Thornwave Labs Inc

PowerMon-5S

Bluetooth LE

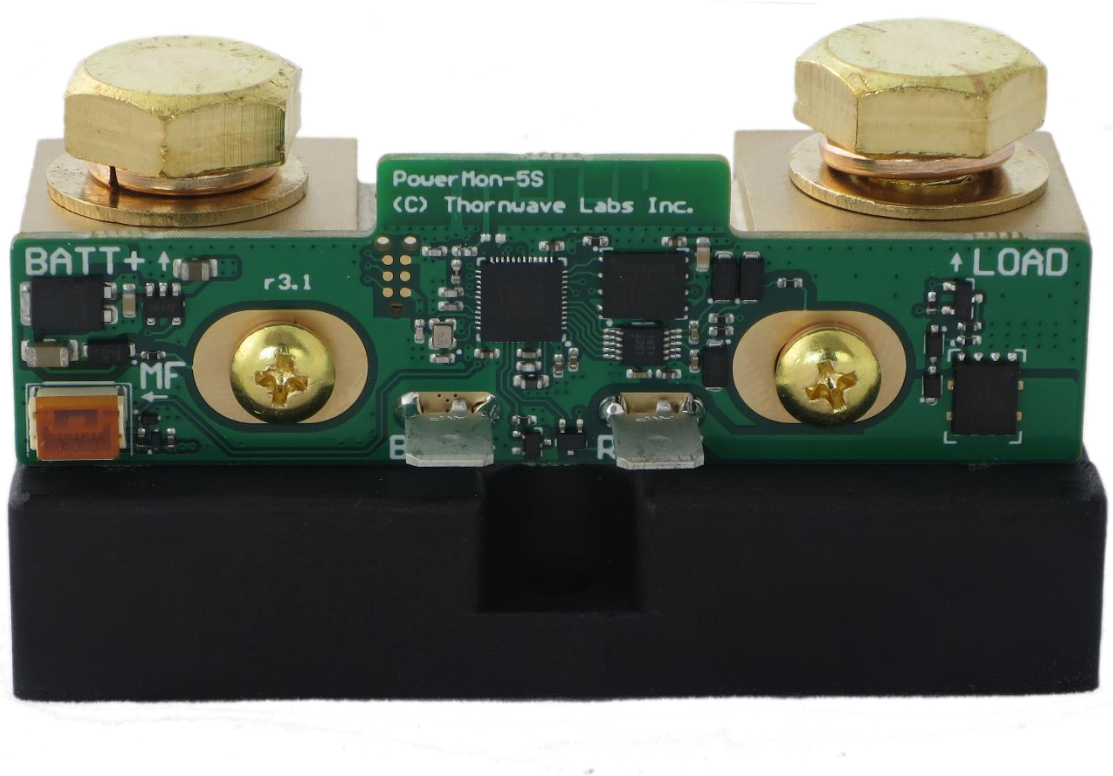
500A Advanced Battery Monitor / DC Power Meter

– USER MANUAL –

Thornwave Labs Inc

BRIEF

PowerMon-5S is a Bluetooth Low Energy Swiss-army knife tool that can be used in any DC circuit. Its primary function is advanced battery monitor / DC power meter. PowerMon-5S allows monitoring of important electrical parameters: voltage (0-65V), current (0-500A bidirectional), peak current, power (W), energy (Wh), battery charge (Ah) and temperature. Many other parameters are computed: the battery state of charge (SoC) as a percentage, remaining time on battery, battery statistics (number of cycles, total discharged capacity, …). The device can log the measured data for up to 3 years, allowing for advanced data analysis and troubleshooting. PowerMon-5S logs data in an internal memory as opposed to inside the mobile application which makes our product better than our competitor's. The device can drive a mechanical or solid-state relay which allows it to function as a low voltage disconnect, high voltage disconnect, over-current disconnect, temperature controller, remote on/off switch, timer, and finally, generator control. A mobile device running either Android or iOS and the PowerMonX app (available for free on Google Play Store and Apple App Store) are required for using this device.



