.1 V, reconnect set-point: 12.6 V for 12 V battery system.

Disconnect set-point: 22.2 V, reconnect set-point: 25.2 V for 24 V battery system.

The BCC measurement accuracy for voltage set-points for load disconnect shall be ± 2 % or better.

5.2.3	TABLE: Load disconnect / load reconnect test	P
Model	ML2430	

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.314	0	0	0	0.51	25°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.045	25.02	19.26	19.06	0.62	25°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.235	0	0.025	0	1.22	25°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.491	12.465	19.28	18.82	0.87	25°C

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.206	0	0	0	0.03	40°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.084	25.059	19.3	19.1	0.46	40°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.264	0	0.025	0	1.48	40°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.458	12.432	19.27	18.8	1.13	40°C

Supplementary information:

Disconnect set-point: 11.1 V, reconnect set-point: 12.6 V for 12 V battery system.

Disconnect set-point: 22.2 V, reconnect set-point: 25.2 V for 24 V battery system.

The BCC measurement accuracy for voltage set-points for load disconnect shall be ± 2 % or better.

5.2.3	TABLE: Load disconnect / load reconnect test	P
Model	ML2440	

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.287	0	0	0	0.39	25°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.104	24.323	18.75	18.54	0.38	25°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.175	0	0	0	0.68	25°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.475	12.445	19.03	18.58	0.99	25°C

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	24 V battery system	22.236	0	0	0	0.16	40°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.147	23.933	18.41	18.22	0.21	40°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.222	0	0	0	1.10	40°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.505	12.479	19.31	18.85	0.75	40°C

Supplementary information:

Disconnect set-point: 11.1 V, reconnect set-point: 12.6 V for 12 V battery system.

Disconnect set-point: 22.2 V, reconnect set-point: 25.2 V for 24 V battery system.

The BCC measurement accuracy for voltage set-points for load disconnect shall be ± 2 % or better.

5.2.3	TABLE: Load disconnect / load reconnect test	P
Model	ML4830	

Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	48 V battery system	44.473	0	0	0	0.16	25°C
f) Low voltage for reconnect (LVR)	48 V battery system	50.499	50.459	19.555	19.441	0.20	25°C
e) Low voltage for disconnect (LVD)	36 V battery system	33.53	0	0	0	0.69	25°C
f) Low voltage for reconnect (LVR)	36 V battery system	37.878	37.84	19.218	19.088	0.21	25°C
e) Low voltage for disconnect (LVD)	24 V battery system	22.453	0	0	0	1.14	25°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.145	25.099	19.295	19.161	0.22	25°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.297	0	0.0219	0	1.77	25°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.469	12.441	19.276	18.853	1.04	25°C
Parameter	Test condition	Measured voltage (V)		Measured current (A)		Accuracy	Chamber temperature
		Battery	Load	Battery	Load	(%)	
e) Low voltage for disconnect (LVD)	48 V battery system	44.543	0	0	0	0.32	40°C
f) Low voltage for reconnect (LVR)	48 V battery system	50.507	50.467	19.594	19.485	0.21	40°C
e) Low voltage for disconnect (LVD)	36 V battery system	33.431	0	0	0	0.39	40°C
f) Low voltage for reconnect (LVR)	36 V battery system	37.903	37.874	19.568	19.391	0.27	40°C
e) Low voltage for disconnect (LVD)	24 V battery system	22.239	0	0	0	0.18	40°C
f) Low voltage for reconnect (LVR)	24 V battery system	25.262	25.24	19.452	19.084	0.25	40°C
e) Low voltage for disconnect (LVD)	12 V battery system	11.162	0	0.023	0	0.56	40°C
f) Low voltage for reconnect (LVR)	12 V battery system	12.638	12.624	19.469	18.675	0.30	40°C

Supplementary information:
Disconnect set-point: 11.1 V, reconnect set-point: 12.6 V for 12 V battery system.
Disconnect set-point: 22.2 V, reconnect set-point: 25.2 V for 24 V battery system.
Disconnect set-point: 33.3 V, reconnect set-point: 37.8 V for 36 V battery system.
Disconnect set-point: 44.4 V, reconnect set-point: 50.4 V for 48 V battery system.
The BCC measurement accuracy for voltage set-points for load disconnect shall be ±2 % or better.

5.3.1	TABLE: Standby self-consumption test			P
Model	ML2420			
Parameter	Test condition	Measured voltage (V)	Measured current (mA)	Limit (mA)
2,1 V/Cell	24 V battery system	25.20	8	20
2,0 V/Cell	24 V battery system	24.00	8	20
1,9 V/Cell	24 V battery system	22.80	9	20
1,8 V/Cell	24 V battery system	21.60	9	20
1,7 V/Cell	24 V battery system	20.40	10	20
2,1 V/Cell	12 V battery system	12.61	16	20
2,0 V/Cell	12 V battery system	12.01	16	20
1,9 V/Cell	12 V battery system	11.41	17	20
1,8 V/Cell	12 V battery system	10.81	18	20
1,7 V/Cell	12 V battery system	10.21	19	20
Supplementary information: Maximum self-consumption limit is 0,1 % of nominal charging current.				

5.3.1	TABLE: Standby self-consumption test			P
Model	ML2430			
Parameter	Test condition	Measured voltage (V)	Measured current (mA)	Limit (mA)
2,1 V/Cell	24 V battery system	25.20	13	30
2,0 V/Cell	24 V battery system	24.01	13	30
1,9 V/Cell	24 V battery system	22.80	14	30
1,8 V/Cell	24 V battery system	21.60	14	30
1,7 V/Cell	24 V battery system	20.40	15	30
2,1 V/Cell	12 V battery system	12.60	23	30
2,0 V/Cell	12 V battery system	11.41	26	30
1,9 V/Cell	12 V battery system	11.41	26	30
1,8 V/Cell	12 V battery system	10.81	27	30
1,7 V/Cell	12 V battery system	10.20	29	30
Supplementary information: Maximum self-consumption limit is 0,1 % of nominal charging current.				

