ALBATROS Power Control and Logging Specification

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Introduction

Scope

This document describes the power control and logging system for the ALBATROS solar system, which accompanies the Victron Energy charge controller.

Conventions

Italics indicate text that is merely intended as commentary or suggestion, or which describes functions that are not going to be implemented right away.

Hardware

Arduino Mega2560

The logging and control functions are implemented in an Arduino (ATMega2560) with the following hardware peripherals and interfaces (to be further detailed in a later section):

- SD card (accessed by SPI)
- RTC with coin cell backup
- Serial ports connected to front panel 3.5mm stereo jack and Victron
- GPIO control of SSR to power on/off the main system
- Bi-color status LED red/green (to indicate logging status; possibly other functions also if useful)

Serial Ports

The Mega2560 provides 4 hardware serial ports which are used as described in the table below.

Port name	**Connection**	**Baud rate**	**Arduino pin**	
			Tx	Rx
Serial	USB connection, opens as monitor in Arduino IDE not used in firmware (except for development)	9600	1	0
Serial1	Front panel stereo jack serial port	9600	18	19
Serial2	Victron controller	19200	16	17
Serial3	Unused		14	15

Datalogging shield

The datalogging shield (Adafruit product 1141) provides the SD interface including level translation from 5V to 3.3V, the RTC (check accuracy vs Chronodot), and a backup battery. The UART interface receives

the signal directly from the Victron charge controller. No level translation is needed from Victron to Arduino as both are 5V based.

The datalogging shield also includes a prototyping area where are mounted the following:

- SSR (Toshiba TLP3543A) with current limiting resistor (390 ohm) on its input LED circuit
- 6 pin single inline Molex header to connect to the two serial ports (3.5mm jack, Victron)
- 3 pin single inline Molex header to connect to the front panel LED, with two current limiting resistors (1.2k)

SSR Current Capacity

The TLP3543A SSR (photorelay) contains two MOSFETS with a common source connection, in its output circuit. We use it in its “C connection” configuration, with both drain pins connected together. In this configuration, it is rated for 10A output current at 25C ambient temperature.

Using it in is C configuration means that it is sensitive to polarity. It must be connected so that (positive) current flows from drain to source. As it is connected in the circuit, the positive supply (from the battery) is connected to the positive SSR connection (MOSFET drains), and the load is connected to the negative SSR connection (MOSFET common source pin).

Do not connect the SSR in reverse. If this is done, it will fail to block current. Further, when the SSR input is not activated, conduction will occur through MOSFET body diodes, resulting in a diode voltage drop and greater, possibly damaging, heat dissipation.

Firmware Description

The firmware performs the following functions:

- Receive, validate, condense, timestamp and log information received from the Victron charge controller, on a regularly sampled basis.
- Log controller actions and exceptions (to a separate file)
- Power up and down the main system, by controlling a GPIO line connected to an SSR (solid-state relay), according to the sensed battery voltage.
- Allow setting of the RTC, and programming of power up/down parameters, via serial port.

Victron Data Reception

The Victron sends a data packet once per second. The format is described in the VE.DIRECT. The firmware decodes the packet and validates the checksum.

Logging

The SD card is assumed to be pre-formatted FAT32.

Logging occurs to two files at a time: one is the timestamped Victron data, the other is event related messages. The file is opened and closed on each log message.

The code is timezone-agnostic, so the time may be set to UTC or local and will be logged in the same way it is set.

Periodic Logging

The Victron data packet is parsed, and selected fields are accumulated over a user-determined period, then written out in CSV format. Each log record includes a timestamp in “unix time” (seconds since 1970/01/01). Time will wrap to negative in 2038. Victron packets include a checksum is validated prior to logging. If the checksum fails, the data is not accumulated.