FEATURES

- Measures voltage, current (bidirectional), peak current, power (W), charge meter (Ah), energy (Wh) and temperature
- Operates at up to 65V, allowing it to work in 12V, 24V and 48V systems
- Measures up to 500A using the integrated high precision shunt
- Data logging for up to 3 years
- Can control one relay or SSR (solid state relay)
- Low / high voltage disconnect
- Over-current disconnect
- Low / high temperature disconnect
- Generator control
- Battery monitor (battery fuel gauge), displays the state of charge in percentage and the remaining time on battery
- Timers
- High quality current shunt materials, best on the market, at 0.25% accuracy
- Uses an integrated temperature sensor but offers the option of connecting an external temperature sensor
- User / master password protection
- Very low power consumption (see Performance Parameters)
- Bluetooth Low Energy radio with internal antenna and long range
- Easy to install, just connect the shunt and add an extra ground wire
- Measures only 3.25” x 1.75” x 1.75” (82mm x 45mm x 45mm)
- Free PowerMonX app available for Android and iOS
- Most parameters can be configured, allowing it to achieve top performance with a all kinds of batteries

TYPICAL APPLICATIONS

- RVs, boats, off-the-grid cabins
- Solar and wind alternative energy
- Vehicle batteries
- Backup electrical systems
- Automation: solar irrigation systems, solar street lights, general purpose DC timers

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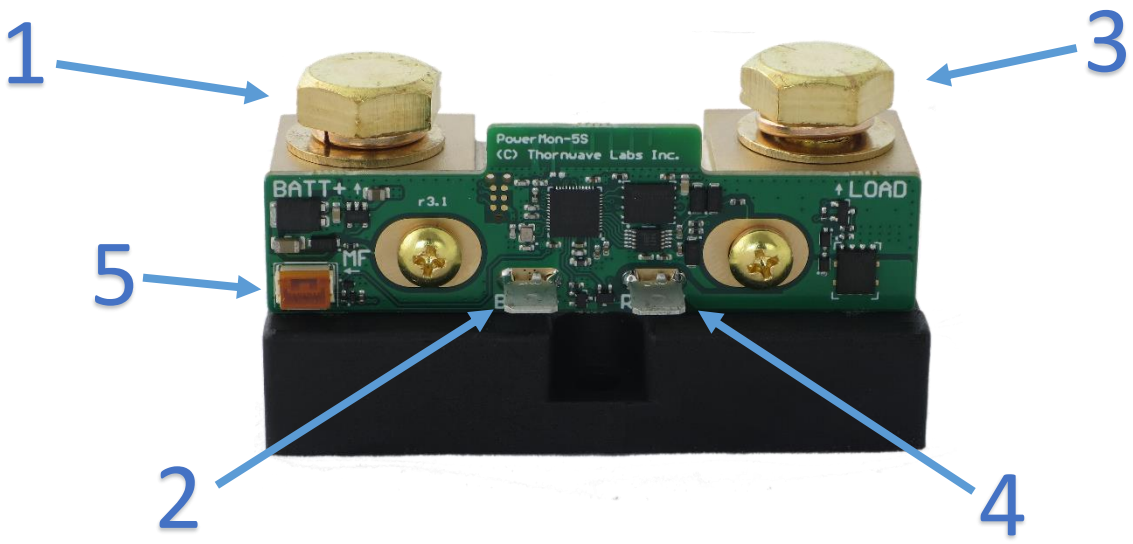
TERMINAL DESCRIPTION



No.	Type	Name	Terminal Description
1	10mm hex bolt	BATT+	Battery positive. PowerMon-5S takes its power from this terminal. It also measures the voltage at this point.
2	¼" blade male terminal	BATT-	Battery negative. Usually also the chassis ground. Connect using the supplied black wire.
3	10mm hex bolt	LOAD	Connect to the loads / charger / solar charge controller
4	¼" blade male terminal	RELAY	Relay output. It drives a mechanical or solid-state relay. This terminal is connected to ground internally by the device when the power is turned ON from the app. Use the supplied blue wire to connect.
5	connector	MF	Multifunction connector. Can be used to connect an external temperature sensor or external pushbutton.

SPECIFICATIONS

Absolute Maximum Ratings [1,2]	
Maximum voltage at BATT+ /LOAD terminals	**+32V (hw rev 3.0)** **+65V (hw rev 3.1)**
Maximum voltage at RELAY	**+32V (hw rev 3.0)** **+65V (hw rev 3.1)**
Maximum current through the RELAY terminal (maximum relay coil current)	**2A**
Maximum current through the shunt	**500A continuous**
Operating temperature	**-30°C to +85°C**

1. Stresses greater than those listed under “Absolute Maximum Ratings” may cause permanent damage to the device.
2. All voltages are referenced to ground (BATT- terminal) unless otherwise specified.