5.3.1	TABLE: Standby self-consumption test			P
Model	ML2440			
Parameter	Test condition	Measured voltage (V)	Measured current (mA)	Limit (mA)
2,1 V/Cell	24 V battery system	25.20	17	40
2,0 V/Cell	24 V battery system	24.02	18	40
1,9 V/Cell	24 V battery system	22.81	18	40
1,8 V/Cell	24 V battery system	21.60	19	40
1,7 V/Cell	24 V battery system	20.40	21	40
2,1 V/Cell	12 V battery system	12.62	31	40
2,0 V/Cell	12 V battery system	12.01	33	40
1,9 V/Cell	12 V battery system	11.41	35	40
1,8 V/Cell	12 V battery system	10.81	37	40
1,7 V/Cell	12 V battery system	10.21	39	40
Supplementary information: Maximum self-consumption limit is 0,1 % of nominal charging current.				

5.3.1	TABLE: Standby self-consumption test			P
Model	ML4830			
Parameter	Test condition	Measured voltage (V)	Measured current (mA)	Limit (mA)
2,1 V/Cell	48 V battery system	50.41	6.2	30
2,0 V/Cell	48 V battery system	48.01	6.4	30
1,9 V/Cell	48 V battery system	45.60	6.5	30
1,8 V/Cell	48 V battery system	43.20	7.0	30
1,7 V/Cell	48 V battery system	40.80	7.0	30
2,1 V/Cell	36 V battery system	37.80	7.4	30
2,0 V/Cell	36 V battery system	36.04	7.8	30
1,9 V/Cell	36 V battery system	34.20	7.9	30
1,8 V/Cell	36 V battery system	32.40	8.3	30
1,7 V/Cell	36 V battery system	30.61	8.8	30
2,1 V/Cell	24 V battery system	25.21	10.1	30
2,0 V/Cell	24 V battery system	24.01	10.5	30
1,9 V/Cell	24 V battery system	22.81	11.3	30
1,8 V/Cell	24 V battery system	21.61	11.6	30
1,7 V/Cell	24 V battery system	20.41	12.6	30
2,1 V/Cell	12 V battery system	12.60	20.2	30
2,0 V/Cell	12 V battery system	12.00	21.3	30

1,9 V/Cell	12 V battery system	11.40	21.9	30
1,8 V/Cell	12 V battery system	10.80	25.1	30
1,7 V/Cell	12 V battery system	10.20	29.2	30
Supplementary information: Maximum self-consumption limit is 0,1 % of nominal charging current.				

5.3.2	TABLE: Efficiency test						P
Model	ML2420						
Power Level (%)	PV			Battery			Efficiency (%)
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery system:							
10%	34.133	1.686	57.5	26.413	2.07	54.67	95.029
20%	36.249	3.029	109.76	26.406	4.047	106.85	97.353
30%	35.816	4.51	161.51	26.4	5.961	157.37	97.436
40%	35.028	6.229	218.16	26.404	8.042	212.35	97.339
50%	36.243	7.509	272.09	26.411	10.028	264.84	97.337
60%	35.823	9.166	328.31	26.407	12.07	318.73	97.081
70%	35.354	10.875	384.44	26.406	14.091	372.1	96.789
80%	36.113	12.18	439.81	26.404	16.07	424.3	96.473
90%	34.989	14.183	496	26.401	18.07	477.07	96.140
100%	35.387	15.639	553	26.393	20.072	529.75	95.732
12 V battery system:							
10%	17.875	1.6122	28.8	13.202	1.9911	26.28	91.237
20%	17.405	3.139	54.62	13.202	3.9581	52.25	95.658
30%	17.914	4.6379	83.07	13.2	6.0184	79.44	95.635
40%	17.552	6.3395	111.25	13.205	8.038	106.14	95.409
50%	17.47	7.972	139.26	13.201	10.07	132.93	95.453
60%	17.806	9.404	167.42	13.206	12.039	158.98	94.958
70%	17.651	11.06	195.19	13.202	13.965	184.37	94.458
80%	17.802	12.671	225.55	13.21	16.031	211.77	93.892
90%	17.529	14.589	255.69	13.2	18.065	238.45	93.257
100%	17.822	16.021	285.48	13.206	20.02	264.39	92.610
Supplementary information:							

5.3.2	TABLE: Efficiency test						P
Model	ML2430						
Power Level (%)	PV			Battery			Efficiency (%)
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery system:							
10%	36.308	2.3446	85.12	26.405	3.093	81.67	95.953
20%	35.528	4.4971	159.76	26.402	5.912	156.09	97.703
30%	35.878	6.714	240.84	26.406	8.911	235.31	97.702
40%	34.995	9.195	321.77	26.402	11.895	314.03	97.597
50%	35.529	11.483	407.93	26.403	15.038	397.04	97.332
60%	35.419	13.903	492	26.405	18.119	478.44	97.170
70%	35.129	16.254	571	26.41	20.956	553.44	96.931
80%	35.554	18.488	657	26.415	24.047	635.2	96.644
90%	35.678	20.812	743	26.413	27.087	715.46	96.361
100%	39.784	20.837	824	26.451	29.988	793.05	96.244
12 V battery system:							
10%	17.903	2.4689	44.19	13.198	3.082	40.68	92.053
20%	17.994	4.6607	83.85	13.207	6.101	80.57	96.084
30%	17.781	6.934	123.28	13.192	8.98	118.46	96.091
40%	17.868	9.313	166.38	13.199	12.072	159.34	95.769
50%	17.692	11.797	208.69	13.204	15.079	199.11	95.411
60%	17.728	14.169	251.16	13.205	18.083	238.80	95.077
70%	17.682	16.593	293.38	13.204	21.021	277.57	94.611
80%	17.715	18.921	335.16	13.204	23.895	315.52	94.140
90%	17.579	21.655	380.63	13.212	26.972	356.35	93.620
100%	18.471	22.873	422.25	13.213	30.001	396.38	93.873
Supplementary information:							

