

SUPERCAPACITOR BASED ENERGY STORAGE MODULE

FOR MICRO UPS APPLICATIONS

WITH A 5V MICRO-USB INPUT

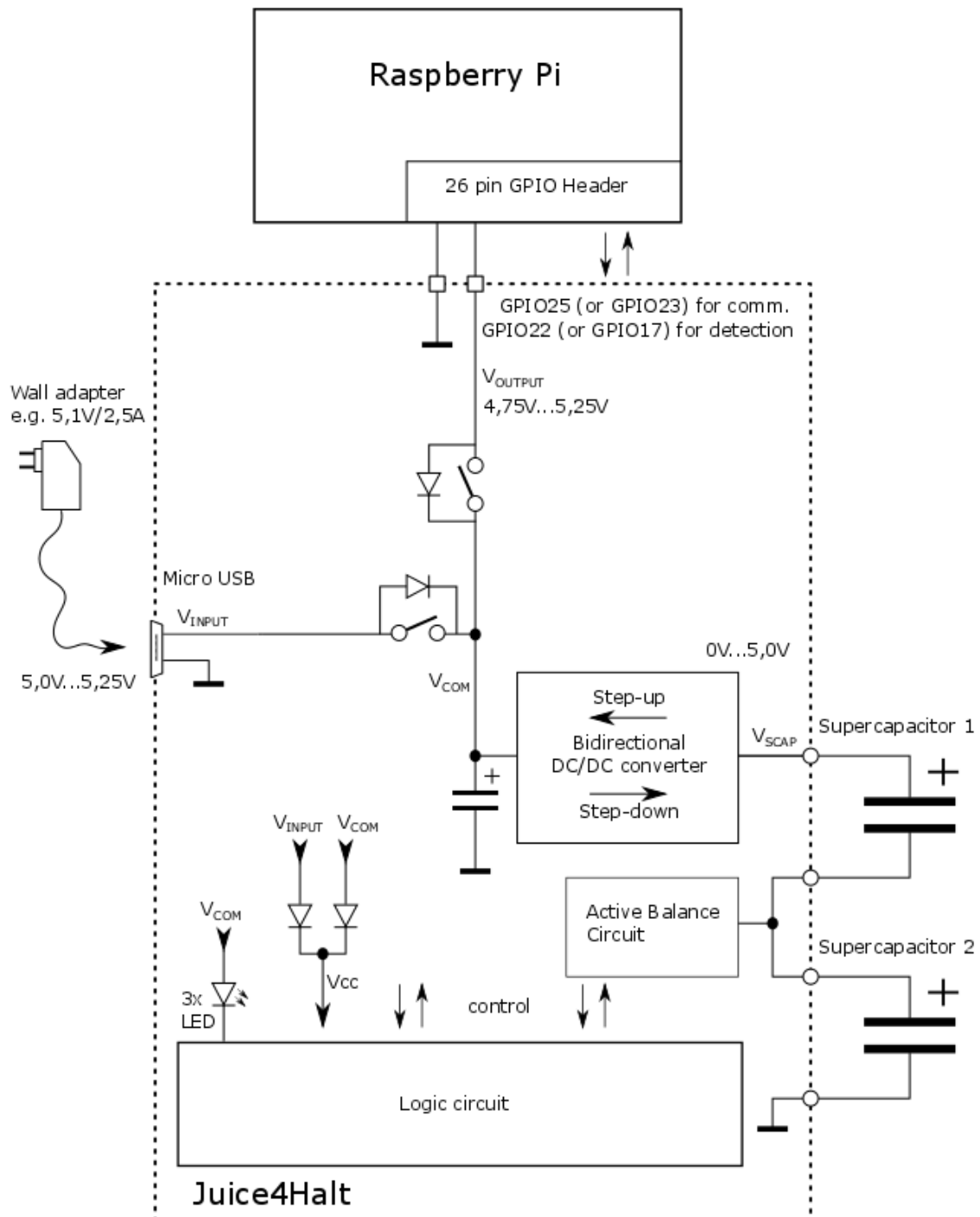
Features

- 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**
- **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-5V-USB | Input voltage 5V Micro-USB connector | |

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, $T_{AMB}=25^{\circ}\text{C}$.

