Product Rev. B 20. Oct 2017

SUPERCAPACITOR BASED ENERGY STORAGE MODULE

FOR MICRO UPS APPLICATIONS

WITH RTC AND RS-485

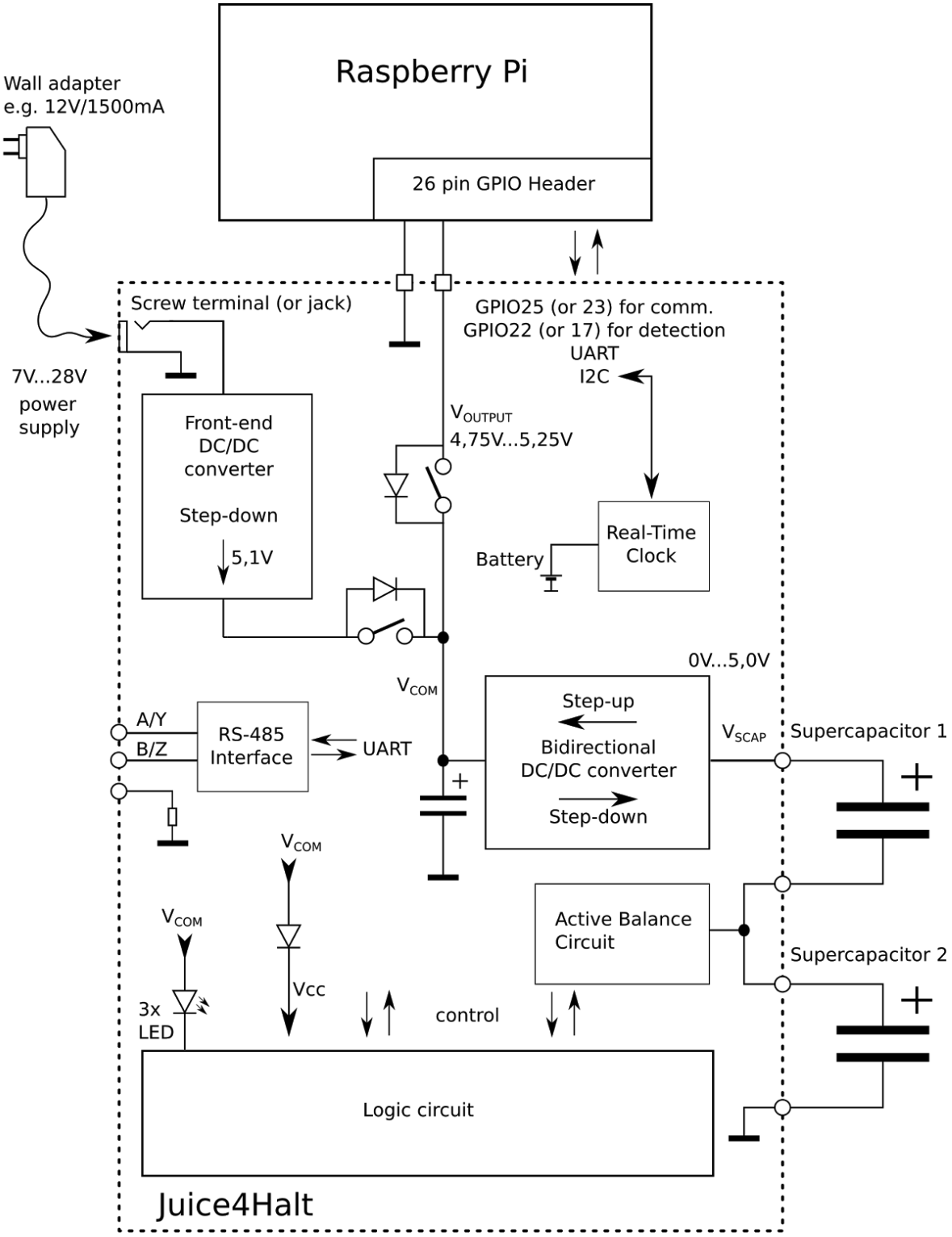
Features

- designed for **Raspberry Pi Models B+, 2, 3**
- **>1 minute backup** time including a **safe shutdown**[1,3]
- **>20 seconds protection**[2,3] against short-term **power failure**
- **Real-Time Clock** with long life Lithium Coin Battery power backup
- **RS-485** Interface
- **high reliability** of operation with peripherals attached to the 5V supply output
- **no battery maintenance**
- **safety and reliability** – no danger of fire or explosion, no danger of overcharging, supercapacitors can be fully discharged for transport
- **environmentally friendly** – no hazardous materials for disposal, supercapacitors contain non-toxic materials
- wide operating temperature range (-40°C to +85°C)[4]

Applications

- the ideal choice for **Last Gasp** applications in embedded systems
- suitable for all 5V **Single Board Computers** (SBC)

Block diagram



Order Information

Part Number	Description	Comments
J4H-HV-TRM-RTC-485	Input voltage 7...28V Real-Time-Clock RS-485 Interface	

Note 1: Once a shutdown has been initiated there is no way back: The procedure must be completed even if the power is restored while shutting down. This is an important feature for protection against repeated power failures.

Note 2: No shutdown will be initiated during this time. The RPi will not notice any short-term power failure. After power is restored the RPi continues with normal operation.

Note 3: The time depends on the current consumption of the RPi (SBC) and on the type of supercapacitors used. This is a typical value for standard configuration: Raspberry Pi 3, OS Raspbian, no peripheral devices attached, 2x supercapacitors 22F/2.7V, T_{AMB}=25°C.

Note 4: The PCB itself is designed for a wide operating temperature range -40°C to +85°C. However, using different supercapacitor types or connector types can reduce the temperature range.