The logging file, a new one each day, is named YYYYMMDD.csv . The following variables are logged:

CSV header entry / description	**Type of accumulation**	**Units**	**Note**
BatVolt Battery voltage	average/min/max	mV	
PVVolt PV voltage	average/min/max	mV	This field often shows small values e.g. 20mV, when there is no connection on the PV lines
PVPwr PV power	average/min/max	W	
BatCur Battery current	average/min/max	mA	Note that since the MPPT 150/35 does not have a load port, this is the net charger current into the battery. It does not register negative when no charging is occurring, despite the fact that the unit takes some current to run.
Error Error code	sample last value		0 = No error 2 = Battery voltage too high 17 = Charger temperature too high 18 = Charger overcurrent 19 = Charger current reversed 20 = Bulk time limit exceeded 21 = Current sensor issue 26 = Terminals overheated 33 = Input voltage (PV) too high 34 = Input current (PV) too high 38 = Input shutdown (from excessive battery voltage) 116 = Factory calibration data lost
State charger state	bitmap		0 = off 2 = fault 3 = bulk 4 = absorption 5 = float
MPPT MPPT tracking state	bitmap		0 = off 1 = voltage or current limited 2 = MPPT tracker active
Load on/off Load	bitmap		

Bitmap accumulation means that for each status number seen within the sample period, the corresponding bit is set in the logged value. For example, if the value 0 is seen during the entire time, the value 1 (bit 0 set) is logged. If the values 0 and 1 were seen, the value 3 (bits 0 and 1 set) is logged.

Some error states will not reset automatically – for details see the Appendix.

Event Logging

Discrete events are logged in a separate file, as they occur. A separate log file is used for this (to record events and triggering criteria to allow reconstruction of algorithm logic in case debugging is needed), but it may also be good to have a field in the main power log – if only because the Victron will not be logging load current, and this is obviously part of understanding what is going on from the perspective of the solar/battery system.

The filename is named YYYYMM.log, and changes on a monthly basis.

Main System Power Control

The Arduino controls one GPIO line that connects or cuts power to the main system, to allow for power conservation by turning off the load under defined conditions.

The load will be turned off if any of the following conditions are true:

1. The sensed battery voltage is below the turn-off threshold VBAT_TURNOFF_MV.
2. The sensed battery voltage is below the turn-on threshold VBAT_TURNON_MV, and the low-voltage condition is asserted
3. The time-of-day is between DAY_START and DAY_END
4. A timeout occurs in receiving Victron data updates (this is normally once per second), i.e. the Victron data is older than MAX_VIC_DATA_AGE seconds. This likely indicates failure of the Victron unit; in any case, we don't know what the voltage is, so it may not be safe to enable the load.

Note that conditions 1 and 2 together implement hysteresis on the low-voltage off condition. The turn-on voltage is to be set higher than the turn-off voltage.

The firmware continuously samples the voltage during a prescribed period MEASURE_START to MEASURE_END, which should describe a period where there is no solar energy (i.e. at night). It accumulates statistics to estimate the linear slope and the intercept. At MEASURE_END, it extrapolates the voltage, based on these collected statistics, HOURS_RESERVE hours in the future (from MEASURE_END), and compares the extrapolated voltage with VBAT_TURNOFF_MV. (This extrapolation would be valid under the assumption that no solar power became available to recharge the battery. If we get solar power the following day, the situation is of course better.) If the extrapolated voltage is greater than VBAT_TURNOFF_MV, it sets a flag which enables the load to run, exceptionally, during the following day.

The run during day flag is not set true, if the HOURS_RESERVE parameter is set negative. This is to allow the daytime running feature to be disabled regardless of the state of the battery.

Note that the daytime running flag is set or cleared only at the end of the measurement period; thus, if the system is not allowed to run overnight, this flag will not be reset and will persist for another day. Also, no minimum data collection period is prescribed for determining the daytime running flag; thus, if the measurement time is set to a very narrow window, or if the system is brought up just before MEASURE_END, the decision will be made with a possibly unreliable amount of data.

The current status of the load control logic may be viewed by entering the 'flags' monitor command. These flags may be directly modified using the fset command.