Performance Parameter	Value
Measured voltage (BATT+)	**7 ~ 32V (hw rev 3.0)** **7 ~ 65V (hw rev 3.1)**
Measured voltage accuracy	**max 0.5%, typ. 0.25% (hw rev 3.0)** **max 0.2%, typ. 0.1% (hw rev 3.1)**
Measured current	**-500A to 500A**
Current monitoring accuracy (using integrated shunt)	**0.5% - without calibration** **0.25% - with calibration**
Integrated current shunt resistance	**0.15 mOhm / ±0.25%**
Power	**max. 30000W**
Power meter	**more than 1000 MWh**
Charge meter	**more than 1000 MAh**
Temperature	**1°C / 1°F resolution**
Data logging sample rate	**1 sec – up to 18 days** **2 sec – up to 36 days** **5 sec – up to 90 days** **10 sec – up to 180 days** **20 sec – up to 1 year** **30 sec – up to 1.5 years** **1 min – up to 3 years**
Current draw (current consumed by the device) (using the latest firmware version)	hw rev 3.0 / hw rev 3.1
at 12V	**3.5 mA** / **1.5mA**
at 24V	**3.7 mA** / **1.6mA**
at 32V	**4.0 mA** / **1.7mA**
at 48V	**------** / **1.8mA**
at 65V	**------** / **1.9mA**

COMPLIANCE STATEMENTS

FCC

ATTENTION: To satisfy RF exposure requirements, this device and its antenna must operate with a separation distance of at least 20cm (8 inches) from all persons and must not be collocated or operating in conjunction with any other antenna or transmitter.

ATTENTION: Changes or modifications not expressly approved by Thornwave Labs Inc could void the user's authority to operate the equipment.

ATTENTION**:** This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference and (2) this device must accept any interference received, including interference that may cause undesired operation.

ATTENTION: Cet appareil est conforme à la Partie 15 des règlements de la FCC. L'opération doit se conformer aux deux conditions suivantes: (1) cet appareil ne peut causer d'interférences nuisibles et (2) cet appareil doit accepter toute interférence reçue, y compris les interférences qui peuvent provoquer un fonctionnement indésirable.

IC RSS-102 RF Exemption

This system has been evaluated for RF Exposure per RSS-102 and is in compliance with the limits specified by Health Canada Safety Code 6.

L'exposition aux radiofréquences de ce système a été évaluée selon la norme RSS-102 et est jugée conforme aux limites établies par le Code de sécurité 6 de Santé Canada.

IC RSS-Gen 8.4

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

SAFETY INSTRUCTIONS

Warning !

Read all the instructions and cautions before using the PowerMon-5S device. Thornwave Labs Inc does not assume responsibility for any injury or property damage caused by improper installation, bad wiring or use of PowerMon-5S outside of its intended purpose. The device should be installed by a professional.

Warning !

The PowerMon-5S device should not be used for any medical purposes, life sustaining equipment, safety applications or any application where equipment failure can cause injury, death, fires, or any other hazard.

Warning !

There are no serviceable parts or fuses inside the power meter! Do not disassemble or attempt to repair! The unit operates with voltages up to 65V which, can be lethal or cause serious and permanent injury.

Warning !

Do not submerge under water or other liquids. The device is neither weatherproof nor waterproof.

Warning !

The device is to be connected to DC circuits only, not exceeding 65V and 500A. Failure to do so will result in equipment damage. Confirm that all connections are tight to avoid excessive heating, sparks or fires. Never connect without using a properly sized fuse or circuit breaker.

Warning !

Batteries are dangerous! Do not short-circuit a battery or the power meter. Batteries can produce flammable and explosive gases and can generate very high currents that can lead to serious consequences including explosion, fire, damage to equipment, personal injury and even death. It is the user's responsibility to operate the equipment in a safe manner. Do not charge batteries in an enclosed environment unless allowed by the manufacturer of the battery. Never connect a load to a battery without using fuses or circuit breakers properly sized for the wires/ equipment.

FUNCTIONAL OVERVIEW

Device power. The PowerMon-5S device is drawing its supply power from the BATT+ / BATT- terminals. If the device loses power, it will forget the internal clock. The device also monitors the voltage between the BATT+ and BATT- terminals.

