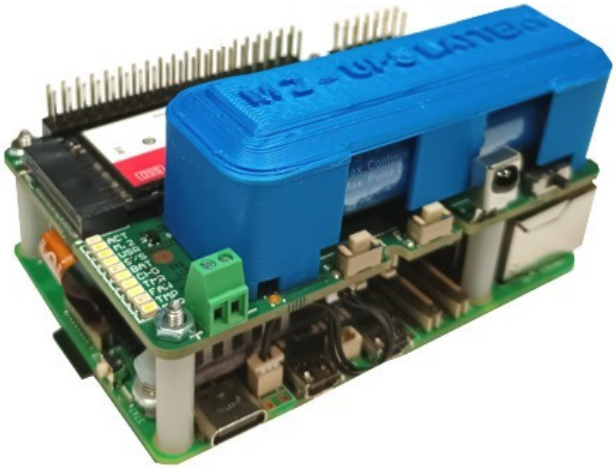
Pi Modules Technologies

M.2 UPS PMH

Standard and Advanced models

M.2 UPS and Power Management HAT

User Guide



Advanced model with 18650 battery and protective cap

Especially designed for Raspberry Pi 5

M2_UPS_PMH_Manual_V98 | 25 October 2026
Application V8B5 (0x08B5) | Bootloader V88 at 38400 bit/s

Hardware installation and operating instructions

www.pimodules.com | support@pimodules.com

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About this manual

This guide explains installation, configuration and operation of the **M.2 UPS PMH**. Identify Standard or Advanced from the assembly and startup banner, then use its matching connectors, battery profile and input ratings. Follow hardware setup, Linux installation and commissioning in that order.

Document revisions

Revision	Date	Changes
V06	20 Oct 2025	Initial consolidated installation guide and register reference.
V07	21 Oct 2025	Advanced assembly photographs and supported backup-source codes.
V08	21 Oct 2026	V88 serial updates, CRC verification and interrupted-transfer recovery.
V09	22 Oct 2026	Product naming, I²C, IR interface, enclosure and Read Only labels.
V12	22 Oct 2026	Automatic Linux installer V01: setup, checks, backups and removal.
V13	22 Oct 2026	Raspberry Pi RTC backup from the M.2 main battery; no separate RTC cell.
V14	22 Oct 2026	Release records, accessories, assembly, backup-source and supply guides.
V17	22 Oct 2026	Optional security chapter removed; existing operating instructions retained.
V8E / V8F	22 Oct 2026	Tool and migration guides; V8F unifies fonts and adds 4000 F energy estimates.
V90 / V91	22 Oct 2026	Pi RTC backup guide; installer automatically disables Pi RTC charging.
V92	24 Oct 2026	Application V8B: USR control, FAN/TMP telemetry, public diagnostics policy; daemon v1.2, installer V03, configurator 02.
V93	24 Oct 2026	V8B4 compact map, persistent/external ULED, installer V06 and matching tools; supercapacitor 4000 F / 4.2 V.
V94	24 Oct 2026	V8B5 external ADC, R75 = 1.00 kΩ, saved range selection, monitor 0A, configurator 06, installer V07 and Resources/Customer packages.
V95	25 Oct 2026	ESD-protected 1-Wire installation; English DS18B20 reader; monitor 0B v2.7; installer V08. Application V8B5 and bootloader unchanged.
V96	25 Oct 2026	Web Panel V02: local/private Internet access, accounts, configuration and Tailscale setup. Firmware V8B5 unchanged.
V97	25 Oct 2026	Updated P2/LED figures, actual panel screens and Tailscale client instructions; port 8080 retained.
V98	25 Oct 2026	Detailed Tailscale account/Pi/client setup; remote-access screenshots; mobile access and VPN-conflict troubleshooting; port 8080 retained.

Software supplied with this manual

Applies to application V8B5 (0x08B5), protected bootloader V88 at 38400 bit/s, Linux installer V08 and optional Web Panel V02, for Standard and Advanced. Panel and tool versions are independent of MCU firmware. Routine application updates do not replace the protected loader.

Component	Status in this edition
Application / bootloader	Application V8B5 (0x08B5); protected bootloader V88, unchanged, 38400 bit/s.
Daemon	v1.6: 250 ms heartbeat; 5-second CPU/fan telemetry; NTP-confirmed hourly RTC synchronization.
Status monitor	Monitor 0B v2.7: ADC, ULED and DS18B20 temperatures; configurator 06. Application V8B5.
Linux installer	V08: first install, detection, reviewed upgrade, uninstall and health check; 41 simulated tests.

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Unlocked firmware features

The feature matrix describes application V8B5 with protected bootloader V88. The Linux daemon supplies CPU temperature and fan state. USR supports manual control or a permanently saved selection that follows SYS, BAT, TMR, FAN or TMP. The selected source LED continues operating on the board. Public firmware omits MCU diagnostic messages. V8B5 also provides one shared Advanced-model ADC measurement, selectable as EXT0 (0–5.2 V) or EXT1 (0–32 V).

Feature	Availability in this package
UPS and charging	Application V8B5: cable/battery recognition, charging control, timed FSSD and low-battery protection, with the matching backup-source profile.
Shutdown and restart	Application V8B5 with daemon v1.6: controlled shutdown, LPR standby and power-return startup. Pi-button control wiring is required.
Optional ON/OFF switch	V8B5 supports the fitted switch in slide-switch mode. Normal mode and switch mode have different runtime behavior.
M.2 hardware RTC	Read/write access through the DS1307-compatible bank at 0x68. Daemon v1.6 performs NTP-confirmed UTC synchronization.
Raspberry Pi RTC backup	Hardware function through the dedicated supply cable and the main M.2 battery; separate from the M.2 RTC driver.
Firmware updates	V88 protected UART bootloader, 38400 bit/s. Button or software entry, Flash CRC32 verification and interrupted-write recovery.
Cold recovery startup	V88 protected loader starts Raspberry Pi once during the specified cold/brownout recovery of an incomplete application write.
Monitoring	Monitor 0B reads the V8B5 public status/command layout. A monitoring read counts as host activity.
Linux setup	Installer V08 installs/configures the existing daemon and tools. 41 simulated installer tests passed; perform reboot and commissioning checks.
Application interfaces	Advanced-model interfaces require matching fitted hardware and application software. The daemon does not implement email delivery, IR decoding or a user scheduler.
Persistent external ULED	Saved SYS/BAT/TMR/FAN/TMP source or manual control; P2 pin 5 with on-board R7 = 3.6 kΩ current limiting.

Identify the running application

sudo i2cget -y 1 0x69 0x30 w

At the default address, V8B5 returns word 0x08B5. Separate byte reads at 0x30 and 0x31 return 0xB5 and 0x08. The protected loader remains V88; record its installed image separately from the application and PCB identity.

Firmware bug fixes and additions

The following are documented development milestones relevant to this package. They are not a complete list of every intermediate build and are not instructions to install an older image. Application and protected-loader changes must be tracked separately.

Milestone	Documented change	Relevance to V8B
V4C	RTC hardware writes enabled with the revised application stack arrangement.	Successful RTC write/read and continuing heartbeat were observed in the reported tests.
V53	Repeated normal power cycles and optional switch-mode behavior were tested.	Established the shutdown and switch workflow used for later validation.
V58	Hardware FSSD/factory-recovery work; normal UPS operation provided the later power-control reference.	Historical factory-button behavior is superseded; do not follow that earlier entry sequence.
V73 baseline	Repeated FSSD/LPR/power-return cycles and cable return during shutdown were validated in the power-control development sequence.	V8B retains the validated power behavior while using the later bootloader entry scheme.
V80	RESET+FSSD selects direct bootloader entry; keyboard-selected factory defaults removed.	No HCM selection menu and no KEY jumper are required.
V84	Protected bootloader moved to 38400 bit/s.	Specify -b 38400 in the Python updater; changing Python alone does not change the loader UART.
V87	Bootloader walking-LED progression reduced to one step per two HEX records.	The indication does not change transfer baud or CRC verification.
V88	Cold/brownout recovery of an incomplete write starts Raspberry Pi once.	Allows Linux/SSH to restart so the complete application can be reloaded.
V8B	Direct USR control; compile-time diagnostics; bounded smaller print buffers; FAN/TMP telemetry retained.	Public application build; protected bootloader and power-control sequence unchanged.
V8B1	Unused variables	Removed unused storage and inactive fragments.
V8B2	Compact public map	Removed unused reserved fields; renumbered registers and matched Linux tools.
V8B4	Persistent ULED mapping	Flash-saved selector 0x0D; manual request remains volatile; original source LED continues.
V8B5	Advanced external ADC	One shared channel: saved EXT0/EXT1 range; R75 = 1.00 kΩ, factors 2.4/20.6; monitor 0B and configurator 06.

Current update acceptance record

Reported bench tests confirmed complete serial transfers at 38400 bit/s, Flash readback/CRC32 verification, and recovery after interrupted uploads, MCU reset and complete power loss. Successful completion is established by the updater's final CRC-verified message, not by LED activity alone.

V8B1 removed unused variables and inactive fragments. V8B2 compacted the public register banks. V8B4 added Flash retention of the USR mapping. V8B5 enables the Advanced external ADC with saved range selection and the R75 = 1.00 kΩ divider. The developer reported a correct 3.3 V test after changing R75. Public and diagnostic builds compiled without errors. A full accuracy sweep over both input ranges remains an assembly acceptance check.

Daemon and host software changes

The Linux tools have independent version numbers. Updating a manual does not automatically change the daemon, monitor, updater or installed MCU image. Keep the extracted package together so that scripts, service files and instructions remain matched.

Component	Version and purpose	Change or validation record
Daemon v1.6	M2_PMH_i2c.py	Compact-map heartbeat, shutdown, temperature/fan and RTC tasks.
Monitor 0B v2.7	M2_PMH_status_0B.py	Read-only current map and saved ULED source.
Configurator 06	M2_PMH_config_06.py	Guarded writes; separate manual request and saved mapping.
Installer V08	install_M2_UPS_PMH.py	Detect, upgrade, uninstall, verify.
Updater 01D	M2_PM_UPS_BL01D.py	Unchanged serial updater; use -i and 38400 bit/s.

Service changes and existing overrides

Daemon v1.6 polls the heartbeat every 250 ms, sends CPU temperature and Linux fan enable state every 5 seconds, and discovers the M.2 RTC by kernel name and bus/address. RTC writes wait for confirmed NTP and repeat hourly. Fan state is a Linux cooling request, not measured rotation speed. Compact-map telemetry supports V8B2, V8B3, V8B4 and V8B5; the supplied configuration and status tools target V8B5.

Installer V08 provides --detect, --upgrade and --uninstall. Under cable power, --upgrade backs up and replaces supported previous installations or recognized manual services, including their known overrides. Unknown custom services are refused for review. Do not run duplicate daemons or delete installer state to bypass a refusal.

```
sudo systemctl cat M2_PMH_i2c.service
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
```

What these tools do not configure

The supplied daemon does not implement email notifications, scheduled application wake events or Raspberry Pi fan cooling profiles. The installer does not flash MCU firmware, modify Raspberry Pi EEPROM or select battery chemistry/current. The monitor is not a substitute for the shutdown service.

Schematics and PCB updates

Identify the actual Standard or Advanced assembly and its PCB markings before fitting accessories. Firmware version, assembly model, PCB revision and protected-loader revision are separate records. The startup PCB/BL value 0x40 is an identification byte and should not be interpreted as a complete board or bootloader change history.

Hardware record	Meaning and action
Standard and Advanced	Use the connector set and power-input ratings specified for the fitted model. Advanced application headers must not be assumed present on Standard.
Pi-button control connection	The M.2 control circuit operates the Raspberry Pi 5 power button through its transistor/contact arrangement. It is not the older Raspberry Pi RUN/PEN connection.
Prototype control-line bias correction	A reported prototype correction removed R4 after reset-time bias of the control transistor caused unintended Pi-button activity. This is a development record, not a general user rework instruction. Follow the schematic for the shipped PCB revision.
RTC backup cable	The optional/specified assembly cable connects the M.2 main-battery RTC backup supply to the dedicated Raspberry Pi 5 RTC power connector.
Backup-source assembly	Cable battery, one 18650 cell and the designated 4000 F option require the matching source arrangement. Do not populate alternative battery connections simultaneously.

Keep a hardware record with the system

Record the PCB marking, assembly model, MCU application version, installed-loader image/hash, backup-source part, switch arrangement and fitted cables. Keep the order-specific schematic/assembly drawing with that record. A firmware banner alone cannot prove that a connector or accessory is fitted.

The assembly and inspection chapters below use external board connections rather than MCU package pin names. Rework should follow the drawing for the exact board; photographs are useful for orientation but do not replace polarity or continuity checks.

System overview and introduction

The M.2 UPS and Power Management HAT combines:

Raspberry Pi 5 Powering

External 5-32 VDC

Passive PoE up to 32 V

Battery backup

Battery Back up for the Raspberry Pi RTC

Power supervision

PCIe SUSCLK 32786 Khz supply

and an M-key M.2 interface in an 85 × 56 mm board designed for Raspberry Pi 5. It supports SSD lengths 2230, 2242 and 2280 and provides backup power to the Raspberry Pi and attached SSD.

During normal operation the Raspberry Pi uses external cable power and the UPS manages battery charging. When external power disappears, the battery supports the system while the controller measures the outage and, when required, requests File Safe Shutdown (FSSD). A Linux service must process that request so the operating system can shut down before power is removed.

System components

Component	Role
Raspberry Pi 5	Runs Linux, applications and the shutdown service.
UPS microcontroller	Supervises power, battery, buttons, timing and power control.
Battery source	Provides temporary power during an outage or mobile operation.
M.2 interface	Connects a compatible PCIe M-key SSD through the Pi FPC interface.
Linux service	Maintains I^2C communication, handles shutdown and synchronizes the UPS RTC.

Two hardware variants

Two models are available. The **Standard Model** provides the core M.2 and UPS functions. The **Advanced Model** adds an external DC input, passive PoE and additional application interfaces. Software support, fitted connectors , Switches, Raspberry Pi 5 RTC Cable, Battery Cover are included in the packega.

Power control principle

The M.2 controller can operate the Raspberry Pi 5 power button through a transistor interface. A shutdown state is different from complete electrical isolation: a cable connected directly to the Raspberry Pi USB-C connector still supplies the Pi power circuitry. Switch-controlled standby therefore also depends on Raspberry Pi EEPROM settings described later.

Standard and Advanced models

The two models share the Raspberry Pi 5 M.2 and UPS functions. The table below summarizes their electrical and mechanical differences; the full comparison is in Technical specifications.

Parameter	Standard	Advanced
Host	Raspberry Pi 5	Raspberry Pi 5
Board dimensions	85 × 56 mm	85 × 56 mm
M.2 SSD lengths	2230 / 2242 / 2280	2230 / 2242 / 2280
M.2 supply capability	5 A	5 A
M.2 reference signal	SUSCLK 32.768 kHz	SUSCLK 32.768 kHz
Battery backup output	5.25 V, up to 5 A continuous	5.25 V, up to 5 A continuous
External source	Pi 5 V GPIO power path	Pi 5 V GPIO and EPR DC input
EPR input	Not fitted	5–32 V DC
Passive PoE	Not fitted	5–32 V DC, variant dependent
Maximum charger current	580 mA	1.1 A
Adjustable charge current	100–580 mA	100 mA–1.1 A
Battery connections	Cable battery or one 18650	Cable battery or one 18650
Supported Battery Chemistry	LiPO, Li-ion, LiFePO4, Supercapacitor 4000 F / 4.2 V	LiPO, Li-ion, LiFePO4, Supercapacitor 4000 F / 4.2 V
Auxiliary backed supplies	Not fitted	5 V / 200 mA and 3.3 V / 200 mA
HAT identification EEPROM	Not fitted	Not fitted

Passive PoE is a dedicated passive DC arrangement. It is NOT compatible with an IEEE 802.3af/at/bt switch or injector. Injector wiring, polarity and the fitted board variant must be confirmed before connection. The maximum DC voltage for passive PoE is 32V DC.

Core features

The **M.2 UPS PMH** combines power backup and a PCIe M-key storage interface on one Raspberry Pi 5 HAT. The controller monitors the source and battery independently of Linux, while the host service turns an FSSD request into an orderly operating-system shutdown.

General

The 85 × 56 mm board uses I²C for routine host interaction. It provides system indicators, a shutdown control, a hardware RTC and support for an optional slide ON/OFF switch as Power Bank. The M.2 interface supports 2230, 2242 and 2280 SSD lengths through a 16-contact Raspberry Pi PCIe FPC connection.

Powering options

In Standard configuration, normal power is supplied through the Raspberry Pi 5 V power path. The Advanced assembly adds the designated (**E**xternal **P**owe**r**ing input) EPR DC input and passive PoE option. Battery backup supports both the Raspberry Pi and M.2 supply. One backup source is used at a time: a compatible cable battery or a cell in the 18650 holder. Battery input is protected against revert polarity insertion.

Battery charging and mobile operation

The charger adapts its demand to source conditions. A source that cannot support both the running system and the requested charging current may produce repeated source transitions. The optional switch provides a controlled mobile-power mode and requests shutdown when moved OFF.

RTC support and system scheduler

The **M.2 UPS PMH** hardware RTC is separate from the Raspberry Pi RTC. The host can read and synchronize it through the DS1307 compatible I²C interface. The hardware specification also provides scheduler functions; application-specific event programming requires the corresponding firmware/API release.

Monitoring and host integration

The Linux service supplies CPU temperature and fan state, handles shutdown requests and synchronizes the UPS RTC. FAN and TMP indicators use this telemetry; they do not control Raspberry Pi cooling.

User and programmer interface

The API uses default I²C banks 0x68 for RTC, 0x69 for status and 0x6B for commands. Manual USR control is at 0x6B:0x09; the saved USR source selector is at 0x6B:0x0D. The ULED signal is also available at P2 pin 5 (USR_LED_H) for user applications and an external enclosure indicator, on assemblies with the application header fitted.

Embedded peripherals and interfaces

Application interfaces on the Advanced model

The Advanced specification includes an external application header, auxiliary backed supplies, a user KEY input and user LED connection, analogue input functions, serial connectivity, an IR receiver interface and a 1-wire interface. Check each fitted connector against the board drawing before connecting equipment.

Interface	Installation considerations
Auxiliary 3.3 V and 5 V	Specified at 200 mA each. Include the load in the total power budget and check behavior while the Pi is OFF.
KEY input	Active-HIGH application input on M.2 where fitted. Use the designated 3.3 V contact and common ground. Not used for bootloader selection.
IR interface	Interface for a compatible infrared receiver on the Advanced model. Follow the board connector labels and receiver pinout; receiver decoding depends on the application software.
Serial interface	Use the documented 3.3 V logic-level connection. A true ± voltage RS-232 interface requires a compatible level converter.
Analogue input	One shared 12-bit ADC measurement on Advanced. EXT0: P2 pin 11, 0–5.2 V; EXT1: P2 pin 12, 0–32 V. Use one input only, other open. R75 = 1.00 kΩ. Saved selector 0x6B:0x08; BCD voltage 0x69:0x12.
1-wire	ESD-protected connector on Advanced, linked to Raspberry Pi GPIO4. Use it for external sensors rather than bare GPIO. Linux 1-Wire setup and English DS18B20 reader are described in the 1-Wire chapter.
ULED for user applications	P2 pin 5 USR_LED_H; GND at P2 1, 6 or 14. On-board R7 = 3.6 kΩ current limiting; no extra resistor needed for the intended external LED connection.

Embedded sensors

Power monitoring uses the fitted PAC1720 device and voltage/current/power measurement circuitry. The available monitoring points differ between Standard and Advanced. Do not apply an external measurement voltage to an unverified application pin.

Serial diagnostics and user applications

The diagnostic terminal is useful for startup and power-transition traces. A user application that also opens the same serial device can interfere with diagnostics or firmware transfers. Give one process ownership of the selected port during each task.

Serial signals are 3.3 V logic level. Connect a compatible adapter and common ground; a true positive/negative-voltage RS-232 connection requires a level converter.

System protection and PCB construction

System protection

The **M.2 UPS PMH** combines MCU supervision, battery cut-off functions and power-path protection. The technical specification lists PPTC, ESD and reverse-polarity measures on the appropriate power inputs. These features do not make every connector tolerant of arbitrary voltage or incorrect wiring.

The Linux service remains essential to File Safe Shutdown. Hardware can sustain the supply and request shutdown, but Linux must close applications and storage before the controller completes its power sequence. Allow enough grace time for the actual workload.

Watchdog and still alive monitoring

A still-alive mechanism can monitor host communication. Select watchdog actions and intervals only from the matching firmware specification. Do not experiment with an undocumented watchdog command on a system with unsaved data.

Power button control

The board operates the Raspberry Pi 5 button through a transistor interface where fitted. The MCU control signal is not an independent hard-reset input on the Raspberry Pi processor. Direct USB-C power remains electrically present when the Pi is in standby.

PCB construction

The supplied **M.2 UPS PMH** specification describes a four-layer PCB with 2 oz copper, immersion-gold finishing, cooling planes and thermal vias. The central opening supports air circulation from the Raspberry Pi official cooler and helps keep the SSD area ventilated.

Enclosure and accessory clearance

A dedicated enclosure specially designed for the **M.2 UPS PMH** and Raspberry Pi 5 assembly is available. Select the enclosure version suited to the fitted SSD, battery arrangement and optional accessories.

Verify the assembled height, battery access, USB-C and Ethernet access, SSD fixing point, cooler clearance and FPC bend radius. Case compatibility cannot be inferred from the Raspberry Pi footprint alone. Keep conductive case parts and loose screws away from the board underside.

Add on equipment and package contents

What is in the package

Check the order-specific packing list before assembly. Models and kits may differ in battery, holder, switch, spacers, FPC cable and accessory connections. A mechanical illustration is not a packing list.

Item to check	Purpose
M.2 UPS PMH HAT and assembly identification	Confirms Standard or Advanced and PCB revision.
Compatible PCIe FPC cable	Connects the Pi PCIe port to the HAT.
Spacers and fixing hardware	Supports the boards and the selected SSD length.
One approved backup source	Cable battery, 18650 or the approved supercapacitor option.
Power-button connection (POGO PIN)	Required for the intended Pi power-control arrangement.
Optional accessories	Slide switch, 18650 Battery Plastic Cover, RTC supply cable and external application connections as ordered.

Batteries and holders

The cable socket and 18650 holder are alternative backup connections. Select cell chemistry, protection, charge current and discharge capability as a complete configuration. Do not parallel two sources through the available connectors.

Supercapacitor option

The 4000 F / 4.2 V supercapacitor option requires its designated assembly and charge profile. Install the selected backup source according to its connector polarity and mechanical mounting arrangement.

Through hole and external parts

For a kit requiring soldering, follow the assembly drawing for its PCB revision and inspect every joint before applying power. Keep fitted components in their designated positions.

Application specific add on extensions

Select accessories for the actual **M.2 UPS PMH** model and PCB revision. The base package and optional items depend on the order. A header location or a reserved register does not by itself provide an installed peripheral or a complete application driver.

Accessory or extension	Selection and use
RTC backup supply cable	Dedicated cable offered by Pi Modules Technologies, from the M.2 main-battery backup supply to the Raspberry Pi 5 RTC connector. No separate Pi RTC battery is needed while this supply is available.
Slide ON/OFF switch	Use the specified onboard part or a compatible external switch wired to the designated switch connections. Enable slide-switch mode for its intended behavior.
18650 protective cover	Use the cover matching the single-cell assembly. Confirm contact insulation, battery access and cooler/SSD clearance.
Dedicated system enclosure	Select the enclosure for the fitted Standard/Advanced board, battery arrangement, SSD, cooler and cable exits.
Advanced application connections	Compatible IR receiver, KEY input, analogue/1-wire connections and serial accessories where fitted. Check interface level, pinout and software support separately.
Serial level converter	The documented serial connection is 3.3 V logic. A true RS-232 connection requires a suitable converter; never connect ± RS-232 levels directly.

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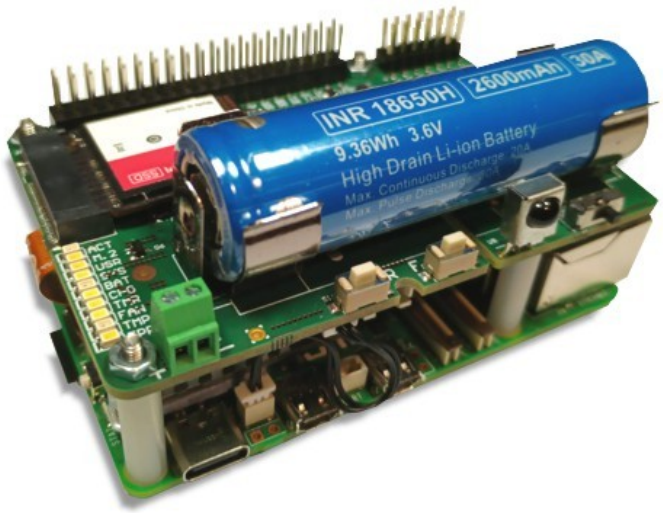
Image 1 M.2 accessory set with the dedicated RTC cable, slide switch, battery cover and matching connectors identified.

Prepare an application extension

Disconnect cable and battery power before attaching hardware. Identify supply, ground, signal direction and maximum signal voltage from the board-specific connection drawing. Check the accessory's pinout independently of its wire colors. Route and secure wires away from the fan, battery contacts, SSD and underside components.

Commission one extension at a time, first under cable power and then with the intended power transitions. Keep the normal shutdown daemon active. Application code must not compete with its shutdown/RTC ownership or repeatedly write reserved registers.

Advanced assembly configurations



Advanced model with a single 18650 battery

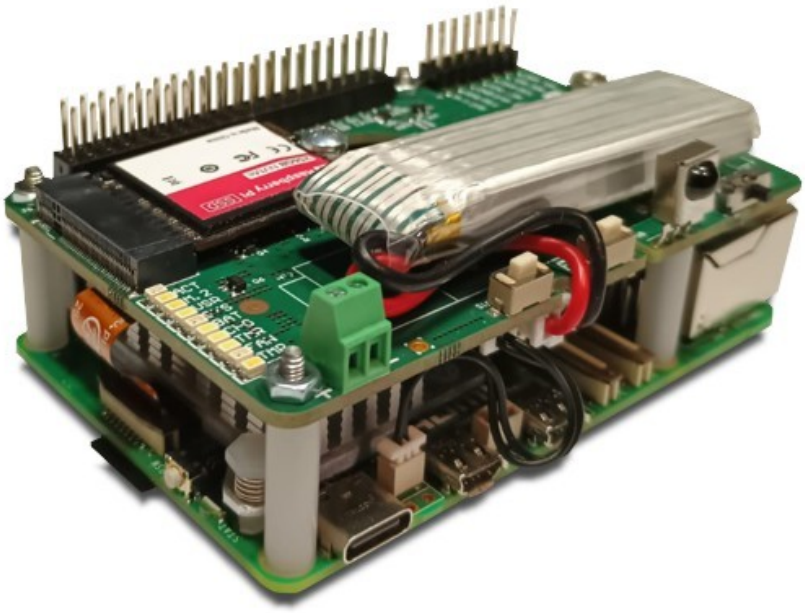
This assembly uses the single-cell 18650 holder. Select the battery profile matching the cell chemistry; 18650 identifies a physical cell size, not its chemistry. The protective-cap configuration shown on the front cover uses the same holder.

Supported backup sources

Only the following four backup sources are supported. Use one backup source at a time and select the corresponding profile before enabling charging.

Backup source	Code	ASCII value
LiPo battery	L	0x4C
Li-ion battery	I	0x49
LiFePO4 battery	F	0x46
Supercapacitor 4000 F / 4.2 V	C	0x43

Ultra high current battery configuration



Advanced model with a 650 mAh ultra high current battery

The cable-connected 650 mAh ultra high current battery is an alternative to the cell in the 18650 holder. Capacity is expressed in mAh; it is separate from charging current, expressed in mA. Use the profile specified for the fitted battery and observe the connector polarity.

Do not connect this battery and a cell in the 18650 holder at the same time. Battery capacity and discharge capability must suit the Raspberry Pi, SSD and attached peripherals. The maximum charging-current specifications remain 580 mA for Standard and 1.1 A for Advanced. Battery Charger is starting and stopping automatically.

Battery and supercapacitor installation

Battery selection and capacity

Choose the backup source by chemistry, usable energy, continuous discharge capability, protection circuit, connector and physical fit. Capacity in mAh alone does not establish that a battery can supply Raspberry Pi 5 and an SSD. Use one approved source and its matching firmware profile.

Source	Specification for selection	Profile
Standard cable battery	Protected 3.7 V, 650 mAh, 15C LiPo specified for the system. Leads and protection must support the complete load.	L / 0x4C
Single 18650 Li-ion	One protected compatible cell. Capacity and permitted current are those on the selected cell's data sheet; confirm actual length and holder fit.	I / 0x49
Compatible LiPo assembly	Use the approved cable/holder arrangement and its labelled voltage, capacity and discharge rating. A cylindrical package does not define chemistry.	L / 0x4C
Compatible LiFePO4 assembly	Use a cell and holder/cable approved for the board, with the correct chemistry-specific charging profile.	F / 0x46
Designated supercapacitor	Use the matched 4000 F / 4.2 V assembly and factory profile, not an arbitrary capacitor with the same capacitance.	C / 0x43

The 18650 name identifies a cell format, not a guaranteed protected-cell length or current rating. Check the actual cell dimensions and the assembled clearance. The listed 650 mAh pack is the defined standard pack; other capacities are not implied to be supplied or approved by this manual.