The fset command is primarily of use for testing the logic implementation. Note that fset should be used only with a good understanding of how the logic is implemented. Note also that some of the flag values will be immediately or quickly recomputed based on factors such as battery voltage or time-of-day.

Setting "run during day" true is a benign way of activating the load during the day. It can then be cleared to turn off the load.

Note on Battery State of Charge

This note provides guidance in choice of low-voltage cutout thresholds.

Typically, for lead-acid batteries, the battery should never be discharged below 0% state of charge, and ideally (to preserve battery cycle life) never or seldom below 50%. Voltages corresponding to these levels can be read off of discharge curves published for a generic battery of the type used, or, preferably, for the particular battery model being used. Note that voltage is also affected by temperature. The expected temperature should be factored in if possible.

Often, many discharge curves are provided, for different rates of discharge. Bear in mind that the discharge rate in this application is quite low relative to battery capacity, likely lower than that corresponding to any of the curves published: a 2A discharge rate on a 200Ah battery corresponds to a C/100 discharge condition, and can almost be considered an open-circuit condition. If the internal resistance of the battery is known or can be estimated, it can be used to adjust voltage thresholds (downwards) by 2A x R_{INT}, from an open circuit voltage. Open circuit voltages corresponding to different states of discharge may not be published, so measurement or creative estimation may be required.

The firmware does not explicitly estimate state of charge, but instead allows setting of voltage thresholds which correspond to states of charge. This works, under the assumptions that:

1. The battery is in a steady state when the voltage reading is taken (i.e. no recent changes in battery current flow);
2. The steady battery current flow is taken into account in estimating state of charge from the battery terminal voltage.

Serial Monitor

Hardware Interface

The serial monitor runs at 9600 baud through the stereo jack mounted on the front panel.

It should be used with any PC serial port program, as follows:

- Set to use the USB serial port (note: the FTDI driver is known in Windows, so should not be a problem to install)
- Set to 9600 baud (8 bits, no parity)
- Set to send a CR upon line entry (this is the terminating character of each command as parsed by the monitor)

The pinout (compatible with FTDI p/n TTL-232R-5V-AJ) is as follows:

Tip: Arduino Rx / Plug (PC) Tx
Ring: Arduino Tx / Plug (PC) Rx
Shield: GND

Note that the interface cable also comes in a 3.3V version; the 5V version should be used in this application.

Command Set

The serial monitor implements the following commands. In the following, *italic font* indicates a variable element in the command, while normal text is literal.

Command	**Meaning**	**Description / note**
help	Display help	Any unrecognized command displays the help.
def	Dump EEPROM fields (variables)	List all EEPROM fields (Note: the in-memory version of the fields)
inv	Invalidate EEPROM	Overwrite a header byte in the EEPROM so that it will be reinitialized on the next restart. Used for testing or to set all fields back to defaults.
set *index value*	Set the configuration variable indicated by *index* (0 and up) to the specified *value*	Values can be integers or times (depending on the variable). Hint: display the fields first with def as a guide to the indexes. For times, minutes and seconds are optional and will default to zero.
com	Commit in-memory fields to EEPROM	All fields at once are written to EEPROM and will then persist through power-off. This must be done after any changes are made, unless the desire is to test these changes without making them permanent.
rtc	Read RTC setting	Display current RTC setting (1 second resolution)
rtc time *time*	Set the RTC time buffer to *time* (hh:mm:ss format)	This **does not immediately set the RTC**, but inputs a time (to be written out to the RTC with the adj subcommand). Minutes and seconds are optional and default to zero.
rtc date *date*	Set the RTC date buffer to *date* (yyyy:mm:dd format)	This **does not immediately set the RTC**, but inputs a date (to be written out to the RTC with the adj subcommand).
rtc adj	RTC adjust. Write the values previously input as *time* and *date*, to the RTC	**Note that both time and date must be entered before adjusting the RTC.** Even if the RTC already has the correct date, it should be set using the rtc command, before adjusting it (to, say, simply adjust the time).
vs	Victron status	Display the latest (numeric) Victron data values.
ls	As in unix ls	Display the contents of the SD card root folder.
cat *file*	Dump contents of specified *file*	Filename is case-insensitive. File contents are sent to the monitor port. Command cannot be interrupted.
rm *file*	Erase specified *file*	This would not normally be done.
reset	Reset the firmware	Jump to address zero. This does not do a hard reset and so may not work if hardware is somehow stuck.

