# EVOLUTION ELECTRIC VEHICLES

v1.0

# LITHIUM-ION BATTERY MANUAL

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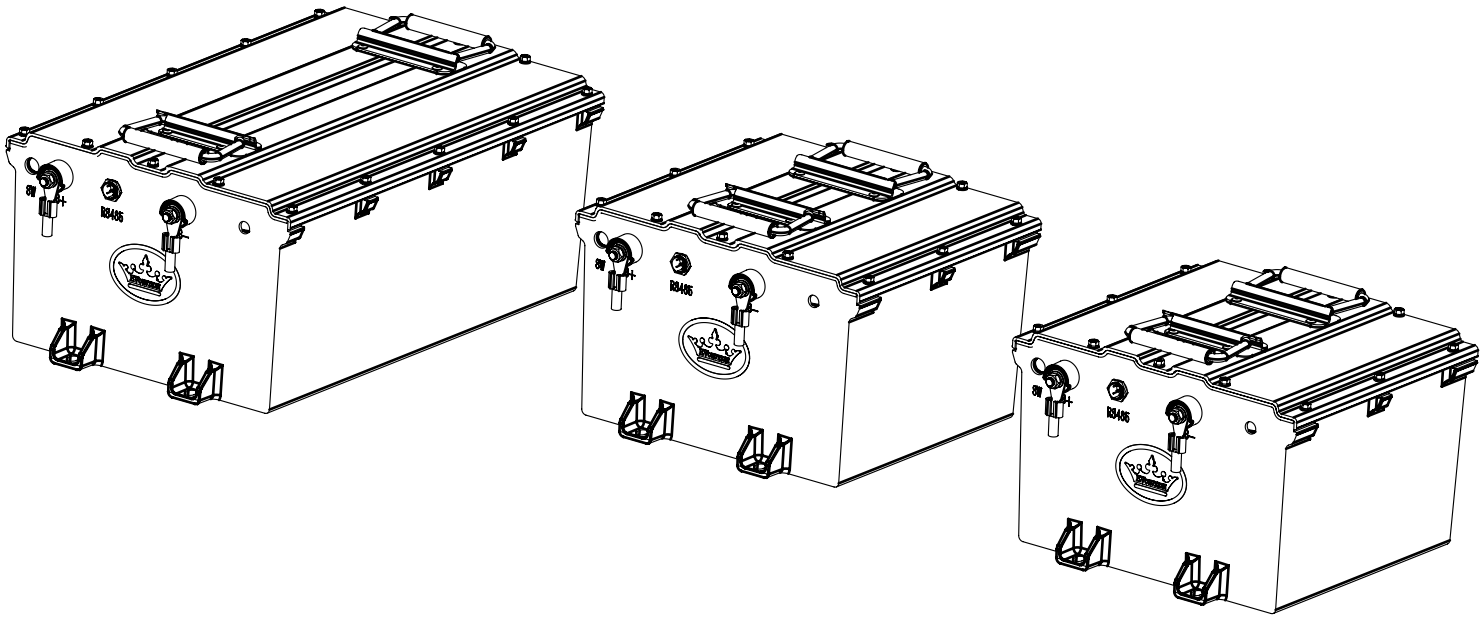

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SAFETY PRECAUTIONS

# 1.Safety Precautions


Observe these instructions and keep them located near the battery for future reference.


The Material Safety Datasheet can be downloaded from the “Material Safety Datasheet menu”.


Work on a li-ion battery should be carried out by qualified personnel only.

## 1.1General Warnings


While working on a li-ion battery wear protective eyeglasses and clothing.


Any uncovered battery material such as electrolyte or powder on the skin or in the eyes must immediately be flushed with plenty of clean water. Then seek medical assistance. Spillages on clothing should be rinsed out with water.