PICTURE IS MISSING

Image 2 Approved battery variants beside their labels, with connector polarity, actual dimensions and continuous-discharge ratings visible.

Charging-current choice

Standard charging is limited to 580 mA; Advanced charging is limited to 1.1 A. These are board limits, not a requirement to charge every cell at that current. Select a source whose permitted charge current is compatible, and use the corresponding approved configuration. The controller may reduce charging when input power is limited.

Fit the cable battery or single cell

1. Shut Linux down normally. Disconnect external power and the backup source before handling connectors or holders. Remove conductive tools, jewellery and loose hardware from the battery area.

2. For the cable battery, inspect the XH 2.5 mm mating connector, lead condition and polarity against the marked board connection. Use the correct prewired connector; do not infer polarity solely from a third-party plug shape.

3. For the 18650 arrangement, inspect the contacts and insulation and confirm the cell's chemistry, polarity and physical fit. Insert only one compatible cell, in the marked direction, without forcing it or damaging its wrapper.

4. Use either the cable battery connection or the 18650 holder. Never connect a cable battery and a cell in the holder together. Keep unused contacts insulated and fit the appropriate cover.

PICTURE IS MISSING

Image 3 Close-up of the cable battery socket and single-cell holder, with positive/negative markings and the two alternative connection routes.

5. Secure the pack or holder so the leads cannot reach the cooler, sharp PCB edges or SSD hardware. Confirm that the holder/cover cannot touch exposed conductive parts when the enclosure is closed.

6. Verify the source profile against the fitted chemistry before permitting charging. Do not experiment with profile changes while an unknown or incompatible source is connected. Use the configuration intended for the supplied assembly.

First charge and acceptance

Apply cable power and observe normal startup. Confirm cable-mode recognition, charging permission and actual charging behavior; permission alone is not proof of charging current. The reported current-limit value is also not a direct current measurement. Inspect supply and battery temperature during the first charge.

A complete charge time cannot be predicted from capacity divided by the maximum board current alone. Charge taper, starting state of charge, load sharing, source limits and temperature all affect it. Charge adequately before the timed FSSD and repeated restart tests, and record the battery used with those results.

Install and test the 4000 F option

Use the designated M.2 supercapacitor assembly and its matched C / 0x43 profile. Verify the module's rated voltage, polarity, connector, mounting and factory configuration from the supplied assembly label/drawing. Do not substitute an unapproved part or combine it with an alternative backup source.

A supercapacitor may remain charged after external power is removed. Disconnect it before fitting other parts and follow the assembly's discharge instructions before handling exposed contacts. Never discharge it by shorting its terminals with a tool.

PICTURE IS MISSING

Image 4 Designated 4000 F assembly fitted to the M.2 system, showing polarity, insulation, fixing points and the approved connection.

Charging and startup

Start under stable cable power. An initially discharged source needs charging before it can provide a useful outage reserve. Allow charging to reach the expected ready condition for the matched assembly; do not judge readiness from elapsed time alone. Repeat tests only after restoring a comparable charge level.

Supercapacitor energy and battery equivalence

For a nominal effective capacitance of 4000 F charged to 4.2 V, the ideal stored energy is $E = ½ \times C \times V^2 = 35{,}280$ J = 9.80 Wh. Dividing by a 3.7 V nominal Li-ion battery voltage gives an energy-equivalent capacity of 2.65 Ah (about 2650 mAh). This total includes energy below the UPS operating range; it is not the usable backup capacity or a recommendation to discharge the module to 0 V.

The V8B5 C profile uses a nominal 2.8 V low-source threshold to request FSSD. Between 4.2 V and 2.8 V, $E = ½ \times 4000 \times (4.2^2 - 2.8^2) = 19{,}600$ J = 5.44 Wh, equivalent in energy to about 1470 mAh at 3.7 V before conversion losses. With an illustrative 85% conversion efficiency, the regulated output receives about 4.63 Wh. Runtime t = 60 × 4.63 / load in watts gives the estimates below; 85% is an assumption, not a measured board efficiency.

Constant output load	Estimated time, 4.2 to 2.8 V at 85%
5 W	About 55.5 minutes
10 W	About 27.8 minutes
15 W	About 18.5 minutes

These are constant-capacitance energy estimates, not measured runtime guarantees. Confirm the effective capacitance over this voltage range for the supplied assembly; voltage-dependent capacitance, ESR, temperature, ageing and converter losses affect the result. A configured runtime timer can request shutdown earlier. The 2.8 V threshold starts FSSD, not an instantaneous power cut: retain reserve for Linux shutdown and the final power sequence. Validate the complete Pi/SSD assembly under its actual load.

Power supply unit recommendations

The external supply must power Raspberry Pi 5, SSD, attached peripherals and battery charging at the same time. Choose a suitable Raspberry Pi 5 USB-C supply and cable; the system guidance calls for at least 3 A and preferably 5 A where the workload requires it. Confirm the supply's actual capability and connector rating, not only the marking on an extension cable.

Estimate the complete power budget

As an illustration, a 5 V, 5 A source has a nominal 25 W budget. An assumed 10 W Pi load, 3 W SSD, 2 W peripherals and 5 W allocated to charging/conversion total 20 W, leaving 5 W nominal margin. These are example assumptions, not measured loads or guaranteed board output ratings; measure the real assembly and allow for startup peaks and cable losses.

Standard and Advanced have different maximum charging currents. Charging power and converter loss must be included in the input budget. If the source is marginal, the controller may reduce charging or report repeated battery/cable transitions even while the cable remains attached.

Choose the correct power input

For ordinary USB-C operation, connect the source to Raspberry Pi 5 as documented. On Advanced, use 5–32 V only at the designated EPR or approved passive-PoE input arrangement, observing its polarity and order-specific connection. Never apply that higher voltage to the Raspberry Pi 5 V header, RTC input or a signal connector.

PICTURE IS MISSING

Image 5 USB-C and Advanced external-power connections, with connector polarity, permitted input locations and cable routing identified.

Check voltage drop under load

Use short, suitable power leads and sound connectors. Test with the SSD active, peripherals connected and charging enabled. Capture cable/battery mode changes, reduced charge current, Linux undervoltage indications and resets. A lightly loaded idle test cannot establish that the supply is adequate during charging or storage activity.

```
vcgencmd get_throttled
sudo journalctl -k -b --no-pager | grep -Ei "voltage|under.?voltage|power"
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
```

Resolve the source/cable problem before repeating outage tests. A successful backup transition is not evidence that the cable supply has enough continuous power for the intended workload.

Assembly of the Magic ON/OFF Switch

Fit the onboard ON/OFF switch

These instructions apply to a kit or board intentionally supplied for user assembly. If the switch and connectors are factory fitted, inspect them rather than removing or reheating them. Work with USB-C, all other external supplies and the backup source disconnected.

1. Identify the dedicated slide-switch footprint and the specified switch. Check orientation, mounting tabs, travel and enclosure access before soldering. The optional switch is an application control, not a contact for switching the full Pi supply current.

2. Seat the part squarely and mechanically support the board. Tack one joint, recheck alignment and free movement, then solder the remaining required joints without bridging adjacent pads.

PICTURE IS MISSING

Image 6 Onboard slide switch positioned in its M.2 footprint before soldering, showing orientation and OFF/ON travel.

3. Inspect both PCB sides for bridges, splashes and excessive protruding leads. Trim only where the assembly requires it and remove loose cuttings. Operate the switch through its full travel and confirm that it cannot contact the case or battery.

4. Before enabling switch mode, place the switch ON so that selecting the mode does not immediately request a deliberate OFF shutdown. Use the Intelligent mobile power bank and slide switch chapter to configure and read back the operating mode.

Use an external switch

Use the specified switch connections and the approved contact arrangement. Transfer every required contact according to the M.2 assembly drawing; do not assume that two arbitrary pads are a simple power switch. Check the contact mapping with power removed and keep the control wiring away from supply and fan wiring.

PICTURE IS MISSING

Image 7 External switch wiring diagram showing each board contact, the matching switch terminal and both switch positions.

After assembly, test ON/OFF with cable present and absent. OFF must produce the intended orderly shutdown and inhibit an unwanted restart in switch mode. Return to normal timed UPS mode if the switch is not being used. This test assumes a working Linux shutdown daemon.

Assembly of the THT 40 Pins Connector

Use the correct 2 × 20 connector supplied for the board and its intended stacking height. Confirm pin-1 orientation, gender, lead length and mechanical clearance against the fitted M.2 assembly. Do not substitute a header whose long ends can touch the battery, cooler or Raspberry Pi components.

1. Disconnect all sources. Inspect the PCB connector footprint, pads and surrounding components. Verify that a factory-fitted socket/header is not being mistaken for an unpopulated assembly location.

2. Align all 40 pins before insertion and support the connector body evenly. For an assembly designed to pass through an existing socket, keep the pins straight and follow that socket's guide alignment. Do not force a bent pin or press on an unsupported PCB.

PICTURE IS MISSING

Image 8 Correct 40-pin connector orientation and pin-1 alignment, shown from the top and mating side of the M.2 board.

3. Seat the connector to the intended height. Tack two diagonally opposed joints where the design calls for soldering, check that the connector is square and parallel, then complete the remaining joints.

4. Inspect every joint for wetting, bridges and loose solder. Check clearance on both sides. Trim leads only if the specified connector/assembly calls for it; do not shorten the functional mating section of a stack-through header.

PICTURE IS MISSING

Image 9 Finished 40-pin joints and connector seating height, with an example of the required underside clearance.

Inspect before powering

With sources disconnected, check for solder bridges and unintended continuity between adjacent supply and ground contacts. Mate the assembly carefully without a one-row or one-column offset. Confirm spacers support the boards and that no connector force is carried by the Pi-button spring contact. Apply cable power first and inspect normal startup before connecting extra loads.

Assembly of the Gold-Plated POGO Pin

The Pi-button contact must meet the designated Raspberry Pi 5 power-button connection used by this M.2 assembly. It is not an instruction to contact an older Raspberry Pi RUN or PEN pad. Identify the correct point from the Raspberry Pi 5/M.2 drawing before fitting the pin.

1. Disconnect external power and the backup source. Fit the correct spacers and temporarily assemble the boards without soldering the contact. Check the available gap, contact centre and clearance from neighbouring copper and components.

PICTURE IS MISSING

Image 10 Raspberry Pi 5 power-button contact location and the matching POGO position on M.2, with the contact centre marked.

2. Fit the specified spring contact in its intended orientation. The spring tip must touch the correct point when the boards are fully supported by their spacers. It must have working travel and must not be rigidly bottomed out, tilted or used as a structural spacer.

3. Where soldering is required, tack the board-side joint while maintaining alignment. Remove power-free trial assemblies as necessary to inspect seating. Complete the specified joint without allowing solder to enter the spring mechanism or contact tip.

PICTURE IS MISSING

Image 11 Side view of the fitted spring contact, showing the supported board spacing, contact alignment and remaining spring travel.

Final mechanical check

Reassemble with the intended SSD, cooler, battery cover and case. Verify contact engagement without PCB bending and confirm that tightening the case does not create a permanent button press. Do not copy spring compression dimensions from another Pi model; use the specified M.2 contact and spacer stack.

Check the power-control function

Start under cable power with the normal Linux daemon running. Verify normal heartbeat, then perform the documented FSSD and power-return cycle. Repeat with the final enclosure fitted and, where used, switch OFF/ON. A Pi that stays in standby or stops unexpectedly can indicate a misaligned or continuously pressed contact; disconnect power and inspect it before altering firmware settings.

A static voltage check alone does not establish correct pulse timing or mechanical contact. When diagnosing a failure, record the actual Raspberry Pi button signal and the serial log around the event. The POGO tip and an internal transistor control point are different measurement locations.

Installation step by step

Complete the hardware preparation and assembly under stable cable power. For Linux setup, choose either the Automatic Linux installer chapter or manual Steps 3–6 below. Steps 7–10 verify operation after either route. Do not run both software setup routes on the same card without reviewing the existing configuration.

Step 1 — Prepare the hardware and operating system

1. Identify the HAT model, PCB revision and firmware supplied with it.

2. Confirm the battery type, polarity and intended backup connector.

3. Check the SSD is a supported PCIe M-key device and select its fixing point.

4. Identify the 16-contact FPC, its contact orientation and both latches.

5. Check spacer heights, cooler clearance and the Pi power-button connection.

6. Keep RESET, FSSD and the optional slide switch accessible for testing.

Software preparation

Boot Raspberry Pi OS from a working microSD or NVMe installation. Confirm network or console access before relying on UPS-controlled shutdown.

```
cat /etc/os-release
uname -a
lsblk -o NAME,SIZE,FSTYPE,MOUNTPOINTS
lspci
```

Back up the operating system and application data before changing storage or power configuration. Verify the selected NVMe device and boot order separately from UPS installation.

Install the hardware, enable I²C, configure the UPS RTC and start the service before performing a cable-loss test.

The latest image of an SD card is available in the download section in ***www.pimodules.com***.

Step 2 — Assemble and inspect the boards

Disconnect cable and battery power before assembly. Use the sequence below, then compare the finished assembly with the hardware figures in this chapter.

Connect a suitable external source before relying on battery startup. The battery isolation and start conditions depend on the assembly. Confirm the MCU startup banner, Linux boot and correct power mode; do not interpret a momentary startup transition as a completed test.

Mechanical assembly

1. Shut down the Raspberry Pi. Remove the USB-C supply, all other power sources and the UPS battery.

2. Fit the Raspberry Pi official cooler and the correct spacers. Keep the cooler air path and the HAT ventilation opening clear.

3. Install a compatible M-key PCIe SSD. Use the fixing point for its length and secure it without bending the board.

4. Fit the HAT onto the 40 pin connector without a one-row or one-column offset. Secure the assembly with the appropriate spacers and screws.

5. Connect the PCIe FPC with the correct orientation at both ends. Open and close the connector latches carefully; do not force the cable. For easy installation fit it first to the Raspberry Pi and then after assembly to the **M.2 UPS PMH** socket**.**

6. Verify the Raspberry Pi power-button contact (POGO PIN) or cable arrangement where fitted. Check clearance around the battery holder, SSD and case.

7. Connect one approved battery with correct polarity. Recheck the selected chemistry before permitting charging.

First power-up checks

Apply external cable power first. Observe the startup indication and confirm that the Raspberry Pi boots. Install or check the Linux service before testing removal of external power. Keep a local serial capture available during initial commissioning.

```
uptime
sudo systemctl status M2_PMH_i2c.service --no-pager
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
```

Verify that the service reports successful I^2C reads and that new errors are not accumulating. Confirm the battery is charging under stable cable power. Do not begin repeated power-cycle tests while the battery state or supply quality is uncertain.

SSD boot configuration is a separate Raspberry Pi task. Confirm the intended SD or NVMe boot path before testing UPS shutdown and restart.

Hardware connections top view

Top view of the Advanced assembly, showing the SSD area, controls, power connections and application interfaces.

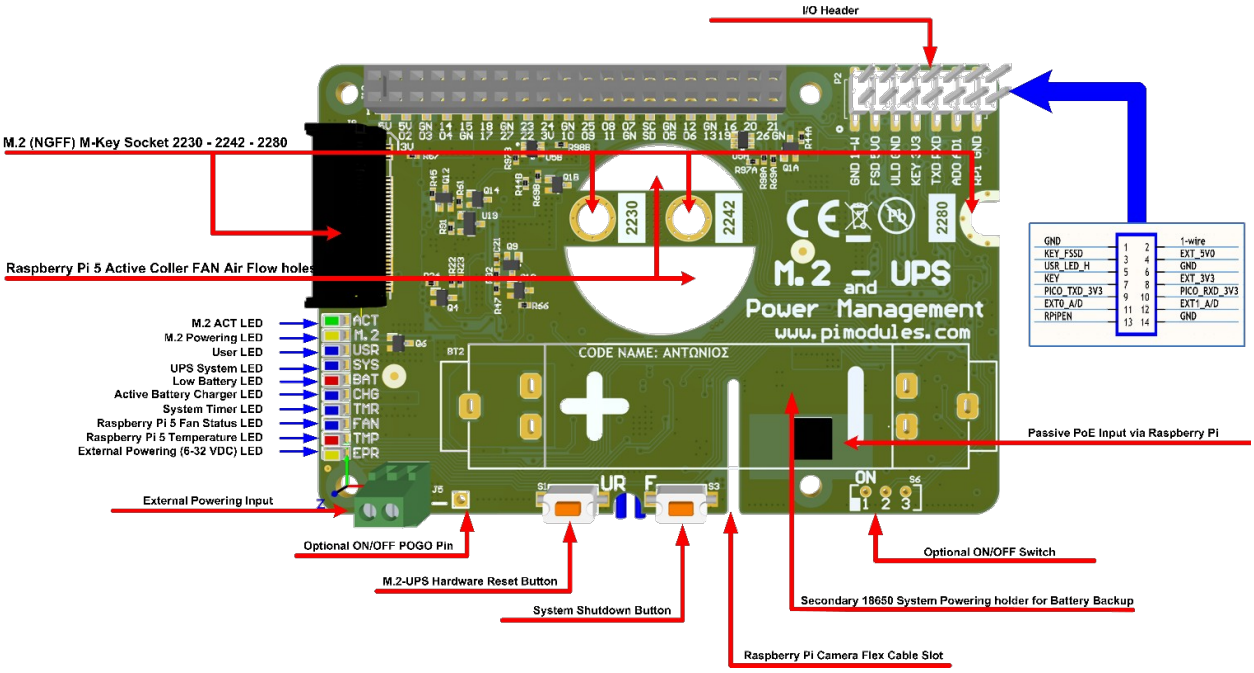


Figure 2 Advanced board top view with original reference annotations

How to use this view

Locate the socket and fixing point for the selected SSD length before fitting the SSD. Keep the central cooler opening clear. Locate RESET and FSSD before commissioning, and make sure a case does not hold either button down.

Use the board labels to identify each connection. KEY is an application input on the Advanced model. Bootloader entry uses only M.2 RESET and FSSD and is available on both Standard and Advanced.

The battery footprint shows polarity markings. Check the markings on the actual fitted holder and battery connector. The external-power terminal shown is an Advanced feature, not a Standard-model connection.

Hardware connections underside view

This underside view shows the controller and power circuitry, PCIe FPC connector, battery socket and the external interface locations. Check that spacers, screws and the Raspberry Pi cooler cannot contact exposed components.

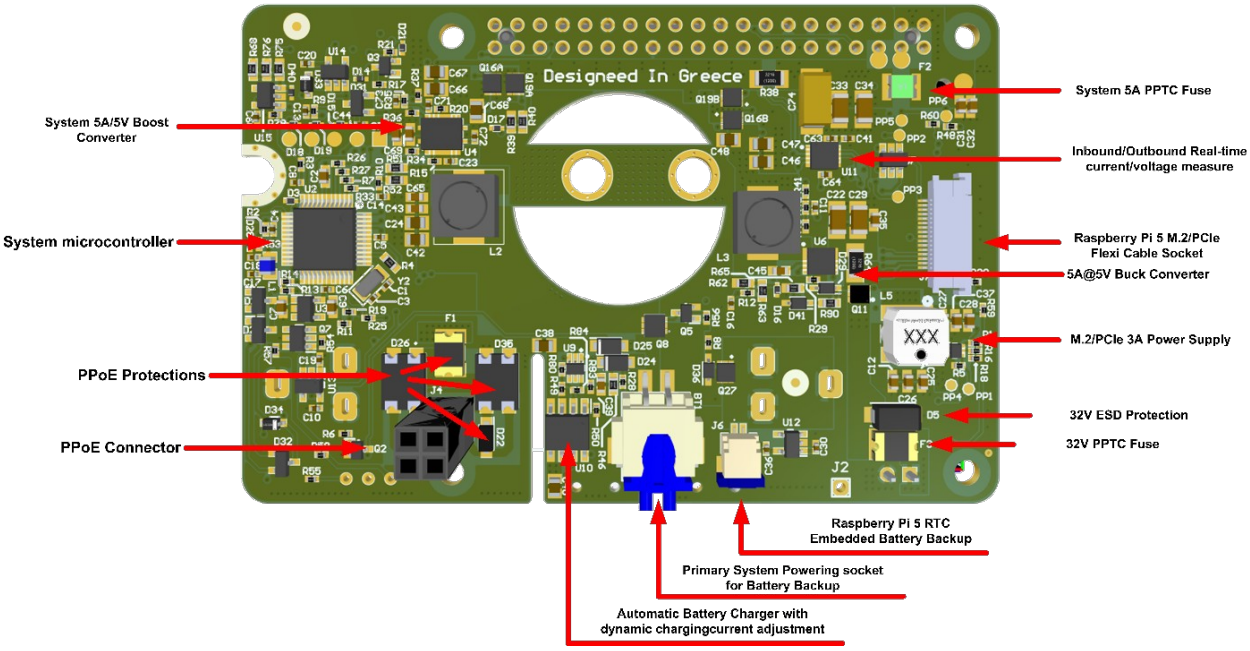


Figure 3 Advanced board underside with original reference annotations

Connections to inspect before assembly

Verify the PCIe cable orientation while the connector is accessible. Confirm the intended battery connection and the Raspberry Pi RTC backup cable route. If the power-button contact is fitted, verify its alignment and insulation before applying power.

The underside view identifies the battery-holder and board-to-board assembly area. Keep the battery contacts insulated from adjacent boards and metal enclosure parts.

SSD and mechanical assembly illustrations

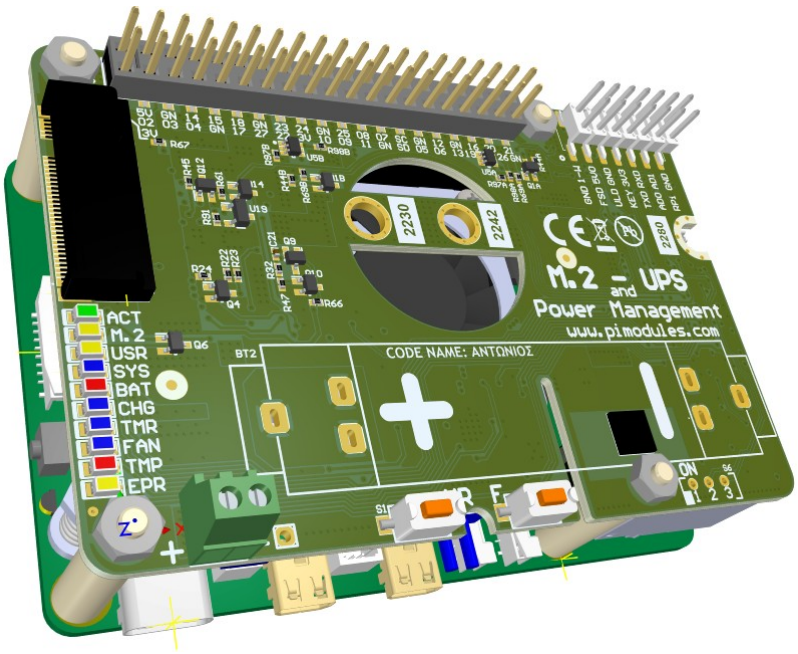


Figure 4 HAT fitted above the Raspberry Pi without battery or SSD

The empty assembly view exposes the SSD mounting positions, central air opening, indicator labels and front controls. It is useful for checking access before fitting the battery holder and storage.

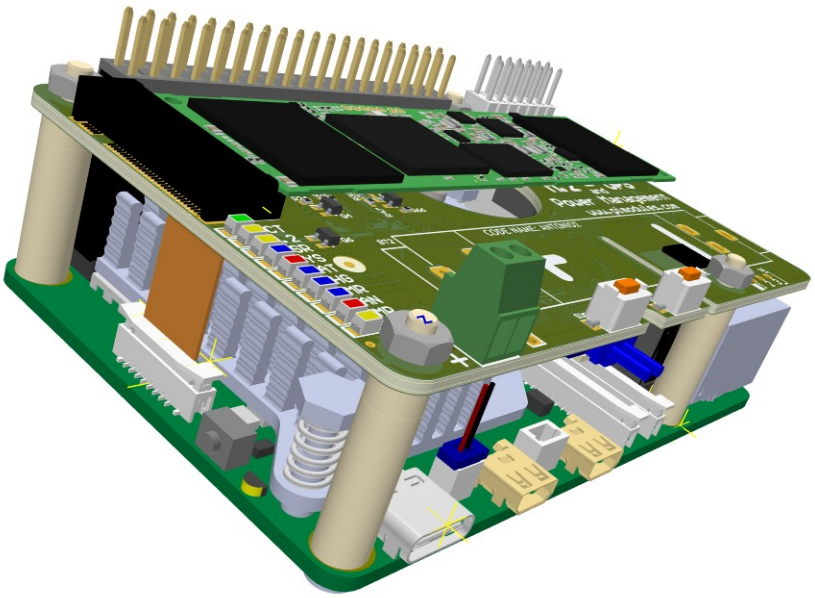


Figure 5 SSD installed with cooler and inter-board spacing visible

Keep the SSD fixing screw, cable bend and cooler opening clear of the battery and enclosure. Secure the assembled boards without bending either PCB.

Power supply and battery preparation

Prepare the external power supply and one compatible backup source before first use. The following steps cover the battery connection, charging profile, safety checks and supply capacity needed by the Raspberry Pi 5, SSD and attached peripherals.

Choose the correct backup source

Use either the cable battery connector or the single-cell 18650 holder. Do not populate both at once. The specified cable connector is XH 2.5 mm. Check polarity at the board and battery; a connector that physically fits is not sufficient evidence of electrical compatibility.

Only these backup sources are supported: LiPo (L, 0x4C), Li-ion (I, 0x49), LiFePO4 (F, 0x46), and the designated 4000 F / 4.2 V supercapacitor (C, 0x43). Select the profile matching the fitted source before charging. Other battery chemistries and backup-source codes are not supported.

The standard battery specification is a protected 3.7 V, 650 mAh, 15C LiPo with suitable high-current leads. Use the charging profile matching the fitted backup source.

Handle batteries safely

Disconnect external power and the battery before mechanical work. Prevent short circuits and reverse polarity. Do not use damaged, swollen or overheated cells. Keep the cell clear of sharp component leads, SSD heat and moving fan parts. Stop operation if abnormal temperature, smell or swelling occurs.

Provide enough supply margin

The external supply must support the Raspberry Pi, SSD, peripherals and charging demand. A marginal supply can cause repeated cable/battery transitions or reduce charging current. The charging algorithm adjusts demand to available power; maximum charge current is not maintained under every condition.

Use an appropriate Raspberry Pi 5 USB-C supply and suitable cables minimum 3A, preferable 5A. Apply 5–32 V only to the designated Advanced EPR or approved passive PoE connection. Never apply that voltage range to the Raspberry Pi 5 V header or an application input.

Runtime planning

Battery runtime depends on usable battery energy, discharge limits, converter efficiency and the complete load. A programmed runtime limit specifies when shutdown begins; it is not a promise that the battery can sustain that interval. Low-battery protection can shorten operation.

Step 3 — Install Linux dependencies and enable I²C

Extract this package into ~/M2_UPS_PMH_Customer_V8B5. Commands below assume Raspberry Pi OS, apt, systemd and the default I²C address group.

```
cd ~/M2_UPS_PMH_Customer_V8B5
sudo apt update
sudo apt install -y python3-smbus i2c-tools util-linux python3-serial
sudo raspi-config nonint do_i2c 0
```

The daemon imports the distribution smbus module. A separate pip environment is not required for this installation. The service runs with the privileges needed for I²C, RTC access and system shutdown.

Enable the I²C interface

```
sudo raspi-config
```

Select Interface Options, then I²C and enable it. On current Raspberry Pi OS, configuration is normally stored in /boot/firmware/config.txt. If using another image, confirm its active boot configuration path before editing.

```
ls -l /dev/i2c-*
sudo i2cdetect -l
```

After applying the interface change, reboot when requested by the configuration tool. Keep stable cable power connected. A raw I²C scan should not be used as a continuous health monitor; the daemon logs provide the routine communication check.

Confirm the configured bus

The daemon uses bus 1 on GPIO2 SDA and GPIO3 SCL. Other overlays or a changed address group require corresponding software changes. Do not move the wiring or change the API address merely because the scan shows several adjacent addresses.

Preserve existing boot settings

```
sudo cp /boot/firmware/config.txt \
  /boot/firmware/config.txt.before-m2-pmh
```

Step 4 — Configure and identify the UPS RTC

Add the RTC overlay

At the default address group, the UPS exposes a DS1307-compatible RTC at 0x68. Add the following line under an applicable [all] section of the active boot configuration, without duplicating an existing entry.

```
sudo nano /boot/firmware/config.txt
```

```
[all]
dtoverlay=i2c-rtc,ds1307
```

If the same section already contains an I²C setting, preserve it. The explicit interface setting, when needed, is dtparam=i2c_arm=on. Do not put the RTC overlay under a section that applies only to another Pi model.

