PowerMon

Bluetooth LE

Advanced Battery Monitor / DC Power Meter

– USER MANUAL –
PowerMon (BT-DCPM) is a Bluetooth Smart (LE) Swiss-army knife tool that can be used in any DC circuit. Its primary function is advanced battery monitor / DC power meter. PowerMon allows monitoring of important electrical parameters: two voltages (0-75V), one current (0-60A using the integrated current shunt or up to 10,000A using an external current shunt), 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 be configured to keep the history of the most important measurements for up to 3 years (data logging function – for hardware revision 2.30 and up). The current measurement can be either unidirectional or bidirectional. In bidirectional mode, PowerMon senses current flow in both directions (positive and negative). 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, battery isolator in multiple battery systems, remote on/off switch and timer. A mobile device running either Android or iOS and the PowerMon app (available for free on Google Play Store and Apple App Store) are required for operating this device.
FEATURES

- Measures two voltages, one current (unidirectional or bidirectional), peak current, power (W), charge meter (Ah), energy (Wh) and temperature
- Operates at up to 75V and 60A of continuous current (75A peak current) using the integrated current shunt
- Can sense up to 160mV of voltage drop across an external current shunt allowing current of up to 10,000A to be measured
- Full differential input for the current shunt, allowing it to be mounted either on the ground side or on the positive side
- Data logging for up to 3 years (data history – for hardware revision 2.30 and up)
- Can control one relay or SSR (solid state relay)
- Low / high voltage disconnect
- Over-current disconnect
- Battery isolator for dual battery bank systems
- Battery monitor (battery fuel gauge), displays the state of charge in percentage and the remaining time on battery
- Lithium iron phosphate battery charge manager
- Timers
- Can use an external temperature sensor
- User / master password protection
- Very low power consumption (see Performance Parameters)
- Bluetooth Smart (LE) radio with internal antenna and long range
- 8-pole terminal block for connecting to the system that will be monitored
- ABS plastic enclosure with mounting flanges, completely enclosed in epoxy potting compound
- Measures only 3.0” x 1.55” x 0.75” (76mm x 39mm x 19mm) including the mounting flanges.
- Weatherproof
- Free PowerMon app available for Android and iOS
- Most parameters can be configured, allowing it to achieve top performance with a variety of current shunts and batteries

TYPICAL APPLICATIONS

- RVs, boats, off-the-grid cabins
- Solar and wind alternative energy
- Vehicle batteries
- Backup electrical systems
- Lithium Iron-Phosphate battery charge manager
- Automatization: solar irrigation systems, solar street lights, general purpose DC timers
## TERMINAL DESCRIPTION / INTERNAL DIAGRAM

![Internal Diagram](image)