Explosion and fire hazard. The terminals of a li-ion battery are always live, therefore do not place metallic items ortools on top of a li-ion battery. Avoid short circuits, too deep discharges and too high charge currents. Use insulated tools. Do not wear any metallic items such as watches, bracelets, et cetera. In case of fire, you must use a type D foam or CO2 fire extinguisher.


Do not open or dismantle the battery. Electrolyte is very corrosive. In normal working conditions contact with the electrolyte is impossible. If the battery casing is damaged do not touch the exposed electrolyte or powder because it is corrosive.


Li-ion batteries are heavy. If involved in an accident they can become a projectile! Ensure adequate and secure mounting and always use suitable handling equipment for transportation.


Handle with care because a li-ion battery is sensitive to mechanical shock.


Do not use a damaged battery.


Do not wet the battery.

## 1.2Charge and Discharge Warnings


Too deep discharges will seriously damage a li-ion battery and can even be dangerous. Therefore, use of an external safety relay is obligatory.


Use only with a EVOLUTION approved BMS.


If charged after the Lithium Battery was discharged below the “Discharge cut -off voltage”, or when the Lithium Battery is damaged or overcharged, the Lithium Battery can release a harmful mixture of gasses such as phosphate.


The temperature range over which the battery can be charged is 0°C to 45°C. Charging the battery at temperatures outside this range may cause severe damage to the battery or reduce battery life expectancy.

SAFETY PRECAUTIONS

The temperature range over which the battery can be discharged is -20°C to 50°C. Discharging the battery at temperatures outside this range may cause severe damage to the battery or reduce battery life expectancy.

## 1.3Transportation Warnings

The battery must be transported in its original or equivalent package and in an upright position. If the battery is in its package, use soft slings to avoid damage.

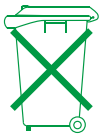
Do not stand below a battery when it is hoisted.

Never lift the battery at the terminals or the BMS communication cables, only lift the battery at the handles.

Batteries are tested according to UN Handbook of Tests and Criteria, part III, sub section 38.3 (ST/SG/AC.10/11/Rev.5).
For transport the batteries belong to the category UN3480, Class 9, Packaging Group II and have to be transported according to this regulation. This means that for land and sea transport (ADR, RID & IMDG) they have to be packed according to packaging instruction P903 and for air transport (IATA) according to packaging instruction P965. The original packaging complies with these instructions.

## 1.4Disposal of lithium batteries

Batteries marked with the recycling symbol must be processed via a recognized recycling agency. By agreement,they may be returned to the manufacturer.



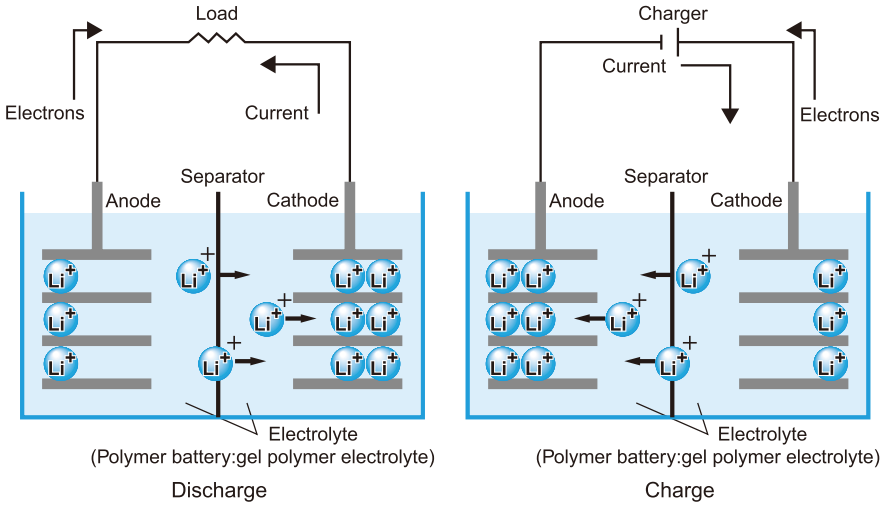
Batteries must not be mixed with domestic or industrial waste .