Reboot and identify the RTC

```
sudo reboot
```

After reconnecting over SSH, inspect the RTC names. The Raspberry Pi 5 already has its own RTC, so the UPS is often rtc1, but enumeration must be checked rather than assumed.

```
ls -l /dev/rtc*
for d in /sys/class/rtc/rtc*; do
  echo "$d"
  cat "$d/name"
done
```

The expected UPS name includes rtc-ds1307 and 1-0068. A driver claiming address 0x68 may appear as UU in an I²C scan. This is normal kernel ownership, not evidence of a missing device.

If no UPS RTC appears

```
sudo journalctl -k -b --no-pager | \
  grep -Ei "rtc|i2c|SDA|probe"
```

Confirm the overlay, I²C bus and bank selection. Save any probe failure. For the specific case of an existing, unbound 1-0068 device, the recovery binding command is documented in the RTC chapter. Do not create a duplicate I²C device or force raw access to a kernel-owned address.

Step 5 — Install the shutdown daemon

Copy the matching script

From the extracted package root, use the files in installation/. On an existing installation, back up the current service and deliberate overrides before replacing them.

```
cd ~/M2_UPS_PMH_Customer_V8B5
sudo install -m 0755 installation/M2_PMH_i2c.py \
  /usr/local/sbin/M2_PMH_i2c.py
```

```
python3 -c "from smbus import SMBus; print('smbus OK')"
python3 - <<'PY'
import ast
from pathlib import Path
ast.parse(Path("installation/M2_PMH_i2c.py").read_text())
print("syntax OK")
PY
```

A syntax check does not validate the firmware protocol or power-control wiring. Use only the script intended for this hardware and application release.

Do not run duplicate daemons

If the service is already installed and healthy, retain its existing unit and review it with systemctl cat. Reinstalling or restarting is unnecessary merely to check the system. A second daemon or a foreground check can compete with the active service for bus access.

```
sudo systemctl cat M2_PMH_i2c.service
pgrep -af M2_PMH_i2c.py
```

Optional read-only check

On a new installation with no daemon running, the supplied script provides a ten-second check mode. It reads the heartbeat without acknowledging shutdown, writing temperature data or synchronizing the RTC. It does not provide operating-system shutdown protection.

```
sudo /usr/bin/python3 /usr/local/sbin/M2_PMH_i2c.py --check
```

Keep external power connected during this check. After it completes, install and enable the normal service before testing an outage.

Step 6 — Install and enable the systemd service

Install the supplied unit. For a service already running, replace its files under cable power and restart it promptly after installation.

```
sudo install -m 0644 installation/M2_PMH_i2c.service.txt \
  /etc/systemd/system/M2_PMH_i2c.service
```

```
[Unit]
Description=M2 PMH I²C heartbeat and shutdown daemon
After=systemd-modules-load.service

[Service]
Type=simple
User=root
ExecStart=/usr/bin/python3 /usr/local/sbin/M2_PMH_i2c.py
Restart=on-failure
RestartSec=2

[Install]
WantedBy=multi-user.target
```

Restart=on-failure allows recovery from a program failure without automatically restarting the daemon after its normal shutdown path. The service does not need to wait for network synchronization before starting I²C polling; its RTC task waits separately for NTP.

Start the service

```
sudo systemctl daemon-reload
sudo systemctl enable --now M2_PMH_i2c.service
sudo systemctl status M2_PMH_i2c.service --no-pager
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
```

Expected startup messages identify daemon v1.6, the 250 ms heartbeat, bus 1 and address 0x6B. Temperature/fan telemetry follows after compatible firmware identification. If NTP is not yet confirmed, the RTC task waits while heartbeat polling continues.

Existing overrides

Use systemctl cat to review drop-in files. An override that supplies --no-rtc-sync prevents automatic RTC updates even if the main unit omits that option. Preserve deliberate site settings and change only the relevant option.

Step 7 — Verify heartbeat, time and charging

M2_PMH_i2c.service polls bus 1, address 0x6B, register 0x00 every 250 ms. Keep the service enabled whenever UPS-controlled shutdown is required.

Check the running service

With the installation complete, confirm that systemd reports the service active and that successful-read totals increase by approximately 240 each minute.

```
sudo systemctl enable M2_PMH_i2c.service
sudo systemctl start M2_PMH_i2c.service
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
```

The installed script is /usr/local/sbin/M2_PMH_i2c.py. A service restart interrupts heartbeat traffic briefly; perform maintenance while cable power is present.

Check the integration settings

```
sudo systemctl cat M2_PMH_i2c.service
timedatectl status
ls -l /dev/rtc*
```

RTC synchronization waits for confirmed NTP synchronization, then writes Linux UTC time to the UPS RTC and repeats hourly. The heartbeat continues while synchronization waits.

Step 8 — Select normal UPS or slide-switch operation

```
sudo i2cget -y 1 0x6b 0x0c b
sudo i2cget -y 1 0x6b 0x01 b
```

Normal UPS operation reads 0x00 and 0x01. Slide-switch operation reads 0xAA and 0xFF. Use the switch configuration chapter to change mode.

Step 9 — Test battery takeover and shutdown

With the battery charged and the service active, remove cable power. Raspberry Pi and the SSD remain running. In normal mode the controller requests FSSD after about 70 seconds, then allows about 30 seconds for shutdown. Keep the battery connected.

Step 10 — Test power return and the optional switch

Reconnect cable power after shutdown and check normal startup. Repeat with cable return during FSSD. If switch mode is enabled, verify OFF prevents startup with cable connected and ON permits it. Complete at least five successive cycles, then inspect the service journal for accumulating errors.

Automatic Linux installer

Installer V08 prepares Raspberry Pi OS for heartbeat and shutdown, CPU/fan telemetry, RTC synchronization, monitoring, configuration and serial firmware updates. It supports first installation and reviewed upgrades from earlier releases. Hardware assembly, source selection, firmware programming and power-loss tests are separate tasks. It installs the 1-Wire reader but does not enable GPIO4 automatically. Enable the optional interface separately when a sensor is fitted.

Supported system and validation status

Use Raspberry Pi 5 Model B, Raspberry Pi OS Bookworm or Trixie, Python 3, apt and systemd. Debian/raspbian version 12 or newer is accepted. This edition accompanies application V8B5 (0x08B5) and the unchanged protected loader V88.

Installer V08 passed 41 simulated host-side installer tests. A previous managed upgrade and post-reboot check were reported successful on Raspberry Pi 5 with Debian 13. The current V06 package installs daemon v1.6, configurator 06 and monitor 0B. Complete --check and the commissioning tests on the actual card and assembled hardware.

Prepare the card and hardware

1. Write Raspberry Pi OS to the microSD card using Raspberry Pi Imager. Set the user name, password, SSH access, network and Wi-Fi country where applicable. Boot Linux and confirm SSH access before starting this procedure.

2. With all power disconnected, assemble the Raspberry Pi and M.2 board, including the 40-pin connection, Pi-button control contact or cable, cooler, spacers and SSD/FPC where used. Connect one approved backup source with correct polarity and matching chemistry.

3. Reconnect a stable cable supply and keep it connected through installation, reboot and verification. Internet access is needed for the initial apt package installation. Do not begin a cable-loss test until the final check and charging verification have passed.

Files supplied in this package

The installer/ directory contains install_M2_UPS_PMH.py, six payload files (daemon, service unit, status monitor, configurator, 1-Wire reader and updater), checksum manifest, instructions and tests. Keep the script and payload/ together. A standalone installer V08 archive is also supplied.

The installer has no graphical interface. Run it from SSH with sudo and the distribution Python. A separate pip installation, virtual environment or desktop session is not required.

Install or upgrade the Linux software

Copy M2_UPS_PMH_Manual_V98.zip to the Raspberry Pi home directory. It extracts to M2_UPS_PMH_Customer_V8B5 and contains both the manual and the matching installation files. The --upgrade option also supports a clean first installation.

```
cd ~
unzip -o M2_UPS_PMH_Manual_V98.zip
cd ~/M2_UPS_PMH_Customer_V8B5/installer
sudo python3 install_M2_UPS_PMH.py --upgrade
```

Alternatively, extract the included standalone M2_UPS_PMH_Installer_V06.zip and run the installer from M2_UPS_PMH_Installer_V06. Choose one route and retain the extracted folder for later checks, upgrades and removal.

What happens during installation

The installer verifies payload checksums, Raspberry Pi model, operating-system support, systemd and the actual boot configuration. It detects existing managed state, recognized manual and legacy services, their overrides and running scripts. --detect reports these without changing configuration. Unknown conflicts stop installation before protection is removed.

It runs apt-get update, then installs python3-smbus, python3-serial, i2c-tools and util-linux. This is not a full operating-system upgrade. With --no-apt, those dependencies must already be present. Python imports are checked before changing the boot configuration or daemon files.

Where the I²C device and tools are already available, it reads the supply-mode status before continuing. A reported battery mode stops installation and asks for cable power. Absence of this early read on a clean card does not prove that the power supply is suitable; stable cable power is still required.

The installer saves original files and service states, updates managed boot/module settings and installs the daemon, service, monitor, configurator and updater. During replacement it stops the existing service and starts the new one promptly. A repeated installation can restart the daemon; keep cable power connected throughout.

Finally, it enables and starts M2_PMH_i2c.service, reserves the selected serial port from its Linux console/getty when UART setup is enabled, and attempts to load i2c-dev. It records installation state and whether boot changes require a reboot.

Restart only after installation succeeds

A successful install command means that the Linux files were installed and the service started. It is not the final hardware check. If REBOOT REQUIRED is printed, reboot while cable power remains connected. The installer does not reboot automatically.

```
sudo reboot
```

SSH disconnects during reboot. Reconnect after Linux has started, then use the check procedure below. If installation prints ERROR, retain the output and resolve that error before treating the installation as complete.

Boot configuration and installed files

The actual boot file is selected as /boot/firmware/config.txt where present, otherwise /boot/config.txt. The installer appends one marked block under [all], enabling I²C and adding the DS1307-compatible RTC overlay and uart0-pi5 overlay where equivalent supported settings are not already present. Other configuration is preserved.

dtparam=i2c_arm=on
dtoverlay=i2c-rtc,ds1307
dtoverlay=uart0-pi5
dtparam=rtc_bbat_vchg=0

The uart0-pi5 line is omitted with --no-uart or an equivalent supported setting. The final RTC line disables Pi RTC charging, overriding earlier settings, including includes. M.2 supplies regulated 3.3 V; config.txt does not set that voltage. Reboot to apply.

Installed path	Purpose
/usr/local/sbin/M2_PMH_i2c.py	Existing daemon v1.6; heartbeat, shutdown requests, CPU temperature and RTC synchronization.
/etc/systemd/system/M2_PMH_i2c.service	Starts the daemon automatically at boot; enabled by the installer.
/opt/M2_UPS_PMH/M2_PMH_status.py	Optional read-only status monitor; not a replacement for the daemon.
/opt/M2_UPS_PMH/M2_PM_UPS_BL01D.py	Existing updater, installed for separate use; never run by the installer.
/etc/modules-load.d/M2_UPS_PMH.conf	Loads i2c-dev during Linux startup.
/var/lib/M2_UPS_PMH/installer.json	Original service/getty states, file hashes, backup references and reboot marker.
/var/backups/M2_UPS_PMH/<UTC timestamp>/	Original versions of files changed by this installation.
/opt/M2_UPS_PMH/M2_PMH_config.py	Installed configurator 06; run with sudo python3.

UART and RTC behavior

On Raspberry Pi 5, uart0-pi5 enables the 40-pin header UART on GPIO14/15 as /dev/ttyAMA0, without RTS/CTS. A console targeting ttyAMA0 is removed from cmdline.txt and its serial getty is masked. An alias is treated the same way only if it resolves to ttyAMA0. The separate ttyAMA10 debug UART is retained.

The daemon identifies the M.2 RTC by rtc-ds1307 and bus/address 1-0068. It waits for confirmed NTP, writes Linux UTC to the RTC, then repeats hourly. The installer itself does not force a clock write or initiate a serial transfer.

Verify after reboot

From the same extracted package, run:

```
cd ~/M2_UPS_PMH_Customer_V8B5/installer
sudo python3 install_M2_UPS_PMH.py --check
```

The check verifies Pi RTC charging is disabled in configuration and, where exposed, at runtime. It tests command-bank reads, requires application 0x08B5 from status word 0x30, checks installed file integrity and reports legacy-service conflicts. It does not scan the bus, transmit serial data or force a clock write.

It finds the M.2 RTC by kernel name and bus/address, checks /dev/ttyAMA0 unless UART setup was excluded, verifies the service and a recent successful heartbeat from its current process, and checks that obsolete services are not active. A UART device node alone does not prove serial wiring or a completed firmware transfer.

NTP synchronization is reported separately. A pending NTP state is informational and does not by itself fail the check: the daemon continues its heartbeat and waits before writing the RTC. A missing interface, absent RTC, failed I^2C read, pending shutdown request, inactive service or missing recent successful heartbeat produces NOT READY and a failed result.

Result / exit code	Meaning
CHECK PASSED / 0	All implemented checks passed. Continue with charging checks and manual commissioning tests.
CHECK NOT PASSED / 2	One or more readiness checks failed. Save the output and resolve the reported cause.
ERROR / 1	Installer precondition, command or file operation failed. Inspect the error and backups.
Interrupted / 130	The command was interrupted. Check state before retrying.

Save the first card test result

```
sudo python3 install_M2_UPS_PMH.py --check 2>&1 | tee M2_install_check.txt
sudo journalctl -u M2_PMH_i2c.service -b -n 25 --no-pager
timedatectl status
```

Retain M2_install_check.txt with the firmware version and test observations. The file captures the text result; a shell pipeline ending in tee does not preserve the Python exit code by default. For an automated pass/fail decision, run --check directly or use shell pipefail.

Before testing a power outage, confirm increasing successful-read totals, adequate battery charge and the intended normal/slide-switch settings. CHECK PASSED does not perform or certify a shutdown, restart, charging-current or battery-capacity test. Continue with installation Steps 7–10 and the Commissioning checks chapter.

Options and repeated installation

Option	Effect
--detect	Read-only inventory of managed and recognized legacy installations.
--upgrade	Install or replace a recognized previous installation, saving backups.
--dry-run	Preview installation/upgrade or uninstall without changes.
--check	Read-only health check; requires application 0x08B5.
--uninstall	Remove installed UPS software; restore supported recorded boot/getty settings; do not restart old UPS daemons.
--no-apt	Skip apt operations; dependencies must already be installed.
--no-uart	Omit UART boot/getty setup where supported.
--help	Display the complete supported command-line syntax.

Use --detect for a read-only inventory and --upgrade --dry-run to review a planned upgrade. Options such as --no-apt and --no-uart apply where supported. Keep cable power connected for changes. Unknown custom installations require review; --upgrade only adopts recognized services and supported installer state.

Rerun without duplicating configuration

sudo python3 install_M2_UPS_PMH.py --detect
sudo python3 install_M2_UPS_PMH.py --upgrade --dry-run
sudo python3 install_M2_UPS_PMH.py --upgrade

V06 upgrades supported managed versions V01 through V05 and recognized manual installations. It retains the original backup set and stores changes before replacement. The managed state is /var/lib/M2_UPS_PMH/installer.json; backups are under /var/backups/M2_UPS_PMH/. External changes to managed boot configuration can block the operation rather than being overwritten.

Uninstall the Linux software

Keep cable power connected. --uninstall removes the installed UPS applications and service, restores recorded boot/module/serial-console settings where supported, and retains dependencies and backups. It does not restore or restart an obsolete shutdown daemon. UPS-controlled Linux shutdown protection is unavailable after removal.

sudo python3 install_M2_UPS_PMH.py --uninstall --dry-run
sudo python3 install_M2_UPS_PMH.py --uninstall

Review the preview and any reported conflicts before removing the software. Reboot when requested to apply restored boot settings. Backup copies and separately copied files in the user home directory remain; these are not automatically launched as a replacement service.

Conflicts and installation failure

Upgrade a recognized manual installation

A recognized service launching /usr/local/sbin/M2_PMH_i2c.py can be adopted with --upgrade. Inspect --detect and the dry-run first. The installer backs up the old script, unit and recognized overrides before installing the current payload. Do not manually remove its state or backup directory.

sudo python3 install_M2_UPS_PMH.py --detect
sudo python3 install_M2_UPS_PMH.py --upgrade --dry-run
sudo python3 install_M2_UPS_PMH.py --upgrade

Unrecognized executables, unsupported service locations, symlinked units, conflicting boot settings or unknown running UPS programs can cause a refusal. Review the exact reported conflict before changing anything; the installer does not terminate arbitrary processes.

For handled failures or an interrupt, the installer attempts to restore files and the prior service state. Packages already installed by apt are retained. Preserve the output and backup directory if rollback reports a problem.

Sudden power loss or an uncatchable process termination cannot guarantee automatic rollback. An incomplete installer record requires review of the saved state and backups before retrying. This Linux recovery is separate from MCU bootloader recovery.

Diagnose a first boot that is not ready

If --check reports firmware 0x08B2 while expecting 0x08B5, the Linux installation may already be correct. Flash firmware/M2_PMH.hex from this package, then repeat --check. Do not accidentally reuse an older ~/M2_PMH.hex. Daemon v1.6 can send telemetry on V8B2/V8B3, but the full V06 check and configuration/status tools require V8B5.

```
sudo journalctl -u M2_PMH_i2c.service -b -n 30 --no-pager
sudo journalctl -k -b --no-pager | grep -Ei "rtc|i2c|SDA|probe"
ls -l /dev/i2c-1 /dev/rtc* /dev/ttyAMA0
sudo systemctl cat M2_PMH_i2c.service
```

Installer questions

Does it update the MCU? No. It copies the Python updater for later use but never runs it, sends a bootloader request or programs a HEX file. Firmware update and interrupted-transfer recovery remain in their own chapters.

Does it choose the battery type or ON/OFF mode? No. Chemistry, charging current, runtime and switch mode remain unchanged. Verify them separately against the fitted hardware. Raspberry Pi EEPROM, boot order, PCIe/SSD configuration, Wi-Fi, network and user accounts are not changed.

The supplied tests cover 41 simulated installer scenarios, including upgrades, legacy active services, integrity checks and uninstall behavior. They do not replace the Raspberry Pi reboot, charging, shutdown and recovery tests.

UPS operation and File Safe Shutdown

Cable powered operation

With a valid external source present, the controller recognizes cable mode and manages battery charging. Charging may start after source qualification and may be reduced when available input power is limited. A charger-enabled flag does not by itself prove that a particular charging current is flowing.

Loss of external power

When external power is removed, the UPS changes to battery operation. With runtime value 0x01, timed FSSD begins after approximately 70 seconds. The normal shutdown grace period is approximately 30 seconds. These are separate intervals.

The Linux service must receive the shutdown request and perform an orderly operating-system shutdown. The controller then completes its power-control sequence. Do not unplug the battery during this sequence.

Event	Expected sequence
Cable removed	Battery supports the running Raspberry Pi and SSD.
Runtime limit reached	Controller initiates FSSD; Linux begins shutdown.
Grace interval completed	Controller finalizes shutdown and power control.
Cable returns before FSSD	Controller qualifies the source and returns to cable operation.
Cable returns during FSSD	Shutdown completes; automatic restart requires the normal-mode return sequence.
Cable returns after shutdown	Normal UPS mode permits automatic restart when the source is accepted.

Cable return during the last seconds of FSSD is a specific commissioning case. Test it together with repeated cycles; a single successful restart does not establish reliable behavior over multiple transitions.

Other shutdown causes

Low battery, a configured switch action or a manual FSSD request can initiate shutdown before the timed limit. An unlimited runtime setting removes the elapsed-time limit only; it does not disable battery protection or manual shutdown.

Intelligent mobile power bank and slide switch

The optional slide switch provides controlled mobile operation and an OFF state with File Safe Shutdown. Enable it only on an assembly with the supported switch wiring and Raspberry Pi button-control connection.

Enable switch mode

```
sudo i2cset -y 1 0x6b 0x0c 0xaa b
sleep 3
sudo i2cget -y 1 0x6b 0x0c b
sudo i2cget -y 1 0x6b 0x01 b
```

Expected values are 0xAA for switch mode and 0xFF for the runtime register. The firmware couples switch mode to unlimited elapsed battery runtime. Low-battery protection remains active.

Return to normal timed operation

```
sudo i2cset -y 1 0x6b 0x0c 0x00 b
sleep 3
sudo i2cget -y 1 0x6b 0x0c b
sudo i2cget -y 1 0x6b 0x01 b
```

Expected values are 0x00 and 0x01. Read back both settings after changing mode.

Raspberry Pi EEPROM prerequisite

For OFF to remain effective when USB-C power is connected directly to the Pi, configure the Pi EEPROM with the following settings. Preserve the existing BOOT_ORDER and unrelated settings. This is a Raspberry Pi configuration operation; the M.2 controller does not write its EEPROM.

```
sudo rpi-eeprom-config --edit

POWER_OFF_ON_HALT=1
WAIT_FOR_POWER_BUTTON=1
```

Apply the EEPROM change using the Raspberry Pi tool instructions and the required reboot before testing. Direct USB-C power remains physically present in standby, and the Raspberry Pi power button can independently affect the Pi.

While ON, cable insertion should change the power source without an unnecessary restart. Switch OFF initiates shutdown. After a manual FSSD with the slide still ON, move the slide OFF for at least two seconds, then ON to request a new start.

System LEDs and user controls

Indicators are listed from top to bottom in the supplied board view: ACT nearest the SSD end, EPR nearest the front controls. EPR is fitted on the Advanced model.

Indicator	Meaning in normal operation
ACT	M.2 SSD activity indication.
M.2	M.2 supply indication.
USR	Manual request at 0x6B:0x09 or saved mapping at 0x6B:0x0D. ULED available at P2 pin 5, USR_LED_H, with on-board R7 = 3.6 kΩ current limiting. SYS/BAT/TMR/FAN/TMP originals remain active.
SYS	System power-mode heartbeat; cadence described below.
BAT	Battery-level indication; interpret with battery measurements.
CHG	Battery charging indication; verify actual current when diagnosing charging.
TMR	Scheduler or timer indication when configured.
FAN	Linux fan enable state supplied by daemon v1.6; not RPM feedback.
TMP	ON above the CPU-temperature threshold (default 50°C); unknown samples do not light TMP.
EPR	Advanced external power status, where fitted.

Manual USR LED control

With USR mapping set to Manual (0), write command 0x09 at address 0x6B: 0 requests OFF and 1 requests ON. The manual request is volatile and resets OFF at MCU startup. Selecting a mapped source overrides the manual request without disabling the source LED. The normal LED gate at 0x0B must permit writes; pre-charge, error, reset and bootloader sequences have priority.

```
sudo i2cset -y 1 0x6b 0x0d 0x00 b
sleep 3
sudo i2cset -y 1 0x6b 0x09 0x01 b
sudo i2cget -y 1 0x6b 0x09 b
sudo i2cset -y 1 0x6b 0x09 0x00 b
```

Persistent ULED mapping

Select which normal indicator ULED follows at command register 0x0D. The selection is stored in MCU Flash after a valid changed value is accepted and is restored after MCU reset or complete power loss. The original SYS, BAT, TMR, FAN or TMP LED keeps operating; USR duplicates its state and blink pattern. This is useful for one external indicator on an enclosed system.

Value	ULED source	Retention
0x00	Manual request at 0x09	Saved selector
0x01	Follow SYS	Saved selector
0x02	Follow BAT	Saved selector
0x03	Follow TMR	Saved selector
0x04	Follow FAN	Saved selector
0x05	Follow TMP	Saved selector

Choose USR LED mapping (menu item 8) in configurator 06 and type YES to apply. Manual request is menu item 7. Selecting Manual restores direct ON/OFF control; the manual request itself resets OFF at MCU startup. Factory defaults select Manual. Invalid selectors above 5 are rejected and the last saved selection is restored. Repeated reads or an unchanged selection do not write Flash.

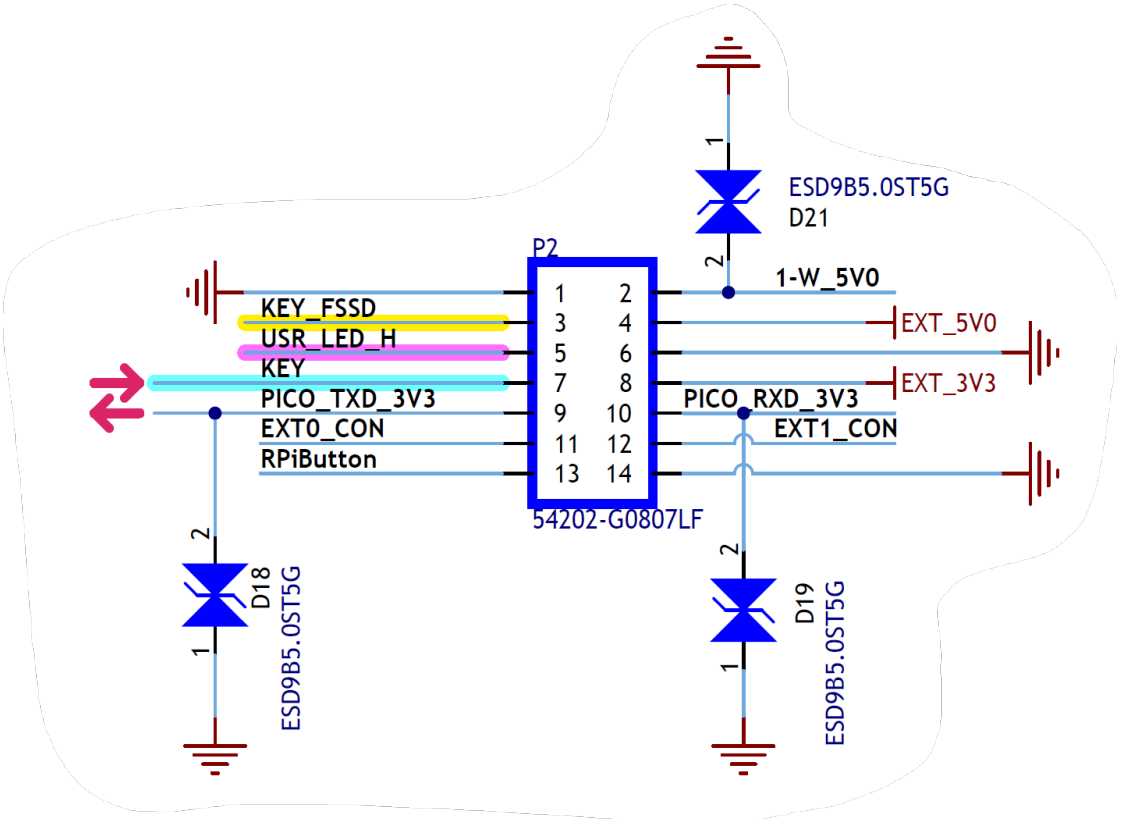
```
# Example: permanently follow SYS
sudo i2cset -y 1 0x6b 0x0d 0x01 b
sleep 3
sudo i2cget -y 1 0x6b 0x0d b
# Normal LED output gate: 1 permits normal indication
sudo i2cget -y 1 0x6b 0x0b b
```

After saving, test a planned MCU reset and a complete power cycle, allowing normal startup to finish. The selected source should return. Pre-charge, error, reset and bootloader indications can temporarily override it. A Linux reboot alone does not establish MCU-reset retention.

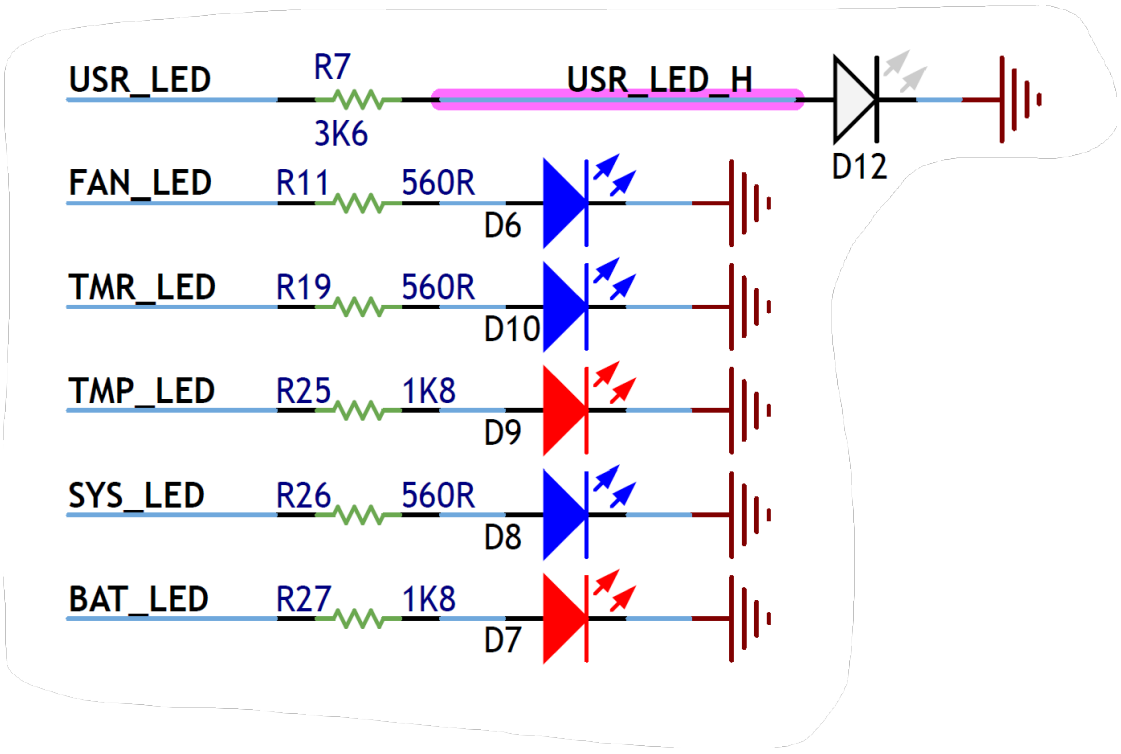
ULED output for user applications

The ULED signal is available on the fitted P2 application header at pin 5, labelled USR_LED_H. Use it for user applications or a front-panel indicator on the dedicated enclosure. Connect the external LED anode to USR_LED_H and cathode to GND (P2 pin 1, 6 or 14). The board already contains the current-limiting resistor R7 (3.6 kΩ); an additional series resistor is not required for this intended LED connection. The on-board USR LED remains connected to the same current-limited node, so external and on-board LED brightness can differ according to their forward voltages. This connection is an indicator output, not a general power output.