Current shunt. PowerMon-5S contains an integrated 500A / 0.25% precision current shunt. The current shunt accepts 3/8" ring terminals. Due to the high current potentially passing through the shunt, make sure that the connections are tight to avoid excessive heating or sparks. Current flowing from BATT+ towards LOAD (discharging current) will appear in the app as a negative value while current flowing from LOAD towards BATT+ (charging current) will appear as a positive value.

Operation. Once the device receives power it will start advertising its presence to other Bluetooth devices. Using a phone or tablet running the PowerMon app (found on the App Store / Play Store) the user can scan for PowerMon devices and connect to one of them at a time (if multiple devices are present). Multiple PowerMon devices can be distinguished after changing their Bluetooth name using the mobile app. This will be displayed by the app upon scanning for Bluetooth devices. The factory default name is "PMON-5S". Once the mobile app is connected to a power monitor device, the app will display all the measured electrical parameters in real-time. Tapping on a measurement value for longer than one second will open a menu that allows operations and configuration specific to that measurement.

Radio performance. The device contains an internal Bluetooth Smart (LE) radio operating in the 2.4GHz ISM band and an internal antenna. For best performance, the device should be installed in such a way to offer a path for radio waves to reach it. Metal walls or enclosures can attenuate or completely shield the device. The mobile device app displays the RSSI value (Received Signal Strength Indication) in real-time.

Power relay control. PowerMon-5S can drive a power relay (either mechanical or solid-state) using the RELAY terminal. When active (relay turned on), the RELAY terminal is internally connected to ground by the PowerMon device. The relay should be connected between its power supply (battery positive, typically), and the RELAY terminal. The low/high voltage disconnect and over-current disconnect functions require the use of a relay / SSR (Solid State Relay).

Low voltage disconnect. When this mode is enabled, and the battery voltage drops below a specified value, the device disconnects the load, protecting the battery from over-discharge. In order to disconnect the load, the voltage has to be below the set threshold for a configurable amount of time. This feature helps in situations where cranking an engine or a short high current load causes the battery voltage to momentarily drop. The device will re-engage the power relay a configured amount of time after the condition that caused it to disconnect is removed.

High voltage disconnect. This function is similar to the low voltage disconnect, but as the name suggests it will disconnect the load when the voltage goes above the disconnect threshold and will reconnect the load when the voltage goes below the reconnect threshold. This mode can be used together with the low voltage disconnect. Possible uses are to protect the load from high voltage conditions, start external chargers or generators, connect to the grid and so on.

Over-current disconnect. When this mode is enabled and the measured current increases above a user specified trip value, the device disconnects the load, protecting the batteries and load from over-current. The device will re-engage the power relay a configured amount of time after the condition that caused it to disconnect is removed.

WARNING! Although PowerMon can disconnect power if an over-current condition occurs, it should not be used to replace circuit-breakers. A properly rated circuit-breaker or fuse should be used to protect the load and the wiring!

Battery fuel gauge. PowerMon is a battery monitor so it can keep track of a battery state of charge. This is accomplished by using coulomb counting. Charging current is displayed as a positive value while discharging current as a negative value. Due to the complex nature of chemical batteries, small errors in measurement and integrating current over long periods of time will introduce errors in the state-of-charge estimation. This is normal and expected. For this reason, the device will re-synchronize its SOC counter with the battery every time a full charge is performed. A full charge is detected based on the chemistry of the battery but in general it requires a voltage higher than a threshold while at the same time the charging current being lower than a threshold. The battery fuel gauge will also take into consideration the Peukert effect. The next table shows the Peukert coefficients used for various battery chemistries.

Battery Chemistry	Peukert Coefficient
Lead Acid - Flooded	1.25
Lead Acid – AGM	1.15
$LiFePO_4$	1.02
Li-Ion/LiPoly	1.02

Time keeping. PowerMon keeps track of time internally. The internal clock can be set by tapping on the Device Time tab for longer than one second. The internal date and time will be updated using the system time provided by the mobile app. PowerMon will only log data when the internal clock is set.

Timer function. The device supports controlling the relay using a set of up to 16 timers. Each timer contains a start time, stop time and repetition. The start time specifies the time of day (HH:MM) when the relay turns on. Stop time specifies the time of day when the relay turns off. A timer does not need to have both a start and stop time set. One of them can be disabled. This kind of timers should be used in pairs: one turns the power on and the second one turns it off. 'Repetition' controls the days when a timer will trigger. This can be either DOW (Day of Week) where the timer repeats on specific days of the week or DOM (Day of Month) where the timer repeats on a specific day of the month (multiple days of the month when using the PowerMon X app).