Note 5: Based on a 30% capacitance decrease from initial value

Note 6: For more details please refer to the Application Note 171

Note 7: The meaning of T_{ST} and T_{TB} is shown in Fig. 7

Note 8: For script file download visit www.juice4halt.com . You can find the script files in the Download area compressed with 7-Zip

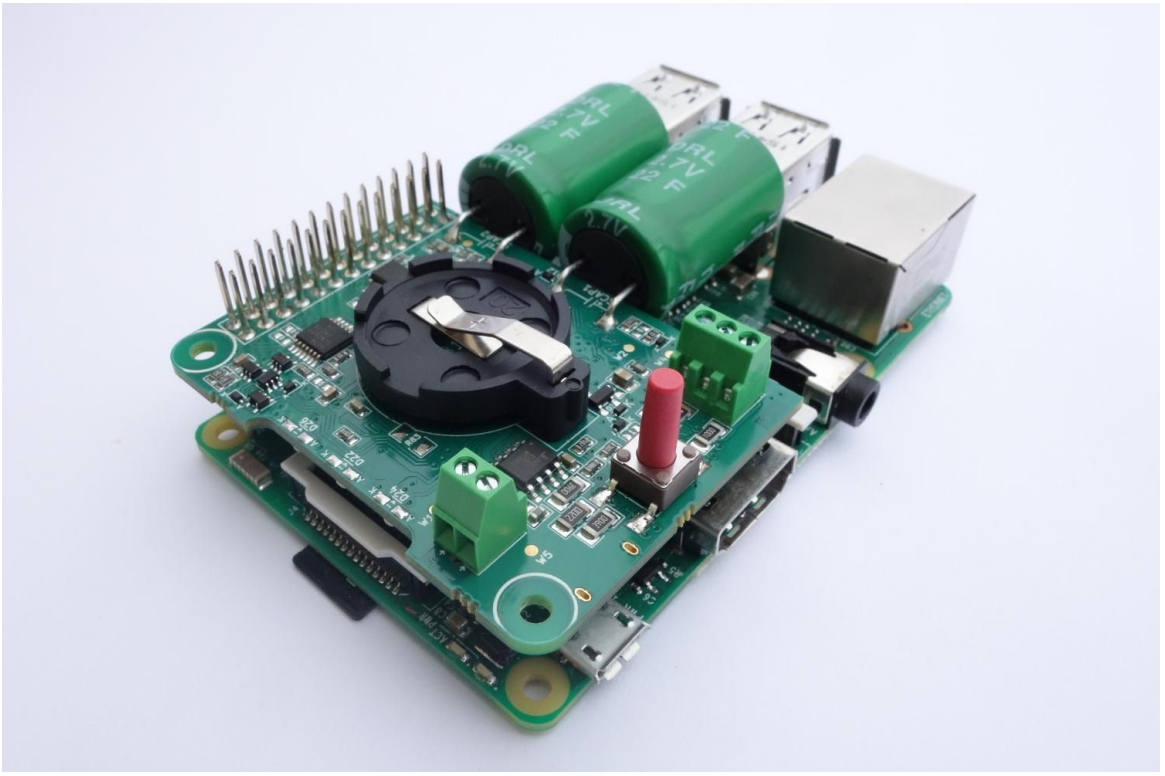


Fig.1: Juice4halt – RTC-485 Model on RPi3

Description

The Juice4halt module is a supercapacitor based energy storage. It contains two independent DC/DC converters. The first one is a bidirectional step-up/step-down converter working as the interface between the stable 5V supply rail and the supercapacitor. During charging the converter works in step-down mode and transports energy from the external power supply to the supercapacitor. In case of a power failure the load device (Raspberry Pi or another SBC) is supplied from the supercapacitor via DC/DC converter working in step-up mode.

The second DC/DC converter is a Front-end step-down converter. The only function is converting a high input voltage down to 5.1V for the 5V rail.

The J4H-HV-TRM-RTC-485 Model

The RTC-485 model requires a 7V…28V power supply with open wires. The wires are held by tightening in a screw terminal on the top side of the board. The external power supply must be capable of supplying the Raspberry Pi and charging the supercapacitors at the same time. Also consider the additional current consumption of other peripheral devices connected to the Raspberry Pi. The required current depends on the voltage of the power supply.

The RS-485 Interface is accessed via a 3-pole screw terminal at the inner side edge of the PCB. The Real-Time Clock uses a lithium coin battery for power backup, when the Raspberry Pi is powered off. The battery holder is situated on the top side of the PCB. A push-button is used as Power ON/OFF switch, and perfectly fits into the shutdown and booting scenarios, leading to a function very typical for all laptop-power-on/off buttons or for ATX power supply soft start buttons.

Fig.2: Juice4halt – RTC-485 Model on RPi3

Technical Specification

General

Parameter	Value	Conditions
Max. Total Backup time T_{TB}[7]	Min. 57 sec.[5] Typ. 81 sec.	operation until supercapacitors not discharged (ca. 1.2V) 2x 22F/2.7V supercapacitors in series, RPi3, OS Raspbian, T_{AMB}=25°C
Backup time for Short-term power failure T_{ST}[7]	Min. 22 sec.[5] Typ. 31 sec.	
Charge time (fast charge) =default configuration	Typ. 25 sec.	
Charge time (slow charge[4])	Typ. 60 sec.	
Operating temperature range (module)	-40°C to +85°C	Assembled PCB
	-25°C to +70°C	Including Push-Button and Screw terminals
Operating temperature range (supercapacitors)	-40°C to +60°C	supercapacitor type: 22F/2.7V/ DxL=16mm x 26mm
Supported SBCs	Raspberry Pi 3	default SBC
	Raspberry Pi 2, B+	100% compatible
	Odroid-C2	UPS function compatible, smaller supercapacitors recommended, RS-485, RTC not tested yet