5.3.2	TABLE: Efficiency test						P
Model	ML2440						
Power Level (%)	PV			Battery			Efficiency (%)
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery system:							
10%	35.454	3.087	109.43	26.408	4.016	106.05	96.907
20%	35.337	6.1936	218.84	26.4	8.111	214.11	97.840
30%	35.382	9.256	327.47	26.407	12.118	319.99	97.717
40%	35.431	12.292	435.46	26.404	16.079	424.56	97.496
50%	35.911	15.125	543	26.407	20.021	528.68	97.348
60%	35.639	18.332	653	26.409	24.012	634.14	97.069
70%	35.963	21.285	765	26.412	28.045	741	96.775
80%	35.288	24.865	877	26.411	32.038	846	96.440
90%	35.703	27.748	991	26.407	36.04	952	96.072
100%	37.018	29.937	1100	26.418	39.934	1050	95.899
12 V battery system:							
10%	18.236	3.019	55.03	13.205	3.993	52.72	95.804
20%	18.115	6.04	109.4	13.199	7.979	105.32	96.275
30%	17.841	9.331	166.46	13.199	12.113	159.88	96.048
40%	17.544	12.558	220.29	13.202	15.964	210.76	95.674
50%	17.488	15.906	278.14	13.203	20.085	265.18	95.342
60%	17.452	19.226	335.5	13.208	24.071	317.93	94.765
70%	17.416	22.522	392.21	13.213	27.956	369.38	94.180
80%	17.605	25.762	453.47	13.215	32.094	424	93.526
90%	17.472	29.429	514	13.214	36.11	477	92.813
100%	18.723	30.952	572	13.215	40.02	528	92.403
Supplementary information:							

5.3.2	TABLE: Efficiency test						P
Model	ML4830						
Power Level (%)	PV			Battery			Efficiency (%)
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
48 V battery system:							
10%	69.22	2.3391	160.87	52.8	2.962	156.09	97.028
20%	70.08	4.5771	320.74	52.803	5.963	314.85	98.161
30%	71.17	6.7522	480.52	52.806	8.943	472.26	98.279
40%	71.29	8.974	640	52.801	11.906	629	98.269
50%	69.99	11.514	806	52.804	14.987	791	98.202
60%	69.77	13.881	969	52.805	17.994	950	98.111
70%	71.25	15.912	1130	52.807	21.033	1110	97.979
80%	71.31	18.174	1300	52.811	24.009	1270	97.844
90%	70.27	20.76	1460	52.815	26.991	1430	97.712
100%	71.8	22.644	1630	52.823	30.027	1590	97.563
36 V battery system:							
10%	51.941	2.4169	124.77	39.606	3.055	120.79	96.815
20%	53.894	4.5499	245.21	39.601	6.0676	240.28	97.989
30%	54.028	6.7748	366.02	39.603	9.059	358.76	98.016
40%	53.806	8.978	483.08	39.606	11.955	473.49	98.016
50%	54.095	11.187	605.18	39.605	14.957	592	97.886
60%	53.826	13.467	724.86	39.603	17.893	709	97.757
70%	54.359	15.582	847	39.601	20.874	827	97.592
80%	53.844	18.087	974	39.606	23.953	949	97.412
90%	52.551	21.011	1100	39.609	27.099	1070	97.220
100%	53.809	22.861	1230	39.609	30.133	1190	97.026
24V battery system:							
10%	35.03	2.3951	83.36	26.403	3.037	80.02	95.99
20%	35.881	4.5996	165.04	26.401	6.096	160.95	97.524
30%	35.839	6.8433	245.25	26.404	9.075	239.6	97.697
40%	35.925	9.083	326.3	26.404	12.058	318.37	97.571
50%	35.39	11.509	407.3	26.409	15.024	396.76	97.412
60%	36.083	13.567	489.5	26.403	18.022	475.83	97.206
70%	35.919	15.92	572	26.41	20.996	554.49	96.974
80%	35.607	18.389	655	26.407	23.986	633.39	96.736
90%	35.109	21.048	739	26.407	26.994	712.83	96.466
100%	35.873	22.954	823	26.417	29.988	792	96.212

12 V battery system:							
10%	18.094	2.371	42.63	13.209	3.004	39.57	92.837
20%	17.706	4.733	83.8	13.2	6.087	80.34	95.871
30%	17.752	6.967	123.67	13.202	9.002	118.84	96.095
40%	17.714	9.346	165.54	13.207	12.018	158.72	95.877
50%	17.833	11.649	207.72	13.199	15.034	198.44	95.531
60%	17.742	14.145	250.95	13.206	18.076	239	95.123
70%	17.498	16.76	293.24	13.213	21.013	278	94.678
80%	17.925	18.742	335.94	13.203	23.973	317	94.222
90%	17.879	21.309	380.96	13.206	27.03	357	93.701
100%	17.962	23.752	426.6	13.221	30.062	397	93.166
Supplementary information:							

5.3.2	TABLE: Voltage Drop			P
Model	ML2420			
Parameter		Load Level	Battery Voltage (V)	Load Voltage (V)
24 V battery system		No Load	26.406	26.416
24 V battery system		100% Load	26.411	26.114
Voltage drop between battery and load @ full load (V)			0.297	
Parameter		Load Level	Battery Voltage (V)	Load Voltage (V)
12 V battery system		No Load	13.204	13.210
12 V battery system		100% Load	13.207	12.911
Voltage drop between battery and load @ full load (V)			0.296	
Supplementary information:				