Command	Meaning	Description / note
reinit	Reinitialize variables from EEPROM	Reread the variables from EEPROM (overwriting any local changes). If EEPROM has been invalidated, firmware defaults will be installed.
status	Dump error status	List each error code with its ID and current state
clear *code* or *	Clear indicated *code*, or all codes	Clear error state for indicated code(s). Note that if underlying condition persists, code will be reset unless it is blocked.
(un)latch *code*	Set indicated code to latching or unlatching	A latched code remains until cleared.
(un)block *code*	Set indicated code to blocked or unblocked	A blocked code does not display on the status LED, even if it is set by the firmware.
flags	List Boolean control flags	Shows the current status of the load control logic.
fset *flag value*	Set flag to value	Values are 1 and 0 (true/false). Note that some flags are immediately recomputed and so the change will not persist. Most useful is to set or clear run-during-day flag.
safe	Enter safe mode (prior to powering down the circuit or removing SD card)	Safe mode busy-waits until an X is received. This can be used to ensure tha

EEPROM Configuration Variables

The following EEPROM configuration variables are defined. They can be listed, modified saved and restored using the def, set, reinit and com commands.

Name	Type	Default	Note
VBAT_TURNOFF_MV	integer	24500	24.50 volts
VBAT_TURNON_MV	integer	24750	24.75 volts
MEASURE_START	time	23:00:00	Start of battery state measurement (not currently implemented)
MEASURE_END	time	05:00:00	End of battery state measurement (not currently implemented)
DAY_START	time	06:00:00	Start of daytime (currently unconditional turn-off of load)
DAY_END	time	18:00:00	End of daytime
HOURS_RESERVE	integer	48	Hours of no-charge reserve if to run in daytime
SLOPE_UV_PER_HOUR	integer	36360	Assumed discharge rate (220Ah, 50% discharge, 2V span, 2A) NOTE: this value is not currently used; instead, it is computed from the data acquired during the battery state measurement.
SECS_PER_LOG	integer	60	1 minute between log entries
MAX_VIC_DATA_AGE	integer	300	Declare a Victron data timeout and shut down the load if this long goes by without getting a valid Victron data packet.

Status manager

The status manager receives reports of system status (normal / error) from various other functions, tracks the status (in most cases latching any error status), and controls the front panel status LED.

At any given time, each status code is either inactive (normal condition) or active (error condition). In addition, each status code is either in latching or non-latching state, and is either blocked or unblocked.

If a status code is in latching state, once it is reported it will remain set until it is cleared through the serial monitor (or through a system reset). If a status code is blocked, even if it is set, it will not affect the front panel LED status.

Thus, the LED error state is displayed if any unblocked status code is in its active (error) state.

The current system status can be displayed by the monitor by typing the status monitor command.

States can be cleared either individually or all together, using the clear monitor command.

Latching and blocking state can be set or cleared for a specified code using the latch, unlatch, block and unblock monitor commands.