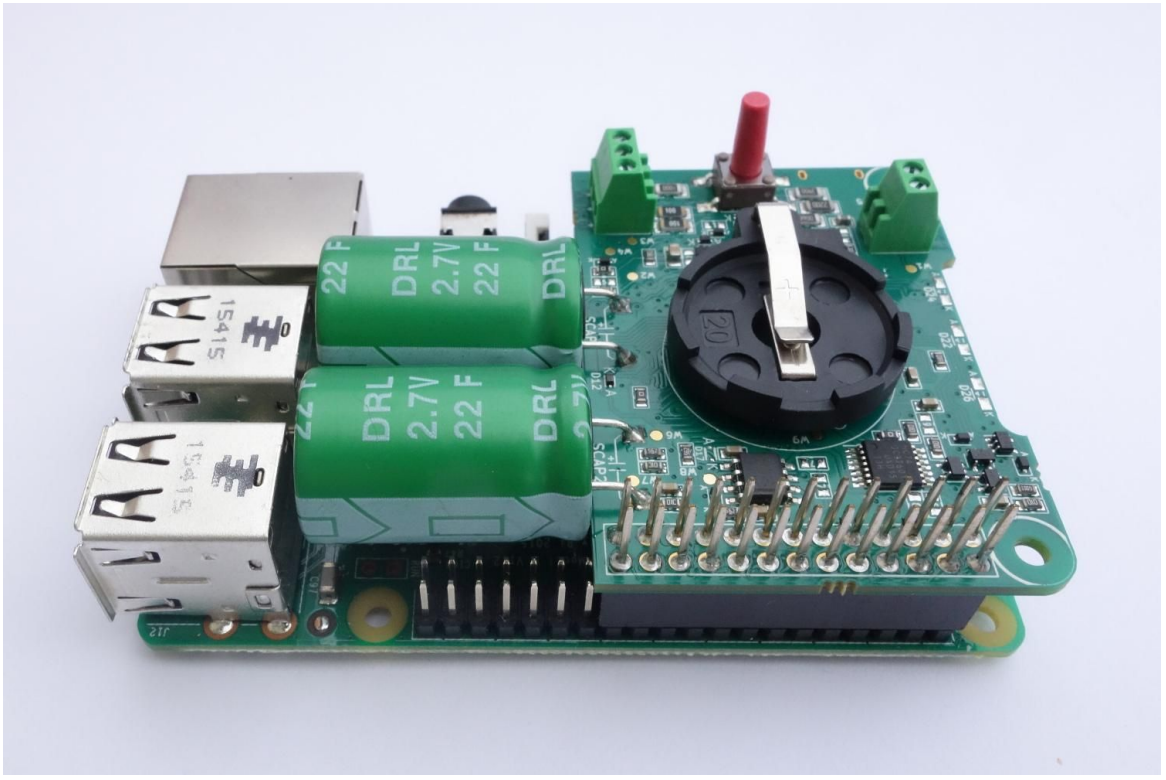


Fig.3: Juice4halt – RTC-485 model on RPi3

Input

- contains reverse polarity protection

Parameter	Value	Conditions
Input voltage range	7.0V DC ... 28.0 DC	at screw terminal
Average input current	1.0A (typ.)	Charge mode+RPi3 Booting at Vin=12V
	0.5A (typ.)	Charge mode+RPi3 Booting at Vin=24V
Current consumption	typ. 15mA	Normal operation (no Charge mode, no Shutdown mode), T_{AMB}=25°C

Output

- Backed up 5V power output for the load device (Raspberry Pi or SBC)

Parameter	Value	Conditions
Output voltage range	4.75V DC ... 5.25V DC	
Output current range	$0A_{AVG}$ ... $1A_{AVG}$	
Typ. output ripple	10 mVpp	at Shutdown mode, T_{AMB}=25°C, ripple at f_{SW}=1200kHz

Supercapacitor Interface

Parameter	Value	Conditions
Working voltage at supercapacitor contacts	1.0V ... 5.25V	
Peak current through supercapacitor	7A	
Charging method	7.5W (fast charge, default) =1.5A at 5V	constant power charging
	2.5W (slow charge[6]) =0.5A at 5V	
Balancing	+/-300mA	Active balance circuit for two supercapacitors in series

Recommended electrical parameters for supercapacitors (two in series)

- the parameters are for each of the two supercapacitors
- the two supercapacitors are balanced by the on-board active balance circuit

Parameter	Value	Conditions
Default rated capacitance	22F	using 5F or 10F will shorten the charge time and the backup time
Min. rated voltage	2.7V	
Max. ESR	100mOhm	
Max. current	>10A	

Dimensions

- only PCB without supercapacitors

Parameter	Value	Conditions
Width	56.0mm	
Length	41.3mm	
Height	19.0mm	without stacking header, push-button and supercapacitors

Mounting

2x13 pins stacking header 2.54mm	Header height 8.5mm
2x mounting hole M2.75 for 2.5mm screws	

When **mounted inside of a PCB stack, note that the Juice4halt module reduces the number of pins to 26**. From the 40 pins of the Raspberry Pi GPIO header at the bottom side only the first 26 will be lead through to the top side of the board. If your stack uses all 40 pins, mount the Juice4halt module on top of the stack or use a suitable short 40-wire flat ribbon cable with appropriate connectors.

Communication Interfaces

Interface	Signal type	Signal line
Boot/Shutdown Communication with the Raspberry Pi (SBC)	Dedicated I/O signal for shutdown procedure and booting, bidirectional	default GPIO25 (optional GPIO23[6]) requires script file running on RPi[8]
Power failure signal (Instant detection of power failure at the power input)	Dedicated signal, configured as Open-Drain output with 100k pull-up	default GPIO22 (optional GPIO17[6])
Communication with the Real-Time-Clock IC	I^2C-bus communication with on-board PCF8563	Pins 3 and 5 of the GPIO interface (SDA and SCL), requires RTC driver installed on RPi
RS-485 Interface	UART	Pins 8 and 10 (TXD and RXD) of the GPIO interface
Indication LEDs	red	Supercapacitor's charge is less than 100%
	yellow	Raspberry Pi or SBC powered on
	green	Charging Enabled (usually when power input connected to a power source)
Output Power ON/OFF	Push-Button for soft-start and soft-shutdown	automatic start (default)
		start after pushing button (optional[6])

Caution: When unplugging the module from the carrier PCB or from the Raspberry Pi, wait until all LEDs are turned off or use the on-board discharge load for discharging.