Do not throw a battery into fire.

# 2.LFP battery technology basics

## 2.1 Lithium-ion battery

Figure1

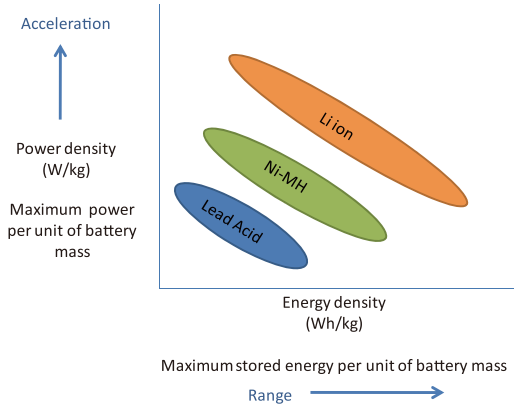



A battery is a device that converts chemical energy into electrical energy and vice versa.The battery categories can be broken down by the chemistries used in the construction of the battery.

- Nickel-cadmium (NiCd) (vented & semi-sealed) - mature but have moderate energy density. Nickel-cadmium batteries have generally been used where long life, high discharge rate and extended temperature range is important. Nickel-cadmium batteries contain toxic metals and are generally being phased out.
- Nickel-metal-hydride (NiMH) - have a higher energy density compared to nickel cadmium at the expense of reduced cycle life. Contain no toxic metals.
- Lithium-ion (Li-ion)- fastest growing battery technology offering high energy density and low weight. Requires protection circuits to limit voltage and current for safety reasons.
- Lead-acid (vented & valve-regulated) batteries .Most economical for larger power applications where weight is of little concern.

Lithium-ion (lithium-ion) batteries are projected to become the most popular battery forfull-battery electric vehicles.Compared with other relevant battery types, lithium-ion batteries have the highest power density.

| Battery type | Lead acid | Ni-Cd | Ni-MH | Lithium-ion |
|---|---|---|---|---|
| Energy density [a] (Wh/Kg) | 35 | 40-60 | 60 | 120 |
| Power density (W/kg) | 180 | 150 | 250-1000 | 1,800 |
| Cycle life [c] | 700 | 2,000 | 2,000 | 3,500 |
| Cost ($/kWh)[d] | 269 | 280 | 500-1,000 | Consumer electronics: 300-800 Vehicles: 1,000-2,000 |
| Battery characteristics | High reliability, low cost | Memory effect | Currently, best value and most popular battery for HEVs | Small size, light weight |
| Application | Car battery, forklift, golf cart, backup power | Replacement for flashlight battery | HEVs, replacement for flashlight battery | Consumer electronics Car battery, forklift, golf cart,backup power |

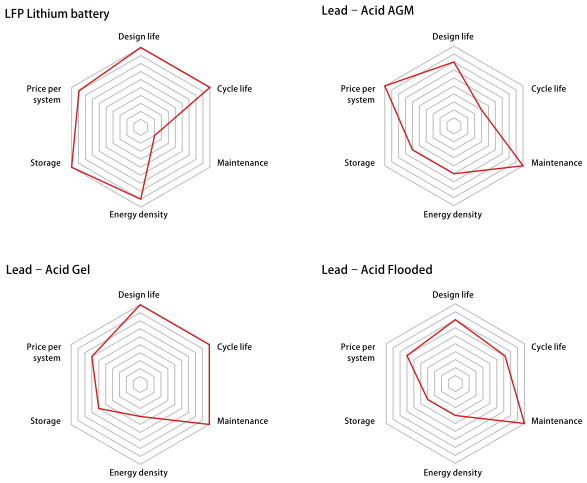


LFP BATTERY BASICS

## Flooded batteries VS Lithium- ion battery?

**>Flooded Lead acid batteries**, as the name suggests, have plates that are immersed in an acid electrolyte.Since they are not sealed, the hydrogen generated during operation escapes directly into the environment, meaning that ventilation systems must be more powerful than those for VRLA and, so,sized adequately . Flooded batteries must be kept and operated upright, and their water levels must be manually topped up. They provide a longer life span and higher reliability than sealed lead acid batteries, but not as high as lithium batteries.