5.3.2	TABLE: Voltage Drop			P
Model	ML2430			
Parameter		Load Level	Battery Voltage (V)	Load Voltage (V)
24 V battery system		No Load	26.407	26.413
24 V battery system		100% Load	26.401	26.196
Voltage drop between battery and load @ full load (V)			0.205	
Parameter		Load Level	Battery Voltage (V)	Load Voltage (V)
12 V battery system		No Load	13.203	13.209
12 V battery system		100% Load	13.207	12.998
Voltage drop between battery and load @ full load (V)			0.209	
Supplementary information:				

5.3.2	TABLE: Voltage Drop		P
Model	ML2440		
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
24 V battery system	No Load	26.406	26.413
24 V battery system	100% Load	26.406	26.194
Voltage drop between battery and load @ full load (V)		0.212	
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
12 V battery system	No Load	13.203	13.209
12 V battery system	100% Load	13.204	12.993
Voltage drop between battery and load @ full load (V)		0.211	
Supplementary information:			

5.3.2	TABLE: Voltage Drop		P
Model	ML4830		
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
24 V battery system	No Load	52.806	52.816
24 V battery system	100% Load	52.805	52.676
Voltage drop between battery and load @ full load (V)		0.129	
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
12 V battery system	No Load	39.602	39.61
12 V battery system	100% Load	39.608	39.476
Voltage drop between battery and load @ full load (V)		0.132	
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
24 V battery system	No Load	26.406	26.413
24 V battery system	100% Load	26.407	26.274
Voltage drop between battery and load @ full load (V)		0.133	
Parameter	Load Level	Battery Voltage (V)	Load Voltage (V)
12 V battery system	No Load	13.204	13.21
12 V battery system	100% Load	13.212	13.074
Voltage drop between battery and load @ full load (V)		0.138	
Supplementary information:			

5.4.1	TABLE: Thermal performance test (Charge state with load output)								P
Model	ML2420								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	35.775	15.292	547	26.386	0.192	4.92	26.185	20.076	525.69
5.4.1	TABLE: Thermal performance test (Charge state without load output)								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	35.53	15.525	552	26.436	19.955	528	0	0	0
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.									

5.4.1	TABLE: Thermal performance test (Charge state with load output)								P
Model	ML2430								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	41.83	19.858	829	26.403	9.907	260	26.291	20.018	526
5.4.1	TABLE: Thermal performance test (Charge state without load output)								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	42.341	19.339	817	26.408	29.76	786	0	0	0
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.									

5.4.1	TABLE: Thermal performance test (Charge state with load output)								P
Model	ML2440								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	41.26	30.253	1240	26.392	20.194	529	26.313	20.008	526
5.4.1	TABLE: Thermal performance test (Charge state without load output)								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	40.12	27.375	1100	26.452	39.710	1050	0	0	0
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.									

5.4.1	TABLE: Thermal performance test (Charge state with load output)								P
Model	ML4830								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
48 V battery voltage	74.24	21.68	1610	52.803	9.708	513	52.713	19.932	1050
5.4.1	TABLE: Thermal performance test (Charge state without load output)								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
48 V battery voltage	83.28	17.238	1440	52.794	26.538	1400	0	0	0
Supplementary information: The test was performed on 48 V battery voltage also valid to 12/24/36 V battery voltage due to the have same current rating.									

5.4.2	TABLE: PV overcurrent protection test						P
Model	ML2420						
Test condition	PV			Battery			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery voltage	39.921	14.778	589	26.407	21.305	562.6	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.2	TABLE: PV overcurrent protection test						P
Model	ML2430						
Test condition	PV			Battery			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery voltage	42.21	19.587	825	26.404	30.09	794	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.2	TABLE: PV overcurrent protection test						P
Model	ML2430						
Test condition	PV			Battery			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery voltage	41.29	27.131	1110	26.421	40.38	1070	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.2	TABLE: PV overcurrent protection test						P
Model	ML4830						
Test condition	PV			Battery			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24 V battery voltage	84.66	19.294	1630	52.806	30.14	1590	
Supplementary information: The test was performed on 48 V battery voltage also valid to 12/24/36 V battery voltage due to the have same current rating.							

5.4.3	TABLE: Load over current protection test						P
Model	ML2420						
Test condition	Battery			Load			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24V battery voltage	24.004	28.317	680	23.6	28.283	668	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.3	TABLE: Load over current protection test						P
Model	ML2430						
Test condition	Battery			Load			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24V battery voltage	24.19	25.575	619	24.04	25.288	608	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.3	TABLE: Load over current protection test						P
Model	ML2440						
Test condition	Battery			Load			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
24V battery voltage	24.101	25.422	613	23.952	25.138	602	
Supplementary information: The test was performed on 24 V battery voltage also valid to 12 V battery voltage due to the have same current rating.							

5.4.3	TABLE: Load over current protection test						P
Model	ML4830						
Test condition	Battery			Load			
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	
48V battery voltage	48.088	26.191	1260	47.933	25.924	1240	
Supplementary information: The test was performed on 48 V battery voltage also valid to 12/24/36 V battery voltage due to the have same current rating.							