On-Board discharge load

- the on-board discharge load should be used before unplugging the module from the carrier PCB. It helps to avoid sparking and excessive current flow when discharging the supercapacitors

Parameter	Value	Conditions
Discharge load	2 Ohm Meander PCB trace used as shunt resistor	at 25°C
Typical Discharge Time at default 2x22F supercapacitors	1 Min.	short the pads R83 with a tweezers (Fig.4)

Caution: The discharged power will shortly heat up the PCB surface. Do not touch the PCB during discharging!

Caution: The on-board discharge load is dimensioned only for max. 2x25F capacity operated at ambient temperature 25°C. Don't use the discharge load when operating higher capacities. Too much heat could damage the PCB.

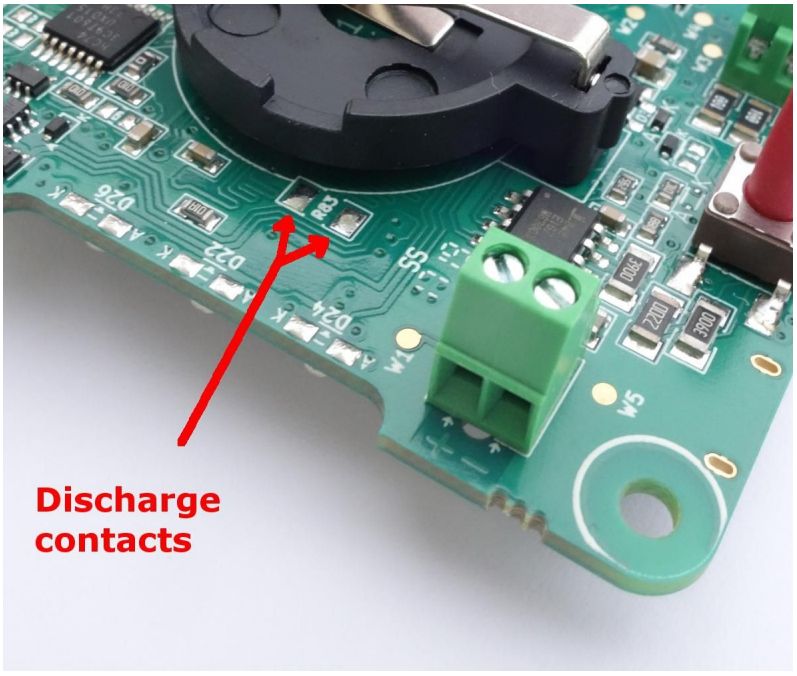


Fig.4: Juice4halt - Discharge contacts

The GPIO interface

The Juice4halt module uses the GPIO header of the Raspberry Pi for communication and for supplying the Raspberry Pi with power.

Several pins are used. For some signals it is possible to use an optional pin instead of the default pin when the default pin is already allocated by another task in your application. The change is done by removing/assembling a 0603-size jumper resistor on the determined positions[6].

Pin1 (3V3)

is used for detecting if the Raspberry Pi is powered up. The GPIO25 (optional GPIO23) is disconnected when the voltage at this pin falls to 0V.

Pin2 and Pin4 (5V)

5V backup power for Raspberry Pi

Pin22 (GPIO25) default
Pin16 (GPIO23) optional[6]

3.3V logic signal for bidirectional Boot/Shutdown communication between the Raspberry Pi and the Juice4halt. The Raspberry Pi reports the following states:

- Boot process completed
- Shut-down process completed

In the other direction, the Juice4halt forces the Raspberry Pi to shutdown when the charge state of the supercapacitors is too low

Pin15 (GPIO22) default
Pin11 (GPIO17) optional[6]

An open-drain power failure signal output with 100k pull-up to 3.3V for an instant power failure detection at the power input.

Pin3 (GPIO2/SDA)
Pin5 (GPIO3/SCL)

These two pins are used as the I^2C interface for communication with the Real-Time Clock.

Pin8 (GPIO14/TXD)
Pin10 (GPIO15/RXD)

These two pins are used as the UART interface for the RS-485 communication.

Pins 6,9,14,20,25 (GND)

These pins are connected to ground.

All other pins are not occupied and can be used by other modules or HATs in the stack.

The RS-485 interface

The Juice4halt module contains a 2-wire RS-485 (or RS-422) transceiver. The transceiver is driven by the Raspberry Pi UART interface on the GPIO14 and GPIO15 pins.

Parameter	**Value**	**Conditions**
RS-485 Interface Communication Type	2-wire, half duplex	Transceiver chip ISL8483E
RX/TX direction control	automatic	driver enabled by a low TX data bit driver disabled 25us after the end of a low TX data bit
	controlled by GPIO24	optional[6]
Failsafe biasing	390R to GND 390R to 5V	
Line Termination	120R	390R//220R//390R+2*10R
Protection	ESD to +/- 15kV	no Surge/Burst protection
Echo-feature	RX always enabled TX enabled at data	optional[6]
Data transmission speed	0...250kbps slew rate limited	25µs transmission pause between TX and RX required

Automatic RX/TX direction control

The driver-enable line follows the data with a short delay (25µs) before disabling the driver. There is no need to adjust the time constant for different transmission speeds. The automatic direction control works from zero to maximum transmission baudrate. The only requirement is a 25µs transmission pause between sent and received data. This short time interval corresponds to a time interval of about 3 data bits at 115kbps. At 9600bps the 25µs time interval corresponds to a fraction of one data bit.

Instead of keeping the transmitter enabled for the entire transmission, the driver is enabled on the leading edge of the start bit or any logic low at the driver's input. It also disables the driver 25 µs after the leading edge of the stop bit or any logic high at the driver's input. When the driver is disabled, the biasing resistors ensure the receiver's

output is a logic high.