Using multiple timers, users can create very complex time schedules.

Examples:

Timer1: START 4:50PM, STOP 5:10PM, REPETITION DOW Sun Mon Tue Wed Thr Fri Sat

This timer will run every day and turn the relay on for 20 minutes, from 4:50PM until 5:10PM

Timer2: START 8:00PM. STOP: disabled, REPETITION DOW Sun Mon Tue Wed Thr Fri Sat

Timer3: START disabled, STOP: 7:00AM, REPETITION DOW Sun Mon Tue Wed Thr Fri Sat

This set of timers used together will turn the relay on every day at 8:00PM and turn it off the following day at 7:00AM.

Timer4: START 12:00AM. STOP: disabled, REPETITION DOM: 1

Timer5: START disabled, STOP: 12:00AM, REPETITION DOM: 8

This set of timers used together will turn the relay on every 1st of the month at 12:00AM and turn it off 7 days later on the 8th of the month at 12:00AM.

Configuration. The following parameters can be configured using the PowerMon app:

Initial Power Status: The default power status when powering the device. If set to on the relay will be turned on automatically when the device receives power.

Trigger on RELAY: If enabled, the device will turn the power on as a response to the RELAY terminal being temporarily pulled to ground using a push button.

Invert RELAY Logic: Enabling this option will invert the behavior of the RELAY terminal, when the power is on the RELAY terminal will be floating and when the power if off it will be driven to ground.

Connect Filter (ms): The duration of time in milli-seconds the LVD (Low Voltage Disconnect), HVD and OCD (Over-Current Disconnect) conditions have to be removed in order to re-engage the power relay.

MF Terminal Function: Selects the function of the MF terminal: Data Output or External Temperature Sensor. The external temperature sensors is only available for hardware revision 2.2 or higher.

Device History: Configure the history sample rate. Possible values are: disabled, every second, 2 seconds, 5 sec, 10 sec, 20 sec, 30 sec or 1 minute.

Low Voltage Disconnect

LVD Connect Threshold: The voltage in volts above which the power relay can re-engage (after the connect filter time has passed). This must be higher than LVD Disconnect Threshold.

LVD Disconnect Threshold: The voltage in volts below which the power relay will disengage.

LVD Filter (ms): The duration of time the voltage has to be below the disconnect threshold for the relay to disengage.

High Voltage Disconnect

HVD Connect Threshold: The voltage in volts below which the power relay can re-engage (after the connect filter time has passed). This must be lower than HVD Disconnect Threshold

HVD Disconnect Threshold: The voltage in volts above which the power relay will disengage.

HVD Filter (ms): The duration of time the voltage has to be above the disconnect threshold for the relay to disengage.

Over-Current Disconnect

OCD Trip Threshold: The current in amperes above which the power relay disengages.

OCD Filter (ms): The duration of time the current has to be above the trip value in order to disengage the relay. In order to function as a circuit breaker this should be set to a very low value between 0ms .. 20ms. Larger values will slow down the reaction to over-current. In some instances, this could be useful.

Auto-Off Timer: If enabled the power will turn off automatically after the specified time since it was turned on has passed. This effectively becomes a turn-off timer.

Battery Fuel Gauge

Battery Chemistry: The chemistry of the battery used.

Number of Cells: Number of cells of the battery. 12V Lead Acid batteries have 6 cells. 12V $LiFePO_4$ have 4 cells. If you have batteries connected in series, add the number of cells in each of them. If batteries are connected in parallel the number of series cells does not change.

Battery Capacity: Battery capacity in Ah. If batteries are connected in parallel, add up their capacities. If batteries are connected in series the capacity does not change. (only the number of cells in series does)

Disconnect on Fuel Gauge: The device will disconnect power (turn the relay off) when the battery state of charge becomes lower than this threshold (in percentage). The “Invert RELAY logic” option can invert this behavior.

Connect on Fuel Gauge: The device will re-connect power (turn the relay ON) when the battery state of charge becomes higher than this threshold (in percentage). The “Invert RELAY logic” option can invert this behavior.

Default Factory Settings. The device can always be reset to the default configuration using the PowerMon app. To do this, connect to a device, tap the right corner menu (iOS) or right corner menu and then About (for Android). Tap on Factory Reset.