Note 4: The PCB itself is designed for a wide operating temperature range -40°C to $+85^{\circ}\text{C}$. 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 – 5V-USB Model on RPi3

Description

The Juice4halt module is a supercapacitor based energy storage. It contains a bidirectional step-up/step-down converter working as the interface between the stable 5V supply rail and the supercapacitor energy storage. 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 J4H-5V-USB Model

The 5V-USB model requires a 5,0V...5,25V power supply with a Micro-USB connector. We recommend using the standard 5,1V/2,5A power supply for Raspberry Pi 3. **Be sure to connect the power supply cord to the Juice4halt module and not to the Raspberry Pi.** The power supply must be capable of supplying the Raspberry Pi and charging the supercapacitors at the same time. The required current also depends on other peripheral devices connected to the Raspberry Pi.

Be aware of using long or thin cables between your power supply and the Juice4halt module. The higher impedance of such cables or wires could lead to voltage drops at the cable influencing the proper function of the module and your Raspberry Pi.



Fig.2: Juice4halt – 5V-USB 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, $T_{AMB}=25^{\circ}C$ |
| 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 |
| 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 | 100% compatible, smaller supercapacitors recommended |



Fig.3: Juice4halt – 5V-USB model on RPi3

Input

| Parameter | Value | Conditions |
|-----------------------|----------------------|--|
| Input voltage range | 5.0V DC ... 5.25V DC | at Micro-USB connector |
| Average input current | 1.8A (typ.) | Charge mode+RPi3 Booting |
| Current consumption | typ. 15mA | Normal operation (no Charge mode, no Shutdown mode), $T_{AMB}=25^{\circ}\text{C}$ |

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 | $0A_{AVG} \dots 1A_{AVG}$ | |
| Typ. output ripple | 10 mVpp | at Shutdown mode, $T_{AMB}=25^{\circ}\text{C}$, ripple at $f_{SW}=1200\text{kHz}$ |

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 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) |

| | | |
|-----------------|--------|---|
| 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) |

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.

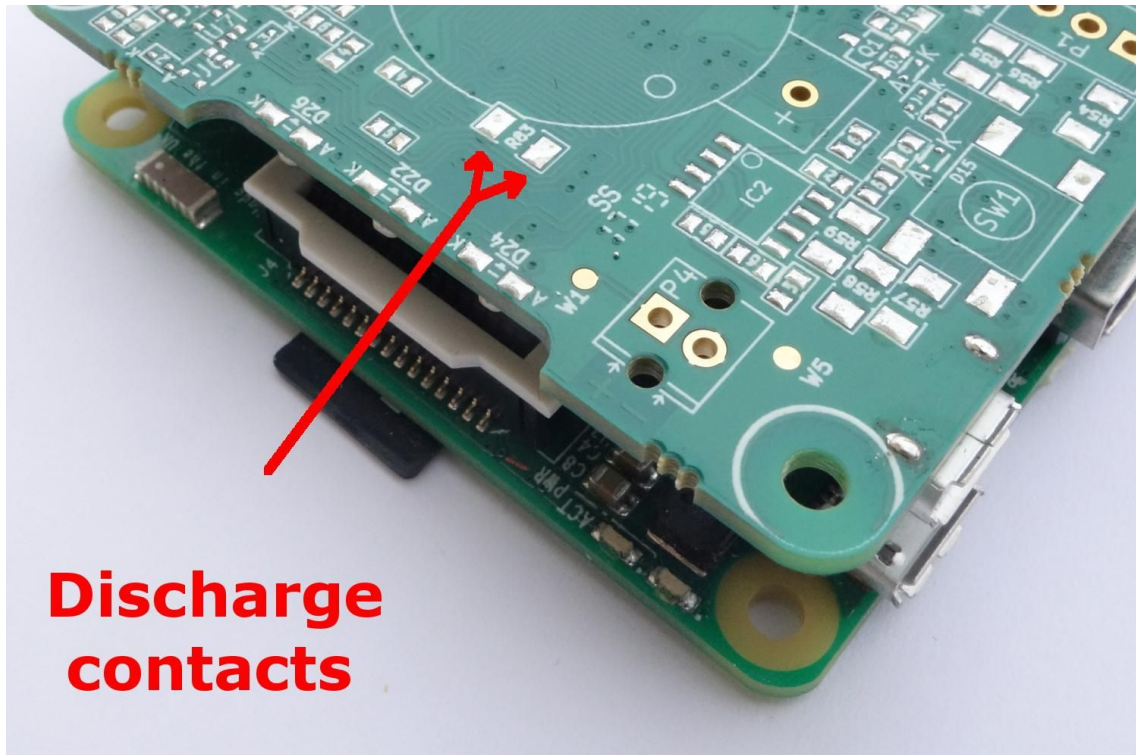


Fig.4: Juice4halt - Discharge contacts

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 positions⁶.