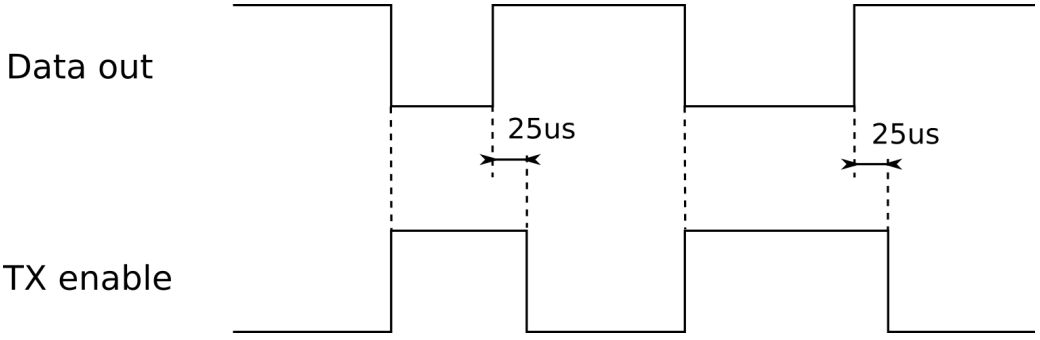


Fig.5: Automatic RX/TX direction control

The Real-Time Clock

The board contains a PCF8563 integrated circuit communicating via I^2C-bus with the Raspberry Pi. A Lithium Coin Battery supplies the RTC chip when the Raspberry Pi is not powered on.

Parameter	**Value**	**Conditions**
RTC chip type	PCF8563	supported by the Raspbian OS
Battery holder	CR2032	3V, Lithium
Battery Lifetime	>20years	at capacity 200mAh
Communication	I^2C-bus	Pins 3 and 5 of the GPIO interface (SDA and SCL), requires RTC driver installed on the RPi

Caution: The RTC battery holder is for stationary applications only, when used in mobile applications we recommend an external battery holder connected by flexible wires soldered to the on-board battery holder contacts.

The Boot/Shutdown Communication signal

The communication between the Raspberry Pi and the Juice4halt runs over a single bidirectional signal line:

Pin22 (GPIO25) default
Pin16 (GPIO23) optional[6]

The signal uses a 3.3V logic. A script file[8] executed on the Raspberry Pi is required. The Raspberry Pi reports the following states:

- Boot process completed
- Shut-down process completed

In the other direction, the Juice4halt forces the Raspberry Pi to shutdown when the charge state of the supercapacitors is too low.

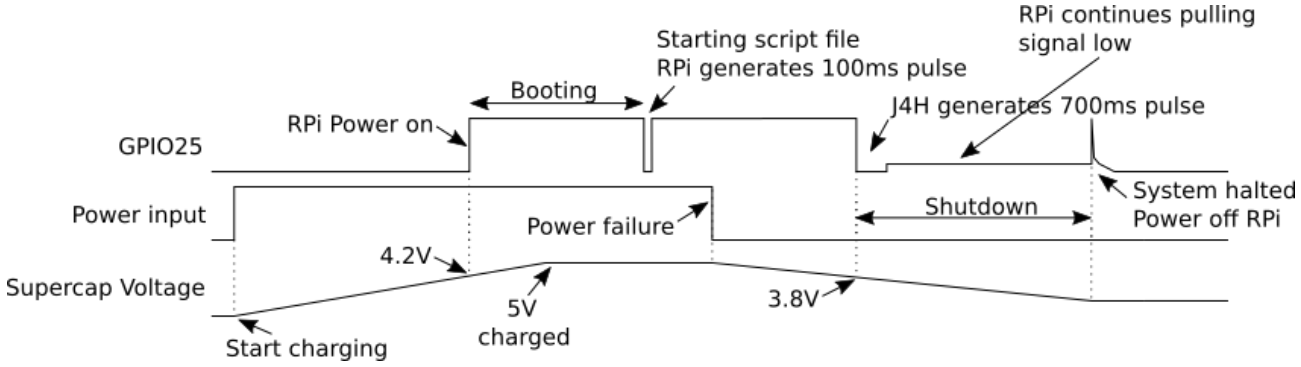


Fig.6: The Boot/Shutdown Communication signal

The Raspberry Pi will not be powered-on immediately after power recovery, but will wait until reaching 4.2V at the supercapacitors. After powering-on the Raspberry Pi starts booting. At the end of the booting process the script file will be executed. A 100ms pulse will be sent to the GPIO25 line signalling to the Juice4halt activation of the automatic shutdown. The 100ms pulse is also indicated by the green LED, by shortly flickering when the script file will be executed and when the communication line is working properly. From now on the Raspberry Pi listens to the GPIO25 line. A 700ms low

pulse sent by the Juice4halt presents a command to immediately start with shutdown, because the voltage at the supercaps is below 3.8V due to a longer power failure. The shutdown will not start immediately after a power failure. When the power recovers before reaching the 3.8V, the Raspberry Pi will keep operating without noticing any change of the power supply. After receiving the 700ms pulse, the Raspberry Pi must stretch the pulse by pulling the line Low and start to shutdown the system. The Juice4halt now listens to the GPIO25 line. When the signal is released to High, the Raspberry Pi has halted it's system and will be powered off. Alternatively when the supercapacitor is discharged before completing the shutdown procedure, the voltage collapses and the Raspberry Pi will be powered off, too.

Caution: The communication protocol is not compatible with the REBOOT command. The Juice4halt has no feedback about a possible reboot. After rebooting the script file will be started again and will send another 100ms pulse to the GPIO25 line causing a deactivation of the automatic shutdown. For rebooting please use the rebootj4h script file[8] instead. This script file will deactivate the automatic shutdown before rebooting.

Caution: Operating the Juice4halt and the Raspberry Pi without installed script file will not enable the automatic shutdown after a power failure.