**>Lithium-ion batteries** are the most suitable existing technology for electric vehicles because they can output high energy and power per unit of battery mass, allowing them to be lighter and smaller than other rechargeable batteries .These features also explain why lithiumion batteries are already widely used for consumer electronics such as cell phones, laptop computers, digital cameras/video cameras, and portable audio/game players. Other advantages of lithium-ion batteries compared to lead acid and nickel metal hydride batteries include high-energy efficiency, no memory effects, and a relatively longer cycle life




### Lithium-ion batteries

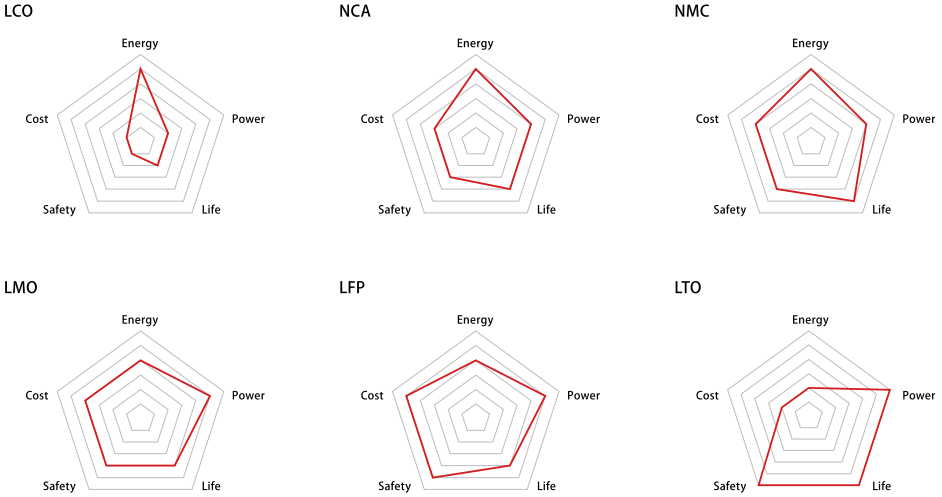
In a lithium-ion battery (LIB), the "cathode" is usually made of a metal oxide, while the anode is usually porous carbon graphite. Both are immersed in a liquid electrolyte made of lithium salt and or ganic solvent. During discharge, the ions flow from the anode to the cathode through the electrolyte and separator; charging reverses the direction, and the ions flow from the cathode to the anode.

A common way to distinguish the main different types of lithium-ion batteries is to consider the cathode composition. The choice of battery depends on various factors, including cell voltage, capacity, energy and power capabilities, cycle life, and temperature of operation.

Various LIB chemistries exist, which can be simplified into six main types based on the composition of the cathode material (items 1 to 5) or anode material (item 6):

1. Lithium cobalt oxide (LCO)
2. Lithium manganese oxide (LMO)
3. Lithium-nickel manganese cobalt oxide (NMC)
4. Lithium iron phosphate (LFP)
5. Nickel cobalt alumina (NCA)
6. Lithium titanium oxide (LTO)

It is not possible to compare these different families precisely, since many aspects other than technology play an important role in performance, such as mechanical form, cell size and active material mix. Different battery manufacturers also combine technologies to improve performance for a specific application.