Connection	Pin or component	Purpose
ULED output	P2 pin 5 / USR_LED_H	External user LED anode; manual or mapped indication
Ground	P2 pins 1, 6 or 14	External user LED cathode and common reference
Current limiting	On-board R7, 3.6 kΩ	Already fitted; no extra series resistor required
Original indicator	On-board USR LED	Remains active with the external indicator



P2 application header: external ULED signal is pin 5 (USR_LED_H); common ground is available at pins 1, 6 and 14.



LED circuit excerpt: R7 = 3.6 kΩ (3K6) already limits USR LED current. The USR_LED_H node is also available on P2 pin 5.

CPU temperature and fan indication

Daemon v1.6 samples CPU temperature and Linux fan state every 5 seconds. Status 0x69:0x16 is packed BCD Celsius (0x46 = 46°C); 0xFF means unknown. Status 0x69:0x19 is 0 OFF, 1 ON or 0xFF unknown. FAN indicates a Linux cooling request, not proof of rotation. TMP requires a running Pi and a valid temperature above the BCD threshold at 0x6B:0x0A, initially 0x50 (50°C). This threshold controls the indicator, not the fan.

sudo i2cget -y 1 0x69 0x16 b
sudo i2cget -y 1 0x69 0x19 b
sudo i2cget -y 1 0x6b 0x0a b
sudo journalctl -u M2_PMH_i2c.service -b -n 12 --no-pager

SYS heartbeat cadence

The normal SYS indication changes approximately every 0.5 seconds on cable power and every 1.5 seconds on battery. Startup and reset sequences temporarily own the LEDs. Bootloader programming uses a separate walking indication, advancing once per two accepted HEX records; its rate follows transfer activity.

Buttons

FSSD is the user shutdown control during normal operation. M.2 RESET resets the UPS MCU and is not a substitute for orderly Linux shutdown. The Raspberry Pi 5 button is a separate physical control, also operated by the UPS transistor interface.

Serial diagnostics

Firmware diagnostic messages

Public firmware V8B5 omits MCU diagnostic messages. A silent application UART is expected; the Linux daemon still records heartbeat, telemetry and RTC events in journalctl. Development builds can enable MCU diagnostics at compilation. Application diagnostic settings do not change the protected bootloader speed.

If expected development-build messages are absent, check the application UART baud rate and routing. Confirm controller operation with SYS activity, I^2C status and the Linux journal before resetting hardware. Preserve logs before investigating an intermittent failure.

RTC operation and time synchronization

The UPS contains its own hardware real-time clock, separate from the Raspberry Pi 5 RTC. The board can also provide backup supply to the Pi RTC through a dedicated cable. These are distinct functions; the auxiliary RTC supply cable does not replace software configuration of the UPS clock.

Raspberry Pi RTC backup from the main battery

The **M.2 UPS PMH** can supply the Raspberry Pi 5 RTC backup input from its main backup battery through the designated RTC supply cable. This uses the same larger battery that provides UPS backup; no separate battery is needed on the Raspberry Pi RTC connector when this connection is fitted.

When external cable power is lost, the M.2 battery continues to support the Raspberry Pi RTC backup supply. The clock can therefore retain its time after Linux has shut down and the Raspberry Pi main operating supply is off, provided the battery remains connected, has sufficient charge and the RTC backup path remains powered. This connection powers the clock backup domain; it does not keep Linux running.

A dedicated RTC backup cable is available from Pi Modules Technologies. It connects the M.2 main-battery backup supply to the dedicated RTC power connector on Raspberry Pi 5. Observe the specified connector orientation and polarity. If the cable is absent or the main battery is removed or depleted, battery-backed time retention cannot be assumed. This is separate from the UPS controller's own RTC and its DS1307-compatible I²C interface.

Identify the RTC device

```
ls -l /dev/rtc*
for d in /sys/class/rtc/rtc*; do
  echo "$d"
  cat "$d/name"
done
```

The UPS DS1307-compatible interface uses I²C address 0x68 and is commonly /dev/rtc1. Device numbering is not guaranteed; identify the rtc-ds1307 1-0068 device before selecting it.

Read and set the UPS clock

```
timedatectl status
sudo hwclock --show --rtc=/dev/rtc1
```

Once Linux time is correct and synchronized, a manual write can be tested with the following command. Replace rtc1 if the verified device has another name. Capture UART output during the test.

```
sudo hwclock --systohc --utc --rtc=/dev/rtc1
sleep 2
sudo hwclock --show --rtc=/dev/rtc1
```

Linux may display local time while firmware diagnostics display UTC. Compare timezone-aware values before diagnosing an apparent one-hour offset.

Retention and recovery

Ordinary Raspberry Pi restart and slide OFF/ON retain the UPS RTC while the controller remains powered. Factory defaults restore a reference date; confirmed NTP synchronization then restores current UTC time.

If the driver failed to bind during boot, inspect the kernel log first. A manual bind is appropriate only when the configured I²C device 1-0068 exists and has no bound driver:

```
sudo journalctl -k -b --no-pager | tail -n 60
echo 1-0068 | sudo tee /sys/bus/i2c/drivers/rtc-ds1307/bind
```

Raspberry Pi 5 RTC battery and charging

The Raspberry Pi 5 has its own RTC and a dedicated J5 (BAT) backup connector next to USB-C. This chapter configures the Pi clock supply. The UPS DS1307-compatible clock remains a separate device; retain its existing overlay and daemon settings.

Choose the RTC backup source

M.2 backup cable: use the dedicated Pi Modules cable from the **M.2 UPS PMH** backup supply to J5, observing polarity and connector orientation. The main UPS battery then also supports the Pi RTC, including after external power loss and Linux shutdown, while the battery and backup path remain powered. A separate RTC coin cell is unnecessary.

The M.2 RTC backup path supplies a nominal regulated 3.3 V when the main battery provides sufficient input headroom. It does not connect the raw battery voltage directly to J5. Below the regulator's operating headroom, the backup voltage falls with the battery.

Separate RTC battery: if the M.2 cable is not fitted, Raspberry Pi offers a rechargeable ML2020 manganese-lithium cell with a matching two-pin plug and mounting pad. Connect one source to J5; do not parallel the coin cell with the M.2 cable. Use only the designated cable, not a loose LiPo/Li-ion cell or a generic battery lead.

Non-rechargeable CR-type cells must not be charged. They are not the recommended backup source for this assembly. Backup duration depends on the actual source, temperature and clock load; a battery-life estimate is not a guaranteed retention period.

Settings for the M.2 RTC backup cable

Keep the Raspberry Pi RTC charger disabled when the M.2 cable supplies J5. Charging the main UPS battery is handled by **M.2 UPS PMH**. The Pi RTC charging setting does not configure that charger. Installer V08 applies this setting automatically; use the manual steps below only when configuring the system yourself.

```
sudo nano /boot/firmware/config.txt
```

In the applicable *[all]* section, replace any enabled *rtc_bbat_vchg* setting with the following. Avoid duplicate or conflicting entries; preserve the UPS RTC overlay and other board settings.

```
[all]
dtparam=rtc_bbat_vchg=0
```

The firmware parameter uses microvolts. Zero, or an omitted parameter, disables the Pi RTC trickle charger. Reboot under cable power, then identify the two clocks:

```
sudo reboot
# Reconnect over SSH after startup:
for d in /sys/class/rtc/rtc*; do
  echo "$d: $(cat "$d/name")"
done
```

Select the onboard Raspberry Pi RTC for the checks on the next page. The UPS clock is the *rtc-ds1307* device at *1-0068*; device numbers can change.

Charging the official ML2020 RTC battery

Use this option only with the separate approved rechargeable RTC cell and the M.2 RTC cable disconnected. The official Raspberry Pi battery is ML2020; do not substitute a different chemistry merely because its connector fits.

The Pi RTC charger supplies up to 3 mA. The documented 3.0 V example is configured in */boot/firmware/config.txt* as follows:

```
[all]
dtparam=rtc_bbat_vchg=3000000
```

Here, *3000000* means 3,000,000 microvolts, or 3.0 V. Save and reboot. To return to the M.2 cable, disable Pi RTC charging again before connecting it. The limits exposed by the driver are not a safe-voltage specification for every battery.

Verify charging and set the Pi clock

The examples below use *rtc0* for the onboard Pi RTC. First verify its name; replace *rtc0* if Linux assigned a different number. These commands must target the Pi clock, not the UPS DS1307-compatible device.

```
cat /sys/class/rtc/rtc0/name
grep . /sys/class/rtc/rtc0/charging_voltage*
sudo hwclock --show --rtc=/dev/rtc0
```

charging_voltage should read *0* with the M.2 cable, or *3000000* for the rechargeable-cell example. The *_min* and *_max* files show driver limits, not a measurement of battery voltage. If these files are absent, verify the Pi RTC identity and kernel support.

After confirming the Linux system time is correct, initialize the Pi RTC in UTC and read it back:

```
timedatectl status
# Run the write only after confirming the system time:
sudo hwclock --systohc --utc --rtc=/dev/rtc0
sudo hwclock --show --rtc=/dev/rtc0
```

Test time retention

Record the Pi RTC time, shut Linux down normally and remove external power while leaving the selected RTC backup connected. Wait several minutes, then restart and check that time advanced correctly. Arrange an offline start for this test so NTP cannot hide a retention failure. Restore normal network synchronization afterwards.

The M.2 daemon synchronizes the UPS clock; do not treat that as proof that the separate Pi RTC retained time. RTC wake alarms and EEPROM low-power changes are separate features and are not required for this backup procedure.

References: Raspberry Pi RTC documentation and official RTC Battery product page; Raspberry Pi firmware parameter reference. The Cytron tutorial provides an additional illustrated guide. The regulated-supply description also uses the TI TLV743P data sheet. Accessed 22 October 2026.

Raspberry Pi RTC documentation
Raspberry Pi RTC Battery
Firmware parameter reference
Cytron illustrated tutorial
TI TLV743P regulator data sheet

Cooling and enclosure integration

Raspberry Pi official cooler

The HAT is designed around the Raspberry Pi 5 official cooler. The central board opening provides an air path above the cooler and helps cool the assembled SSD. The fan remains connected to and controlled by the Raspberry Pi.

Fit the cooler using its Raspberry Pi instructions before placing the HAT above it. Route the fan cable without trapping it between boards. Check that neither the SSD nor a battery lead obstructs the fan or ventilation opening.

Temperature and fan indications

The daemon supplies Raspberry Pi CPU temperature as a packed BCD byte every five seconds. FAN and TMP are separate indicators. The official cooler remains controlled by Raspberry Pi; this package does not configure fan cooling profiles.

```
cat /sys/class/thermal/thermal_zone0/temp
vcgencmd measure_temp
vcgencmd get_throttled
```

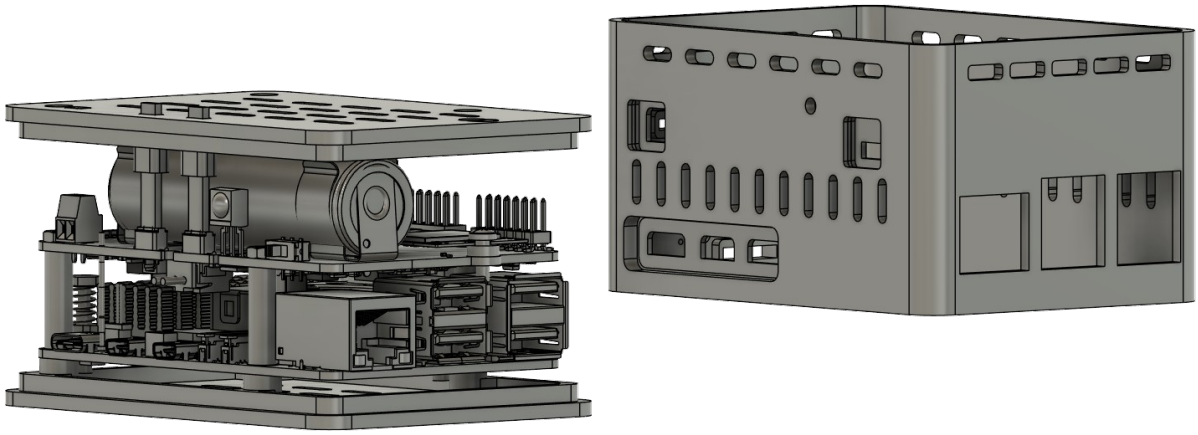
The sysfs temperature value is normally expressed in thousandths of a degree Celsius. Record temperature under the intended enclosure and workload, with battery charging enabled, rather than testing only at idle.

Case compatibility

A dedicated enclosure is available for the Raspberry Pi 5 and **M.2 UPS PMH** assembly, allowing both boards to be housed together as one complete system. Choose the enclosure configuration to match the Standard or Advanced model and the fitted SSD, battery and cooler. Check connector and button access when assembling the enclosure.

Confirm the complete mechanical assembly, not just the HAT outline. The enclosure must accommodate the chosen SSD, battery holder, access to FSSD and RESET, optional switch travel and cable entry. Keep the board underside insulated from metal panels.

An enclosure can change both thermal behavior and button access. Repeat the charging, cable-loss and restart tests after the final enclosure is fitted.



Dedicated enclosure for Raspberry Pi 5 and M.2 UPS PMH — V601 with buttons extending 2 mm above the top cover.

External analogue voltage measurement

Available inputs and hardware

The Advanced model provides one shared external ADC measurement with two resistor-divider inputs. Both signal inputs are available on the fitted P2 application header. Select EXT0 for 0–5.2 V at P2 pin 11, or EXT1 for 0–32 V at P2 pin 12. Connect the signal return to P2 GND at pin 1, 6 or 14. The Standard model does not provide this external measurement.

Connect only one input at a time. Leave the unused input open, including its signal wire. The inputs join a common buffer and ADC channel; changing the software range changes the conversion factor and does not switch or isolate the physical input. Do not ground the unused input.

V8B5 requires R75 = 1.00 kΩ, tolerance ±0.5% or better. R76 = 1.4 kΩ gives EXT0 a divider factor of 2.4; R68 = 19.6 kΩ gives EXT1 a factor of 20.6. Earlier assemblies must have the correct divider before the voltage reading is used. Do not exceed the connector range or apply negative voltage.

Range selection and retention

Run the configurator and choose item 10, External ADC input range. Enter 0 for EXT0 or 1 for EXT1, review the change and type YES exactly. Keep cable power connected. The firmware saves an accepted changed selection and restores it after MCU reset or complete power loss; factory defaults select EXT0. Unchanged or invalid requests do not cause repeated Flash writes.

```
sudo python3 /opt/M2_UPS_PMH/M2_PMH_config.py
```

Direct commands for EXT0:

```
sudo i2cset -y 1 0x6b 0x08 0x00 b
sleep 3
sudo i2cget -y 1 0x6b 0x08 b
sudo i2cget -y 1 0x69 0x12 w
```

For EXT1, first disconnect EXT0 and leave pin 11 open. Write 0x01 instead of 0x00 to register 0x08. Allow the save and filtering delay before reading. Do not change this selector on the Standard model.

Read the voltage and verify the result

```
sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py
sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py --watch 5
```

Monitor 0B shows the ADC and external inputs section with the saved input/range and selected voltage in volts. Raw register 0x69:0x12 is a little-endian packed-BCD word in 0.01 V units: 0x0330 means 3.30 V, 0x0500 means 5.00 V and 0x1234 means 12.34 V. It is not a binary millivolt count. 0xFFFF means unavailable; an open input does not necessarily produce 0xFFFF.

The conversion uses a nominal 3.300 V reference and the fitted divider. Display resolution of 0.01 V is not a guaranteed accuracy specification. Resistor tolerances, actual reference voltage, buffer behavior and noise affect the result. Use a multimeter to check known voltages in each selected range. Begin with a low positive voltage and verify the selected input before increasing it.

A 3.3 V bench input was reported correct after R75 was changed to 1.00 kΩ. This confirms basic readout operation on the tested assembly; it does not establish calibrated accuracy over 0–32 V. Initial checks at several voltages and saved-range retention should be completed for each assembled system.

1-Wire sensors and protected connection

Use the protected M.2 connector

The Advanced model provides an ESD-protected 1-Wire interface connected to Raspberry Pi GPIO4. Use the M.2 1-Wire connector for external sensors instead of connecting the data lead directly to the Raspberry Pi header. This routes the external signal through the protection provided on M.2. ESD protection reduces the risk from electrostatic discharge; it does not make the connection tolerant of incorrect wiring or arbitrary overvoltage.

1. With power disconnected, connect the DS18B20 DATA lead to the designated M.2 1-Wire signal, GND to common ground and VDD to the designated compatible sensor supply. Follow the M.2 connector labels and the sensor pinout. The example uses a normally powered three-wire sensor, not parasite-power wiring. Do not connect the sensor to either ADC input.

Enable the interface in Raspberry Pi OS

2. Connect cable power and log in through SSH. Run the configuration utility:

sudo raspi-config

Select Interface Options, then 1-Wire, then Yes. Finish and reboot. Menu numbering may vary with the Raspberry Pi OS version. GPIO4 must not be assigned to another function.

sudo reboot

3. Reconnect through SSH and check discovery. A DS18B20 normally appears as a directory beginning with 28-. Discovery can take a few seconds:

ls /sys/bus/w1/devices/

The Linux w1-gpio and w1-therm drivers perform bus timing and temperature conversion. Python reads their sysfs interface; there is no need for a third-party Python sensor library or a change to the M.2 MCU firmware. Installer V08 installs the reader but deliberately leaves enabling this optional GPIO interface to the user.

Run the supplied English reader

4. After installing or upgrading this package, run one reading or continuous display:

python3 /opt/M2_UPS_PMH/M2_PMH_1wire.py
python3 /opt/M2_UPS_PMH/M2_PMH_1wire.py --watch 5

The package-local copy is optional_monitor/M2_PMH_1wire.py. The script prints each detected DS18B20 identifier and temperature in Celsius, validates the kernel-reported CRC and reports missing devices, malformed samples, read errors or timeouts in English. Ctrl+C stops continuous display. It does not configure GPIO or write to the UPS command bank.

5. The normal status program includes the same temperatures:

sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py

Monitor 0B v2.7 adds a 1-Wire DS18B20 temperatures section. --degrees F also converts these temperatures to Fahrenheit. No connected sensor is reported as an optional interface without a detected device. A sensor error is shown against that sensor; normal heartbeat/shutdown service operation is independent of the reader.

Python example and verified sensor test

The following minimal English example demonstrates the Linux interface. The supplied standalone reader adds bounded reads and fuller error reporting. The family prefix 28- selects DS18B20 devices; other 1-Wire device types need their appropriate driver and application support.

```
from pathlib import Path

sensors = sorted(Path("/sys/bus/w1/devices").glob("28-*/w1_slave"))
if not sensors:
    print("No DS18B20 sensors found.")

for sensor in sensors:
    try:
        lines = sensor.read_text().splitlines()
        if len(lines) < 2 or not lines[0].strip().endswith("YES"):
            raise ValueError("CRC check failed or incomplete response")
        temperature = int(lines[1].split("t=")[1]) / 1000
        print(f"{sensor.parent.name}: {temperature:.2f} C")
    except (OSError, ValueError, IndexError) as error:
        print(f"{sensor.parent.name}: ERROR: {error}")
```

The tested Raspberry Pi 5 and M.2 assembly detected DS18B20 28-000003c6469c. Four reported readings were 29.62°C, 31.38°C, 31.25°C and 31.06°C, each passing the CRC check. This confirms sensor discovery and temperature readout on the tested connection.

If no sensor appears, check the designated 1-Wire connector, common ground, sensor power and DATA wiring, GPIO4 assignment and the post-configuration reboot. Do not substitute the ADC header inputs for 1-Wire. Recheck the sensor pinout before changing wiring.

Linux configuration reference: https://www.raspberrypi.com/documentation/computers/configuration.html
Linux temperature-driver reference: https://docs.kernel.org/w1/slaves/w1_therm.html

Web panel and private remote access

Web Panel V02 provides a browser interface for **M.2 UPS PMH** application V8B5. Use a modern browser on Windows, Linux, Android or iOS to read status and, with an administrator account, change the supported configuration settings. The web service runs on Raspberry Pi 5; no MCU update is needed for the panel.

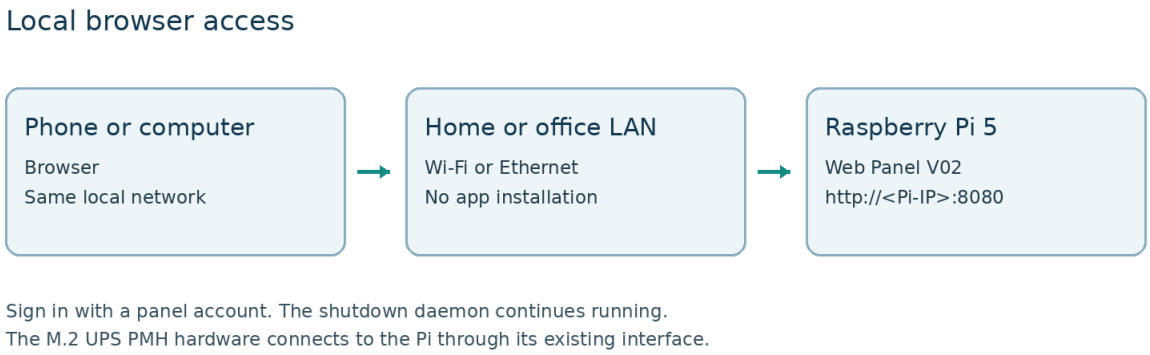


Figure — Browser access on the same local network

What the panel shows

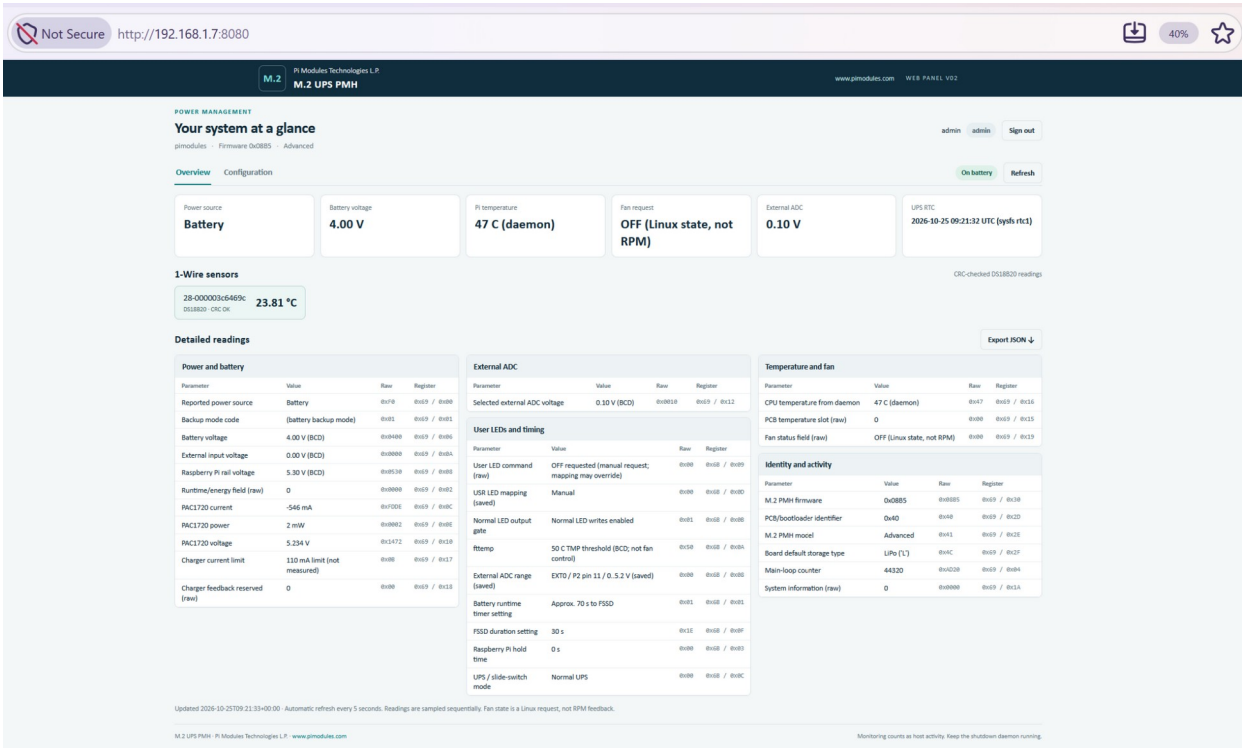
Overview contains six summary readings: power source, battery voltage, Raspberry Pi CPU temperature, Linux fan state, selected external ADC voltage and UPS RTC. Detailed tables show power and battery, temperature and fan, external ADC, identity and activity, and user LEDs and timing. Detected DS18B20 sensors are read through the existing Linux 1-Wire interface. Enable and wire that optional interface as described in its own chapter.

The compact layout adapts to the screen: six summary tiles fit across a desktop, detailed groups use balanced columns, and smaller screens stack the content. The available width determines the arrangement. Values can be exported as JSON. Fan state is a Linux enable request, not RPM; battery charge percentage is not inferred. Keep the interpretation and calibration limits described in the register reference.

Requirements and version scope

Install and verify the main Linux package first. M2_PMH_i2c.service must already be active, and application identifier 0x08B5 must be loaded. The panel uses matching configurator 06 and monitor 0B modules. Standard and Advanced retain their existing hardware restrictions. Keep stable cable power during installation. The optional panel neither replaces the UPS daemon nor changes battery chemistry, Pi EEPROM, the application HEX or the protected bootloader.

Web panel overview example

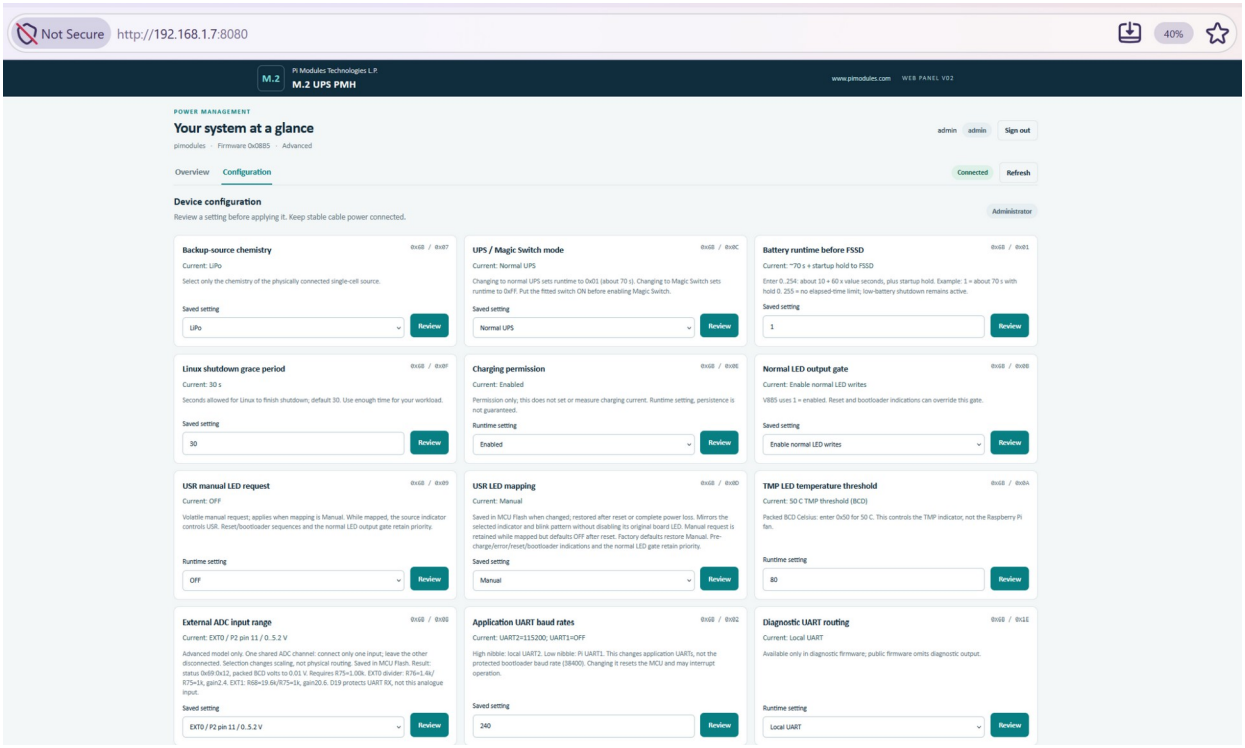


Web Panel V02 overview on the tested Advanced board. The example shows battery operation; values are a captured snapshot.