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) optional⁶

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) optional⁶

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)

Not used in this model.

Pin8 (GPIO14/TXD)

Pin10 (GPIO15/RXD)

Not used in this model.

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 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) optional⁶

The signal uses a 3.3V logic. A script file⁸ 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.

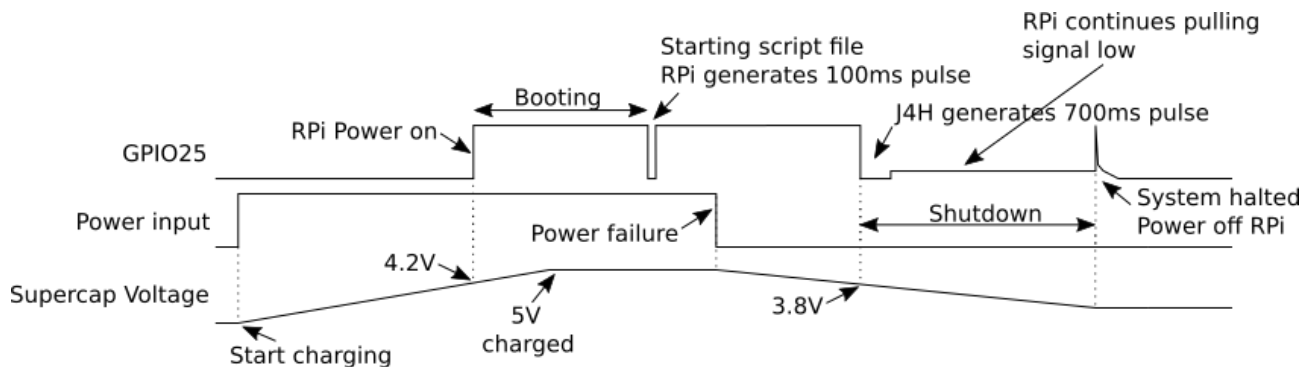


Fig.6: The Boot/Shutdown Communication signal

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 file⁸ 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) optional⁶

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 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 Note⁶.

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.

Note: The immediate start functionality for the 5V-USB model is planned to be implemented in the Product Revision B of the board. This will be available in the course of the year 2018.

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 its shutdown.