5.4.4	TABLE: Battery reverse polarity test								P
Model	ML2420								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Power (W)	Current (A)	Power (W)
24 V battery voltage	36.09	0.016	0.58	26.363	0	0	0	0	0
12 V battery voltage	18.05	0.019	0.34	13.202	0	0	0	0	0
Supplementary information:									

5.4.4	TABLE: Battery reverse polarity test								P
Model	ML2430								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Power (W)	Current (A)	Power (W)
24 V battery voltage	36.09	0.014	0.51	26.367	0	0	0	0	0
12 V battery voltage	18.05	0.02	0.36	13.21	0	0	0	0	0
Supplementary information:									

5.4.4	TABLE: Battery reverse polarity test								P
Model	ML2440								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Power (W)	Current (A)	Power (W)
24 V battery voltage	36.10	0.012	0.43	26.341	0	0	0	0	0
12 V battery voltage	18.05	0.023	0.42	13.195	0	0	0	0	0
Supplementary information:									

5.4.4	TABLE: Battery reverse polarity test								P
Model	ML4830								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Power (W)	Current (A)	Power (W)
48 V battery voltage	72.19	0.009	0.65	52.873	0	0	0	0	0
36 V battery voltage	54.14	0.017	0.92	39.59	0	0	0	0	0
24 V battery voltage	36.10	0.02	0.72	26.444	0	0	0	0	0
12 V battery voltage	18.05	0.027	0.49	13.252	0	0	0	0	0
Supplementary information:									

5.4.5	TABLE: PV generator reverse polarity test								P
Model	ML2420								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	35.997	0	0	25.961	19.228	-499.18	25.893	19.135	495.46
12 V battery voltage	18.07V	0	0.49	13.103	19.953	-261.45	12.999	19.671	255.7
Supplementary information:									

5.4.5	TABLE: PV generator reverse polarity test								P
Model	ML2430								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	36.001	0	0	26.337	19.609	-516.44	26.298	19.451	511.51
12 V battery voltage	17.996	0	0	13.189	19.993	-263.7	13.141	19.326	253.97
Supplementary information:									

5.4.5	TABLE: PV generator reverse polarity test								P
Model	ML2440								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
24 V battery voltage	36.002	0	0	26.175	19.778	-517.68	26.034	19.631	511.06
12 V battery voltage	17.996	0	0	13.175	19.975	-263.17	13.1	19.309	252.95
Supplementary information:									

5.4.5	TABLE: PV generator reverse polarity test								P
Model	ML4830								
Test condition	PV			Battery			Load		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
48 V battery voltage	72.009	0	0	52.776	19.805	-1045.22	52.623	19.606	1031.7
36 V battery voltage	54.004	0	0	39.587	19.823	-784.75	39.48	19.631	775.03
24 V battery voltage	36.002	0	0	26.377	19.712	-519.95	26.287	19.565	514.3
12 V battery voltage	17.995	0	0	13.198	19.845	-261.92	13.102	19.66	257.58
Supplementary information:									