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Terminal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GROUND</td>
<td>System ground</td>
</tr>
<tr>
<td>2</td>
<td>MF</td>
<td>Multi-function (for hardware revision 2.20 and up). Supports pushbutton input or external temperature sensor</td>
</tr>
<tr>
<td>3</td>
<td>RELAY</td>
<td>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</td>
</tr>
<tr>
<td>4</td>
<td>ES+</td>
<td>External shunt connection. When using the internal current shunt connect this terminal to ES- (terminal 5)</td>
</tr>
<tr>
<td>5</td>
<td>ES-</td>
<td>External shunt connection. When using the internal current shunt connect this terminal to ES+ (terminal 4)</td>
</tr>
<tr>
<td>6</td>
<td>NC</td>
<td>DO NOT CONNECT!</td>
</tr>
<tr>
<td>7</td>
<td>V2</td>
<td>Second monitored voltage. Can measure the voltage of a second battery.</td>
</tr>
<tr>
<td>8</td>
<td>V1</td>
<td>Main power. This is the main voltage that will be monitored. The device also draws its power form this terminal.</td>
</tr>
<tr>
<td>9</td>
<td>IS-</td>
<td>Internal shunt connection. The measured current is flowing from IS+ to IS- or backwards. Do not connect if using an external shunt.</td>
</tr>
<tr>
<td>10</td>
<td>IS+</td>
<td>Internal shunt connection. The measured current is flowing from IS+ to IS- or backwards. Do not connect if using an external shunt.</td>
</tr>
</tbody>
</table>
### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Absolute Maximum Ratings ¹,²</th>
<th></th>
</tr>
</thead>
</table>
| Maximum voltage at V1 and V2 | +65V (hw rev 2.00)  
+75V (hw rev 2.20 and up) |
| Maximum voltage at RELAY | +18V (hw rev 2.00)  
+32V (hw rev 2.20 and up) |
| Maximum current through the RELAY terminal  
(maximum relay coil current) | 0.5A |
| Maximum current through IS+ and IS-  
(using the integrated current shunt) | 60A continuous, 75A peak |
| Maximum current  
(using an external current shunt) | depends on external shunt  
(up to 10,000A) |
| Maximum differential input sense voltage ES+ to ES-  
(using an external shunt) | -75V to +75V |
| Maximum common mode input sense voltage (ES+, ES-,  
IS+, IS-) | -2V to +75V |
| 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 unless otherwise specified.
<table>
<thead>
<tr>
<th>Performance Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured voltage (V1, V2)</td>
<td>0 to 60V (hw rev 2.00)</td>
</tr>
<tr>
<td></td>
<td>0 to 75V (hw rev 2.20 and up)</td>
</tr>
<tr>
<td>Measured voltage accuracy</td>
<td>max 0.5%, typ. 0.25%</td>
</tr>
<tr>
<td>Measured current (using integrated shunt IS+, IS-)</td>
<td>0 to 60A</td>
</tr>
<tr>
<td>Current monitoring accuracy (using integrated shunt)</td>
<td>1% - without calibration</td>
</tr>
<tr>
<td></td>
<td>0.5% - with calibration</td>
</tr>
<tr>
<td>Integrated current shunt resistance</td>
<td>0.5 mOhm / ±1%</td>
</tr>
<tr>
<td>Voltage at external shunt input (ES+ to ES-)</td>
<td>0 – 160mV / ~20µV resolution</td>
</tr>
<tr>
<td>Current monitoring accuracy (using external shunt)</td>
<td>depends on external shunt precision, typically better than 1% (with calibration)</td>
</tr>
<tr>
<td>Minimum external current shunt resistance</td>
<td>0.1 mOhm</td>
</tr>
<tr>
<td>Power (using integrated shunt)</td>
<td>max. 4500W</td>
</tr>
<tr>
<td>Power meter</td>
<td>more than 1000 MWh</td>
</tr>
<tr>
<td>Charge meter</td>
<td>more than 1000 MAh</td>
</tr>
<tr>
<td>Battery state-of-charge monitor</td>
<td>0% ... 100%</td>
</tr>
<tr>
<td>Temperature</td>
<td>1°C / 1°F resolution</td>
</tr>
<tr>
<td>Data logging sample rate (for hardware rev 2.30 and up)</td>
<td>1 sec – up to 18 days</td>
</tr>
<tr>
<td></td>
<td>2 sec – up to 36 days</td>
</tr>
<tr>
<td></td>
<td>5 sec – up to 90 days</td>
</tr>
<tr>
<td></td>
<td>10 sec – up to 180 days</td>
</tr>
<tr>
<td></td>
<td>20 sec – up to 1 year</td>
</tr>
<tr>
<td></td>
<td>30 sec – up to 1.5 years</td>
</tr>
<tr>
<td></td>
<td>1 min – up to 3 years</td>
</tr>
<tr>
<td>Current draw (current consumed by the device) (using the latest firmware version)</td>
<td>at 12V 5.4 mA</td>
</tr>
<tr>
<td></td>
<td>at 24V 5.7 mA</td>
</tr>
<tr>
<td></td>
<td>at 36V 6.0 mA</td>
</tr>
<tr>
<td></td>
<td>at 48V 6.3 mA</td>
</tr>
<tr>
<td></td>
<td>at 60V 6.6 mA</td>
</tr>
<tr>
<td></td>
<td>at 72V 6.9 mA</td>
</tr>
</tbody>
</table>
COMPLIANCE STATEMENTS

FCC

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 device. Thornwave Labs Inc does not assume responsibility for any injury or property damage caused by improper installation, bad wiring or use of PowerMon outside of its intended purpose. The device should be installed by a professional.

Warning !
The PowerMon 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 75V which can be lethal or cause serious and permanent injury.

Warning !
Do not submerge under water or other liquids. The device is weatherproof but not waterproof.

Warning !
The device is to be connected to DC circuits only, not exceeding 75V and 60A (using the integrated current shunt). Failure to do so will result in equipment damage. Higher currents are supported when using an external current shunt. Confirm that all connections are tight to avoid excessive heating and sparks. Never connect the V1 or VS terminals to a power source without using a fuse or circuit breaker. A 0.1A to 5A fuse or circuit breaker is required.

Warning !
Batteries are dangerous! Do not short-circuit a battery or the power meter. Batteries can produce flammable and explosive gases and can generate extremely 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 device is drawing its supply power from the V1 terminal. Make sure that V1 is always present. If the device loses its power it will forget the battery state, time and date and access passwords.