Operating the Raspberry Pi with installed script file but without the Juice4Halt module will cause an immediate shutdown after booting has completed.

The Power Failure signal

The Raspberry Pi will not be instantly informed about a possible power failure. The one and only information about the power failure is the shutdown command, usually coming 31 seconds after the power failure.
In some applications it is convenient, to know the instant state at the power input. By knowing, that the system runs in backup mode the Raspberry Pi can immediately switch the system into low power operation and so prolong the backup time, or it can trigger the shutdown earlier before reaching the 3.8V level at the supercapacitors.
For detecting an instant power failure at the power input the following pin is used:

Pin15 (GPIO22) default
Pin11 (GPIO17) optional[6]

The pin is an open-drain signal output with a 100k pull-up to 3.3V
The signal state is indicated by the green LED.

Caution: The signal contains also the short 100ms Low-pulse when the script file execution is started on the RPi. This is the only exemption, when the signal shortly doesn't copy the situation at the power input.

The Power ON/OFF Button

The Juice4halt module contains a push button which works as a Power ON/OFF Button. During Normal operation, when the system is running and the power is available, the Power Button can be used to force a shutdown of the Raspberry Pi followed by a power-off. The operation is safe and without a system crash. When the Raspberry Pi has been powered-off, it can be powered-on again by pushing the Power Button.

Configuration at first start

- Initial state: all LEDs are dark

  After attaching power to the Juice4halt module for the first time, the Raspberry Pi (SBC) will start booting automatically when the supercapacitor's voltage has reached 4.2V. This is the default setting of the Power Button.

  However, the default setting can be changed so that the Raspberry Pi will not be powered-on automatically after reaching 4.2V, but will wait until the power Button is pushed. If the button will be pushed before reaching the 4.2V, the Raspberry Pi will be powered-on after reaching 4.2V at the supercapacitors.

Configuration at power failure followed by a shutdown

- Initial state: red LED is on

  After a power failure followed by a shutdown the Raspberry Pi will be powered-on automatically when the power is recovered again. Even if the power is recovered during the shutdown, the shutdown will be completed, then the Raspberry Pi will be powered-off and on again. This is the default setting of the Power Button.

  However, the default setting can be changed so that the Raspberry Pi will not be powered-on automatically after a power recovery, but it will wait until the Power Button is pushed.

For more information how to change these settings, please read the Application Note[6].

The script file download

For proper operation of the Juice4halt module it is necessary to install the basic script file on the Raspberry Pi. For script file download visit www.juice4halt.com . You can find the script files in the Download area compressed with 7-Zip.

script file	**Function**	**Comment**
shutdown_script	automatic shutdown	basic script file, enables communication between the RPi and the Juice4halt
rebootj4h	software reboot command	use this file instead of using the default REBOOT command

Skipping the charge mode (Immediate start)

After attaching power to the Juice4halt module, the Raspberry Pi (SBC) will not start booting immediately. The default setting is to wait until the supercapacitors have enough charge (=reaching 4.2V) and then power-on the Raspberry Pi. This is a protection feature that helps to avoid system crashes due to power failures occurring during the boot process.

However, the control logic of the Juice4halt module can be changed to allow powering-on the Raspberry Pi immediately after attaching power to the input contacts. The Raspberry Pi will start booting even if the supercapacitors are not charged enough to cover a power failure during the booting phase. For more information how to change this setting, please read the Application Note[6].

Caution: The immediate start is recommended only if the application can guarantee an uninterrupted power supply for the first moment, when the supercapacitors are being charged.

Typical performance characteristics

Figure 7 shows a typical operation of the Juice4halt module with a RPi3 load.
The Shutdown mode is very short, because the RPi3 needs only a few seconds for it's shutdown.