The six overview tiles identify power source, battery voltage, Pi temperature, fan request, selected ADC input voltage and UPS RTC. Below them, the 1-Wire section shows the sensor identifier, temperature and CRC result. Detailed tables give the formatted value, raw field and register address. Export JSON saves the displayed snapshot. The browser address in this example is the local Pi address on port 8080.

This image records application firmware 0x08B5 and a detected DS18B20. It does not establish calibration of current, power or open analogue inputs. Fan status is the Linux request, not measured fan speed. A status page can remain useful during a brief cable loss, but the normal UPS shutdown policy continues to apply.

Web panel configuration example



Web Panel V02 configuration screen. Review each change and confirm it before applying; saved and runtime settings are labelled separately.

The example includes backup-source chemistry, switch mode, runtime, shutdown grace, charging permission, normal LED gate, manual USR request, saved USR mapping, TMP threshold, external ADC range and UART settings. Use only settings appropriate for the fitted hardware. The full list continues below the visible part of the page; scroll when necessary.

Review opens the confirmation step; it does not immediately write a register. Type YES exactly when the proposed change is correct, then apply and verify. Leave the shutdown daemon running. On a phone the same controls stack vertically, while desktop screens use the available columns.

Install or upgrade the web panel

1. Log in through SSH. From the extracted Customer or Resources package, enter its web_panel directory. Replace the example package name below with Resources if that is the bundle you extracted.

```
cd ~/M2_UPS_PMH_Customer_V8B5/web_panel
sudo python3 install_webpanel.py
```

Alternatively, copy the supplied standalone Web Panel V02 ZIP to the Pi home directory and run:

```
cd ~
unzip -o M2_UPS_PMH_WebPanel_V02.zip
cd ~/M2_UPS_PMH_WebPanel_V02
sudo python3 install_webpanel.py
```

2. The installer verifies its package, Raspberry Pi model, active UPS service, firmware identifier and cable power. It installs the Python web dependencies using apt, creates a dedicated unprivileged m2web service account and installs M2_PMH_web.service. The UPS heartbeat/shutdown daemon stays running. Installation requires Internet access for dependencies.

3. On a first installation, create the admin account password. It must contain at least eight characters. Both initial entries are visible in the SSH terminal; enter the same password twice. There is no supplied default real-device password. An upgrade retains existing accounts and passwords rather than asking for a replacement.

4. The installer prints the local URL. Open it in a browser on a computer or phone on the same local network. The following address is an example only; use the actual Pi address:

```
http://192.168.1.7:8080
```

5. Sign in as admin with the password you created. Confirm the firmware identity, power source and live readings before changing a setting. If the Pi IP address changes, find it through SSH:

```
hostname -I
sudo python3 install_webpanel.py --check
```

The web installer and the main Linux installer are separate tools. The panel installer does not configure optional 1-Wire GPIO4. It backs up the previous web application and restores it if web service installation fails. A web panel upgrade does not require reflashing firmware.

Read status and change a setting

Overview and live readings

Open Overview after signing in. While the page is visible, the browser refreshes at approximately five-second intervals. Hardware status is cached by the service; polling pauses after approximately 30 seconds without an authenticated status request. Reading registers counts as host activity under the existing firmware rules. Do not use the panel to prove a no-host-activity shutdown test while it is polling.

Configuration workflow

1. Sign in with an administrator account and open Configuration. Viewers can read status but cannot apply changes.

2. Select one supported setting and enter or choose its new value. Unsubmitted fields are retained across normal refreshes. The panel does not provide arbitrary register writes.

3. Select Review. Check the setting name, previous value and proposed value. A preview does not write hardware.

4. Type YES exactly, then select Apply and verify. A confirmation expires after 90 seconds, belongs to the current session and can be used only once.

5. Wait for readback verification and refresh the displayed value. If another program changed the value after Review, the request is rejected so that you can review it again.

The server repeats the existing firmware, model, cable-power, command-state and range checks at apply time. Saved settings retain the firmware-managed Flash behavior; volatile requests remain volatile. Examples include the saved USR LED mapping and external ADC range, or the temporary manual USR request. Sequence priorities and the normal LED output gate still apply. Hardware unavailable on Standard cannot be added by software.

If communication or readback fails, the panel does not automatically retry a potentially completed write. Refresh and inspect the current value before submitting another deliberate change. UART settings can restart the MCU; review the existing warning and save work first. Bootloader entry, firmware upload and factory defaults are not web actions in V02.

Access roles and session behavior

Administrator accounts can review and apply supported settings; viewer accounts are read-only. Sessions have a 30-minute idle lifetime. Password changes or account revocation invalidate affected sessions. The interface requires same-origin session tokens and limits repeated login attempts. These controls complement the private network connection; they do not make this HTTP service suitable for direct public exposure.

Tailscale setup step 1 Create your account

Tailscale is a separate private-network service. It allows a phone or computer outside the Pi local network to reach the same M.2 UPS PMH panel. The Pi runs the web service and Tailscale; every remote viewing device also runs Tailscale. This section is a complete first-time setup sequence. Keep the Pi online and cable powered throughout installation.

1. On your PC or phone, open https://tailscale.com and choose Get Started or Sign up. Read the service terms and select the usage/plan appropriate for your personal or business deployment. A trial indicator is a Tailscale account condition, not a permanent product entitlement.

2. Select an identity provider you already use, such as Google, Microsoft, GitHub or Apple, from the choices shown. Authenticate with that provider and complete any requested multifactor check. Tailscale uses the provider identity; it does not create a separate Tailscale email/password login.

3. Complete the onboarding prompts. Use the same provider and account when authorizing Raspberry Pi and connecting your phone or PC. If you deliberately use multiple accounts or organizations, select the same private network, called a tailnet, on each device.

4. If the page reports that it cannot find your account, choose Sign up for a new account, or return to login and select the provider/account you previously registered. Merely entering a different email does not join an existing private network.

5. After onboarding, open the Tailscale administration console and its Machines list. Each authorized device appears there. You may authorize Raspberry Pi from a browser on your PC; a screen or web browser on the Pi itself is not required.

Keep the two logins separate

Tailscale sign-in authorizes membership in your private network. The panel sign-in controls read/write access to the M.2 interface. The panel account is admin or another account you created with its own panel password. Neither the Linux pi account nor the Tailscale email is automatically a panel username. Use the existing panel credentials after connecting the VPN.

No credentials are supplied in the package. Do not put passwords, temporary authorization links or private account data into a public manual or customer screenshot. Official identity reference: https://tailscale.com/docs/integrations/identity

Tailscale setup step 2 Authorize Raspberry Pi

1. Connect by SSH to Raspberry Pi using its local address. Confirm the main UPS Linux installation is running. Copy and extract the Customer or Resources V8B5 bundle in the Pi home directory. To install/upgrade the optional web panel and add Tailscale together, run:

```
cd ~
unzip -o M2_UPS_PMH_Customer_V8B5.zip
cd ~/M2_UPS_PMH_Customer_V8B5/web_panel
sudo python3 install_webpanel.py --with-tailscale
```

For a Resources bundle, substitute Resources for Customer in the ZIP and directory name. Existing web-panel accounts are retained. For a panel that is already installed and working, configure only the VPN instead:

```
cd ~/M2_UPS_PMH_Customer_V8B5/web_panel
sudo python3 install_webpanel.py --tailscale-only
```

2. The installer installs Tailscale when needed and enables the Linux tailscaled service. The automatic repository setup supports the Debian/Raspberry Pi OS bookworm and trixie targets described in REMOTE_ACCESS.txt. It reuses an installed Tailscale client. The UPS daemon remains running; no MCU firmware or battery setting is written.

3. When the terminal displays To authenticate, visit followed by an HTTPS link, leave the SSH session open. Open that exact current link in a browser on your PC or phone. Do not press Ctrl+C to copy it; use the terminal selection/copy function or right-click method appropriate for your SSH client.

4. Sign in with the provider/account created in step 1 and approve the Pi connection. Complete any device-approval requirement imposed by your Tailscale administrator. Return to SSH and look for Success. An authorization link is temporary and should not be copied from a printed example.

5. If the installer login wait expires, or you interrupted it, the local panel remains installed. Continue authorization without reinstalling:

```
sudo tailscale up
```

6. After success, identify the Pi private IPv4 address and check network membership:

```
tailscale ip -4
tailscale status
```

Use the address returned by this Pi. A 100.x address shown in an example or screenshot belongs to that example and must not be copied blindly. The web-panel URL is http://<Pi-Tailscale-IPv4>:8080. Keep the port 8080. The following sections connect Windows or a phone to the same network.

Connect through the Internet with Tailscale

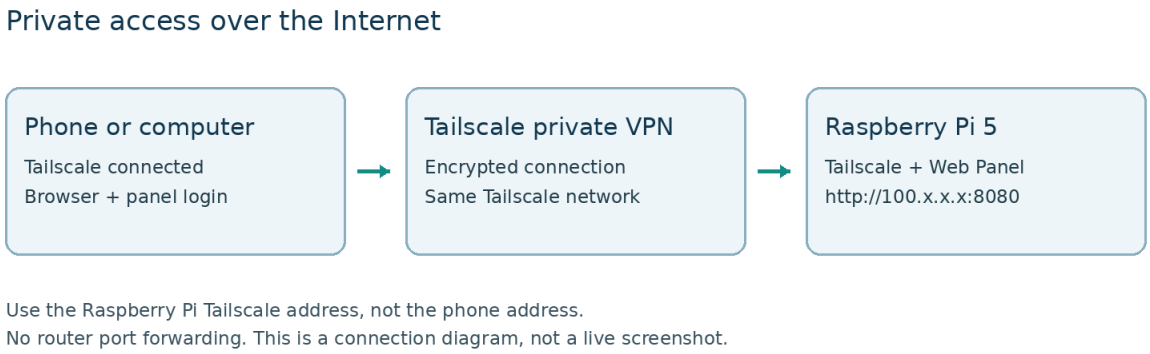


Figure — Remote access through a private Tailscale network

1. Keep the Pi online with stable cable power. To install or upgrade the panel and add Tailscale, run from web_panel or the standalone extracted panel directory:

sudo python3 install_webpanel.py --with-tailscale

If the panel is already installed and only remote access is needed, use:

sudo python3 install_webpanel.py --tailscale-only

The latter command verifies the package and running web service, then configures remote access without reinstalling the panel, changing its accounts or accessing UPS registers. Installation without either flag remains local-only.

2. Open the official Tailscale authorization link printed in SSH, using a browser on your computer or phone. Sign in to your selected Tailscale account and authorize this Pi. Device approval may also be required by the network administrator. The Tailscale account is separate from the panel account.

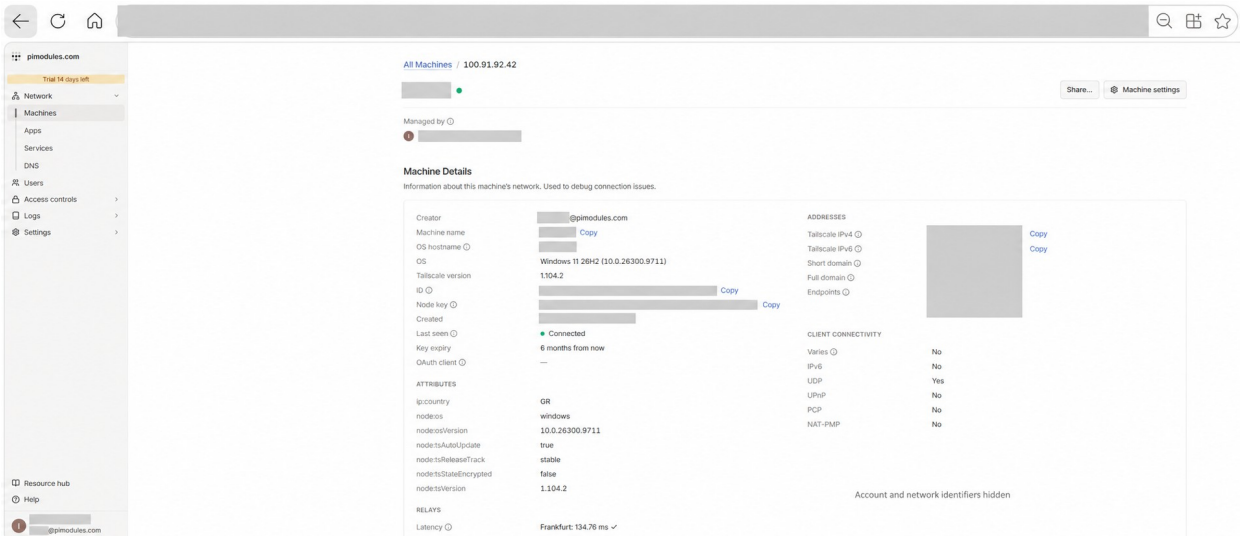
3. Install the official Tailscale application on the phone or computer. Sign in to the same Tailscale network and enable its VPN connection. Download: https://tailscale.com/download

4. Use the private Pi URL printed by the installer. It contains the Raspberry Pi Tailscale IPv4 address. To obtain that address again:

tailscale ip -4

Open http://<Pi-Tailscale-IP>:8080 and sign in with your existing panel credentials. For example, http://100.101.102.103:8080 is an illustrative private address, not an address assigned to your board. Use the Pi address, not the phone address. V02 instructions use numeric IPv4 addresses to match the panel Host-header checks.

Tailscale device registration example



Tailscale device details example after registration. Account and network identifiers are hidden; UI layout may change.

Open Machines in the administration console and select the intended device. Confirm the operating system, Connected/last-seen status and assigned addresses. Register the Raspberry Pi and each viewing client in the same private network. The supplied console example shows a Windows viewing PC, not the Raspberry Pi; use the Raspberry Pi entry to find the panel destination address.

Device state is not the panel login

A registered, connected client is ready to carry VPN traffic. It does not automatically log you into the panel. Likewise, a green device status alone does not prove that TCP port 8080 is reachable; complete the browser test. Keep the Pi powered, its Internet connection available and M2_PMH_web.service active.

Check the account plan and device-key expiry in the console. Existing key-expiry and access-policy settings are retained by the installer. Renew authorization when required. For commercial installations, choose a suitable service plan; trial text visible in an example is not a promise of free business use.

Install Tailscale on Windows or a phone

Tailscale connects the Raspberry Pi and your viewing device into the same private network, also called a tailnet. Install the client at both ends. The panel itself remains an HTTP service on TCP port 8080; no port change, router forwarding or public IP address is required for this workflow.

Windows client

1. Visit https://tailscale.com/download and choose Windows. Run the official installer on the PC you will use to access the panel.
2. Open Tailscale from the Windows notification area and choose the sign-in option. Complete authentication in the browser using the same Tailscale network/account used to authorize Raspberry Pi.
3. Confirm that the PC is connected and the Pi appears in the device list or administrator console. Open the Pi private address in any normal browser, followed by :8080.
4. Sign in to the web panel with the existing panel username and password. The Tailscale sign-in and panel sign-in are separate.

Android phone or tablet

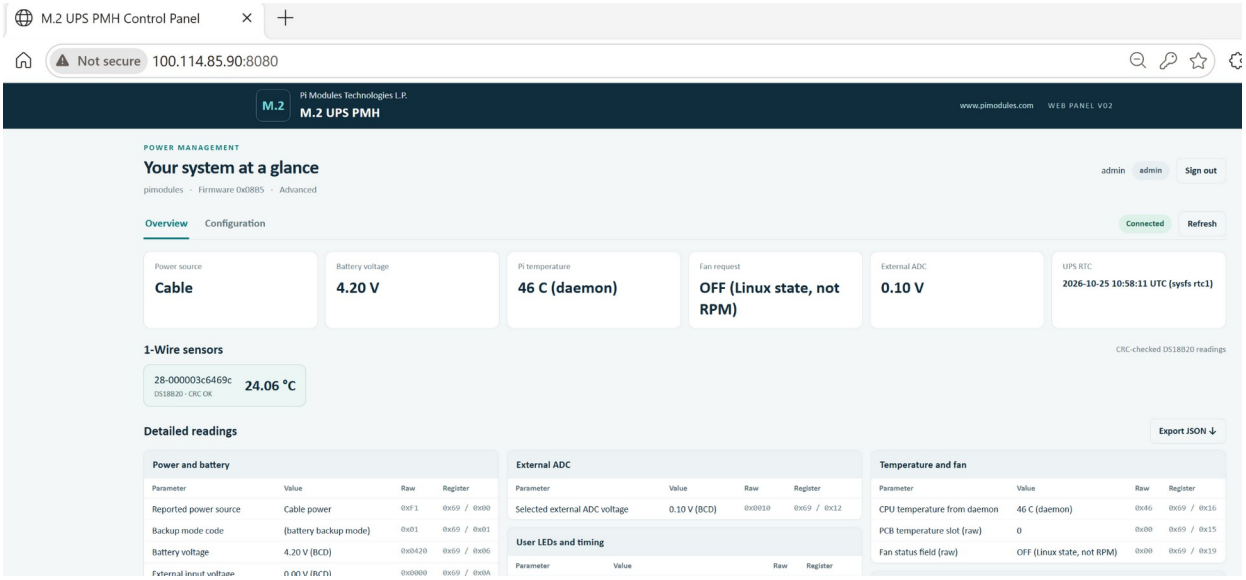
1. Install the official Tailscale app from Google Play or the official download page.
2. Open the app, start the setup and accept the Android VPN configuration prompt. Sign in to the same Tailscale network as Raspberry Pi.
3. Enable the Tailscale connection. Open the normal phone browser and enter the Raspberry Pi Tailscale IPv4 address with :8080.
4. Sign in to the panel. Keep Tailscale connected while using the remote address.

iPhone or iPad

1. Install the official Tailscale app from the Apple App Store.
2. Open it, sign in to the same Tailscale network as the Pi and allow the requested VPN configuration.
3. Connect Tailscale, then open Safari or another browser at the Pi private IPv4 address with :8080.
4. Sign in with the panel account. A separate custom M.2 application is not required.

Client controls and button labels may change with operating-system and Tailscale versions. Use the official app and its current connection status. If another VPN prevents connectivity, inspect its compatibility before replacing or disabling an existing connection.

Open the panel from a mobile phone



Panel V02 reached at a Raspberry Pi Tailscale address on port 8080. This is the supplied desktop-browser capture; a phone uses the same URL and responsive interface.

1. Install Tailscale from Google Play on Android or the Apple App Store on iPhone. Open it, authenticate with the same provider/account or approved tailnet as the Pi, accept the VPN configuration prompt and enable its connection.
2. Open the phone browser, enter http:// followed by the Raspberry Pi Tailscale IPv4 address and :8080. Do not enter the phone own Tailscale address.
3. Sign in with the panel account, for example admin, and its existing panel password. A wrong username can appear to be a password problem.
4. Turn Wi-Fi off, leave mobile data and Tailscale connected, then reload and verify live updates. This is the test that establishes access outside the local LAN.
5. Both Overview and Configuration work on a phone; the layout adapts to the available width. Viewer accounts remain read-only and administrator changes still require Review, exact YES confirmation and readback.

The supplied capture confirms access from a PC through the private Tailscale address. It is not a phone screenshot or proof that the phone mobile-data test has been completed. The browser may label the page Not secure because it uses HTTP; requests to the private Tailscale address travel through the VPN. Local LAN HTTP and a public HTTPS website are different paths.

Use local and remote access on port 8080

Both access paths can be used at the same time. They connect to the same Raspberry Pi service, present the same hardware readings and use the same panel accounts. You do not switch a mode in the MCU or web panel.

Local network access

Connect the phone or computer to the Pi local network, using Wi-Fi or Ethernet. Tailscale is not required for the local address. Determine the Pi LAN IPv4 address using:

hostname -I

For a Pi at 192.168.1.7, open the following example URL. Your actual address can differ:

http://192.168.1.7:8080

Remote Internet access

Keep the Pi connected to its Internet router and Tailscale. On the viewing PC or phone, connect Tailscale to the same private network. Ask the Pi for its private IPv4 address:

tailscale ip -4

For example, if the command reports 100.101.102.103, open:

http://100.101.102.103:8080

This 100.x address is an example only. Use the address assigned to Raspberry Pi, not the address of the phone or PC. Type http:// explicitly and retain :8080. No public HTTPS service or Tailscale Serve/Funnel endpoint is configured by this package. The encrypted VPN protects the path addressed through Tailscale; the ordinary LAN URL remains HTTP.

Daily operation and restart

The PC may be switched off while Raspberry Pi and M.2 continue running. The Linux Tailscale service is enabled at startup; the client on the viewing device must also be connected when using the remote address. If the Pi is shut down or has no power/Internet connection, remote access cannot start it. A valid VPN connection does not bypass the panel login or configuration guards.

For the outside-network test, disconnect phone Wi-Fi and use mobile data with Tailscale enabled. Open the same Pi private URL and check that readings update. Return to the LAN URL whenever local-only access is preferred. Do not publish port 8080 through a router to make this test work.

Finish authorization and verify remote access

If authorization is not completed within 45 seconds, the installer reports that remote setup is incomplete and leaves the installed local panel available. Finish the interactive authentication through SSH:

sudo tailscale up
tailscale status
tailscale ip -4

An already connected Tailscale installation is reused. Existing Tailscale preferences are not reset. If tailscale up asks for previous nondefault flags, review its instructions rather than blindly resetting them. The automatic repository installer supports Debian and Raspberry Pi OS bookworm/trixie. It adds the official signed apt repository; existing repository files are not overwritten. For another OS, follow the official Tailscale Linux instructions in the package reference file.

Test from outside the local network

1. Keep Raspberry Pi connected to its Internet router. On the phone, turn off Wi-Fi, enable mobile data and leave Tailscale connected.
2. Open the Pi Tailscale URL and sign in. Confirm that readings update and match the known board.
3. Test a reversible setting only after confirming the hardware and current operating state. Use a viewer account when monitoring alone is sufficient.
4. Reconnect or reboot the Pi as appropriate, then verify that remote access returns. The Linux tailscaled service is enabled at boot, but both endpoints still require Internet connectivity.

Remote access boundaries

The panel continues listening on port 8080 on the Pi. Connections addressed to its Tailscale IP travel through the encrypted VPN; the ordinary local LAN URL remains HTTP. This package does not configure public hosting, router forwarding, Tailscale Funnel, exit nodes, subnet routing, Tailscale SSH or a public HTTPS endpoint. Do not forward port 8080 from the Internet.

Tailscale network policy and any existing Pi firewall must allow the selected client to reach TCP port 8080. The installer changes neither policy nor firewall rules. Other members of a permissive Tailscale network may also be able to reach the panel; keep network membership controlled and use separate panel accounts. Device approval, expired keys, service terms and commercial plan limits are managed in Tailscale. Key-expiry settings are not changed by this installer.

Acceptance status

V02 passed 41 automated host tests. The user subsequently authorized Raspberry Pi and a Windows PC, reached the panel at the Pi private Tailscale address and signed in successfully after resolving a VPN conflict and correcting the panel username. The supplied desktop capture records that access. Complete the separate phone test with Wi-Fi off and mobile data active to verify access through the cellular network.

Troubleshoot VPN conflicts and panel sign in

Another VPN can block Tailscale

During the reported Windows test, Tailscale peers responded but the browser, curl and TCP port test failed while NordVPN was in use. The panel became reachable after NordVPN was disconnected. Treat this as an observed conflict on that PC, not as a universal failure of either product. Other VPN firewall rules, kill switches or overlapping routes can affect private-network access.

For a controlled diagnosis, disconnect the other VPN on the viewing device, leave Tailscale connected and retry the Pi private URL. On Android and iOS, another active VPN can prevent Tailscale from being the active VPN. Check the client connection state. Do not disable the Windows firewall, remove Pi firewall rules or forward port 8080 as a first response.

If both VPN services must be used on one computer, review their official compatibility and split-tunnel options and test the result. The M.2 installer does not change third-party VPN or security-product configuration. Reference: https://tailscale.com/docs/reference/faq/other-vpns

Panel unavailable versus incorrect credentials

A browser network error occurs before panel authentication. Confirm Tailscale is connected, the Pi is online and its web service is active. A displayed panel login page means the HTTP service has been reached; then check the panel username and password. Use admin only if that is the account you configured. Do not enter a Tailscale email or the Linux pi login unless you explicitly created that name as a panel account.

Use these tests when gathering a report

```
# Raspberry Pi SSH
sudo systemctl is-active M2_PMH_web.service
sudo ss -ltnp 'sport = :8080'
curl --noproxy '*' --connect-timeout 5 http://127.0.0.1:8080/api/session
tailscale status

# Windows PowerShell: substitute the Pi private address
Test-NetConnection <Pi-Tailscale-IP> -Port 8080
curl.exe --noproxy "*" --connect-timeout 10 http://<Pi-Tailscale-IP>:8080/api/session
```

A JSON response from /api/session confirms an HTTP response without writing UPS settings; user:null means no signed-in panel session. A working tailscale ping alone does not prove host TCP access. Relayed connections through DERP can carry the panel normally; direct connection not established is not by itself a panel fault.

Maintain accounts and diagnose the web service

Change the administrator password

From the extracted panel installer directory, use the visible password reset option:

sudo python3 install_webpanel.py --reset-password

This updates admin without reinstalling, restarting the service, accessing hardware or changing other accounts. It retains the application secret and invalidates the changed account's old sessions. For SSH account administration with hidden password entry, use:

sudo python3 /opt/M2_UPS_PMH_WebPanel/accounts.py set admin --role admin
sudo python3 /opt/M2_UPS_PMH_WebPanel/accounts.py set viewer --role viewer
sudo python3 /opt/M2_UPS_PMH_WebPanel/accounts.py disable viewer

At least one enabled administrator must remain. The panel installer retains accounts during upgrades. Keep account configuration and backups restricted to administrators.

Check service and connection

sudo python3 install_webpanel.py --check
sudo journalctl -u M2_PMH_web.service -b -n 30 --no-pager
tailscale status
sudo journalctl -u tailscaled -b -n 30 --no-pager

If local access fails, verify the Pi address, web service, active UPS daemon, firmware 0x08B5 and current logs. If local access works but remote access fails, verify Internet access on both devices, the same Tailscale network, authorization/approval, device-key validity, VPN connection, access policy and firewall. The check command reports the private URL when connected; it cannot prove reachability from a remote phone.

The installed application is /opt/M2_UPS_PMH_WebPanel. Accounts and the session secret are in /etc/M2_UPS_PMH_WebPanel/config.json. The service stores a rotating audit record in /var/lib/M2_UPS_PMH_WebPanel/audit.jsonl without passwords. Its systemd identity is m2web, with the required I^2C group access; the HTTP application does not run as root.

Remove the optional panel

sudo python3 install_webpanel.py --uninstall

Removal stops only the web panel and retains its accounts, audit data and backups. The UPS daemon and Tailscale remain available. To disconnect Tailscale separately, use sudo tailscale down only when it will not remove your sole management connection.

Further instructions and official references

The web_panel directory contains README.txt, REMOTE_ACCESS.txt, START_PL.txt and validation records. Official references: https://tailscale.com/docs/install/linux and https://tailscale.com/docs/reference/tailscale-cli/up. Pi Modules Technologies L.P. supplies the panel integration; Tailscale is a third-party service. www.pimodules.com

Application integration

Time and event data

Keep the UPS RTC in UTC. Applications can read power status, voltage, temperature and system information through the register reference at the end of this manual.

The bundled daemon performs heartbeat, shutdown handling, temperature reporting and RTC synchronization. It does not configure scheduled wake events or deliver email notifications.

Interactions with switch and UPS shutdown

A deliberate switch OFF state and battery protection take priority in the power-control design. Configure one shutdown owner and avoid competing applications changing command-state or power-mode settings.

User applications and notifications

Applications may use monitoring data to record power events or send notifications. Email broadcasting described in the prospectus requires a host application and network configuration; the reference heartbeat daemon v1.6 does not implement email delivery.

Safe application design

Let the system service own the shutdown handshake and RTC synchronization. Avoid multiple programs writing the command-state register. Keep application reads bounded and handle I^2C errors without retry loops that monopolize the bus.

If application data must be flushed during FSSD, integrate that work with normal systemd shutdown ordering and test its worst-case completion time. A file-safe power sequence depends on the actual operating system and storage behavior.

Commission the intended workload

Test event logging, storage writes and the expected network loss together with UPS operation. A passing idle test does not establish that a high-write workload completes within the configured grace interval.

Programming interface and I²C address groups

Examples use Linux bus 1 and the default address group. Addresses and offsets are hexadecimal. The appendix lists the V8B5 field layout, access types, encoding and reserved locations.

Address group	Addresses
Default	0x68–0x6F
Alternate 1	0x58–0x5F
Alternate 2	0x48–0x4F
Reduced no RTC group	0x69 and 0x6B

A scan showing several consecutive addresses can represent register banks of the same controller. It does not imply that eight independent physical devices are fitted. A device claimed by a Linux driver may appear as UU.