## How does a lithium-ion battery work?

A lithium-ion battery is a rechargeable battery in which lithium ions move between the anode and cathode, creating electricity flow useful for electronic applications. In the discharge cycle,lithium in the anode (carbon material) is ionized and emitted to the electrolyte. Lithium ions move through a porous plastic separator and insert into atomic-sized holes in the cathode (lithium metal oxide). At the same time, electrons are released from the anode. This becomes electric current traveling to an outside electric circuit. When charging, lithium ions go from the cathode to the anode through the separator. Since this is a reversible chemical reaction, the battery can be recharged .

## Charge/discharge mechanism.

Battery charging and discharging occur through the migration of lithium ions between the cathodes and anodes and the exchange of electrons through doping and dedoping.

More specifically, during charging lithium is dedoped from cathodes consisting of a lithium-containing compound, and the interlayers of carbon in anodes are doped with lithium. Conversely, during discharge lithium is dedoped from between the carbon layers in anodes, and the compound layers in cathodes are doped with lithium. Reactions occurring in lithium ion rechargeable batteries employing LiCoO2(lithium cobaltate) in cathodes and carbon in anodes are shown in Figure1.

By means of the initial charging, which takes place during battery manufacture, lithium ions migrate from the lithium compound of the cathode to the carbon material of the anode.

Initial charge

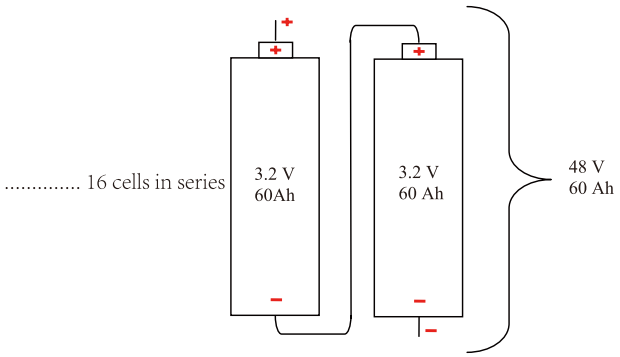
$$LiCoO_2 + C \rightarrow Li_{1-x}CoO_2 + Li_xC$$

Subsequent discharge reactions occur through the migration of lithium ions from the anode to the cathode.

discharge

$$Li_{1-x}CoO_2 + Li_xC \leftrightarrows Li_{1-x+dx}CoO_2 + Li_{x-dx}C$$

charge




A lithium-ion battery cell contains four main components: cathode, anode, electrolyte and separator . Lithium-ion battery cells are sold in “battery packs,” which include battery management systems (BMS) . For Evolution lithium battery pack it contains 16 cells in each pack ,connected in series circuit .BMS system is integrated inside of battery packs.

## Guide to Understanding Battery Specifications

A battery is a device that converts chemical energy into electrical energy and vice versa. This summary provides an introduction to the terminology used to describe, classify, and compare batteries for electric vehicles. It provides a basic background, defines the variables used to characterize battery operating conditions, and describes the manufacturer specifications used to characterize battery nominal and maximum characteristics.

## Battery Basics

- **Cell, modules, and packs** – Electric vehicles have a high voltage battery pack that consists of individual modules and cells organized in series and parallel. A cell is the smallest, packaged form a battery can take and is generally on the order of one to six volts. A module consists of several cells generally connected in either series or parallel. A battery pack is then assembled by connecting modules together, again either in series or parallel.

- **Battery Classifications** – Not all batteries are created equal, even batteries of the same chemistry. The main trade-off in battery development is between power and energy: batteries can be either high-power or high-energy, but not both. Often manufacturers will classify batteries using these categories. Other common classifications are High Durability, meaning that the chemistry has been modified to provide higher battery life at the expense of power and energy.

- **C- and E- rates** – In describing batteries, discharge current is often expressed as a C-rate in order to normalize against battery capacity, which is often very different between batteries. a C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. a 1C rate means that the discharge current will discharge the entire battery in 1 hour. For a battery with a capacity of 100 Amp-hrs, this equates to a discharge current of 100 Amps. A 5C rate for this battery would be 500 Amps, and a C/2 rate would be 50Amps. Similarly, an E-rate describes the discharge power. A 1E rate is the discharge power to discharge the entire battery in 1 hour.