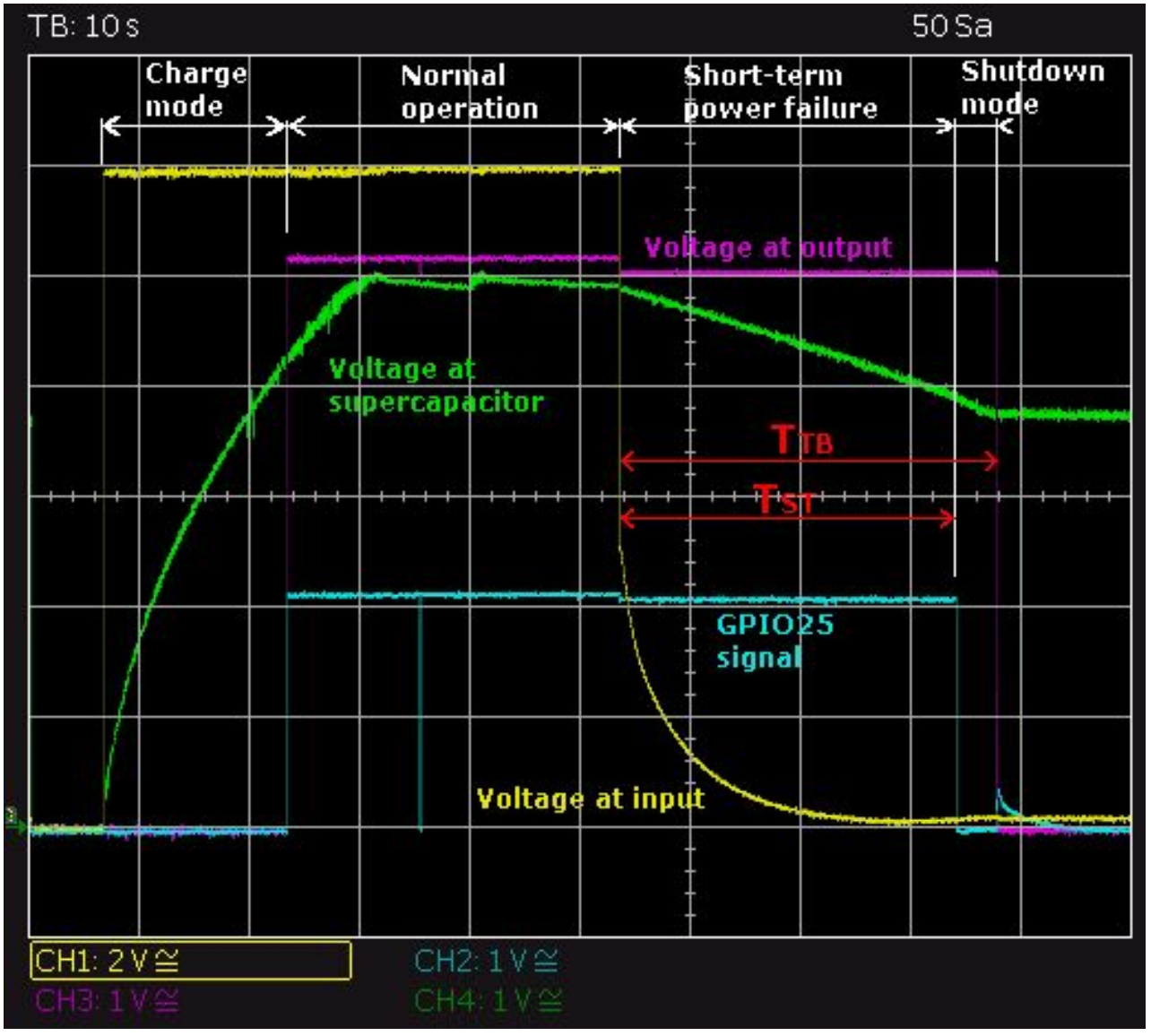


Fig.7: Juice4halt - Operation with RPi3

Modes of operation

Charge mode

- Charging the supercapacitors using the step-down DC/DC converter when the external power supply voltage is available at the input
- The load device at the output (Raspberry Pi or SBC) stays disconnected from 5V power rail until the supercapacitor's voltage rises above 4.2V

Normal operation

- The Raspberry Pi (SBC) is powered from the external power supply
- The supercapacitors are either being charged or charging is completed.

Short-term power failure

- Starts when input voltage falls below 4.8V
- External power supply will be disconnected
- The Raspberry Pi (SBC) is supplied from the energy stored in the supercapacitors.
- The Raspberry Pi (SBC) receives the information about the power failure via Power Failure signal, but it is not forced to shut down yet.
- In case of a power recovery the system continues with Normal operation, the supercapacitors will be charged again.
- Ends when supercapacitor voltage falls below 3.8V. The Shutdown mode is started.

Shutdown mode

- Starts when the supercapacitor voltage falls below 3.8V during Short-term power failure mode.
- The Raspberry Pi (SBC) remains supplied from the supercapacitors via step-up DC/DC converter

- The information about power failure is communicated to the Raspberry Pi (SBC). The Raspberry Pi (SBC) must immediately start with shutdown procedure.
- A power recovery during this mode has no influence on the shutdown procedure. The procedure will be completed and the the Raspberry Pi (SBC) will be powered off regardless of the external power.
- After completing the shutdown procedure or latest when the voltage at the supercapacitors falls below 1V the Raspberry Pi (SBC) will be disconnected from the 5V supply rail.
- Waits until external power supply voltage will be recovered to start Charge mode again

Typical backup times

The times T_{ST} and T_{TB} shown in Figure 7 depend on the current consumption of the Raspberry Pi (SBC) and on the type of supercapacitors used. Table 1 shows typical values for the following configuration:

- no peripheral devices attached
- 2x supercapacitors 22F/2.7V/85mΩ
- T_{AMB}=25°C
- The Raspberry Pi (SBC) is replaced by a constant current load

The current consumption of the Raspberry Pi 3, with running OS Rasbian equals to an average constant current of ca. 250mA when shutting down. For other SBCs or loads with different total shutdown currents use Table 1 for estimation of the backup times.

output load (constant current)	**Backup time for Short-term power failures T_{ST}**	**Max. Total Backup time $T_{TB\ (max)}$**
100mA	53 sec.	141 sec.
200mA	33 sec.	87 sec.
I_{AV} (Raspberry Pi 3)	31 sec.	81 sec.
300mA	24 sec.	62 sec.
400mA	19 sec.	47 sec.
500mA	16 sec.	39 sec.
600mA	13 sec.	32 sec.
700mA	11 sec.	27 sec.
800mA	9 sec.	23 sec.
900mA	8 sec.	20 sec.
1000mA	7 sec.	18 sec.