WARNING: When resetting to the factory defaults, all custom settings and timers will be erased, including the device calibration and the battery fuel gauge internal state. The device Bluetooth name will not be changed.

MOBILE APPLICATION – POWERMON

The PowerMon device requires a mobile device running Thornwave Labs' PowerMon app which is available free of charge for both Android and iOS platforms and can be found on Google Play Store and Apple App Store. The mobile device used needs to be equipped with a Bluetooth Smart (LE) adapter. The app will not install on devices that are too old to support Bluetooth Smart (4.0).

PowerMon allows the following operations to be performed:

- scan for PowerMon devices and display a summary of measurements (voltage, temperature, battery state of charge and power status)
- connect to devices and obtain real-time measurements
- set the device configuration (external shunt parameters, low voltage disconnect, high voltage disconnect overcurrent disconnect, battery fuel gauge,… see the **Configuration** paragraph)
- zero the current reading offset
- calibrate the current reading
- rename the device
- reset the power and charge meters back to zero
- manually turn the power relay ON/OFF
- update the internal device clock from the mobile device current time and date
- create, edit and delete timers
- reset to factory defaults
- configure the password protection function
- update the device firmware (when new releases are published)

Scan for devices. The first screen that appears after PowerMon is launched is the scan screen. If the mobile device Bluetooth adapter is not enabled PowerMon will prompt the user to enable it before continuing. The app will then display all the PowerMon devices that are within range. Each advertisement packet contains the device name, firmware version, the battery voltage and the device temperature. All this information will be displayed by the app together with the device RSSI (Receiver Signal Strength Indication). The RSSI value is a direct indicator of the signal strength received from a device. In most scenarios involving Bluetooth, this is a negative number and is measured in dBm (decibel referenced to 1mW). Typical values range from -110dBm being a very weak signal to -30dBm or better being a very strong signal. For a reliable connection, an RSSI of at least -100dBm is required.

Measurement limits. The app allows setting measurement limits. When a measurement value is in between the specified limits it will be displayed with black. If the measurement is outside of the specified limits (less than the low limit or more than the high limit) it will be displayed in red. This feature allows for easy identification of parameters that are not within normal limits. In order to configure the limits, tap on the top right corner menu button when on the scan screen. The voltage limits set here are also used in the main screen.

Connect to PowerMon devices. In order to connect to a device, tap on it in the scan list. The app will switch to the main screen which can be used for all the interactions with a connected device. The main screen displays the real-time electric parameter measurements. By long-tapping on a parameter tab, the user can access a menu that is specific for that parameter. This will allow to set measurement limits, zero the current offset, calibrate the current reading, reset the power and the charge meters and manually control the power relay.

Zero the current offset. Due to the high sensitivity of the current measurement circuitry inside the PowerMon-5S device, the value displayed may have a small offset (measurement is different than zero even when the actual current is zero). Typically, this is less than 0.1A. In situations where the measurement precision is critical, the offset can be zeroed. To do this, disconnect the LOAD terminal wire from the device or make sure the actual current is zero. This can also be achieved by turning the power relay off from the application (in case the system is wired with a relay). Tap on the “Current” tab and then “Zero Current”. The operation will take 3 seconds to complete during which do not allow any current to pass through the device. Also, do not zero the current offset if the actual current is greater than zero. Doing so will introduce a very large offset. Basically, any current that is flowing through the shunt when the Zero Current operation is performed will become the new indicated zero.

Current calibration. Typically, the device can measure current with better than 1% precision. If higher precision is required, the current measurement can be calibrated allowing better than 0.5% precision. To calibrate the current reading, a multimeter capable of measuring current with a precision better than 0.5% is required. Connect the multimeter leads in series with the current to be measured and read the actual value of the current. Tap on the “Current” tab, “Calibrate Current” and then type the actual value measured by the multimeter. The sign of the current does not matter. Once calibrated, the only way to change the calibration is to reset the device to factory defaults or re-calibrate. The device will not accept a calibration current different from the actual current reading by more than 10%.

Renaming the device. Renaming the device can be achieved using the top right menu button and taping on “About”. The maximum name length is 8 characters.

Timers. From the “Timers” screen, users can create new timers, edit or delete them.