## Battery Condition

This section describes some of the variables used to describe the present condition of a battery.

- **State of Charge (SOC)(%)** – An expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time.

- **State of Health (SOH)(%)** – An expression of the present battery Health（Life expection/Capacity） as a percentage of maximum life span. SOH is generally calculated using current/voltage/cell resistance integration to determine the change in battery life span expectation over time.

- **Depth of Discharge (DOD) (%)** – The percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity. A discharge to at least 80 % DOD is referred to as a deep discharge.

- **Terminal Voltage (V)** – The voltage between the battery terminals with load applied.Terminal voltage varies with SOC and discharge/charge current.

- **Open-circuit voltage (V)** – The voltage between the battery terminals with no load applied. The open-circuit voltage depends on the battery state of charge, increasing with state of charge.

- **Internal Resistance** – The resistance within the battery, generally different for charging and discharging, also dependent on the battery state of charge. As internal resistance increases, the battery efficiency decreases and thermal stability is reduced as more of thecharging energy is converted into heat.

## Battery Technical Specifications

This section explains the specifications you may see on battery technical specification sheets used to describe battery cells, modules, and packs.

- **Nominal Voltage (V)** – The reported or reference voltage of the battery, also sometimes thought of as the "normal" voltage of the battery.

- **Cut-off Voltage** – The minimum allowable voltage. It is this voltage that generally defines the "empty" state of the battery.

- **Capacity or Nominal Capacity (Ah for a specific C-rate)** – The coulometric capacity, the total Amp-hours available when the battery is discharged at a certain discharge current (specified as a C-rate) from 100 percent state-of-charge to the cut-off voltage. Capacity is calculated by multiplying the discharge current (in Amps) by the discharge time (in hours) and decreases with increasing C-rate.

- **Energy or Nominal Energy (Wh (for a specific C-rate))** – The "energy capacity" of the battery, the total Watt-hours available when the battery is discharged at a certain discharge current (specified as a C-rate) from 100 percent state-of-charge to the cut-off voltage. Energy is calculated by multiplying the discharge power (in Watts) by the discharge time (in hours). Like capacity, energy decreases with increasing C-rate.

- **Cycle Life (number for a specific DOD)** – The number of discharge-charge cycles the battery can experience before it fails to meet specific performance criteria. Cycle life is estimated for specific charge and discharge conditions. The actual operating life of the battery is affected by the rate and depth of cycles and by other conditions such as temperature and humidity. The higher the DOD, the lower the cycle life

- **Specific Energy (Wh/kg)** – The nominal battery energy per unit mass, sometimes referred to as the gravimetric energy density. Specific energy is a characteristic of the battery chemistry and packaging. Along with the energy consumption of the vehicle, it determines the battery weight required to achieve a given electric range.

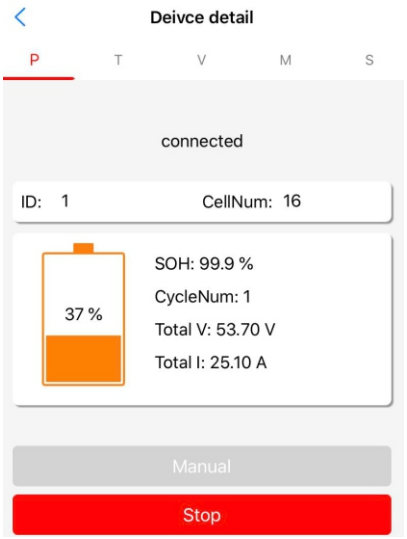
- **Maximum Continuous Discharge Current** – The maximum current at which the battery can be discharged continuously. This limit is usually defined by the battery manufacturer in order to prevent excessive discharge rates that would damage the battery or reduce its capacity. Along with the maximum continuous power of the motor, this defines the top sustainable speed and acceleration of the vehicle.