Table 1: Typical backup times

PCB assembly

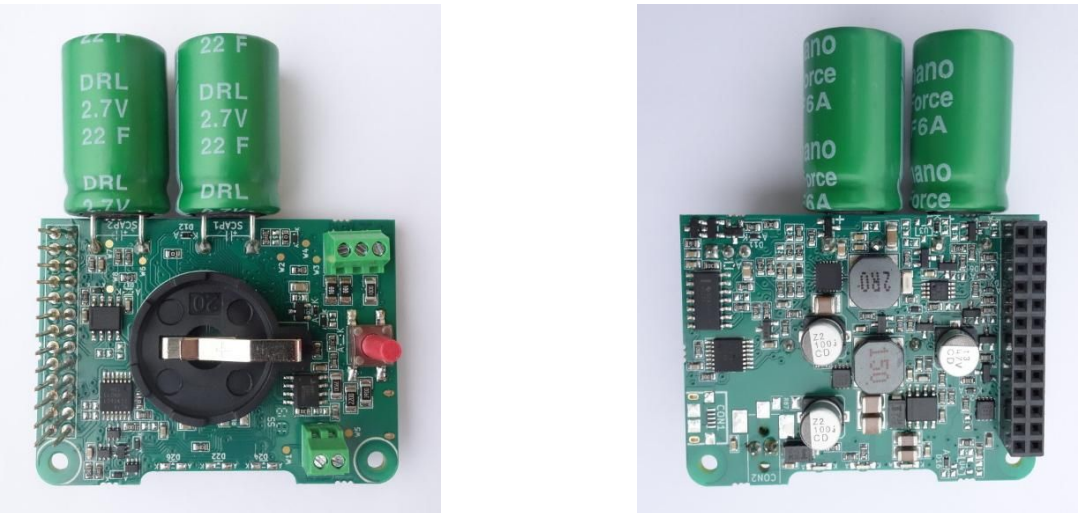


Fig.8: Juice4halt – RTC-485 model, top and bottom side

PCB Mechanical Drawing

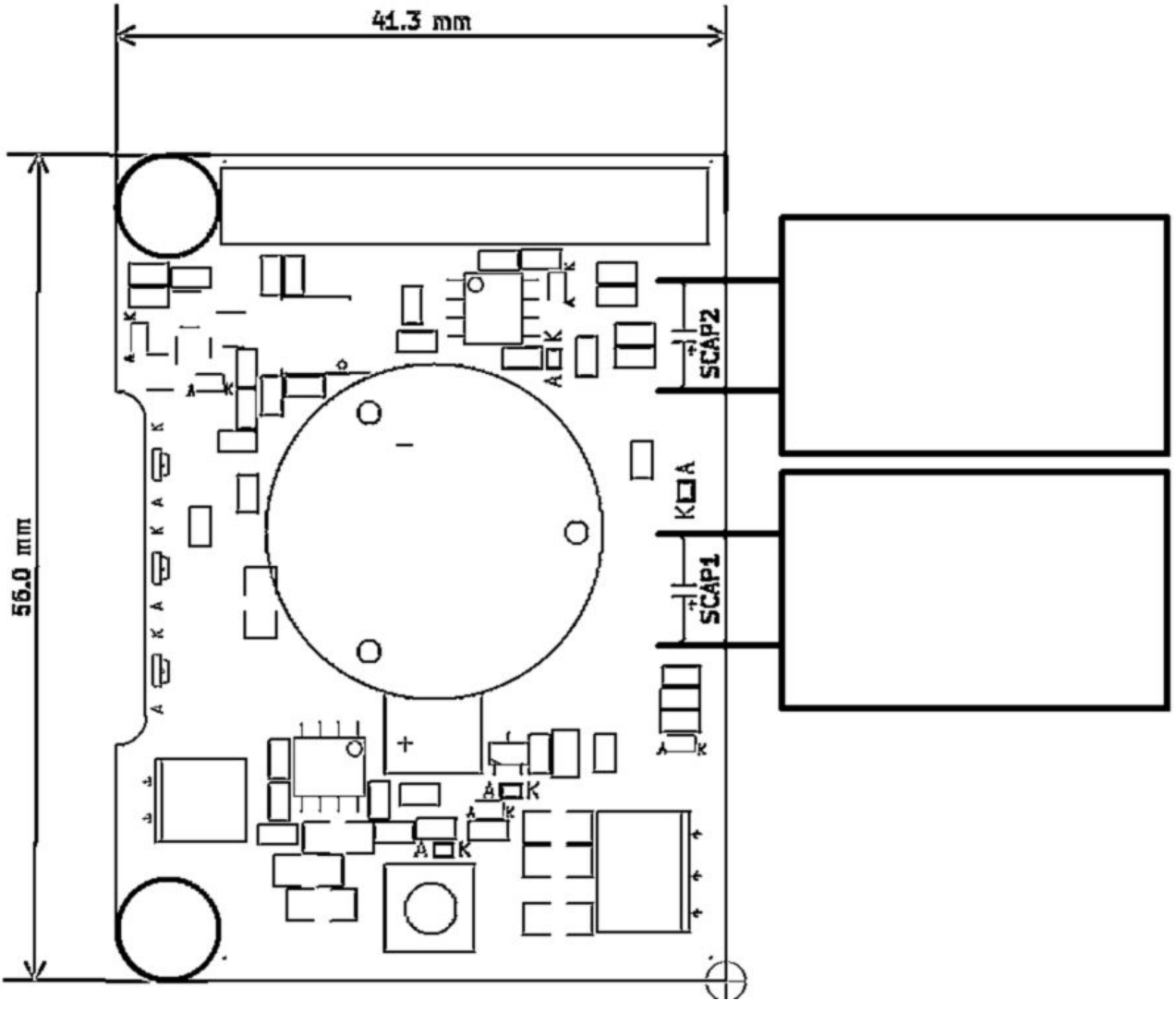
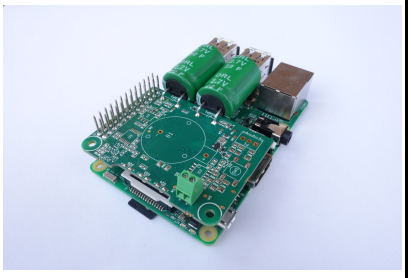
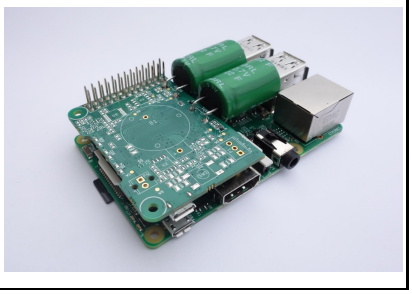


Fig.9: PCB top view drawing

Related products

Product	Description	Comments
J4H-HV-TRM	• Supercapacitor based energy storage module for micro-UPS applications • designed for Raspberry Pi • 7V...28V screw terminal input	
J4H-5V-USB	• Supercapacitor based energy storage module for micro-UPS applications • designed for Raspberry Pi • 5V Micro-USB input	

Revisions and Changes

Product Revision

Rev	Date	Description
A	May 2017	Initial release
B	Oct 2017	added test points and silkscreen printing changed mounting holes to non-plated M2,75

Datasheet Document Revision

Rev	Date	Description
20	Oct 2017	Initial release