The currently defined status codes are as follows. All codes are currently latching and unblocked by default. **Latching and blocked settings are currently volatile (not saved in EEPROM)**

Code (index)	Name	Description
0	SD card access error	This code is set whenever an access to the SD card fails. Even if not set to latching, it will persist until explicitly cleared.
1	Victron data timeout	The Victron has failed to send a valid data packet for longer than the MAX_VIC_DATA_AGE parameter. This may mean the Victron is toast. This code automatically clears when data is received.
2	Victron error state	The Victron has sent an error code. Some error codes self-reset, some don't. This condition will self-clear if it is set non-latching and if the Victron error itself clears up.
3	Battery voltage low	The load turned off because of a low voltage state (lower than VBAT_TURNOFF_MV). This condition will self-clear if it is set non-latching and if the voltage recovers.
4	RTC access error	The RTC library indicated an error when the RTC was accessed. It is assessed only on power-up when RTC accessibility is checked. Even if not set to latching, it will persist until explicitly cleared, after which time it will only be re-checked on firmware reset.

Status Interface

Status interface denotes a visual indication of system status using the front panel LED. A bi-colour (green / red) LED is mounted on the front panel. It indicates load and system status as follows:

- A green (or predominantly green) LED indicates normal status. A red (or predominantly red) LED indicates that at least one unblocked error state is set.

- A predominantly-on LED indicates that the load is currently turned on. A predominantly-off LED indicates that the load is currently turned off. When the load is on, the green or red colour is displayed for most of the one-second cycle, with the other-colour LED lit up briefly during the blink period. This blink serves to give positive indication that the firmware is running.

This is summarized as follows:

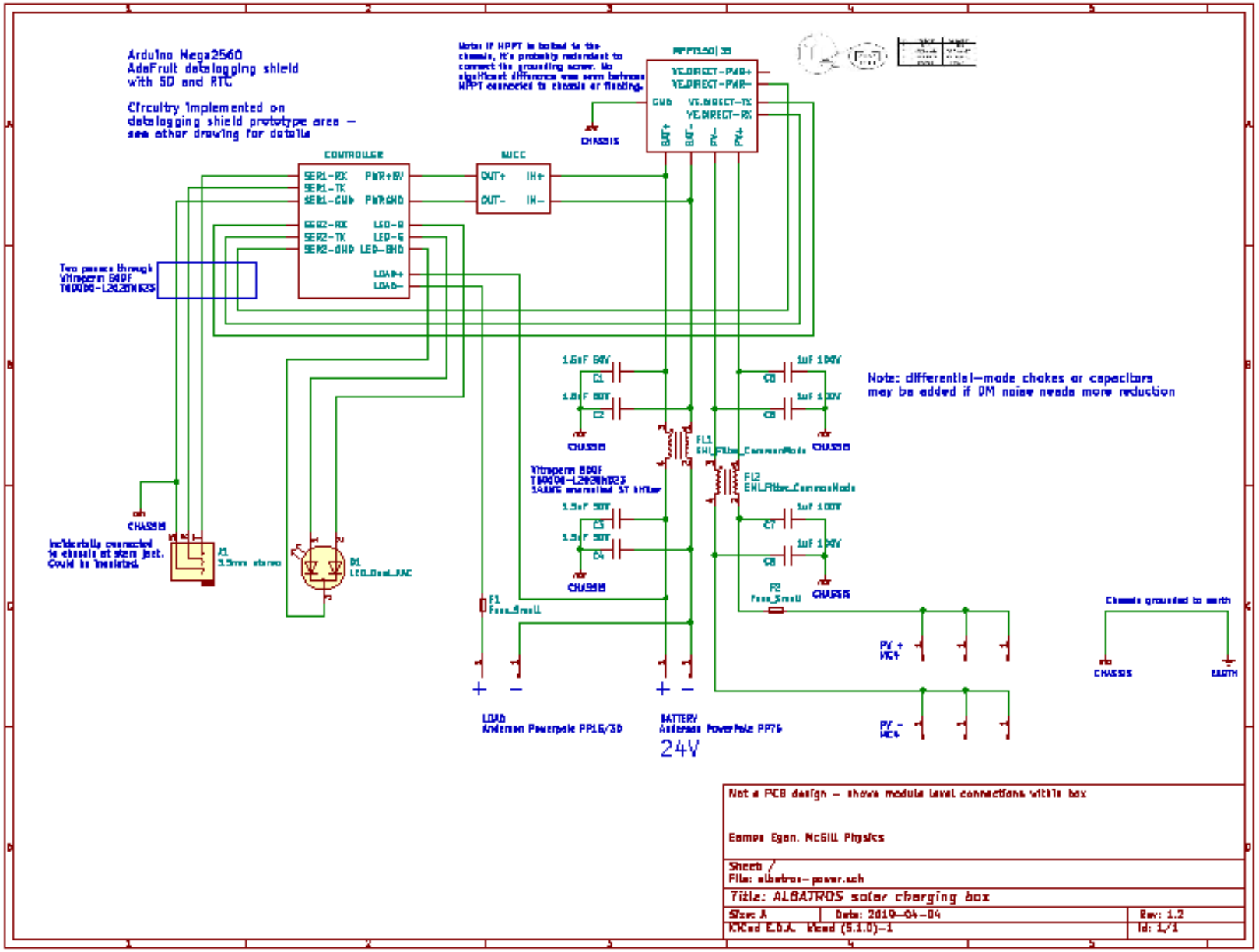
Load	**System status**	**LED pattern**
OFF	Normal	Brief green blink, once per second
OFF	Error	Brief red blink, once per second
ON	Normal	Solid green with the red LED blinking briefly once per second
ON	Error	Solid red with the green LED blinking briefly once per second