**Integrated current shunt.** When using the integrated current shunt, the ES+ and ES- pins should be connected together using a wire bent in a U shape and attached to the supplied terminal block. The current to be monitored should be routed through the IS+ and IS- terminals. An internal current shunt of 0.5mOhm exists in between these two terminals. The aluminum, hex set screw terminal blocks (IS+ and IS-) can accept wires up to 6AWG in size. In order to minimize the voltage drop on wires and connections, use the thickest wires that fit inside the terminals (6AWG). The common mode voltage at IS+ and IS- can be in between -2V and +75V relative to ground, allowing the current shunt to be placed either on the positive side of the circuit or on the ground wire (negative side). Current flowing from IS+ to IS- will be displayed as a positive value and current from IS- to IS+ will be displayed as a negative value. The current sign can be flipped from the device configuration as well.

**External current shunt.** To monitor a large current or a very small current more accurately, an external current shunt can be used. This method allows monitoring current up to 1,000A with reasonable resolution or even higher current if resolution can be sacrificed. Using a higher resistance current shunt, current in the milliamp range can be measured accurately. The external current shunt resistor should be connected to the ES+ and ES- inputs. To avoid noise the wires should be as short as possible. Twisting the sense wires reduces noise even further. The IS+ and IS- terminals should be left unconnected. The common mode voltage at ES+ and ES- can be in between -2V and +75V relative to ground, allowing the current shunt to be placed either on the positive side of the circuit or on the ground wire. Current flowing from the ES+ to ES- sides of the external shunt will be displayed as a positive value and current from ES- to ES+ will be displayed as a negative value. The current sign can be flipped from the device configuration as well.

**Operation.** Once the device receives power it will start advertising its presence to other Bluetooth devices. Using a cell-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 “DCPM”. Once the mobile app is connected to a power monitor device, the app will display all the measured electrical parameters and update them in real-time. Tapping on a measurement value for longer than 1 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. Installation on non-metallic surfaces is preferred. The mobile device app displays the RSSI value (Received Signal Strength Indication) in real-time.
**Power relay control.** PowerMon can drive a power relay (either mechanical or solid-state) using the RELAY output (terminal 3). When active (relay turned on), the RELAY terminal is internally connected to ground by the 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. In this mode PowerMon can also operate as a battery isolator. The relay is used to connect the house batteries in parallel with the starting battery. The LVD filter value should be set to 5000ms. The disconnect threshold should be set to 13.2V and the connect threshold to 13.6V. When the engine is started and the alternator starts charging the starting battery, the voltage will start increasing. When the voltage reaches 13.6V (the connect threshold) the relay engages and connects the house batteries to the starting battery, this way allowing all batteries to be charged. When the engine is stopped the voltage will quickly drop below 13.2V (the disconnect threshold) and the relay disengages, isolating the house batteries from the starting battery. The house batteries voltage can be monitored using the V2 input. Note that the thresholds (13.6V and 13.2V) are just an example. They can be configured to best fit the application.

**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. For the battery fuel gauge to work properly the current should be sensed bidirectionally. Charging current should be positive and discharging current should be negative. 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.

<table>
<thead>
<tr>
<th>Battery Chemistry</th>
<th>Peukert Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Acid - Flooded</td>
<td>1.25</td>
</tr>
<tr>
<td>Lead Acid – AGM</td>
<td>1.15</td>
</tr>
<tr>
<td>LiFePO₄</td>
<td>1.02</td>
</tr>
<tr>
<td>Li-Ion/LiPoly</td>
<td>1.02</td>
</tr>
</tbody>
</table>

**LiFePO charge manager.** PowerMon can manage the charging of a lithium iron phosphate battery. This function cannot be used together with the other disconnect functions. If enabled, the mobile app will automatically disable the other functions. A relay must be placed in between the battery and the charger, or power source used for charging (for example the vehicle alternator). The function of this relay is to disconnect the charger from the battery if a full charge is detected or the power supply is turned off (for example the engine is tuned off). To use the LiFePO charge manager, connect the V1 input to the battery positive and V2 input to the charger positive. The internal shunt and the relay should be wired in between the charger and the battery. (see wiring diagrams at the end of the manual).

The user configures the number of LiFePO cells connected in series (4 for a 12V battery) and the total capacity of the battery in Ah. These parameters are used to calculate a few thresholds as seen in the table below. At least one disconnect condition has to be true for at least 2 seconds for the disconnect to take place. The connect conditions must be true for time specified in “Connect Time” for the connect to take place (default is 10 seconds).