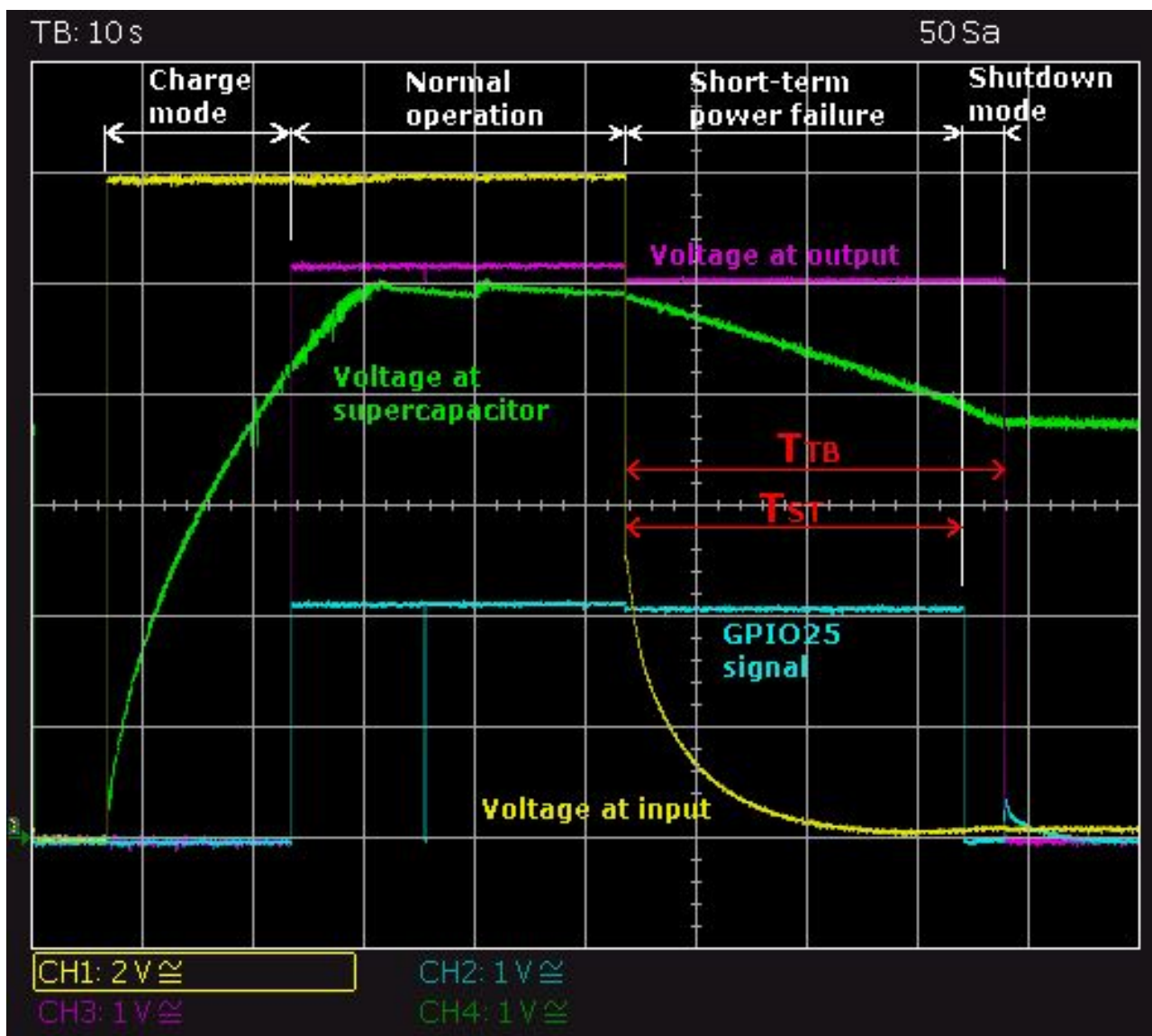


Fig.7: Juice4halt - Operation with RPi3

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/85m Ω
- $T_{AMB}=25^{\circ}\text{C}$
- 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 – 5V-USB model, top and bottom side