Default access	Purpose	Access
0x68	DS1307-compatible RTC	Linux RTC driver
0x69	Status bank	Read; host temperature and fan writes at 0x16 and 0x19
0x6A	Internal RTC structure	Reserved; use 0x68
0x6B	Command bank	Read / described writes
0x6C–0x6E	Reserved banks	Leave unchanged
0x6F	Diagnostic snapshot	Development build only; public V8B5 returns zero.

Non-destructive configuration checks

```
sudo i2cget -y 1 0x6b 0x0c b
sudo i2cget -y 1 0x6b 0x01 b
sudo journalctl -u M2_PMH_i2c.service -b -n 10 --no-pager
```

Use the released API definitions for all other writes. Arbitrary register writes can change power behavior, initiate shutdown or alter persistent settings. Do not force raw I²C access to an RTC address already owned by the kernel driver.

The complete byte layout is in the Register and variable reference at the end of this manual and in reference/REGISTER_MAP_V8B5.csv. Use the described fields and leave reserved locations unchanged.

Module status registers and monitoring

Status information uses default bank 0x69. Multi-byte values are little-endian. Host CPU temperature at 0x16 and Linux fan state at 0x19 are supplied by daemon v1.6. Other public status fields are read-only to user applications.

Monitoring functions

Information	How it should be interpreted
Power mode	Current accepted source state; correlate with cable/battery transition messages.
Battery voltage	A measurement, not a universal percentage. Chemistry, current and temperature affect interpretation.
Supply voltage and current	Use the correct channel and sign convention. Advanced inputs add monitoring points.
Charger state	Separate commanded enable, charging activity and measured current.
CPU temperature	Host-provided telemetry in the reference daemon, rather than an independent Pi CPU sensor inside the MCU.
System and restart reasons	Read with the matching firmware definitions; preserve the raw value and timestamp.

Heartbeat diagnostics

```
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
systemctl show M2_PMH_i2c.service \
  -p ActiveState -p NRestarts -p ExecMainStartTimestamp
```

Successful-read totals should increase while the host is running. Error totals are cumulative for that daemon process. NRestarts counts systemd automatic restarts, not every possible manual stop/start; compare the process start timestamp and Linux uptime as well.

Counter wraparound

MCU diagnostic counters can wrap at their declared width. A count falling from a high value to a small value is not by itself proof of a reset. A new startup banner, reset-cause report and reinitialized state provide stronger evidence.

Hardware RTC register interface

At the default address group, Linux accesses the UPS clock through the DS1307-compatible bank at 0x68. The date/time bytes use binary-coded decimal (BCD). Prefer the kernel RTC interface over direct register writes.

Offset	Date or time field	Encoding
0x00	Seconds	BCD seconds; use the supported clock control behavior.
0x01	Minutes	BCD minutes.
0x02	Hours	BCD hours; the reference system uses 24 hour time.
0x03	Day of week	Driver and firmware convention must agree.
0x04	Day of month	BCD calendar day.
0x05	Month	BCD month.
0x06	Year	Two-digit BCD year in the firmware-supported range.

BCD example

A minute byte of 0x27 represents decimal 27 minutes, not decimal 39. A complete date write must contain a valid combination of fields. Use hwclock or the supplied daemon so the Linux driver applies the intended format.

Commit behavior

The MCU captures incoming date/time bytes and commits a completed request outside the transfer handler. Serial diagnostics show QUEUED and COMMIT_END. Confirm the new time by reading it back.

Distinguish the two RTCs

The Raspberry Pi 5 RTC and the UPS RTC have separate Linux device entries and separate functions. Verify /sys/class/rtc names before setting a clock. A generic hwclock command without --rtc can select the wrong one.

Module command registers

The default command bank is 0x6B. Runtime, serial, switch and supported configuration fields are listed in the final register reference. The shutdown handshake at 0x00 is owned by the Linux daemon.

Offset	Function	Established behavior
0x00	Host state and shutdown handshake	Read by the daemon. Shutdown requests 0xCC and 0x77 are recognized by v1.2; an acknowledgement is followed by Linux poweroff.
0x01	Battery runtime control	0x01 gives the default of about 70 seconds before timed FSSD. 0xFF disables the elapsed-time limit.
0x0C	Slide switch enable	0xAA enables switch mode and couples runtime to 0xFF; 0x00 returns to normal mode and runtime 0x01.

Read back after configuration

```
sudo i2cget -y 1 0x6b 0x01 b
sudo i2cget -y 1 0x6b 0x0c b
```

Do not treat 0x01 as a literal one-second runtime, or 0xFF as a battery-protection bypass. The timed limit, FSSD grace interval, switch behavior and low-battery decisions are separate parts of the operating sequence.

Persistent and runtime state

Some settings are retained by the controller while others are runtime handshakes or counters. Do not assume every write is persistent or that reading a value back proves it has been saved. Use the documented mode-setting procedure and verify behavior after a controlled restart.

Reserved fields

Reserved locations occupy bytes in the bank but do not authorize a hardware action. Leave them unchanged. A field name alone does not establish that a peripheral is fitted or active.

Bootloader entry and factory defaults change program flow or persistent settings. Use the dedicated firmware-update procedure. RESET plus FSSD selects only the bootloader; it does not erase configuration or select factory defaults.

Bootloader entry and recovery

The V88 bootloader loads and verifies the UPS application through the Raspberry Pi serial port. Standard and Advanced use the same procedure. Keep stable cable power connected. The KEY header is not required. RESET plus FSSD opens the bootloader directly; there is no Hardware Command Mode menu and no button-selected Factory Defaults.

Two ways to enter the bootloader

Use either the two M.2 buttons or the software command while the application is running. Before starting, have the matching HEX file and upload command ready. Close other programs using the loader UART and stop the optional status monitor. Keep the normal shutdown service installed and enabled.

Entry using RESET and FSSD

1. Connect a suitable cable supply and keep Raspberry Pi running with SSH available.

2. Press and hold M.2 RESET. While holding RESET, press and hold FSSD.

3. Release RESET while continuing to hold FSSD. After approximately one second, release FSSD. Do not keep it held for several seconds; a key not released within the startup release window cancels the request.

4. The controller checks cable power and enters the bootloader. Tested V83 and later entry was approximately three seconds from the application entry message; this is an observation, not a guaranteed startup time.

5. Start the prepared upload within 15 seconds of actual bootloader entry. Do not make a second FSSD press. This entry path does not deliberately reset Raspberry Pi.

Entry using an SSH command

The simplest software procedure is the combined entry-and-update command in the next chapter. To enter the bootloader alone, write 0xBB to command address 0x6B, register 0x00:

```
sudo i2cset -y 1 0x6b 0x00 0xbb b
```

The application must be running and must have accepted cable power. The write restarts the M.2 controller into its protected loader. It does not intentionally press the Raspberry Pi power button. After this command use the manual-entry upload command with -j, within the 15-second window.

The 15 second entry window

The limit applies before the first accepted application Flash write. If no write starts, the bootloader returns to the intact application through a resume path. Serial probes, noise, malformed records and incomplete lines do not extend this window. Application initialization follows the timeout, so the visible return can take longer than 15 seconds.

Once an actual write begins, the bootloader saves a persistent incomplete-update marker before modifying the application. The 15-second exit is then disabled. The loader remains in recovery until a complete transfer, successful Flash verification and end-of-file command finish the update. It will not start a partly written application.

Bootloader LED indication

USR, SYS, BAT, TMR, FAN and TMP form a walking sequence during programming. The V88 loader advances this sequence once per two HEX records, including an all-off step between cycles. It indicates transfer activity, not a calibrated percentage. Use the Python progress and final CRC result to determine completion. ACT, M.2, CHG and EPR are not part of this programming animation.

Interrupted transfer and power loss

If a transfer is interrupted after writing begins, keep or restore cable power and send the entire firmware again from the beginning. No buttons or new I²C loader request are needed while recovery is active. The same recovery state survives an MCU reset and loss of power. A new valid image can replace the interrupted image; verification applies to the image selected for the new attempt.

If interruption happens before the first application write, the previous image remains intact. In that case the normal 15-second timeout still applies; enter the bootloader again if necessary. A correct update clears the recovery condition and resumes the application.

Automatic Raspberry Pi startup during recovery

In V88, an incomplete update combined with an MCU power-up or brownout reset invokes one Pi power-button sequence after the supply paths are enabled: 0.5 seconds released, 6 seconds pressed, 2.25 seconds released, 0.5 seconds pressed, then released. The initial long press establishes an OFF state before the final wake pulse; a Pi already booting during this recovery can therefore restart.

This recovery sequence takes about 9.35 seconds before the loader wait. Allow another 60–90 seconds for Linux and SSH to become available. Recovery has no 15-second upload deadline after writing has already begun, so there is time for Raspberry Pi to boot. Run the recovery upload command once SSH returns.

The sequence is not used for ordinary button or I²C loader entry, MCU RESET alone, watchdog or software reset, a completed-update resume, or startup with an intact application. If only the MCU is reset while Pi stays running, recovery leaves its power button released.

Factory defaults

RESET plus FSSD no longer selects factory defaults. The software maintenance request at command register 0x00 remains available as code 0xDD, subject to the documented application conditions. Use it only when restoring configuration is intended. It is separate from bootloader recovery and can restore the RTC reference date. Routine firmware programming does not require factory defaults.

Local and remote firmware updates

Application and protected bootloader

The application provides UPS operation. The protected bootloader receives application updates and recovery transfers. The Python updater excludes the loader, configuration and activation-marker regions from application writes. Consequently, uploading a combined HEX through Python does not replace its protected loader. A newer application banner does not prove that a newer loader is installed.

Initial installation or loader replacement

For ICSP programming use a verified combined M2_PMH.hex built for application V8B5 with the matching V88 protected loader. The standalone loader HEX is for maintenance and is not a complete application. Follow the programmer procedure for the fitted board and power arrangement.

Routine UART application uploads leave the V88 protected loader unchanged. Rebuilding or reinstalling that loader is not required for application V8B5. Use only the correct verified application image; check the package manifest before programming.

Serial connection and preparation

The supplied V88 loader uses 38400 bit/s, 8 data bits, no parity and 1 stop bit. The updater default is still 9600 for compatibility, so always supply -b 38400. Application diagnostic UART speed, normally 115200, is a different setting and does not change loader speed. Select the UART actually wired to the board; the tested assembly uses /dev/ttyAMA0.

```
sudo apt install -y python3-serial python3-smbus
cd ~/M2_UPS_PMH_Customer_V8B5/firmware
python3 ../updater/M2_PM_UPS_BL01D.py -G -f M2_PMH.hex
```

The -G command validates Intel HEX locally without entering BL or writing hardware. Retain a known complete copy of the HEX and use SHA256SUMS.txt to identify the supplied files. Close serial terminals on the loader UART. The read-only monitor should be stopped; it is not needed for programming.

Automatic entry and upload from SSH

Use this command while the UPS application is running under accepted cable power. Omitting -j allows Python to send the I²C bootloader request automatically:

```
sudo python3 ../updater/M2_PM_UPS_BL01D.py -v -i -k \
  -p /dev/ttyAMA0 -b 38400 -f M2_PMH.hex
```

Upload after buttons or during recovery

Use this command after RESET plus FSSD, after a separate 0xBB I²C command, or when an interrupted update has already left the board waiting in BL. It does not depend on the UPS application responding to I²C:

```
sudo python3 ../updater/M2_PM_UPS_BL01D.py -v -i -j -k \
  -p /dev/ttyAMA0 -b 38400 -f M2_PMH.hex
```

Meaning of the upload options

-v enables progress information; -i skips the application version read; -j skips I²C bootloader entry; -k skips the extra I²C reset after programming. The serial loader completes its own verified exit. None of these options disables Flash readback or CRC32 verification. Keep -j for a board already in BL, and omit it only when requesting entry from a running application.

Progress and completion

Tested transfers of 6356 records and 76245 application bytes took about two minutes at 38400, compared with about six minutes at 9600. Duration depends on image size, Flash operations and host timing. Progress is reported roughly every 5 percent; it is not printed for every record. Do not interrupt a valid transfer merely because output is temporarily quiet.

The updater verifies 26 Flash ranges for the tested image and sends the final end-of-file command only after all ranges match. The record count and range count can differ with another image. Successful completion is explicitly reported as:

```
Transfer completed; programmed application Flash CRC32 verified
```

An early ACK timeout or NAK may be recovered during connection negotiation. Flash readback available confirms a valid protocol reply; it is not proof of completed programming. Treat the update as successful only after the final CRC-verified completion message. A timeout or CRC mismatch during data transfer requires investigation and a complete retry.

Repeat after an interruption

Restore stable cable power, allow Pi to start, and use the command with -i -j -k at 38400. The transfer starts at record one; it does not continue at the interrupted percentage. Do not issue factory defaults to repair an incomplete image. If the protected bootloader itself is damaged, use ICSP; application recovery cannot reconstruct it.

Checks after an update

1. Confirm the final CRC-verified completion message and the expected application version in the startup banner.

2. Confirm the application resumes and successful heartbeat reads increase. I²C is unavailable while BL runs, so the daemon may record errors during programming; check that new errors stop after application return.

3. Read back switch mode and runtime. Check RTC synchronization, charging and one orderly shutdown/return cycle before further cable-loss testing.

```
sudo systemctl start M2_PMH_i2c.service
sudo journalctl -u M2_PMH_i2c.service -b -n 15 --no-pager
uptime
```

If you stopped the service manually, restart it only after the application has returned. Do not force raw access to a kernel-owned RTC device and do not repeatedly trigger I²C entry while the board is already in BL.

Troubleshooting

Symptom	Checks and next action
SSH unavailable; Pi LED red	Check whether the Pi has shut down or is waiting for its power button. Inspect UART and supply state before assuming a crash.
Repeated MCU startup banners	Save the log from before the restart. Record firmware and reset-cause fields. Check power and escalate with the complete capture.
No serial messages	Check baud rate, logic levels, adapter and common ground. Compare LEDs and I²C activity.
RTC device missing	Inspect /dev/rtc*, RTC names and kernel probe errors. Confirm address selection and driver binding.
RTC write times out	Stop repeated writes. Capture kernel and daemon logs plus UART. Check whether heartbeat still responds.
Battery does not charge	Confirm cable mode, battery chemistry, protection state and available supply margin. Check measured current as well as CHG indication.
Cable/battery mode oscillates	Check supply, USB-C lead, connectors and load. Capture transitions with charging enabled.
No timed FSSD	Read switch mode and runtime. Switch mode 0xAA normally sets runtime 0xFF.
No restart after cable return	Check mode, physical switch, completion of FSSD and Pi EEPROM standby settings. Test return during FSSD separately.
One I²C error at startup	Observe later totals. A single historical error differs from an increasing error count; preserve both for diagnosis.
USR remains OFF after configuration	Type YES exactly; y cancels. Check manual versus mapped mode, selector 0x0D and LED gate 0x0B. External ULED uses P2 pin 5 and GND; R7 = 3.6 kΩ current limiting is already on the board.
Installer expects 0x08B5 but reads 0x08B2	Flash firmware/M2_PMH.hex from the current package, then repeat --check. Do not use an older home-directory HEX.

Collect a useful report

```
uptime
sudo journalctl -u M2_PMH_i2c.service -b -n 30 --no-pager
sudo journalctl -k -b --no-pager | tail -n 60
sudo i2cget -y 1 0x6b 0x01 b
sudo i2cget -y 1 0x6b 0x0c b
```

Include a complete serial capture, not only the new startup banner. Note whether a reset was manual, the cable-return timing and the exact battery and supply used.

Commissioning checks

Expected results

Run the following checks after installation and after changing battery, supply, storage or enclosure. Keep the serial capture and service journal for diagnosis.

Test	Expected result
Cable operation	Stable source recognition; charging starts when conditions permit.
Cable removed	Pi and SSD continue on battery; no unintended reboot.
Timed FSSD	About 70 s with runtime 0x01, followed by about 30 s grace.
Cable return during FSSD	Shutdown completes, then normal-mode startup follows.
Cable return after shutdown	Startup after the cable source is accepted.
Repeated cycles	At least five consistent shutdown / return cycles.
Slide OFF / ON	OFF requests shutdown; ON permits startup.
RTC and service	Correct time after NTP; successful reads increase without growing error totals.
BL idle exit and recovery	No write: return after 15 s. Interrupted write: remain in BL across reset/power loss and accept a full verified retry.
ULED retention	Select a source, allow save, then verify after MCU reset and complete power cycle. Original source LED remains active.

Frequently asked questions

Answers to common installation, operation, recovery and firmware-update questions for Standard and Advanced assemblies.

What does the M.2 UPS and Power Management HAT do?

It combines an M-key PCIe interface with battery backup, power monitoring and File Safe Shutdown for Raspberry Pi 5. The UPS supports the Pi and SSD while Linux finishes its shutdown.

Which models are available?

Standard provides the core M.2 and UPS functions. Advanced adds the designated 5–32 V external input, passive PoE and additional application interfaces. The final appendix compares both assemblies.

Is it compatible with other Raspberry Pi models?

This product is designed for Raspberry Pi 5. Do not assume compatibility with another Raspberry Pi model because its GPIO connector fits.

Is installation completely plug and play?

Mechanical connection alone is not sufficient for File Safe Shutdown. Enable I²C, configure the RTC interface and install the supplied Python daemon and systemd service as described in the installation chapters.

Does the HAT need another USB-C cable?

In normal Standard operation, keep the supply connected to Raspberry Pi 5 USB-C. The HAT receives power through the 5 V GPIO power path and supplies backup power through that path during an outage.

Can higher external input voltages be applied to the Raspberry Pi header?

No. The Raspberry Pi header is a 5 V power path. The 5–32 V range applies only to the designated Advanced EPR input or approved passive PoE input.

Can I use another HAT above this board?

Only when the connector arrangement, mechanical clearance, I²C addresses and combined power budget permit it. Check the fitted header and SSD, cooler and battery clearance before stacking.

Will it fit an existing case?

A dedicated enclosure specially designed for the **M.2 UPS PMH** and Raspberry Pi 5 assembly is available. Choose the version matching the board and fitted battery, SSD and cooler. For other cases, verify the full assembly and connector access; the board footprint alone does not establish compatibility.

Which SSDs can be fitted?

The board accepts compatible PCIe M-key devices in 2230, 2242 and 2280 lengths. Mechanical fit does not prove driver or boot support. Validate the intended NVMe or other PCIe device separately.

What is the M.2 reference clock?

The interface provides a 32.768 kHz SUSCLK reference. This signal is separate from the DS1307-compatible RTC interface used by Linux.

What backup current is available?

The specification gives a total backup supply capability of 5.25 V at up to 5 A continuous, with backup also covering the SSD. Battery discharge capability, connectors, wiring and thermal conditions must support the actual load.

Can I connect the 18650 battery and cable battery together?

No. Use one backup source at a time. These are alternative connections; connecting cells in parallel without a suitable management circuit can cause uncontrolled current between them.

Which batteries are supported?

Only LiPo (L, 0x4C), Li-ion (I, 0x49), LiFePO4 (F, 0x46), and the designated 4000 F / 4.2 V supercapacitor (C, 0x43) are supported. Use one source at a time with the matching charge profile and adequate discharge capability. The standard battery specification is a protected 3.7 V, 450 mAh, 15C LiPo.

Can I use a supercapacitor?

Use only the designated 4.2 V 4000 F assembly with its approved profile. The cycle-life comparison uses the FAQ reference of more than 20000 cycles. Published component temperature limits differ (+65°C or +70°C upper limit); see the Supercapacitor cycle life and temperature chapter. These are not ratings for the complete Raspberry Pi assembly.

Is the metallic battery holder insulated?

A protective plastic cap is available for the metallic battery holder. Fit the cap as intended to reduce accidental contact with nearby circuitry. Maintain clearance and inspect the assembled holder and insulation before applying power.

What is the maximum charging current?

Standard: 580 mA. Advanced: 1.1 A. Charging demand is adjusted dynamically to available cable power, starting at a low current. The maximum is not a guaranteed current for every battery or supply condition.

Why does charging start slowly or reduce its current?

The supply must power the Pi, SSD, peripherals and charger together. The controller reduces charging demand when source margin is limited and increases it as conditions permit. Check measured battery current as well as CHG indication.

Why can battery mode appear while the cable is connected?

An insufficient source or excessive voltage drop can make the cable path unacceptable under load. Check supply rating, USB-C lead, connectors, peripheral load and charging demand.

How quickly does backup take over?

The line-interactive transfer-time specification is a maximum of 50 microseconds. Advanced online power paths are specified at zero transfer delay.

What protects the battery and power path?

The supplied documentation describes battery monitoring and cut-off protection, a 5 A PPTC and controlled power switching, with additional input protections on the applicable model. Use a compatible protected battery and the correct polarity.

When does timed shutdown begin?

In normal mode, command register 0x01 defaults to 0x01 and timed FSSD begins after approximately 70 seconds on battery. A separate grace interval of approximately 30 seconds follows.

Can I extend battery runtime?

A runtime value of 0xFF removes the elapsed-time limit. For values 0x00–0xFE, the timed threshold is approximately 10 + 60 × value seconds. Low-battery protection remains active.

What happens if cable power returns during FSSD?

The shutdown sequence completes before the normal-mode restart sequence begins. Test return near the end of the grace interval and several successive cycles. In switch mode, the physical switch must permit ON.

How does the optional slide switch work?

Enable slide-switch mode with 0xAA at 0x6B register 0x0C; runtime becomes 0xFF. OFF requests safe shutdown and holds the Pi off even with USB-C connected, using the documented Pi EEPROM configuration and button connection. ON permits normal cable or battery operation.

Which GPIO pins are required by the daemon?

Normal communication uses I²C and the shared ground; the daemon uses no extra Raspberry Pi GPIO. The optional 1-wire interface uses Raspberry Pi GPIO4 where implemented. Power control requires the documented Pi button connection.

What do the LEDs show?

The PCB row is ACT, M.2, USR, SYS, BAT, CHG, TMR, FAN, TMP and EPR. FAN and TMP are separate indicators. SYS normally flashes about every 0.5 s on cable and 1.5 s on battery. EPR is an Advanced indicator.

Can I monitor or control the UPS with scripts?

Yes. Use the released I²C API and the supplied daemon. The default banks include RTC at 0x68, status at 0x69 and commands at 0x6B. Do not write undocumented offsets or run a second shutdown daemon.

Are scheduler and event-triggered applications available?

The bundled daemon manages heartbeat, shutdown, temperature and RTC synchronization. It does not configure scheduler events or send email. Reserved scheduler fields are identified in the register appendix.

Does the UPS contain a separate DS1307 chip?

No. The UPS controller exposes its RTC through a DS1307-compatible I²C interface, with a 32.768 kHz clock source. Linux uses the rtc-ds1307 driver. This clock is separate from the Raspberry Pi 5 RTC.

Can the HAT back up the Raspberry Pi RTC too?

Yes. The **M.2 UPS PMH** main battery backs up the Raspberry Pi 5 RTC through the dedicated cable, including after power loss and Linux shutdown. No separate RTC battery is needed while this backup supply is available.

Why does the RTC display a different hour?

The daemon writes UTC after Linux confirms NTP synchronization and then hourly. Linux tools may display local time. Compare timezone-aware values before adjusting the clock; do not copy an incorrect Linux time into the UPS RTC.

Does a normal restart reset the UPS RTC?

Ordinary Raspberry Pi restart and switch OFF/ON should retain it while the UPS controller remains powered. Factory defaults deliberately restore a reference date; a later confirmed NTP synchronization restores current time.

Why does i2cdetect show UU at 0x68?

UU means a Linux kernel driver owns the address. It is expected when the RTC driver is bound. Read the clock through /dev/rtcN after verifying its name rather than forcing direct access to the claimed address.

What is the bootloader used for?

It accepts a complete application HEX through the Python updater, verifies actual Flash using CRC32, and protects recovery after interruption. The V88 loader uses 38400 bit/s. Python does not replace the protected loader; use ICSP when installing a new loader.

How do I enter the bootloader?

With cable power connected, hold M.2 RESET and FSSD, release RESET, then release FSSD after about one second. No second press or KEY jumper is required. Alternatively, use the automatic SSH update command without -j, or write 0xBB to 0x6B register 0x00. RESET plus FSSD does not select factory defaults.

Which external voltages can the Advanced model accept?

The designated EPR and passive PoE inputs are specified for 5–32 V DC. Check polarity, wiring, input current and source rating. The allowed input range alone does not make every solar panel suitable.

Can EPR and passive PoE be connected together?

The supplied FAQ specifies one of these external sources at a time. Use EPR or passive PoE, following the input wiring for the fitted Advanced assembly.

Can EPR and Raspberry Pi USB-C be connected together?

The supplied specification permits GPIO 5 V and EPR to be present together through the designed power paths, with source selection by the controller. Do not parallel supplies through arbitrary wiring.

Is passive PoE compatible with standard active PoE?

Do not assume it is. This is a dedicated passive DC arrangement, with no claim here of IEEE 802.3af/at/bt negotiation. Use a compatible injector and verify its voltage, pin assignment and polarity.

What should I capture when a test fails?

Save uptime, the daemon journal, kernel errors and the complete serial trace preceding the event. Record firmware, supply, battery, switch position and exact cable sequence. Note whether any reset was manual.

Which software files belong with this manual?

This release supplies PDF and Word manuals, installer V08, daemon v1.6, monitor 0B (v2.7), configurator 06, the V8B5 register CSV, application HEX and unchanged 01D updater. Resources additionally supplies firmware and protected-loader sources and validation reports. README.txt identifies matching files and launch commands. The English M2_PMH_1wire.py reader is also included and installed at /opt/M2_UPS_PMH/.

Does Standard need the Advanced KEY header for recovery?

No. Standard and Advanced both use M.2 RESET and FSSD. The Advanced KEY input is not used for bootloader entry.

Why must I release FSSD after RESET?

Release FSSD after about one second so startup can debounce the release and proceed into BL. There is no command-selection menu. Keeping FSSD held beyond the startup release deadline cancels the request.

Does entering BL stop Raspberry Pi 5?

Ordinary button or I²C bootloader entry does not intentionally press the Pi power button. During BL the UPS application and I²C are unavailable. V88 cold recovery after an incomplete write is different: it deliberately establishes Pi OFF, then wakes Pi so SSH can be used to retry the update.

Can I leave the loader after an interrupted Flash write?

Before the first application write, the 15-second idle exit can return to the intact image. After a write starts, the persistent marker keeps recovery active across MCU reset and complete power loss. Send the whole image again and wait for verified completion. The incomplete application is never intentionally executed.

Why do I get repeated ACK timeouts?

Check -b 38400, the selected UART, cable power and whether BL is active. A command using -j cannot enter BL by itself. If no write began and the 15-second window expired, request entry again. Close other programs using the same UART.

Can I change baud rate only in Python?

No. The loader and Python must use the same speed. V88 requires -b 38400. Replacing a 9600-bit/s loader requires ICSP; a routine application upload leaves the old loader in place.

Why does an interrupted transfer start from zero?

Recovery accepts a complete new image and rewrites it from the beginning. This avoids relying on partly programmed data. The final CRC check verifies the newly selected image.

Will Raspberry Pi start after a power failure during programming?

With the V88 protected loader installed, an incomplete-write marker plus a power-up or brownout reset triggers one Pi startup sequence. Allow roughly 9.35 seconds for that sequence and then Linux boot time. An MCU RESET alone does not invoke this sequence.

How do I know which bootloader is installed?

Keep the ICSP installation record and HEX hash. The application version banner and the PCB/BL identification byte 0x40 do not by themselves distinguish all loader revisions or serial speeds.

Does the 15 second limit interrupt a long upload?

No. It applies only before the first accepted application Flash write. Once writing starts, recovery waits for a complete verified transfer, including across MCU reset or power loss.

Can I measure two external voltages at once?

No. EXT0 and EXT1 feed one common ADC buffer. Connect only the selected input and leave the other open. The saved range selector changes scaling only.

Why does the ADC reading differ from my multimeter?

Check that R75 is 1.00 kΩ and that the selected EXT0/EXT1 range matches the connected pin. An older divider with V8B5 conversion factors gives an incorrect result. Then check the reference voltage, wiring and measurement tolerances.

Technical specifications

Electrical and mechanical comparison of Standard and Advanced assemblies. Standard maximum charging current is 580 mA; Advanced maximum is 1.1 A. Ratings apply to the designated input, output and fitted assembly.