The following table shows the conditions used by PowerMon to decide whether to connect or disconnect the charger from the battery (turn the relay ON/OFF). V1 is connected to the battery and V2 to the charger. Current refers to the current flowing in between the battery and the charger. “C” refers to the battery capacity. Care should be exercised to ensure that the current is positive when the battery is being charged and negative if it is being discharged. If wired backwards, use the “Flip Current Sign” option to fix it.

**WARNING!** PowerMon cannot be used as a charge current limiter or LiFePO cell balancer. A properly sized battery charger is required to recharge LiFePO batteries. Thornwave Labs Inc. does not assume any responsibility for expensive battery damage.
<table>
<thead>
<tr>
<th>Connect Conditions (10 sec. delay used)</th>
<th>Disconnect Conditions (2 sec. delay used)</th>
</tr>
</thead>
<tbody>
<tr>
<td>battery voltage (V1) less than 3.32V / cell AND charger voltage (V2) at least 0.2V above the battery voltage (V1)</td>
<td>battery voltage (V1) greater than 3.65V / cell</td>
</tr>
<tr>
<td>charging current (I) less than C/100 or 1 Amp, whichever is greater</td>
<td>full charge is detected: battery voltage (V1) greater than 3.5V /cell AND charging current (I) less than C/20</td>
</tr>
</tbody>
</table>

**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.

**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.

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

Examples:

*Timer 1*: 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

*Timer 2*: START 8:00PM. STOP: disabled, REPETITION DOW Sun Mon Tue Wed Thr Fri Sat

*Timer 3*: 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.

*Timer 4*: START 12:00AM. STOP: disabled, REPETITION DOM: 1

*Timer 5*: START disabled, STOP: 12:00AM, REPETITION DOM: 8
This set of timers used together will turn the relay on every 1\textsuperscript{st} of the month at 12:00AM and turn it off 7 days later on the 8\textsuperscript{th} of the month at 12:00AM.
Configuration. The following parameters can be configured using the PowerMon app:

Current Sense Voltage Range: The current shunt resistor voltage drop measurement range. This should be adjusted to be higher than the maximum expected voltage drop across the current shunt.

<table>
<thead>
<tr>
<th>Unidirectional (positive current only)</th>
<th>Bidirectional (positive and negative current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+160mV</td>
<td>-</td>
</tr>
<tr>
<td>+150mV</td>
<td>-</td>
</tr>
<tr>
<td>+120mV</td>
<td>-</td>
</tr>
<tr>
<td>+90mV</td>
<td>±80mV</td>
</tr>
<tr>
<td>+60mV</td>
<td>±60mV</td>
</tr>
<tr>
<td>+30mV</td>
<td>±30mV</td>
</tr>
<tr>
<td>-</td>
<td>±15mV</td>
</tr>
<tr>
<td>-</td>
<td>±7.5mV</td>
</tr>
</tbody>
</table>

Current Shunt Resistance: The resistance value of the current shunt used (in milli-Ohms). By default, it is set to 0.5mOhm which is the integrated shunt resistance.

Flip Current Sign: Allows the current sign to be flipped by software. Can be used to correct a wiring mistake without having to re-wire the device.

Meter Voltage Source: The voltage used to calculate power and energy. V1 or V2 can be selected.

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 is 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 Voltage Source:* The voltage used by the low voltage disconnect feature. V1 or V2 can be selected.

*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 Voltage Source:* The voltage used by the high voltage disconnect feature. V1 or V2 can be selected.

*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 Voltage Source:** The voltage used by the battery fuel gauge feature. V1 or V2 can be selected.

**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 LiFePO₄ 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.

LiFePO Charge Manager

**Number of Cells:** Number of cells of the battery. 12V LiFePO₄ 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)

**Default Factory Settings.** The default configuration for PowerMon is to use the integrated current shunt. 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.
**Configuration example.** Let’s suppose that current of up to 400A needs to be measured bidirectionally. For this purpose, we will use a 500A / 50mV current shunt.