PCB Mechanical Drawing

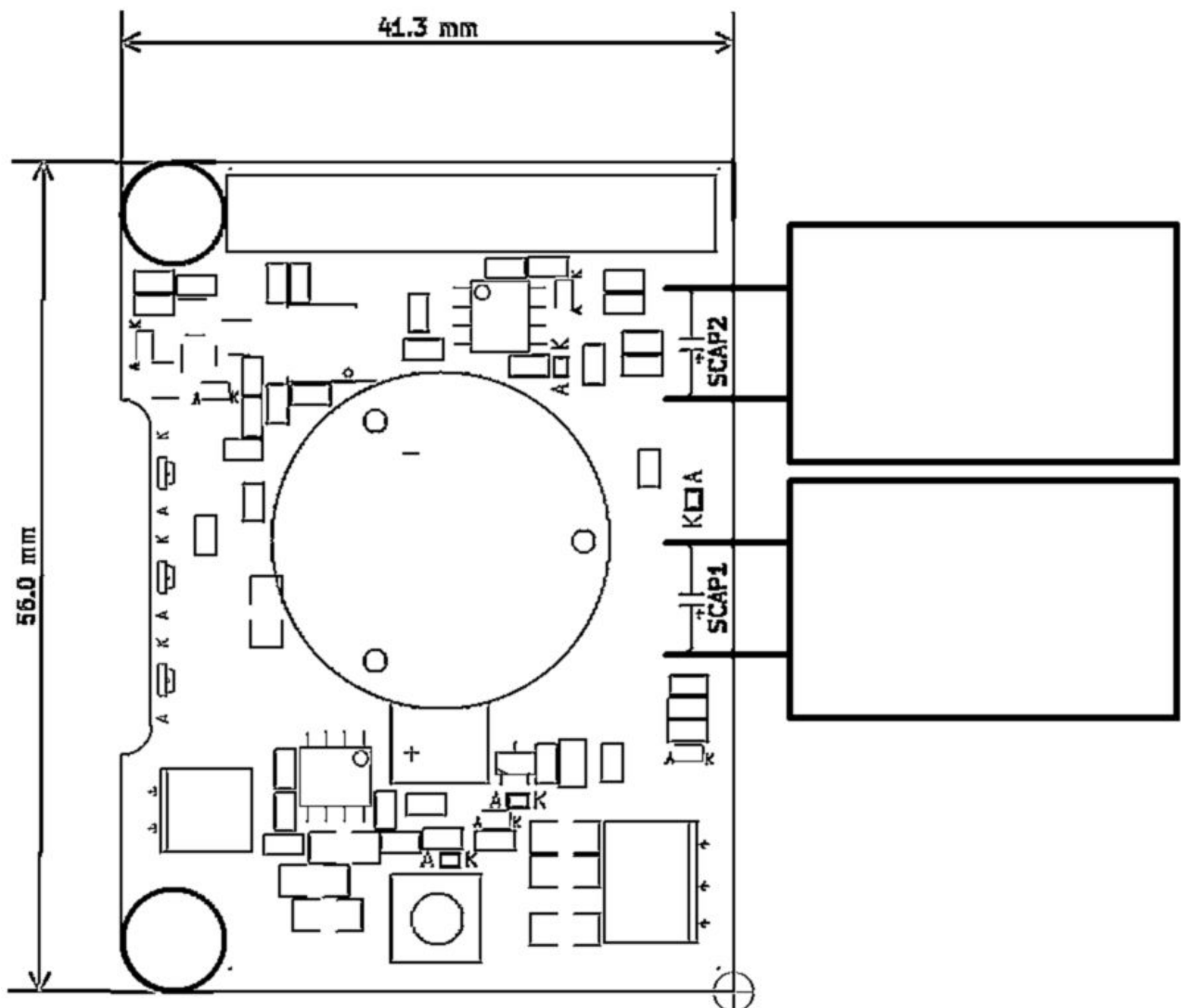
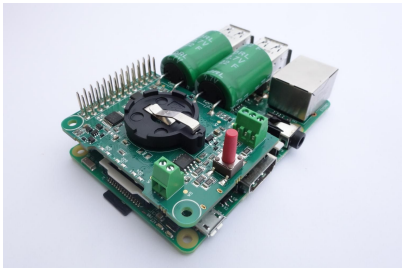
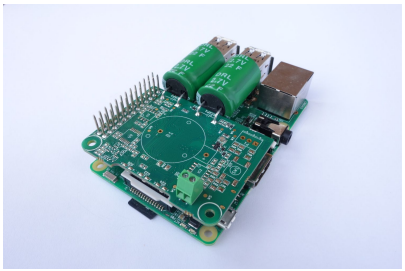


Fig.9: PCB top view drawing

Related products

| Product | Description | Comments |
|--------------------|---|--|
| J4H-HV-TRM-RTC-485 | <ul style="list-style-type: none"> • Supercapacitor based energy storage module for micro-UPS applications • designed for Raspberry Pi • 7V...28V screw terminal input • Real-Time Clock • RS-485 interface • Power ON/OFF Button |  |
| J4H-HV-TRM | <ul style="list-style-type: none"> • Supercapacitor based energy storage module for micro-UPS applications • designed for Raspberry Pi • 7V...28V screw terminal input |  |

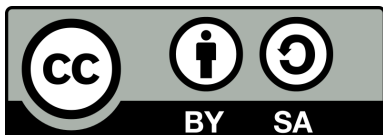
Revisions and Changes

Product Revision

| Rev | Date | Description |
|-----|----------|-----------------|
| A | Oct 2017 | Initial release |
| | | |

Datasheet Document Revision

| Rev | Date | Description |
|-----|----------|-----------------|
| 20 | Oct 2017 | Initial release |
| | | |



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