Appendix: Pictures

ML2420 Front View

ML2420 Bottom View

ML2420 Rear View

ML2420 Top View

ML2430 / ML2440 Front View

ML2430 / ML2440 Bottom View

ML2430 Rear View

ML2430 Top View

ML2440 Rear View

ML2440 Top View

ML4830 Front View

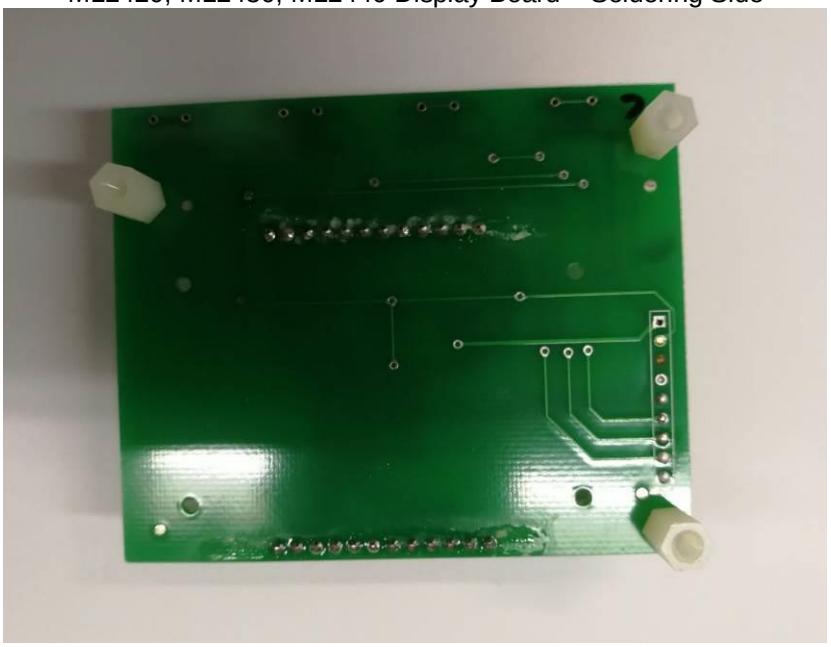
ML4830 Bottom View

ML4830 Rear View

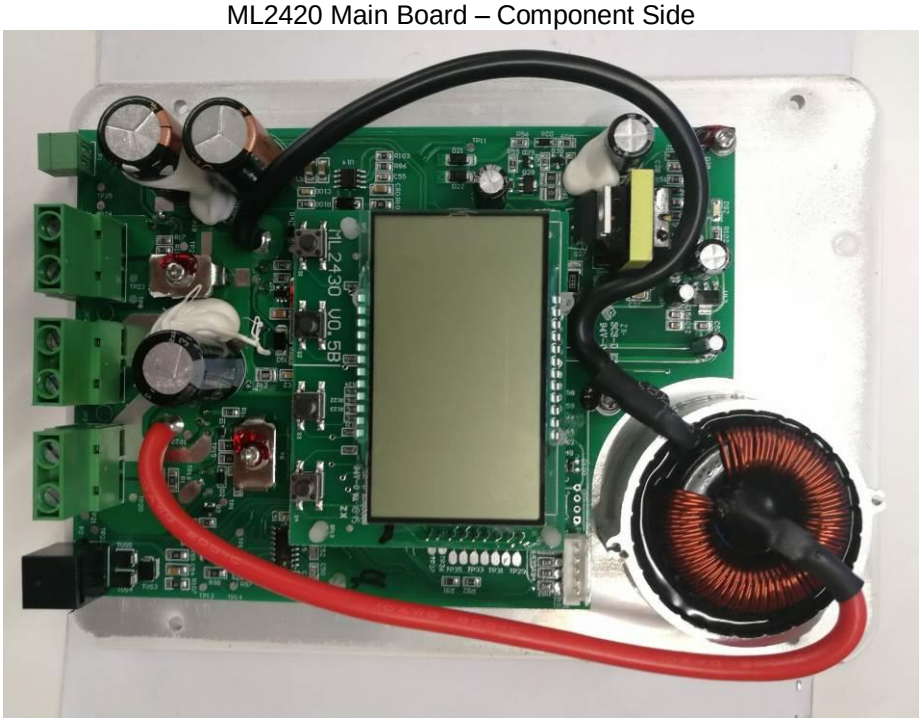
ML4830 Top View

ML2420, ML2430, ML2440 Display Board - Component Side

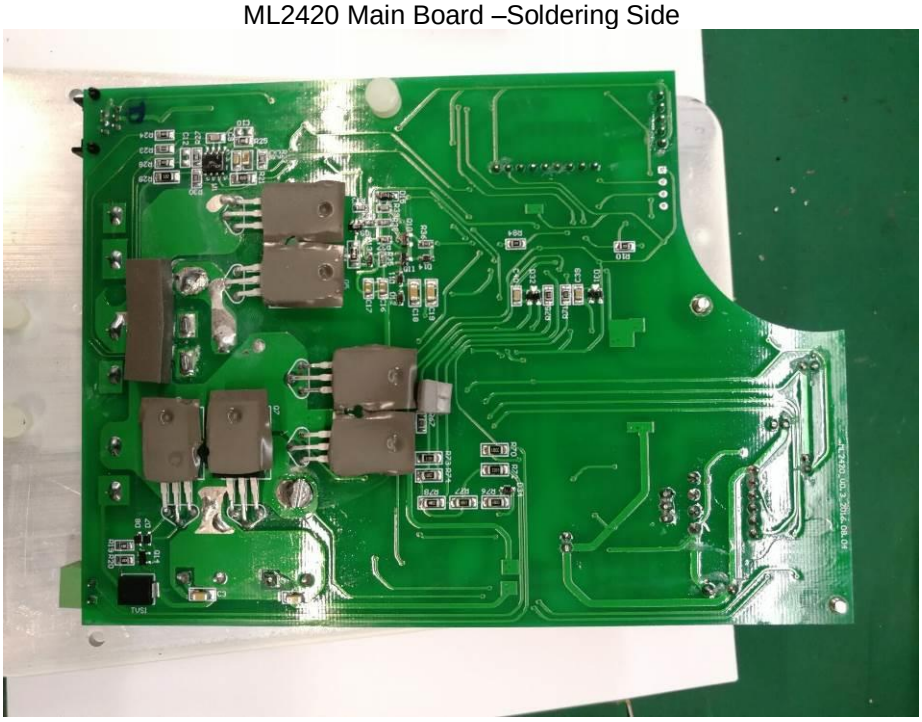
ML2420, ML2430, ML2440 Display Board – Soldering Side