Ohm’s law states: \( V = I \times R \)

This means that the voltage drop across a resistor is equal to the current passing through that resistor multiplied by the resistance value. Rearranging that equation, we get: \( R = \frac{V}{I} \). Using this we can calculate the resistance of the shunt:

\[
\frac{0.05V (50mV)}{500A} = 0.0001Ohm = 0.1mOhm
\]

In order to properly configure PowerMon we set the Sense Resistor to 0.1mOhm and Sense Voltage Range to ±60mV since this is the next higher range available that can be used for measuring up to 50mV. Using the ±60mV range allows a current up to ±600A to be measured but the 500A shunt rating should not be exceeded.
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, two voltage readings (V1 and V2) 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 practical scenarios involving Bluetooth, this is a negative number and is measured in dBm (decibel referenced to 1mV). 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. This menu also allows disabling of V2 measurement in case it is not used. 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 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 current wires from the device (or from the external shunt) 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 than the actual current reading by more than 10%.

**Renaming the device.** Renaming the device can be achieved using the top right menu button and tapping 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, LiFePO₄ 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.

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

V/I measurement with internal shunt

Displays:
- battery voltage
- current in/out from the battery
- power/energy in/out from the battery

V/I measurement with internal shunt
+ low voltage disconnect
+ over-current disconnect
+ remote ON/OFF

Displays:
- battery voltage
- current in/out from the battery
- power/energy in/out from the battery
- power relay status (ON/OFF)
V/I measurement with external shunt

Displays:
- battery voltage
- current in / out from the battery
- power / energy in / out from the battery

V/I measurement with external shunt
+ low voltage disconnect
+ over-current disconnect
+ remote ON/OFF

Displays:
- battery voltage
- current in / out from the battery
- power / energy in / out from the battery
- power relay status (ON/OFF)
Timer only
Displays:
- battery voltage
- power relay status (ON/OFF)

Battery isolator only
Displays:
- engine battery voltage
- house battery voltage
- isolator relay status (ON/OFF)
Battery isolator with house battery monitor (internal shunt)

Displays:
- engine battery voltage
- house battery voltage
- isolator relay status (ON/OFF)
- current in / out from the house battery
- power / energy in / out from the house battery

House battery

to load

Engine battery

Fuse
to engine and alternator

Battery isolator with house battery monitor (external shunt)

Displays:
- engine battery voltage
- house battery voltage
- isolator relay status (ON/OFF)
- current in / out from the house battery
- power / energy in / out from the house battery

External Shunt

House battery

to load

Engine battery

Fuse
to engine and alternator

Relay SPST
LiFePO Battery Charge Manager (internal shunt)

Displays:
- LiFePO battery voltage
- engine battery / charger voltage
- charge relay status (ON/OFF/NCH)
- charging current

LiFePO Battery

Relay SPST

to engine and alternator

Engine battery

LiFePO Battery Charge Manager (external shunt)

Displays:
- LiFePO battery voltage
- engine battery / charger voltage
- charge relay status (ON/OFF/NCH)
- charging current

External Shunt

Relay SPST

to engine and alternator

Engine battery
Dimensions are in inch.
<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT-DCPM</td>
<td>PowerMon - Bluetooth smart DC power meter / battery monitor with low/high voltage disconnect, over-current disconnect, timers, LiFePO charge manager, and data logging</td>
</tr>
</tbody>
</table>
## Changelog:

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/1/2017</td>
<td>Initial preliminary version.</td>
</tr>
<tr>
<td>8/7/2017</td>
<td>Added FCC/IC required warnings.</td>
</tr>
<tr>
<td>8/9/2017</td>
<td>Revised FCC/IC required warnings.</td>
</tr>
<tr>
<td>7/17/2017</td>
<td>Added FCC required statement.</td>
</tr>
<tr>
<td>9/10/2017</td>
<td>Added “Voltage Source” configuration parameter.</td>
</tr>
<tr>
<td>9/18/2017</td>
<td>Added “Mobile Application - PowerMon” section.</td>
</tr>
<tr>
<td>11/21/2017</td>
<td>Added “Timers” sections.</td>
</tr>
<tr>
<td>3/8/2018</td>
<td>Added new features implemented in the latest firmware release: peak current, high voltage disconnect, battery fuel gauge</td>
</tr>
<tr>
<td>5/9/2018</td>
<td>Added new features implemented in the latest firmware release: password lock, disconnect on fuel gauge</td>
</tr>
<tr>
<td>6/11/2018</td>
<td>Added paragraph about master/user password locking.</td>
</tr>
<tr>
<td>10/12/2018</td>
<td>Added PowerMon brand name. Updated the device specifications. Improvements.</td>
</tr>
<tr>
<td>11/12/2018</td>
<td>Added LiFePO charge manager sections.</td>
</tr>
<tr>
<td>3/24/2020</td>
<td>Added references to the data logging function.</td>
</tr>
<tr>
<td>6/16/2020</td>
<td>Corrected minor issues.</td>
</tr>
</tbody>
</table>