Feature	Standard	Advanced / Passive PoE
Raspberry Pi® 5 System Compatibility		
Compatible Raspberry Pi Models	Especially Designed for Raspberry Pi® 5	Especially Designed for Raspberry Pi® 5
HAT EEPROM	Not Exist	Not Exist
HAT Dimensions	85mm x 56mm	85mm x 56mm
Raspberry Pi® 5 System Interfaces		
Use I²C API for Raspberry Pi® 5 interaction User selectable addresses	GND, SDA0, SCL0 I²C Addresses 1: 68 69 6a 6b 6c 6d 6e 6f I²C Addresses 2: 58 59 5a 5b 5c 5d 5e 5f I²C Addresses 3: 48 49 4a 4b 4c 4d 4e 4f I²C Addresses 4: 69 6b	GND, SDA0, SCL0 I²C Addresses 1: 68 69 6a 6b 6c 6d 6e 6f I²C Addresses 2: 58 59 5a 5b 5c 5d 5e 5f I²C Addresses 3: 48 49 4a 4b 4c 4d 4e 4f I²C Addresses 4: 69 6b
Selectable use of Raspberry Pi® 5 RS232 serial0	GND, TXD0, RXD0 OFF(HiZ)	GND, TXD0, RXD0 OFF(HiZ)
Raspberry Pi® 5 RTC Powering	Offered via dedicated cable supplying Raspberry Pi RTC via UPS Battery	Offered via dedicated cable supplying Raspberry Pi RTC via UPS Battery
Selectable use of Raspberry Pi® GPIO	I²C only for interaction with	I²C only for interaction with GPIO_GEN4 (only if 1-wire is used)
Passive Cooling	4 layers PCB 2oz copper with enhanced ground and cooling planes, covered with huge number of thermal vias Cooling hole over Official Cooling FAN for air circulation	4 layers PCB 2oz copper with enhanced ground and cooling planes, covered with huge number of thermal vias Cooling hole over Official Cooling FAN for air circulation
Active Cooling	Hole Placed exactly above the Official Raspberry FAN Offers improved Cooling for the Raspberry Pi 5 as also SSD above	Hole Placed exactly above the Official Raspberry FAN Offers improved Cooling for the Raspberry Pi 5 as also SSD above
Dedicated Passive PoE on PCB	none	5V-32V DC with reverse polarity, 2 level ESD and PPTC fuse protection Continuously current measure over Passive PoE supply on 12V-32V
M2. Interface		
Supported M.2 SSD Interfaces	2230 – 2242 – 2280	2230 – 2242 – 2280
Supported M.2 SSD Height	3.2mm	3.2mm
Supported M.2 SSD Cooling	Via Official Raspberry Pi 5 Cooler Air Pass Hole	Via Official Raspberry Pi 5 Cooler Air Pass Hole

Feature	Standard	Advanced / Passive PoE
M.2 SSD Indicators	ACT, M.2 (PWR)	ACT, M.2 (PWR)
Supported Power Supply Current	3A	3A
Supported M.2 32.768 kHz Clock	Yes	Yes
UPS Functionality on M2. SSD	Yes	Yes
Power Monitoring		
UPS Type	Line Interactive on Raspberry Pi® 5V GPIO	Line Interactive on Raspberry Pi® 5V GPIO On-line on EPR On-line on PPoE
UPS Response time	Line Interactive Maximum 50 uS	Line Interactive Maximum 50 uS On-Line 0 uS
Automatic Restart on Cable Power Return	YES	YES
Raspberry Pi Battery Backup	5.25V@5A current continuous supply to Raspberry Pi via 5V GPIO Pins Power Backup cover also the M.2	5.25V@5A current continuous supply to Raspberry Pi via 5V GPIO Pins Power Backup cover also the M.2
Cable Power Input	Raspberry Pi® GPIO 5V	Raspberry Pi® GPIO 5V UPS External Power Input 5V-32V DC supplying Pi with 5V@5A Can be used both (GPIO 5V and EPR) at the same time (isolated with ZVD)
Cable Power Monitoring Point	Raspberry Pi® GPIO 5V	Raspberry Pi® GPIO 5V/EPR/PPoE
UPS Activation Powering Triggers/Thresholds	Proprietary Algorithm of Falling Power Peak Analysis Programmable by user Self-learning system	Proprietary Algorithm of Falling Power Peak Analysis Programmable by user Self-learning system
Cable Powering Reactivation	After 10s of continuously cable powering (without power spikes)	After 10s of continuously cable powering (without power spikes) on any cable power source (GPIO or External or Passive PoE)
Auxiliary 5V and 3V3 Battery Backed Supply on I/O Pins	none	5V@200 mA current and 3V3@200 mA continuous supplies on I/O Pin battery backed, with possibility to continuous supply auxiliary devices with Raspberry Pi disconnected
Power Back-up		
Total Back-up Power	5.25V 5A continuously Supply	5.25V 5A continuously Supply
Number Power Back-up Sources	Two (One at the time can be used)	Two (One at the time can be used)

Feature	Standard	Advanced / Passive PoE
Power Back-up Source Types	Cable Battery or 18650 Socket (One at the time can be used)	Cable Battery or 18650 Socket (One at the time can be used)
Supported Batteries Power Back-up		
Supported Batteries Chemistry	LiPO, LiFePO4, Li-Ion, Super Capacitor 4000 F / 4.2 V	LiPO (standard Supported with system), LiFePO4, Li-Ion, Super Capacitor 4000 F / 4.2 V
On bard XH-2.5mm Battery Socket (with mechanical reverse polarity protection)		
Default (standard)	PCM Protected LiPO 3.7V, 450 mAh 15C with silicone high current cables	PCM Protected LiPO 3.7V, 450 mAh 15C with silicone high current cables
Optional bigger Capacities Batteries	LiPo, Li-ion and LiFePO4 only; use the matching source profile.	LiPo, Li-ion and LiFePO4 only; use the matching source profile.
On bard 18650 Battery Holder (with electronic reverse polarity protection)		
18650 Support	Single 18650 cell: Li-ion, LiFePO4 or compatible LiPo only; use the matching source profile.	Single 18650 cell: Li-ion, LiFePO4 or compatible LiPo only; use the matching source profile.
Charging process		
LiPO/LiFePO4/Li-Ion/Super Capacitor	Automatic Selected: Full Charging Cycle Trickle Charging	Automatic Selected: Full Charging Cycle Trickle Charging
Maximum Charging Current	580mA	1.1A
Charging Current Setting	Yes, from 100mA to 580 mA Dynamically Decrease/Increase the charging current to appropriate level according to cable power available	Yes, from 100mA to 1.1 A Dynamically Decrease/Increase the charging current to appropriate level according to cable power available
Batteries Protection		
Standard LiPO 450 mAh	PCM and on-board cut-off protection system overcharge or over discharge, over voltage and under voltage PCB temperature monitoring (if battery is placed on PCB)	PCM and on-board cut-off protection system overcharge or over discharge, over voltage and under voltage PCB temperature monitoring (if battery is placed on PCB)
High-Capacity Li-Ion, LiPO, LiFePO4	PCM and on-board cut-off protection system overcharge or over discharge, over voltage and under voltage PCB temperature monitoring (if battery is placed on PCB)	PCM and on-board cut-off protection system overcharge or over discharge, over voltage and under voltage PCB temperature monitoring (if battery is placed on PCB)

Feature	Standard	Advanced / Passive PoE
Battery Electrical Isolation System	Battery is Electrically Isolated (however cable connected) until system start up for the first time and receive 5V from GPIO	Battery is Electrically Isolated (however cable connected) until system start up for the first time and receive 5V from GPIO (or Passive PoE or 5V0-32V from EXT
Optional	Slide ON/OFF switch (external or internal), OFF always with File Save shutdown functionality	Slide ON/OFF switch (external or internal), OFF always with File Save shutdown functionality
Independent of the Cable Battery Powering		
Direct Battery Powering (Intelligent Power Bank) with Internal/External ON/OFF Slide Switch	Optional ON/OFF Slide Switch with File Safe Shutdown functionality when switching to OFF (keep battery powering ON until system shutdown)	Optional ON/OFF Slide Switch with File Safe Shutdown functionality when switching to OFF (keep battery powering ON until system shutdown)
Additional Features		
Power Consumption Measure	Dedicated IC measuring Inbound/Outbound Current/Voltage/Power	Dedicated IC measuring Inbound/Outbound Current/Voltage/Power
ESD Protected True 5V0/3V3 1-wire interface	Not implemented	ESD-protected M.2 1-Wire connector, linked to Raspberry Pi GPIO4. Enable Linux w1-gpio / w1-therm. Monitor 0B and the English reader support DS18B20 sensors.
Independent from Raspberry Pi ® 3V3 battery backed supply @200 mA With battery Back-up (Raspberry Pi® 5 can be OFF when the power Auxiliary 3V3 source is available)	Not implemented	Yes On separated pins
Independent from Raspberry Pi ® 5V0 supply @200 mA With battery Back-up (Raspberry Pi® 5 can be OFF when power Auxiliary 5V0 source is available)	Not implemented	Yes On separated pins
External analogue voltage measurement	Not fitted	One shared 12-bit ADC with buffered, software-filtered reading. P2 header EXT0 pin 11: 0–5.2 V; EXT1 pin 12: 0–32 V. Use one input at a time, unused input open. R75 = 1.00 kΩ. Saved range selection; voltage displayed to 0.01 V (not an accuracy guarantee).
3V3 RS232 Port that can be programmed as: primary Raspberry Pi® Port Secondary (independent from the existing on Raspberry Pi®)	Not implemented	Yes

Feature	Standard	Advanced / Passive PoE
System LEDs Indicators	ACT – SSD activity M.2 – SSD power USR – user indication SYS – system status BAT – battery level CHG – charger status TMR – timer FAN – official cooler activity TMP – Raspberry Pi core temperature	ACT – SSD activity M.2 – SSD power USR – user indication SYS – system status BAT – battery level CHG – charger status TMR – timer FAN – official cooler activity TMP – Raspberry Pi core temperature EPR – external power status
User LED Indicator	White USR LED. External LED connection by soldered cable on Standard. Manual ON/OFF at 0x09 or Flash-saved SYS/BAT/TMR/FAN/TMP mapping at 0x0D. On-board R7 = 3.6 kΩ limits current; the original source LED remains active.	White USR LED. External ULED at P2 pin 5 (USR_LED_H), cathode to GND. Manual ON/OFF at 0x09 or Flash-saved SYS/BAT/TMR/FAN/TMP mapping at 0x0D. On-board R7 = 3.6 kΩ; no extra series resistor required for the intended LED connection.
System Keys	UPSR, FSSD	UPSR, FSSD
User Programmable Key	AKEY (soldered cable only)	AKEY
External Connectivity to Keys	FSSD, AKEY With capability to connected external KEYs) Optional ON/OFF slide Switch	FSSD, AKEY With capability to connected external KEYs) Optional ON/OFF slide Switch
Independent to Raspberry Pi® Watchdog (Still Alive)	Yes	Yes
Battery Backed Hardware Real Time Clock and Calendar	Yes/Selectable When UPS (power cycling is used)	Yes/Selectable When UPS (power cycling is used)
System Switch ON/OFF	Optional Supported with Embedded or external ON/OFF slide switch or external one (even is system is powered by USB C) Selectable/Combined In addition to Raspberry Pi 5 Push button	Optional Supported with Embedded or external ON/OFF slide switch or external one (even is system is powered by USB C) Selectable/Combined In addition to Raspberry Pi 5 Push button
Solar Panel Supply Input	on 5V0 USB-C battery charging current adopted to existing solar conditions	on 5V0 USB-C on EPR (5V-32VDC) battery charging current adopted to existing solar conditions
System Cooling		
Advanced Automatic Active Cooling System (FAN)	Raspberry Pi official cooler controlled by the Pi; CPU temperature supplied through the Linux daemon.	Raspberry Pi official cooler controlled by the Pi; CPU temperature supplied through the Linux daemon.
Passive Cooling	Thought extended hole system supporting air circulation, extended cooling copper planes	Thought extended hole system supporting air circulation, extended cooling copper planes

Feature	Standard	Advanced / Passive PoE
System Control		
Vital System Information	Thought Registers Set accessed via I²C API	Thought Registers Set accessed via I²C API
Selected Vital System Information	Local serial diagnostic output.	Local serial diagnostic output.
Programmable/Accessible all the system parameters via I²C API	Supported settings and status fields are listed in the register appendix; reserved fields remain unchanged.	Supported settings and status fields are listed in the register appendix; reserved fields remain unchanged.
SysInfo Register	Yes, Provide core information about the system: System FSSD Reason - System Wakeup Reason - Power Management Restart Reason -	Yes, Provide core information about the system: System FSSD Reason - System Wakeup Reason - Power Management Restart Reason -
M.2 - UPS & Power Management HAT Running Register	YES, provide information to remote user if system is running properly	YES, provide information to remote user if system is running properly
Remote and local Bootloader for Live Firmware Update	YES	YES
e-mail sending on event	Host application required; not supplied by the daemon.	Host application required; not supplied by the daemon.
Measuring and Monitoring System		
Real Time Raspberry Pi® System current measure	Dual High-side bi-directional Hardware Current Sensing Monitor with power calculation (5V0 path)	Dual High-side bi-directional Hardware Current Sensing Monitor with power calculation (5V0 path) (5V0-32V DC path)
Powering Mode Status	YES	YES
Battery Level	YES	YES
Raspberry Pi® 5V level	YES	YES
External Powering Level	NO	YES
Passive PoE Level	NO	YES
Raspberry Pi® Core Temperature	YES	YES
Raspberry Pi® Active cooler FAN status	Linux fan enable state supplied every 5 seconds by daemon v1.6; not rotation-speed feedback.	Linux fan enable state supplied every 5 seconds by daemon v1.6; not rotation-speed feedback.
A/D(s) Level	Not fitted	P2 header: EXT0 pin 11 (0–5.2 V), EXT1 pin 12 (0–32 V). One shared ADC; connect one input only. R75 = 1.00 kΩ.

Feature	Standard	Advanced / Passive PoE
Charger Status	YES	YES
Scheduler		
Time/Calendar Scheduler	Basic scheduler register interface.	Basic scheduler register interface.
Shutdown/Wake-up on	Timed battery limit; low battery; FSSD button; optional slide switch; accepted cable return.	Timed battery limit; low battery; FSSD button; optional slide switch; accepted cable return.
Manufacturing		
PCB Manufacturing	4 Layers, 2 OZ Copper, 6mils/6mils Immersion Gold Plated Lead-free alloy assembly	4 Layers, 2 OZ Copper, 6mils/6mils Immersion Gold Plated Lead-free alloy assembly

A Complete Description of the M.2 UPS PMH Programming Registers

Applies to application V8B5 (0x08B5), using the compact register layout introduced in V8B2. Status bank 0x69 contains 52 bytes; command bank 0x6B contains 40 bytes. B = one byte; W = two bytes. Multi-byte values are little-endian; signed values use two's complement. BCD stores decimal digits. A matching CSV is supplied.

Unused named reserved fields were removed and offsets renumbered in V8B2. Do not reuse scripts or offsets from V8B/V8B1. Physical alignment bytes still exist and must remain unchanged. Saved settings are processed in the foreground; allow at least three seconds and read back. Volatile requests do not persist through MCU reset.

Persistent settings and migration

V8B5 uses settings schema 0x0019. It migrates supported earlier settings while preserving existing source, mode and scheduler values. The new ULED selector defaults to Manual until changed. Only an accepted changed selector causes a foreground Flash save. The internal 88-byte settings record appends map_uled at byte 86 (0x56); its validity marker begins at byte 84 (0x54). These internal offsets are not public I²C register addresses. Applications use command 0x0D.

Status bank — 0x69

Offset	Variable	Type / access	Description
00	mode	U8 Read Only	Accepted power mode: 0xF0 battery; 0xF1 cable.
01	backing_mode	U8 Read Only	Backup-source mode code; 0x01 indicates battery backup.
02	rtime	U16 Read Only	Reserved runtime / energy field; not a battery percentage.
04	Foreground loop counter	U16 Read Only	Foreground-loop counter; wraps modulo 65536.
06	batlevel	U16 Read Only	Battery voltage, packed BCD in 0.01 V units; 0x0390 = 3.90 V.
08	rpilevel	U16 Read Only	Raspberry Pi supply voltage, packed BCD in 0.01 V units.
0A	eprlevel	U16 Read Only	External source voltage, packed BCD in 0.01 V units; zero when inactive.
0C	curilevel	S16 Read Only	PAC1720 channel 1 signed current, mA.
0E	pwrlevel	S16 Read Only	PAC1720 channel 1 signed power field, mW; 16-bit storage.
10	vltlevel	U16 Read Only	PAC1720 channel 1 voltage, binary mV.
12	aEXT0level	U16 Read Only	Selected Advanced external input voltage, packed BCD in 0.01 V units. 0x0500 = 5.00 V; 0xFFFF unavailable. Historical name; selector at 0x6B:0x08 chooses EXT0 or EXT1.
14	key_pressed	U8 Read Only	Application KEY status code, where fitted: 0 no event, 1 or 2 input event.
15	PCB_temp	U8 Read Only	PCB temperature slot; raw, no active temperature conversion guaranteed.
16	RPI_temp	U8 R/W host	CPU temperature, packed BCD Celsius; 0xFF unknown. Daemon v1.6 sends every 5 seconds.

Offset	Variable	Type / access	Description
17	BAT_chg_stat	U8 Read Only	Charger current-limit code; multiply the binary value by 10 for mA.
18	BAT_chg_real	U8 Read Only	Reserved charger-feedback slot; not a measured-current value.
19	FAN_status	U8 R/W host	Linux fan state: 0 OFF, 1 ON, 0xFF unknown. Daemon v1.6 sends every 5 seconds; not RPM feedback.
1A	sysinfo	U16 Read Only	System information word: bits 3:0 FSSD reason; 7:4 wake reason; 11:8 restart reason.
1C	RS232_status	U8 Read Only	Serial status byte; raw.
1D	RS232_data	16 bytes Read Only	16-byte serial receive buffer; raw bytes.
2D	pcb_version	U8 Read Only	PCB / bootloader identification byte, hexadecimal.
2E	Model identifier	U8 Read Only	Assembly identifier: ASCII A (0x41) or S (0x53).
2F	default_battery	U8 Read Only	Factory backup-source identification, ASCII chemistry code.
30	firmware_version	U16 Read Only	Application firmware identifier; V8B5 reads 0x08B5.
32	dummy	U16 Reserved	Reserved trailing word; leave unchanged.

Command bank — 0x6B

Offset	Variable	Type / access	Description
00	M2_PMH_state	U8 R/W volatile	Linux heartbeat / shutdown handshake. 0xCC and 0x77 are daemon shutdown requests; daemon acknowledges with 0x00. Maintenance commands are listed below.
01	bat_run_time	U8 R/W saved	0x00–0xFE: timed FSSD after about 10 + 60 × value seconds. 0x01 default (70 s); 0xFF no elapsed-time limit. Low-battery protection remains active.
02	RS232_rate	U8 R/W saved	Packed baud nibbles: high local UART, low Pi UART. 0 off, 1=4800, 2=9600, 3=19200, 4=38400, 5=57600, F=115200. Default 0xF0.
03	rpi_hold_on	U8 R/W saved	Pi startup hold setting, seconds; default 0. A changed zero is clamped to 1 by the runtime handler.
04	Serial routing slot	U8 Reserved	Serial routing slot; do not modify.
05	sta_timer	U8 R/W volatile	Still-alive countdown byte; 0xFF disables it. Expiry is a controller action; leave disabled for the supplied daemon.
06	enable5V	U8 Reserved	Auxiliary supply-control slot; leave unchanged.
07	battype	U8 R/W saved	Backup profile: L=0x4C LiPo, I=0x49 Li-ion, F=0x46 LiFePO4, C=0x43 designated 4000 F / 4.2 V supercapacitor. Match the fitted source.
08	setA_D	U8 R/W saved	Advanced ADC range: 0 EXT0 / P2 pin 11 / 0–5.2 V; 1 EXT1 / P2 pin 12 / 0–32 V. Default 0. Saved after accepted change. Connect one input only; leave the other open. Requires R75 = 1.00 kΩ.

Offset	Variable	Type / access	Description
09	uled	U8 R/W volatile	Manual USR request: 0 OFF, 1 ON. Applies when mapping is 0; resets OFF at MCU startup. ULED is also available at P2 pin 5, with on-board R7 = 3.6 kΩ current limiting.
0A	fttemp	U8 R/W volatile	TMP indicator threshold in packed BCD Celsius; startup 0x50 = 50 C. Not a Raspberry Pi fan cooling profile.
0B	LED_OFF	U8 R/W saved	Normal LED gate: 1 enables normal indication, 0 inhibits normal writes. System sequences temporarily own outputs.
0C	on_the_go	U8 R/W saved	0x00 normal UPS, runtime becomes 0x01. 0xAA optional slide-switch mode, runtime becomes 0xFF. Default 0x00.
0D	map_uled	U8 R/W saved	Persistent ULED source: 0 Manual, 1 SYS, 2 BAT, 3 TMR, 4 FAN, 5 TMP. Saved on accepted change; restored after MCU reset/power loss. Original LED remains active; P2 pin 5 provides the same current-limited indication.
0E	chg_ctrl	U8 R/W runtime	Charger permission: 0 disables; 1 enables charging when power and battery conditions permit. Default 1; permission is not measured current.
0F	fssd_duration	U8 R/W saved	Linux shutdown grace interval in seconds; default 30 (0x1E).
10	rpi_OFF_time_reg	U8 R/W runtime	No-host-activity timeout in minutes; default 5. Foreground uses 60 × value + startup hold seconds.
11	ad_corectionf	S8 Reserved	Signed calibration byte; normal startup resets correction to zero.
12	Scheduler_Sel	U8 Reserved	Scheduler selection slot; not configured by the supplied daemon.
13	BS_action_time	U8 R/W saved	Basic scheduler action-duration byte; raw. Do not alter during UPS commissioning.
14	BS_inaction_time	U8 R/W saved	Basic scheduler inactive-duration byte; raw.
15	Alignment byte	U8 Reserved	Physical alignment only; leave unchanged.
16	BS_Start_time	U16 R/W saved	Basic scheduler time word: low byte minute 0–59, high byte hour 0–23, binary; 0xFFFF special value.
18	BS_multipier	U8 R/W saved	Basic scheduler duration multiplier byte; raw.
19	BS_RUN	U8 R/W saved	0x00 stops basic scheduler and sets runtime 0x01; 0xFF starts action and sets runtime 0xFF. Leave 0x00 for ordinary UPS use.
1A	SAS_number	U8 Reserved	Scheduler event-number slot; leave unchanged.
1B	SAS_run	U8 Reserved	Scheduler event-run slot; leave unchanged.
1C	ps_checking_time	U8 R/W saved	Cable-check interval: value × 250 microseconds; minimum 10, default 30 (7.5 ms).
1D	BAT_level_report	U8 R/W saved	Battery report scheduling interval byte, seconds; default 5. 0xFF suppresses regular level messages.
1E	debug_mode	U8 R/W volatile	Diagnostic routing: 00 off, F0 local, 0F Pi UART, FF both. Effective only when M2_DEBUG_BUILD=1; public build 0 omits diagnostics.

Offset	Variable	Type / access	Description
1F	RS232_data	8 bytes Reserved	Eight-byte serial transmit slot; leave unchanged.
27	Alignment byte	U8 Reserved	Physical trailing alignment; leave unchanged.

System information reason codes

FSSD reason (low nibble): 1 button, 2 low battery, 3 low supercapacitor, 4 timed battery limit, 5 simple scheduler, 6 event/time scheduler, 7 event. Wake reason (next nibble): 1 button, 2 running Pi, 3 Pi cable power, 4 external power, 5 simple scheduler, 6 event/time scheduler, 7 event. Restart reason (bits 11:8): 1 power-up, 2 hardware reset, 3 watchdog, 4 other. Zero indicates no published reason in that field.

Command-state maintenance codes — 0x6B / 0x00

Normal applications leave this byte to the daemon. The following codes change routing, configuration or program flow; use the dedicated recovery procedures for factory defaults and firmware updates.

Code	Action
0x00	Idle / daemon acknowledgement.
0x11	Save Pi UART diagnostic routing at 115200 and reset MCU.
0x22	Save local UART diagnostic routing at 115200 and reset MCU.
0x33	Save diagnostic output OFF and reset MCU.
0x99	Publish 0x77 shutdown request to the Linux daemon.
0xAA	Unconditional FSSD request.
0xDD	Factory defaults maintenance request.
0xEE	M.2 controller reset request.
0xFF	Local bootloader request.
0xBB	Pi-side bootloader request.
0xCC	Outgoing Linux shutdown request; no user maintenance action.
0x60	Select default I²C group and reset.
0x68	Select reduced no-RTC address group and reset.
0x50	Select alternate group 0x58–0x5F and reset.
0x40	Select alternate group 0x48–0x4F and reset.

RTC bank — 0x68

Offset	Field	Encoding / range
00	Seconds	BCD 00–59; driver manages control bits.
01	Minutes	BCD 00–59.
02	Hours	BCD 00–23 in the supplied 24-hour configuration.

Offset	Field	Encoding / range
03	Weekday	Driver calendar weekday code.
04	Day	BCD 01–31, valid for the selected month.
05	Month	BCD 01–12.
06	Year	BCD 00–99, interpreted as 2000–2099.
07 and above	Reserved compatibility area	Use the Linux RTC driver for clock access.

Address 0x6A exposes an internal RTC structure and is reserved for this package. Addresses 0x6C–0x6E are reserved banks. The supported Linux clock interface is 0x68.

The optional private diagnostic bank is disabled in the public V8B5 build and returns zero. The following layout applies only to a diagnostic build. Public status and RTC access remain available when MCU diagnostic messages are omitted.

Diagnostic snapshot — 0x6F

Offset	Variable	Description
00	Format identifier	0x58; identifies the snapshot format, not the running firmware.
01	Foreground stage	Raw stage identifier.
02	Flags	Bit 0: Pi running; bit 1: FSSD status.
03	Charger wiper	Raw potentiometer position.
04–05	Tick counter	U16, seconds, modulo 65536.
06–07	Stage age	U16 seconds since the checkpoint, modulo 65536.
08–09	Loop counter	U16 foreground-loop counter.
0A	Local bus operation	0 none; 1 write8; 2 read8; 3 read16; 4 potentiometer write.
0B	Local bus address	Seven-bit address for the recorded operation.
0C	Local bus register	Register or wiper payload, depending on operation.
0D	Power mode	0xF0 battery; 0xF1 cable.
0E	Target stage	Raw checkpoint target.
0F	Serial diagnostic failures	Low byte of the diagnostic transmit-failure counter.

Read-only inspection examples

sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py
sudo i2cget -y 1 0x69 0x30 w
sudo i2cget -y 1 0x69 0x06 w
sudo i2cget -y 1 0x6b 0x0c b

Reading and decoding register values

Firmware identification is hexadecimal. A battery voltage word 0x0390 means 3.90 V, not binary 912 mV. Status updates can be suspended in low-power or bootloader operation; zero or stale reserved fields are not proof of an attached sensor.

These tables describe V8B5. The public offsets are unchanged from V8B2–V8B4. V8B4 made ULED mapping persistent; V8B5 activates the saved external ADC selector and selected voltage result. The older V8B/V8B1 layout is incompatible.

Byte and word transfers

U8 is one unsigned byte. U16 is a two-byte unsigned word with its low byte at the listed offset and its high byte at the next offset. S8 denotes a signed byte. The b and w suffixes in i2cget select byte and SMBus word reads respectively. A word read beginning at an unaligned or incorrect offset combines unrelated fields.

sudo i2cget -y 1 0x69 0x30 w
sudo i2cget -y 1 0x69 0x06 w
sudo i2cget -y 1 0x6b 0x01 b

The firmware word is 0x08B5. Battery voltage 0x0390 represents BCD digits 0390, or 3.90 V. Runtime 0x01 is a binary minute setting plus approximately ten seconds, not one second.

BCD and binary are different encodings

BCD stores two decimal digits per byte. For example 0x42 represents 42 in a BCD minutes field, but 66 in an ordinary binary field. Convert voltage/temperature fields according to the encoding stated in the table; do not apply the BCD conversion to counters, masks, current-limit codes or firmware identifiers.

A charger current-limit code is binary and is multiplied by 10 to obtain mA. For example 0x3A is decimal 58 and represents a 580 mA limit. This is a requested or reported limit, not a measured battery current. A charge-permission value of 1 also does not establish that current is flowing.

Access and update rules

Read Only fields are controller-published status. R/W saved fields are settings processed by the firmware and retained when its settings handler saves them. R/W volatile fields are working state and can change immediately. R/W runtime fields are not a promise of persistence. Reserved fields must be left unchanged, even if a read returns zero or an apparently meaningful value.

Read one field or a defined group at a time. Status is updated asynchronously, so separate reads need not describe the same instant. A diagnostic snapshot is useful for troubleshooting but does not make unrelated status-bank reads atomic. Counters can wrap; use modulo arithmetic when comparing them.

The supplied daemon owns the heartbeat/shutdown handshake. Keep it running during normal monitoring. A successful read contributes host activity, so continuous polling can affect tests intended to exercise absence of the host. Do not use broad write loops or force access through an attached kernel driver.

Configuration examples and interactions

Run these examples only on the intended unit, under stable cable power. First read and record the existing values. Change one setting at a time and allow the firmware to process it before reading it back. The examples use bus 1 and the default command bank 0x6B.

Battery runtime at offset 0x01

The binary values 0x00 through 0xFE request approximately 10 + 60 × value seconds before timed FSSD. Thus 0x00 gives about 10 seconds, 0x01 about 70 seconds, and 0x02 about 130 seconds. The Linux shutdown grace interval follows the FSSD request and is a separate setting. 0xFF disables the elapsed-time limit; low-source protection remains active.

```
sudo i2cget -y 1 0x6b 0x01 b
sudo i2cset -y 1 0x6b 0x01 0x02 b
sleep 3
sudo i2cget -y 1 0x6b 0x01 b
```

Normal UPS and switch mode at offset 0x0C

Writing 0xAA enables the optional ON/OFF switch mode and sets runtime to 0xFF. Place the fitted switch ON before enabling this mode. Writing 0x00 selects normal UPS operation and restores runtime 0x01. Select the mode first; set a different normal-mode runtime afterwards if required. A later mode change can overwrite that runtime choice.

```
# Return to normal UPS operation and its default 70-second limit
sudo i2cset -y 1 0x6b 0x0c 0x00 b
sleep 3
sudo i2cget -y 1 0x6b 0x0c b
sudo i2cget -y 1 0x6b 0x01 b
```

Charging and shutdown interval

Offset 0x0E is charging permission: 0 inhibits charging and 1 permits it when source and battery checks allow. It does not choose chemistry or force current. Offset 0x07 selects the backup-source profile and must match the fitted assembly, including the designated 4000 F / 4.2 V supercapacitor for profile C.