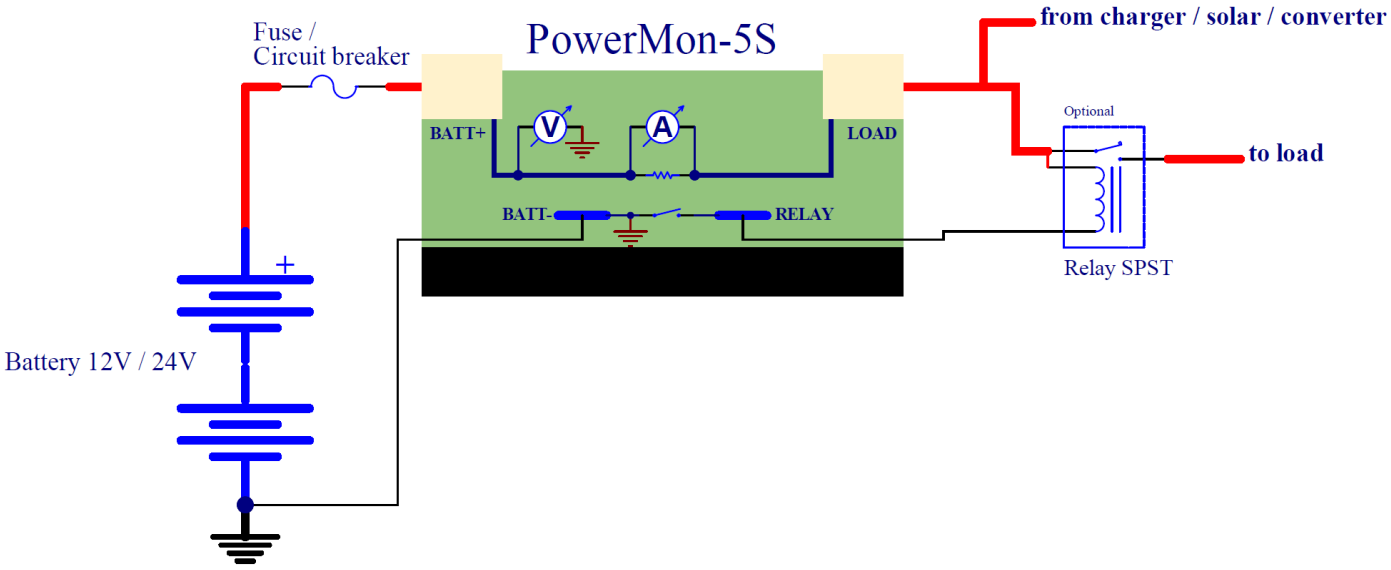
Battery Fuel gauge. The device implements a fuel gauge functionality for lead-acid, $LiFePO_4$ and other lithium batteries. When the device is first powered on, the fuel gauge will display "-----" meaning that it is not synchronized with the battery. A full charge is required to bring the SOC in sync with the battery. By tapping on the Battery tab for longer than one second a few options relating to the fuel gauge will be shown. The user can manually force a battery synchronization or retrieve the battery statistics. Do keep in mind that forcing the battery synchronization can lead to an inaccurate battery state-of-charge indication until the first full charge event occurs.

Password lock. The device can be locked using a master / user password scheme. Various functions become unavailable when they are password locked. When the user attempts to use one of the locked functions, the app will ask for the required password (user or master). If the master password is entered instead of the user password all the functions become unlocked. The user password will not be accepted instead of the master password. Once a correct password has been entered the device will unlock only the set of functions that apply to that password. The user password will unlock only a sub-set of functions while the master password will unlock all functions. If the master password is not set, the user password unlocks all the functions of the device. Once a set of functions have been unlocked, they will stay in this state until the device is disconnected, after which they will revert to the locked state (if any password has been set). This protection scheme allows the device to still be operated by a user while allowing only the manufacturer or technician (the master) to make configuration changes that may affect the proper or safe functioning of the system. The password lock function can be accessed from the About page.