Load Control Flags

The flags command lists the current state of the flags used to determine whether the load runs. They are described as follows

Index	Name	Description
0	Low voltage cutoff	
1	Data age cutoff	
2	daytime	
3	measure time	
4	load on	
5	run during day	

Appendix – System Diagram



Appendix – MPPT Error Codes

Transcribed from https://www.victronenergy.com/live/mppt-error-codes. All entries are left in, including ones that are not listed in the MPPT 150/35 manual, just in case the manual is not up to date. For a list of the errors included in the 150/35 manual, see the log file description.

Err 2 - Battery voltage too high

This error will auto-reset after the battery voltage has dropped. This error can be due to other charging equipment connected to the battery or a fault in the charge controller. This error can also occur if the battery voltage is set to a lower voltage than the actual battery voltage.

Err 3, Err 4 - Remote temperature sensor failure

Check if the T-sense connector is properly connected to a remote temperature sensor. Most likely cause: the remote T-sense connector is connected to the BAT+ or BAT- terminal. This error will auto-reset after proper connection.

Err 5 - Remote temperature sensor failure (connection lost)

Check if the T-sense connector is properly connected to a remote temperature sensor. This error will not auto-reset.

Err 6, Err 7 - Remote battery voltage sense failure

Check if the V-sense connector is properly connected to the battery terminals. Most likely cause: the remote V-sense connector is connected in reverse polarity to the BAT+ or BAT- terminals.

Err 8 - Remote battery voltage sense failure (connection lost)

Check if the V-sense connector is properly connected to the battery terminals.

Err 17 - Controller overheated despite reduced output current

This error will auto-reset after charger has cooled down. Check the ambient temperature and check for obstructions near the heatsink.

Err 18 - Controller over-current

This error will auto-reset. If the error does not auto-reset disconnect the charge controller from all power-sources, wait 3 minutes, and power up again. If the error persists the charge controller is probably faulty. A cause for this error can be switching on a very large load on the battery side.

Err 20 - Maximum Bulk-time exceeded

This error can only occur when the maximun bulk-time protection is active. This error will not auto-reset. This error is generated when the battery-absorption-voltage is not reached after 10 hours of charging.

This protection is default disabled in all Solar Chargers.

It is default enabled on the Skylla-i and the Skylla IP44.

Our advice is to not enable it on solar chargers.

Err 21 - Current sensor issue

This error will not auto-reset.

Disconnect all wires, and then reconnect all wires. Also, make sure the minus on the MPPT charge controller (PV minus/Battery minus) is not bypassing the charge controller.