ML2420 Main Board – Component Side

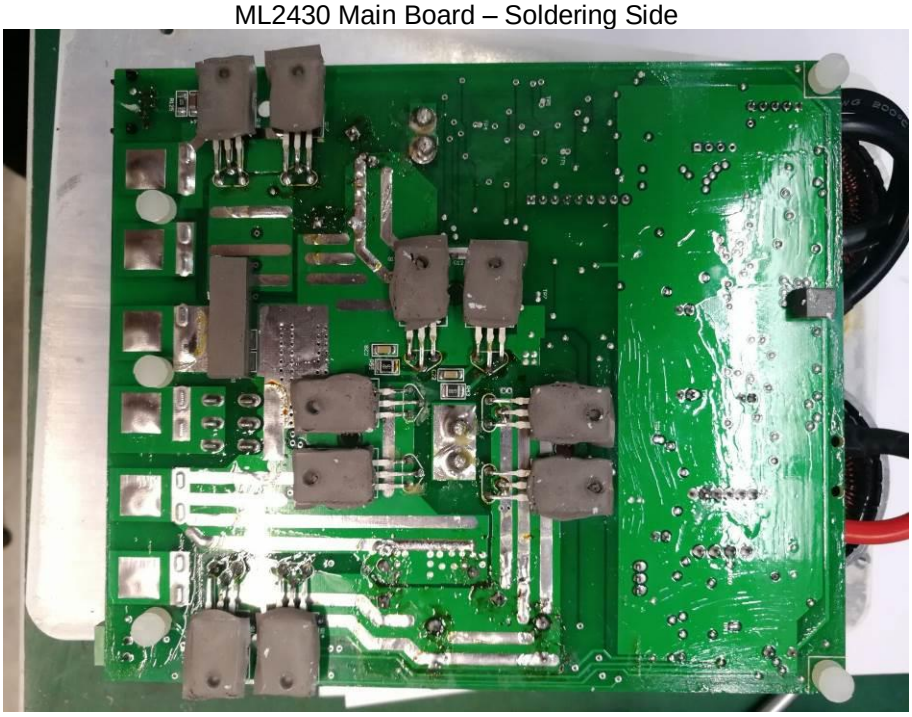


ML2420 Main Board –Soldering Side

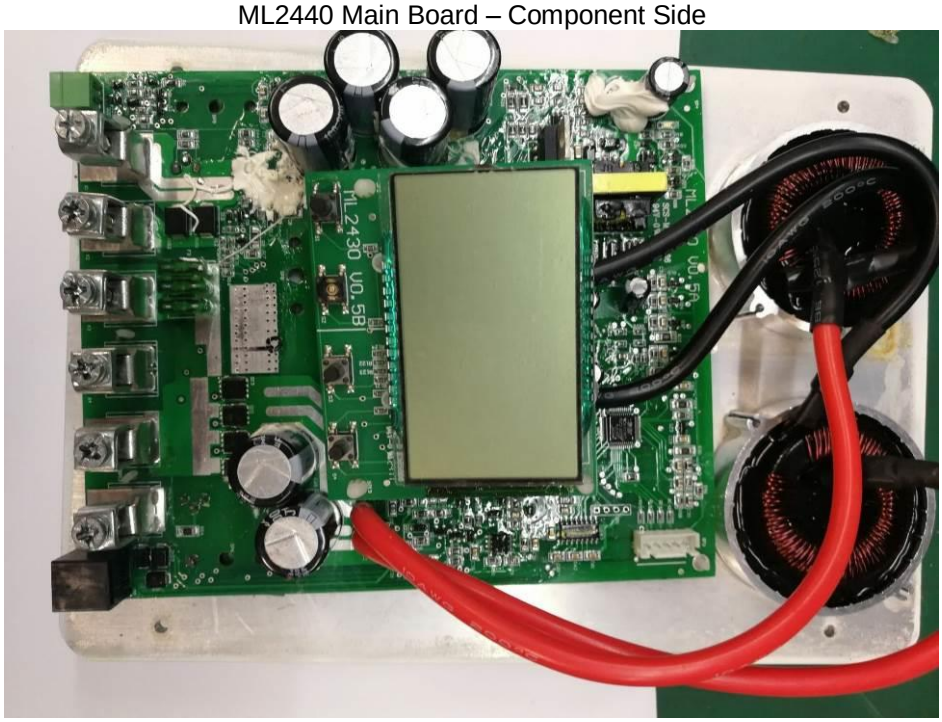


ML2430 Main Board – Component Side

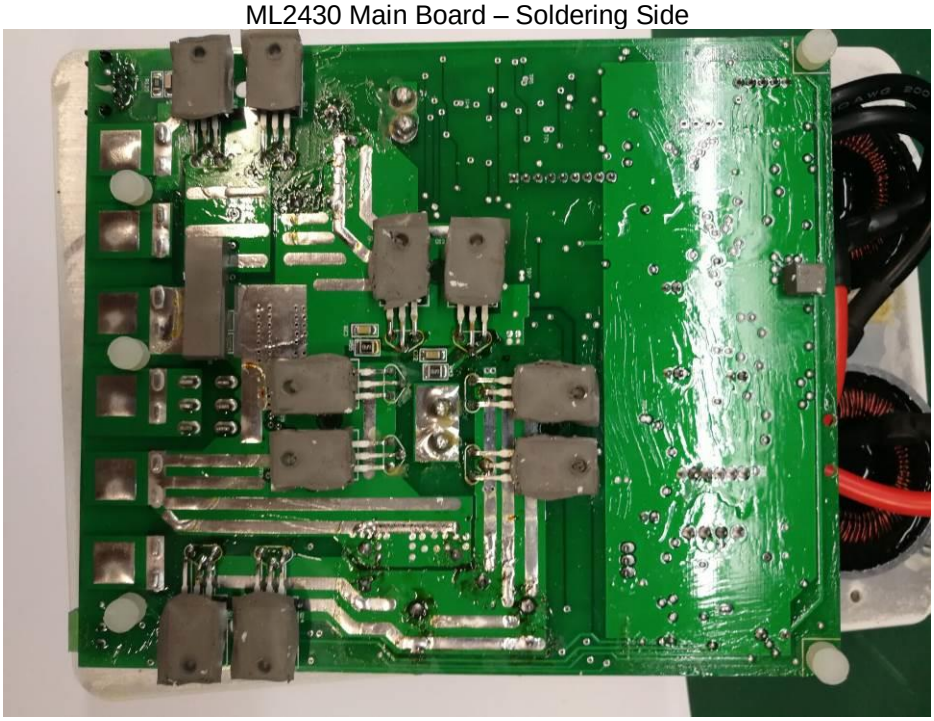
ML2430 Main Board – Soldering Side



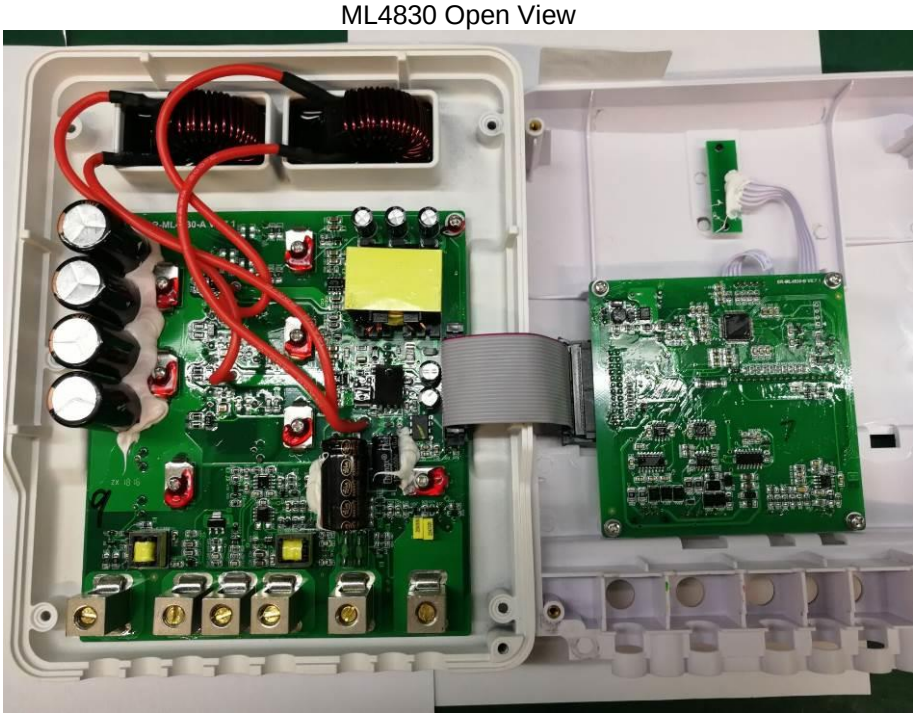