Offset 0x0F is the Linux shutdown grace interval in seconds, default 30 (0x1E). Offset 0x10 is the separate no-host timeout in minutes, default 5. Neither is the ordinary battery-runtime limit. Retain supplied still-alive and scheduler settings during ordinary UPS commissioning.

Output and serial settings

LED gate 0x0B permits normal writes when 1. USR manual request is 0x09; persistent mapping is 0x0D; TMP BCD threshold is 0x0A. System sequences retain priority. UART rate 0x02 affects application UARTs, not the 38400-bit/s loader. Diagnostic routing 0x1E has no effect when diagnostic messages were omitted at compilation.

After a settings change, repeat the relevant functional check: normal cable operation, battery FSSD, LPR, cable return during FSSD and after shutdown, and switch behavior where fitted. A matching readback establishes the stored value, not the complete power-control result.

Maintenance commands and RTC access

Command byte 0x6B / 0x00

This byte is also the live Linux handshake. The maintenance-code table describes actions, not persistent user settings. A command may be consumed and cleared before it can be read back. Verify the resulting log or operating state instead of repeatedly writing it until the byte remains visible.

The 0xCC and 0x77 values are shutdown requests observed by the daemon; it acknowledges through 0x00 before requesting Linux poweroff. Do not overwrite this handshake during FSSD. A user request such as 0x99 or 0xAA deliberately starts a shutdown action and can terminate SSH.

Enter the Pi-side protected bootloader

```
sudo i2cset -y 1 0x6b 0x00 0xbb b
```

Run the updater promptly within the clean-application loader entry window. Use -j when the board is already in the bootloader, so the updater does not try another application-side entry command. The ordinary application register banks can be unavailable during loader operation.

```
sudo python3 M2_PM_UPS_BL01D.py -v -i -j -k \
  -p /dev/ttyAMA0 -b 38400 -f M2_PMH.hex
```

The 15-second entry window ends after the first actual Flash write. An incomplete write remains in recovery until a complete verified application is supplied. Use the detailed firmware-update and recovery chapters for the full procedure. The local-loader code 0xFF is a different routing request; it is not the normal Pi-side upload command.

Factory defaults and controller reset

The 0xDD maintenance request selects factory defaults; 0xEE requests an MCU reset. These actions may disturb the running Pi through the normal power sequence. Save required settings before use. Factory defaults restore the RTC reference date; NTP synchronization restores current time. There is no button-selected factory-default menu.

Address-group commands also reset the controller. Once the group changes, the old addresses no longer describe the active interface, and the supplied daemon/RTC configuration may need corresponding changes. Do not use those commands as a connectivity test.

Use the Linux RTC driver

Bank 0x68 provides the DS1307-compatible clock interface. Identify the registered device by its driver/name rather than assuming that it will always be rtc1. When rtc-ds1307 owns address 0x68, use hwclock; do not force raw transfers past that driver. Confirm the Linux clock and NTP state before writing system time to the RTC.

```
timedatectl status
sudo hwclock --show --rtc=/dev/rtc1
# Only after confirming the Linux system time is correct:
sudo hwclock --systohc --utc --rtc=/dev/rtc1
sudo hwclock --show --rtc=/dev/rtc1
```

The RTC year range is 2000–2099 in this interface. Linux displays a local-time conversion when configured to do so while the RTC is kept in UTC. An apparent timezone difference does not by itself indicate an incorrect register write. The separate Raspberry Pi RTC power cable supplies the Pi clock domain; it does not merge the two clock interfaces.

Technical support: support@pimodules.com | www.pimodules.com

Tools and SD to SSD migration

This edition supplies daemon v1.6, monitor 0B (v2.7) and configurator 06 for V8B5. Installer V08 installs the tools at stable paths. The protected loader remains V88. The following chapters cover monitoring, guarded configuration and SD-to-NVMe migration.

Files and launch commands

Installer V08 installs Python dependencies and the tools below. Keep the shutdown service running while using the monitor or configurator. If using package-local scripts, first extract the complete archive to the stated directory.

sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py
sudo python3 /opt/M2_UPS_PMH/M2_PMH_config.py

The status tool only reads. Opening the configuration menu, refreshing it and exporting settings also only read. A configuration change requires an explicit YES confirmation. Keep cable power connected and the heartbeat/shutdown service running.

Installed and package local paths

The installer provides /opt/M2_UPS_PMH/M2_PMH_status.py (monitor 0B) and /opt/M2_UPS_PMH/M2_PMH_config.py (configurator 06). These stable names replace the need to copy numbered files manually. Package-local alternatives are shown below.

cd ~/M2_UPS_PMH_Customer_V8B5
sudo python3 optional_monitor/M2_PMH_status_0B.py
sudo python3 configuration/M2_PMH_config_06.py

A “No such file or directory” error indicates a missing or incorrect path, not an I²C failure. Use the stable /opt paths after installation, or the actual extracted package directory. Avoid older numbered scripts left in the home directory.

Version naming and chapter guide

Tool package numbering is independent of firmware and manual numbering. Configurator 06 and monitor 0B target application 0x08B5. The service identifies compatible telemetry layouts before sending temperature and fan values.

The next pages describe the status monitor, the configuration menu and its settings, followed by SD-to-SSD preparation, cloning, first boot and recovery.

Status monitor 0B

Monitor 0B v2.7 uses the compact V8B5 map and shows clocks, identity, power readings, timers, serial settings, LEDs and scheduler fields. Its saved ULED mapping field names Manual, SYS, BAT, TMR, FAN or TMP. Fan status reflects the Linux cooling request, with unknown samples identified explicitly. The ADC and external inputs section shows the saved range, connector pin and selected voltage in volts; 0xFFFF is displayed as unavailable. Its 1-Wire section automatically lists detected DS18B20 identifiers, temperatures and CRC status through the Linux driver. No sensor is an optional not-detected state, not an MCU communication error.

sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py
sudo python3 /opt/M2_UPS_PMH/M2_PMH_status.py --watch 5

A single invocation prints one report and exits. --watch 5 repeats every five seconds; press Ctrl+C to stop. --show-map displays the map, --degrees F selects Fahrenheit, and --no-rtc skips RTC reporting. Use the default bus 1 and address group unless the installation has deliberately been changed.

Reading the report

Firmware should read 0x08B5. Factory and active backup-source profiles may differ; the active profile must match the fitted source. The PCB/bootloader identity byte does not identify the protected loader image. The monitor refuses to decode unsupported firmware as the current map.

Linux local time and RTC UTC can differ by the configured timezone. The monitor uses the Linux RTC interface, with sysfs fallback when hwclock is unavailable. It does not force I²C access past the kernel RTC driver.

Charging enabled means permission to charge; the current limit is not a measured charge current. Battery voltage does not establish charge percentage. PAC1720 calibration and the current/power relationship remain to be validated; do not use these fields as charging acceptance criteria.

```
M.2 UPS PMH Status | Monitor 0B v2.7
Firmware 0x08B5 | Advanced | Illustrative values
------------------------------------------------------------
Power source                    Cable power
Battery voltage                 3.90 V
Raspberry Pi CPU temperature     46 C
Linux fan state                 ON
USR LED mapping                 Follow SYS (saved)
ADC and external inputs
External ADC range              EXT0 / P2 pin 11 / 0..5.2 V
Selected external ADC voltage   3.30 V (0x0330, BCD)
------------------------------------------------------------
1-Wire DS18B20 temperatures
28-000003c6469c                 31.06 C (CRC OK)
------------------------------------------------------------
Example report; readings are not a live capture.
```

Illustrative monitor 0B report with example values for V8B5. This is not a measurement from a connected board.

Reads count as host activity. Stop repeated monitor/configurator reads before testing no-host timeout behavior. Leave the shutdown daemon running during ordinary UPS power-loss tests. Values are sampled sequentially, not as one simultaneous snapshot.

Configuration tool 06

Configurator 06 supplies a guarded menu for V8B5. Opening, refreshing and exporting are read-only. A write requires a supported model, compatible firmware, cable power, an idle command byte, a validated selection, exact YES confirmation and readback. Firmware flashing, factory reset and raw arbitrary writes are excluded.

sudo python3 /opt/M2_UPS_PMH/M2_PMH_config.py
sudo python3 /opt/M2_UPS_PMH/M2_PMH_config.py --show

--show prints the current configuration and exits without writes. --guide explains operation without opening the hardware. The menu shows firmware, model, power source and each setting's raw value and interpretation.

Change one setting

1. Select the setting number and press Enter. Read the current value and the displayed limits or choices. Enter the new decimal value or 0x-prefixed hexadecimal value; chemistry also accepts L, I, F or C. An empty new-value entry cancels.

2. Review the change and its side effects. Type YES exactly to apply; y and any other response cancel. Selecting the current value sends no write.

3. Wait for the settling delay and verified readback, then refresh with R. For the saved ULED mapping, verify retention after an MCU reset or complete power cycle once the foreground save has completed. A Linux reboot alone does not reset the UPS controller.

Example for the tested Li-ion assembly: select 1, enter I, verify that the installed battery is Li-ion, and type YES only if a change is required. Do not change chemistry merely to match a screenshot.

Menu action	Operation
R	Refresh current values; no settings are written.
E	Export a new JSON reference snapshot. Enter a filename; existing files are not overwritten. There is no automatic restore/import.
H	Show help and operating notes.
Q or Enter	Exit the menu.

Write guards and recovery

Writes require firmware 0x08B5, a recognized Standard or Advanced model, cable power and an idle command byte. Mode changes are blocked while the basic scheduler runs; runtime changes require normal UPS mode. Resolve a refusal before retrying.

If a write or readback is uncertain, the tool does not automatically repeat the write. Refresh, inspect the current state and decide whether another action is needed. UART-rate changes reset the MCU: save work first and expect a brief interruption. Keep the power cable connected throughout.

The menu was reported working on the target Pi. This does not validate every setting under every hardware combination; retain the known working configuration unless a change is needed.

Configuration settings reference

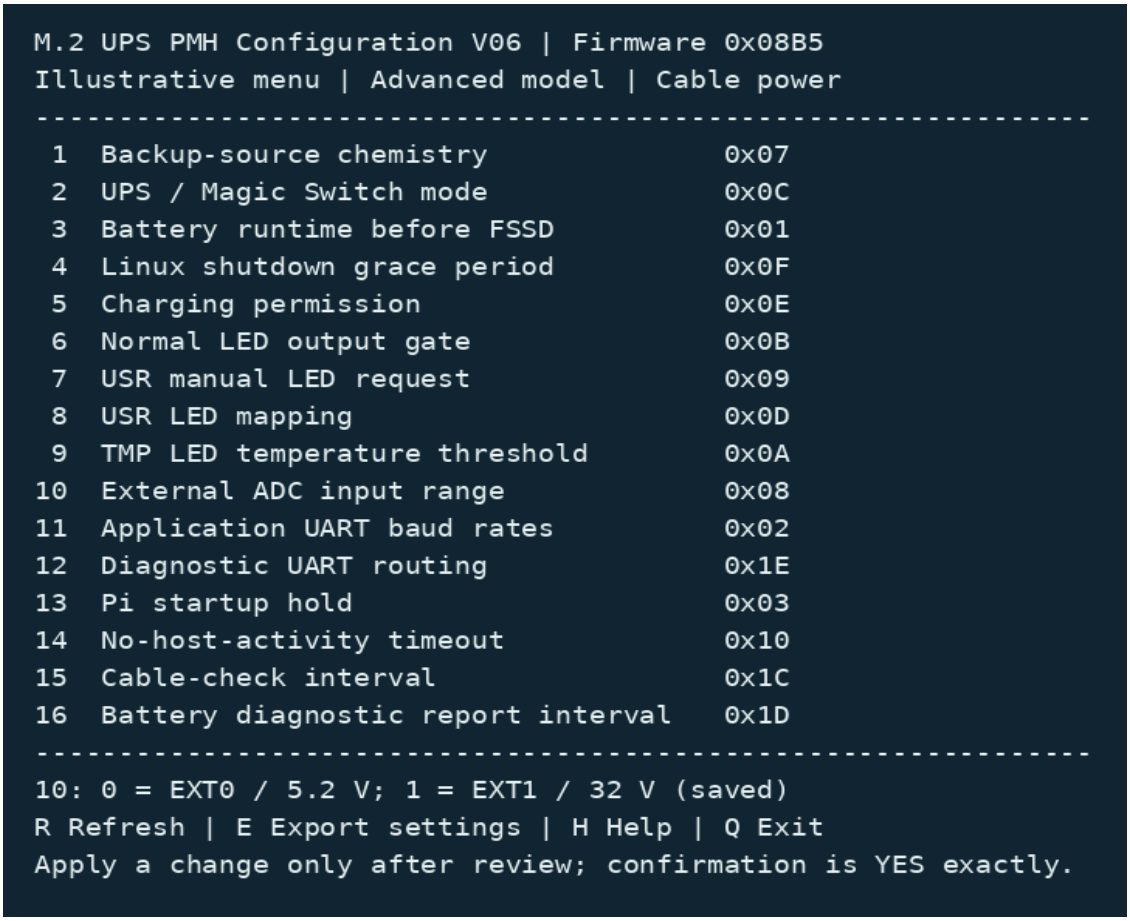
Menu numbers below refer to configurator 06. All offsets are in command bank 0x6B. USR manual request and USR mapping are separate settings. The mapping is saved; the manual request and TMP threshold are volatile. External ADC input range is item 10 and is writable on Advanced only; subsequent menu numbers have shifted.

No and setting	Allowed value and effect
1 Backup-source chemistry 0x07	Select only the chemistry of the physically connected single-cell source.
2 UPS / Magic Switch mode 0x0C	Changing to normal UPS sets runtime to 0x01 (about 70 s). Changing to Magic Switch sets runtime to 0xFF. Put the fitted switch ON before enabling Magic Switch.
3 Battery runtime before FSSD 0x01	Enter 0..254: about 10 + 60 x value seconds, plus startup hold. Example: 1 = about 70 s with hold 0. 255 = no elapsed-time limit; low-battery shutdown remains active.
4 Linux shutdown grace period 0x0F	Seconds allowed for Linux to finish shutdown; default 30. Use enough time for your workload.
5 Charging permission 0x0E	Permission only; this does not set or measure charging current. Runtime setting, persistence is not guaranteed.
6 Normal LED output gate 0x0B	V8B5 uses 1 = enabled. Reset and bootloader indications can override this gate.
7 USR manual LED request 0x09	Volatile manual request; applies when mapping is Manual. While mapped, the source indicator controls USR. Reset/bootloader sequences and the normal LED output gate retain priority.
8 USR LED mapping 0x0D	Saved in MCU Flash when changed; restored after reset or complete power loss. Mirrors the selected indicator and blink pattern without disabling its original board LED. Manual request is retained while mapped but defaults OFF after reset. Factory defaults restore Manual. Pre-charge/error/reset/bootloader indications and the normal LED gate retain priority.
9 TMP LED temperature threshold 0x0A	Packed BCD Celsius: enter 0x50 for 50 C. This controls the TMP indicator, not the Raspberry Pi fan.
10 External ADC input range 0x08	Advanced only. 0 EXT0 / P2 pin 11 / 0–5.2 V; 1 EXT1 / P2 pin 12 / 0–32 V. Saved in Flash. Connect one input only; leave the other open. Hardware R75 = 1.00 kΩ. Status voltage is 0x69:0x12, BCD 0.01 V.
11 Application UART baud rates 0x02	High nibble: local UART2. Low nibble: Pi UART1. This changes application UARTs, not the protected bootloader baud rate (38400). Changing it resets the MCU and may interrupt operation.
12 Diagnostic UART routing 0x1E	Available only in diagnostic firmware. Public firmware omits diagnostic output; this setting cannot enable code that is not present.
13 Pi startup hold 0x03	Seconds. Factory value may be 0; when changed, firmware clamps 0 to 1. Also contributes to battery-runtime and host-timeout timing.
14 No-host-activity timeout 0x10	Minutes; default 5. Keep the heartbeat/shutdown daemon running. Runtime setting.
15 Cable-check interval 0x1C	Value x 250 microseconds. Minimum 10; default 30 = 7.5 ms.
16 Battery diagnostic report interval 0x1D	Seconds; default 5. 255 suppresses regular battery-level messages.

Settings marked runtime are not guaranteed to persist. Other entries use firmware-managed retention; the configurator verifies immediate readback only. UART settings affect application UARTs, not the protected bootloader baud rate of 38400 bit/s.

Configuration menu example

The illustration shows configurator 06 with example V8B5 values, including item 10 for the saved ADC range. It is a terminal-layout example, not a live measurement. Use values read from your assembly.



Illustrative configurator 06 menu showing the separate manual USR request and saved USR mapping.

Example interaction

To inspect battery chemistry, enter 1. Press Enter at the new-value prompt to leave it unchanged. If the physically installed battery requires another profile, enter the matching code, review the displayed change and type YES to apply it.

An export made with E is a reference snapshot. It can help compare settings after migration or a planned restart, but is not an automatic recovery or restore command.

SD to NVMe SSD preparation

This procedure transfers a conventional Raspberry Pi OS installation on a Raspberry Pi 5 from microSD to an NVMe SSD attached through PCIe. It copies Linux, installed packages, user files and UPS service configuration. It does not copy the Pi EEPROM or the M.2 controller firmware/settings, which reside outside the SD card.

Scope: a standard FAT boot partition and ext4 root filesystem. The Debian login banner alone does not establish that the image is Raspberry Pi OS. For generic Debian, encryption, LVM, RAID, unusual partitions or external application data, validate a suitable migration method before using these commands. This procedure has not yet been reported tested on the target assembly.

1 Prepare power and identify both disks

Back up important data separately. Use a compatible NVMe SSD with sufficient capacity; an SSD at least as large as the SD card simplifies sizing. Installing an M.2 SATA drive is not equivalent to NVMe. Shut down and disconnect both cable power and backup battery before fitting the SSD or PCIe ribbon; removing USB power alone does not make a UPS assembly unpowered.

Start the existing SD system with stable cable power. Keep the shutdown daemon running. Record the following output and identify disks by name, size, model and mountpoints:

```
cat /etc/os-release
findmnt -no SOURCE /
findmnt -no SOURCE /boot/firmware
lsblk -o NAME,SIZE,MODEL,FSTYPE,MOUNTPOINTS,PARTUUID
df -h / /boot/firmware
```

The examples below require source /dev/mmcblk0 (root typically mmcblk0p2) and target /dev/nvme0n1. If root is already on NVMe, stop: these commands are not an SD-to-SSD migration. Never select the SD disk as the destination.

2 Enable PCIe only if needed

If the NVMe disk is absent, check the powered-off hardware assembly first. For an adapter without automatic HAT+ configuration, edit /boot/firmware/config.txt and enable dtparam=pciex1 in an applicable [all] section. Preserve existing I²C, RTC and UART settings. Reboot from SD, then repeat lsblk. Keep the default PCIe speed for initial validation.

```
sudo nano /boot/firmware/config.txt
# Under [all], if not already enabled:
# dtparam=pciex1
sudo reboot
```

If an SSD already contains a bootable system, ensure SD remains the source during preparation. EEPROM BOOT_ORDER=0xf461 selects SD, then NVMe, then USB. Change it only if needed, using sudo rpi-eeprom-config --edit; reboot and verify the root device again. Keep a copy of the original EEPROM configuration.

Clone the SD system to SSD

3 Prepare the cloning utility

The rpi-clone project supports NVMe destinations and is intended/tested for Raspberry Pi OS. Download its source, inspect the instructions and record the revision used. The commands below assume a new ~/rpi-clone-m2 directory; if it exists, inspect it rather than deleting it blindly.

```
sudo apt update
sudo apt install -y git rsync
git clone https://github.com/geerlingguy/rpi-clone.git \
  ~/rpi-clone-m2
cd ~/rpi-clone-m2
git rev-parse HEAD
sudo install -m 0755 rpi-clone rpi-clone-setup /usr/local/sbin/
```

4 Quiesce applications and confirm the target

Stop your databases, containers and other applications that write important data, using their normal shutdown procedures. Keep SSH, networking and M2_PMH_i2c.service running. A live filesystem copy is not an atomic database backup. Do not run updates or edit files while cloning.

```
findmnt -no SOURCE /
lsblk -o NAME,SIZE,MODEL,FSTYPE,MOUNTPOINTS
systemctl is-active M2_PMH_i2c.service
```

Confirm root is on mmcblk0 and the destination is nvme0n1. Unmount any mounted destination partitions individually after checking that they are not used by the running system. Close file-manager windows that automatically mount them. Never unmount the source root or source boot partition.

5 Clone and wait for completion

DESTRUCTIVE STEP: the following command initializes /dev/nvme0n1 and erases its existing data. Proceed only after positively identifying this disk as the intended SSD and backing up its contents.

```
sudo rpi-clone nvme0n1 -f
```

Read the source/destination summary before accepting the prompts. The target is the entire disk name nvme0n1, not nvme0n1p1 or nvme0n1p2. Wait for a successful completion and follow the prompt to unmount the clone. If an error occurs, remain on SD and resolve it before changing boot order.

The cloned root and boot configuration must refer to the destination partitions. Do not manually replace the generated SSD fstab or cmdline.txt with the original SD versions. Record the final lsblk output so the SSD partition IDs can be compared if boot troubleshooting is needed.

Keep the SD card unchanged after cloning. Changes made to the SD system after the copy will not automatically appear on the SSD. Restart application services only on the system you intend to keep using.

Boot from SSD and verify the UPS

6 Select NVMe boot

Save the current EEPROM configuration, then edit it. Set BOOT_ORDER=0xf416 (NVMe, SD, USB, repeat; digits are processed right to left). For a non-HAT+ PCIe adapter, also set PCIE_PROBE=1. Preserve unrelated settings.

```
sudo rpi-eeprom-config > ~/m2-eeprom-before-ssd.txt
sudo rpi-eeprom-config --edit
# BOOT_ORDER=0xf416
# PCIE_PROBE=1  (for a non-HAT+ adapter)
sudo reboot
```

Leave the SD installed for this reboot so the pending EEPROM update can apply. After reconnecting, inspect sudo rpi-eeprom-config and findmnt -no SOURCE /. This reboot may already select SSD. If EEPROM editing/updating is blocked or unavailable, resolve that first; the M.2 configurator does not manage Pi EEPROM.

7 Prove an SSD-only boot

Run sudo poweroff and wait for Linux to finish shutting down. Fully remove cable and backup power before removing the SD card. Keep the card safe, restore the normal battery and cable connections, and boot with only the SSD present.

```
findmnt -no SOURCE /
findmnt -no SOURCE /boot/firmware
lsblk -o NAME,SIZE,FSTYPE,MOUNTPOINTS
df -h /
systemctl is-active M2_PMH_i2c.service
cd ~/M2_UPS_PMH_Customer_V8B5/installer
sudo python3 install_M2_UPS_PMH.py --check
sudo python3 ../optional_monitor/M2_PMH_status_0B.py
sudo python3 ../configuration/M2_PMH_config_06.py --show
```

Root must resolve to the SSD root partition (normally nvme0n1p2) and boot to its boot partition (normally nvme0n1p1). Confirm usable free space, network access, application data, active UPS service, firmware 0x08B5 and the correct battery profile. If this package was not present when cloned, copy/extract it first or use the installer directory actually copied.

Repeat the controlled UPS test with important work saved: a short cable interruption, then a planned longer interruption with enough time for graceful shutdown, followed by cable-return startup. Monitor/configurator reads count as host activity; close them before a no-host timeout test. SSD load can change shutdown duration, so confirm the configured grace period is sufficient.

8 Roll back when needed

Power off and fully isolate cable and battery before changing hardware. If SSD boot fails, disconnect the SSD and reinstall the retained SD to boot the original system. Boot-order fallback does not guarantee recovery from a kernel failure on an otherwise readable SSD. Reconnect the SSD only while fully unpowered; check power, ribbon orientation, boot order and partition IDs before another attempt. Never run the clone command in the reverse direction by accident.

References checked 22 October 2026: Raspberry Pi documentation, “PCIe connector” and “Boot from PCIe”: https://www.raspberrypi.com/documentation/computers/raspberry-pi.html#boot-from-pcie ; rpi-clone project instructions: https://github.com/geerlingguy/rpi-clone .

Supercapacitor cycle life and temperature

The designated supercapacitor offers potential advantages for frequent power interruptions and wider ambient temperatures. The comparisons below distinguish arithmetic reference ratios from verified service-life guarantees. They do not qualify an alternative battery for use with this UPS.

Cycle count comparison

Using 20,000 cycles as the reference from the existing M.2 FAQ, the cycle-count ratio is 40× against 500 cycles, 20× against 1000 cycles, or 10× against 2000 cycles.

For context, ASOL specifies at least 500 cycles for its 502540 LiPo example at 100% depth of discharge, 0.2C and 25°C. EEMB advertises more than 2000 cycles for its standard LiFePO4 pouch family. The 1000-cycle value is an additional comparison scenario, not a rating assigned to every Li-ion battery. These examples are not recommended replacement cells.

Ratios compare the stated reference counts only. Different capacity-retention endpoints, discharge depths, currents and temperatures prevent a guaranteed 40× or 10× service-life claim. Partial top-ups are not necessarily full cycles; calendar ageing also matters. The PM_097 page mentions up to 100,000 cycles without a matching detailed test protocol. Retain the 20,000-cycle comparison basis until the exact supplied part and test conditions are confirmed.

Calendar life independent of cycle count

Calendar life is the time until ageing makes the source unable to meet its capacity or backup-time requirement, even if it is rarely cycled. Cycle count cannot be converted into a reliable service life in years. In standby UPS use, temperature and sustained charge voltage/state of charge are particularly important.

Published examples illustrate the range: Tektronix gives a general 2–3 year expectation for its conventional Li-ion batteries even without full cycling. Eaton describes selected supercapacitor products with calendar lives up to 20 years, dependent on voltage and temperature. However, Schneider Electric reports estimated service lives of 10 years or more for some engineered Li-ion UPS batteries. Therefore, neither 2–3 years for every battery nor 20 years for every supercapacitor is valid.

For the supplied 4.2 V / 4000 F assembly, a verified calendar-life specification is not available in the cited product information. A precise year rating or a multiple of battery calendar life cannot yet be assigned. Obtain the manufacturer's endurance/ageing data for the exact part at the intended temperature and standby voltage; Eaton's ratings cannot be transferred to PM_097.

Practical assessment: repeat the same backup-load test periodically and compare supported time, voltage sag and temperature with the initial result. Replace the storage element when it no longer provides the required Linux shutdown reserve. This applies even if its nominal cycle count has not been reached.

Supercapacitor temperature and energy ratings

Temperature range comparison

PM_097 lists −40 to +65°C in its technical table, but −40 to +70°C in its feature description. Using the narrower published range gives a 105°C span. The LiPo example above and the Panasonic/Sanyo NCR18650B reference sheet both specify −20 to +60°C for discharge, an 80°C span.

Against that −20 to +60°C discharge range, −40 to +65°C extends the cold limit by 20°C and the hot limit by 5°C: the span is 25°C wider, or 31.25% wider.

If −40 to +70°C is confirmed for the supplied part, the span becomes 110°C: 30°C or 37.5% wider, with a 20°C lower cold limit and a 10°C higher hot limit. EEMB's cited LiFePO4 family lists −10 to +60°C; compared with that 70°C span, −40 to +65°C is 35°C or 50% wider. These percentages compare interval widths, not absolute Celsius temperatures.

Charging is a separate limit: the cited LiPo and NCR18650B references specify 0 to +45°C for charging. Do not infer that the supercapacitor can be charged throughout its advertised operating range; confirm separate charge/discharge limits for the exact part. The Raspberry Pi, SSD, charger and enclosure may impose tighter system limits.

Energy rating and source notes

The energy chapter uses the ideal constant-capacitance model: 9.80 Wh total and 5.44 Wh between 4.2 and 2.8 V. PM_097 separately lists 14 Wh; this is not consistent with 4000 F constant capacitance at 4.2 V. A hybrid device or a different capacitance definition requires its discharge curve or measured energy integral. Do not present the calculated battery equivalence as a certified module capacity.

Sources checked 22 October 2026: Pi Modules PM_097, pimodules.com/product/4000f-super-capacitor; ASOL 502540, asolbattery.com/product/asol-502540-3-7v-500mah-lithium-polymer-battery/; EEMB LiFePO4 pouch family, eemb.com/products-50; Panasonic/Sanyo NCR18650B reference datasheet, version 13.11 R1 (2012). Calendar-life references: Tektronix, Lithium-Ion Battery Maintenance Guidelines (tek.com); Eaton, Supercapacitor module resource center (eaton.com); Schneider Electric, Life Expectancy of APC Lithium Ion Batteries, FAQ000265882 (se.com).