If the error remains, please contact the dealer, there might be a hardware defect.

Err 26 - Terminal overheated

Power terminals overheated, check wiring, including the wiring type and type of strands, and/or fasten bolts if possible.

This error will auto-reset.

Err 28 - Power stage issue

This error will not auto-reset.

Disconnect all wires, and then reconnect all wires. If the error persists the charge controller is probably faulty.

Err 33 - PV over-voltage

This error will auto-reset after PV-voltage has dropped to safe limit. This error is an indication that the PV-array configuration with regard to open-circuit voltage is critical for this charger. Check configuration, and if required, re-organise panels.

Err 34 - PV over-current

The current from the solar-panel array has exceeded 75A. This error could be generated due to an internal system fault. Disconnect the charger from all power-sources, wait 3 minutes, and power-up again. If the error persists the controller is probably faulty, contact your dealer.

Err 38, Err 39 - PV Input shutdown

To protect the battery from over-charging the panel input is shorted.

Possible reasons for this error to occur:

- The Battery voltage (12/24/48V) is set, or auto-detected, incorrectly. Use VictronConnect to disable auto-detect and set the Battery Voltage to a fixed voltage.
- There is another device connected to the battery, which is configured to a higher voltage. For example a MultiPlus, configured to equalise at 17 Volts, while in the MPPT this is not configured.

- The battery is disconnected using a manual switch. Ideally the charger should be switched off before disconnecting the battery, this avoids a voltage overshoot on the charger output. If necessary the voltage trip-level for the PV Short protection can be increased by raising the Equalization voltage set-point (note: equalization does not have to be enabled in this case).
- The battery is disconnected using a Lithium charge relay connected to the “allow-to-charge” output of a BMS. Consider wiring this signal to the Remote terminal of the charger instead. This shuts down the charger gracefully without creating a voltage overshoot.

Error recovery:

- Error 38: First disconnect the solar panels and disconnect the battery. Wait for 3 minutes, then reconnect the battery first and next the panels.
- Error 39: The charger will automatically resume operation once the battery voltage drops below the float level for 1 minute.

If the error persists the charge controller is probably faulty.

Information 65 - Communication warning

Communication with one of the paralleled controllers was lost. To clear the warning, switch the controller off and back on

Information 66 - Incompatible device

The controller is being paralleled to another controller that has different settings and/or a different charge algorithm.

Make sure all settings are the same and update firmware on all chargers to the latest version

Err 67 - BMS Connection lost

The charger is configured to be controlled by a BMS, but it does not receive any control messages from a BMS. The charger stopped charging, as a safety precaution.

Check the connection between the charger and the BMS.

How to reset the charger, to de-couple it from the BMS

When the charger needs to operate in stand-alone mode again, not controlled by a BMS, it needs to be reset:

- VE.Can solar chargers, go into the setup menu, and change setting ‘BMS’ from ‘Y’ to ‘N’ (setup item 31).
- VE.Direct solar chargers, reset the charger to factory defaults with VictronConnect, and then reconfigure it.

Note that (solar-)chargers automatically configure themselves to be BMS-controlled when they are connected to one; either direct or via a Color Control GX or Venus GX.

Err 114 - CPU temperature too high

This error will reset after the CPU has cooled down. If the error persists, check the ambient temperature and check for obstructions near the air inlet and outlet holes of the charger cabinet. Check manual for mounting instructions with regard to cooling. If error persists the controller is probably faulty.

Err 116 - Calibration data lost

If the unit does not work and error 116 pops up as the active error the unit is faulty, contact your dealer for a replacement.

If the error is only present in the history data and the unit operates normally this error can be ignored safely. Explanation: when the units power up for the very first time in the factory, it does not have calibration data and an error 116 is logged. Obviously this should have been cleared, but in the beginning units left the factory with this message still in the history data.

Documentation To-Do List

- EEPROM format and upgrade paths
- Hardware implemented on shield (schematic)