ML2440 Main Board – Component Side



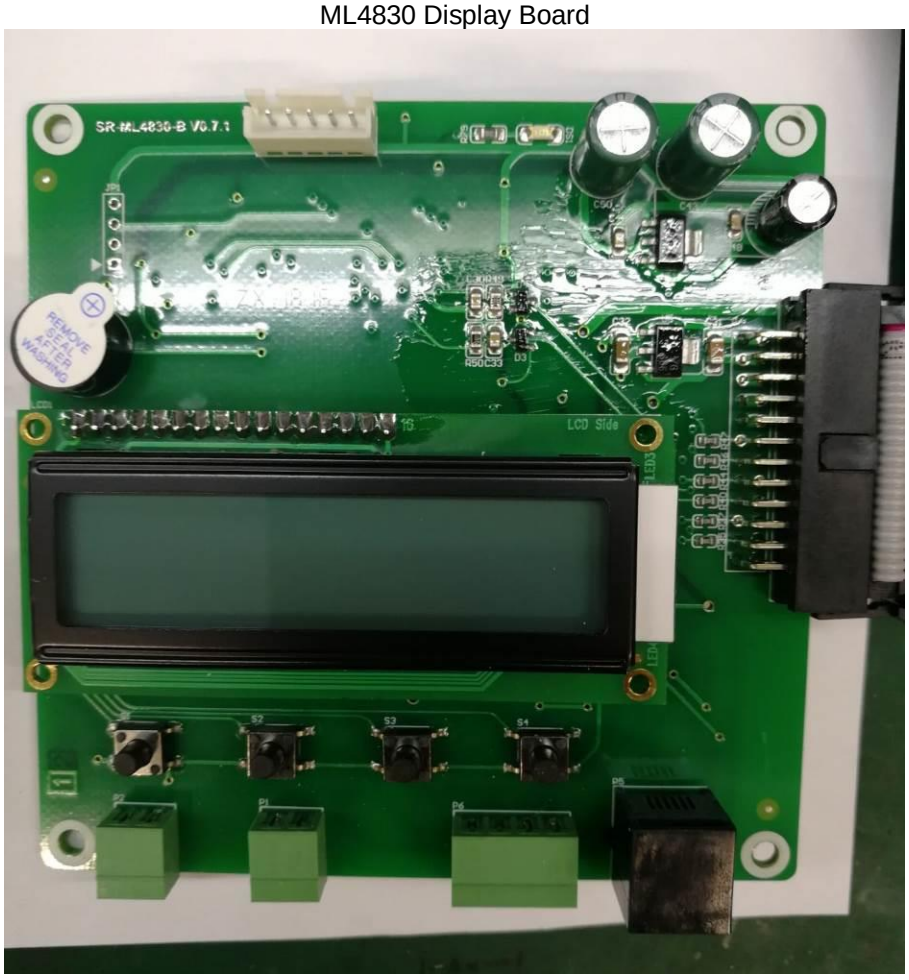
ML2430 Main Board – Soldering Side



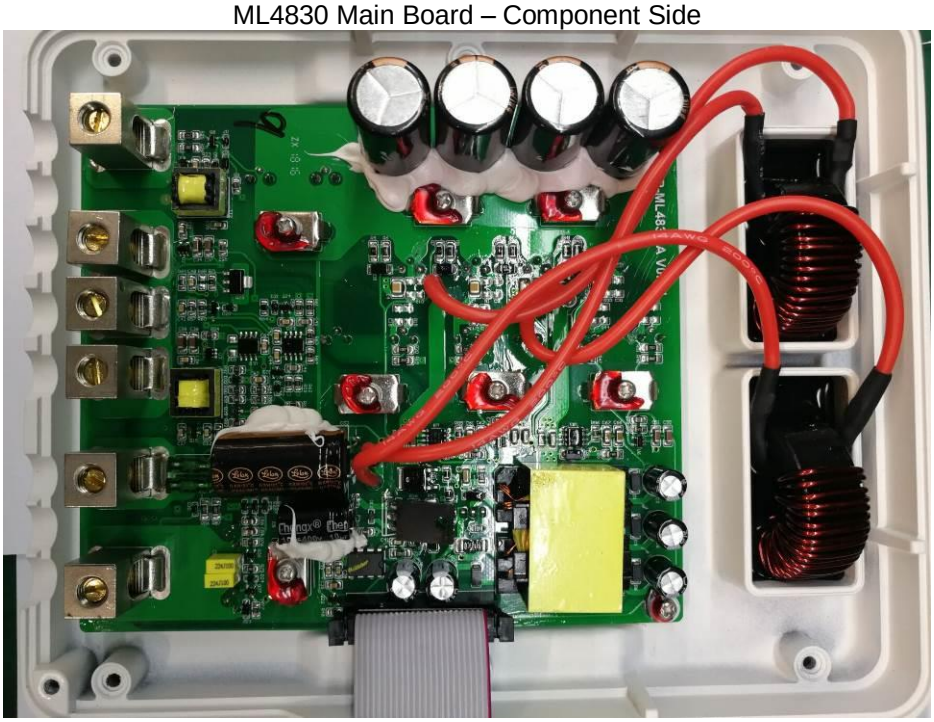
ML4830 Open View



ML4830 Display Board



ML4830 Main Board – Component Side



ML4830 Main Board –Soldering Side

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