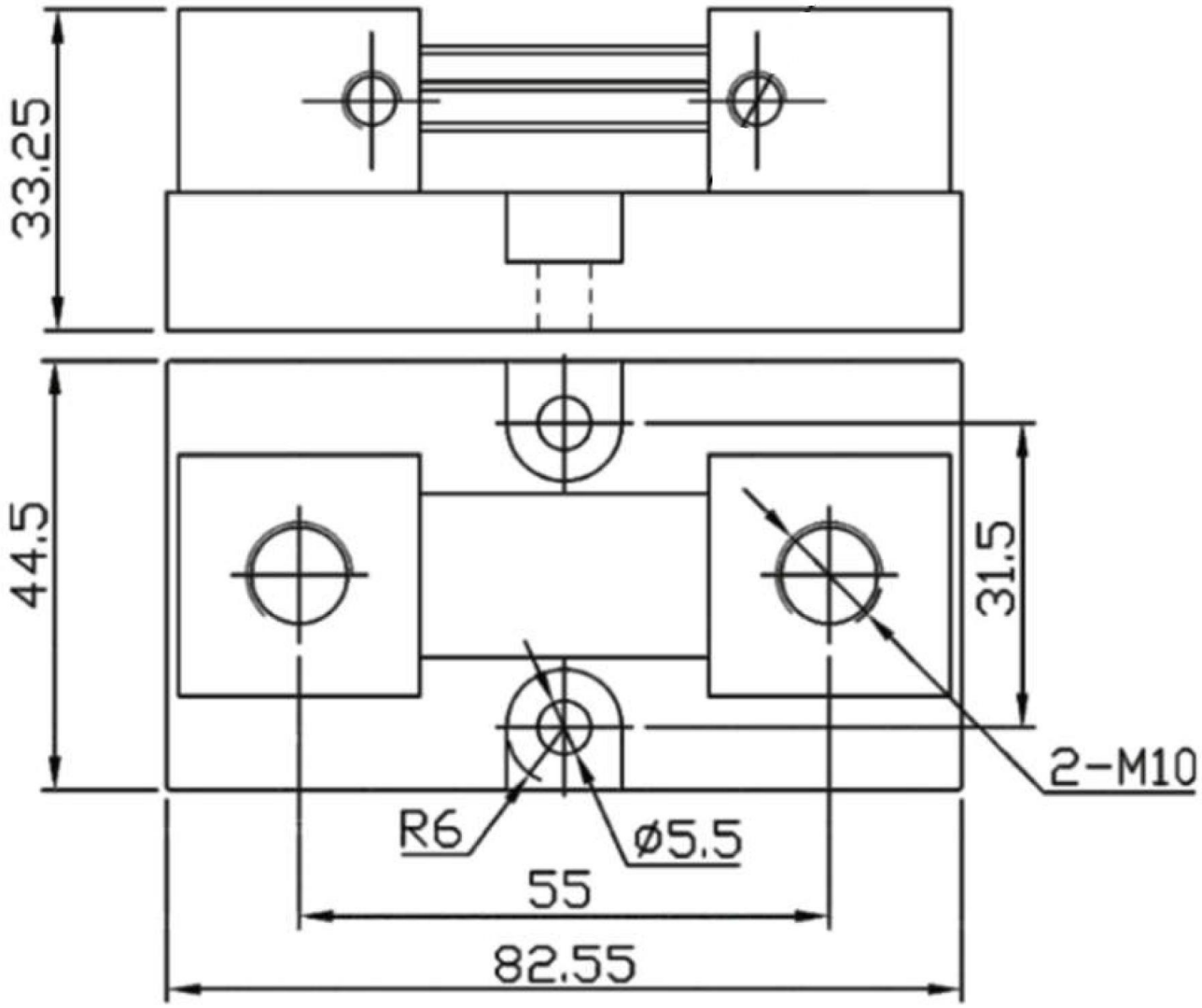
The next table describes which set of functions are affected by the master / user passwords.

Function	Master Password Required	User Password Required
View monitored data		
Save configuration	YES	YES
Device rename	YES	YES
Reset to factory defaults	YES	YES
Zero current offset	YES	YES
Calibrate current	YES	YES
Reset peak current		YES
Reset power meter		YES
Reset charge meter		YES
Turn power ON/OFF		YES
Force fuel gauge sync.	YES	YES
Remove master password	YES	
Remove user password		YES
Timers (add / edit / delete)		YES
Set time		YES
Firmware upgrade	YES	YES

WIRING DIAGRAM



DIMENSIONS



Dimensions are in mm.

ORDERING

Part Number	Description
PowerMon-5S	PowerMon-5S - Bluetooth smart DC power meter / battery monitor with low/high voltage disconnect, over-current disconnect, timers, and data logging

Changelog:

Date	Revision Description
12/17/2019	Initial preliminary version.
3/6/2020	Updated wiring diagram.
3/23/2020	Updated dimensions. Corrected text.
6/16/2020	Corrected minor issues.