- **Maximum 30-sec Discharge Pulse Current** –The maximum current at which the battery can be discharged for pulses of up to 30 seconds. This limit is usually defined by the battery manufacturer in order to prevent excessive discharge rates that would damage the battery or reduce its capacity. Along with the peak power of the electric motor, this defines the acceleration performance (0-25 mph time) of the vehicle.

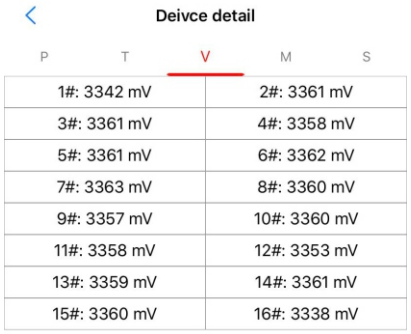
- **Charge Voltage** – The voltage that the battery is charged to when charged to full capacity. Charging schemes generally consist of a constant current charging until the battery voltage reaching the charge voltage, then constant voltage charging, allowing the charge current to taper until it is very small.

- **Float Voltage** – The voltage at which the battery is maintained after being charge to 100percent SOC to maintain that capacity by compensating for self-discharge of the battery

- **(Recommended) Charge Current** – The ideal current at which the battery is initially charged (to roughly 70 percent SOC) under constant charging scheme before transitioning into constant voltage charging.
- **(Maximum) Internal Resistance** – The resistance within the battery, generally different for charging and discharging.




.Battery specifications display example with from Evolution battery pack -1.




| | |
|---|---|
| 1#: 3342 mV | 2#: 3361 mV |
| 3#: 3361 mV | 4#: 3358 mV |
| 5#: 3361 mV | 6#: 3362 mV |
| 7#: 3363 mV | 8#: 3360 mV |
| 9#: 3357 mV | 10#: 3360 mV |
| 11#: 3358 mV | 12#: 3353 mV |
| 13#: 3359 mV | 14#: 3361 mV |
| 15#: 3360 mV | 16#: 3338 mV |

.Battery specifications display example with from Evolution battery pack-2.

# 3.Introduction

## 3.1Lithium iron phosphate battery

The lithium iron phosphate battery (LiFePO4 or LFP) is the safest of the mainstream lithium battery types. A single LFP cell has a nominal voltage of 3.2V. A 48 V LFP battery consists of 16 cells connected in series.
LFP is the chemistry of choice for very demanding applications. Some of its features are:
• Rugged - It can operate in deficit mode during long periods of time.
• High round trip efficiency.
• High energy density - More capacity with less weight and volume.
• High charge and discharge currents - Fast charge and discharges are possible.
• Flexible charge voltages.

The lithium iron phosphate battery is therefore the chemistry of choice for a range of very demanding applications.

## 3.2Lithium battery models

The Lithium Smart Battery is available in a variety of capacities and with same voltages, namely 48V. These are all available battery models:
• LiFePO4 Battery 48V/60Ah .
• LiFePO4 Battery 48V/110Ah .
• LiFePO4 Battery 48V/130Ah .
• LiFePO4 Battery 48V/180Ah .

## 3.3Battery Management System（BMS）

The battery cells in the Smart Lithium batteries are protected against over-charge, under-charge, charging at too low temperatures as well as charging at too high temperatures.
As part of the protection the battery has an integrated Balancing, Temperature and Voltage control system. The Battery Management System, the BMS monitors each individual battery cell; it balances the cell voltages and in case of high or low cell voltage or in case of high or low cell temperature, it will generate an alarm signal. The alarm signal is received by the BMS and the BMS will turn off loads or chargers accordingly.
A BMS is essential for a correct operation of the lithium battery. The lithium battery is not allowed to be used without one. In addition to this you will also need to ensure that the BMS correctly controls all loads and charge sources that are connected to the battery.

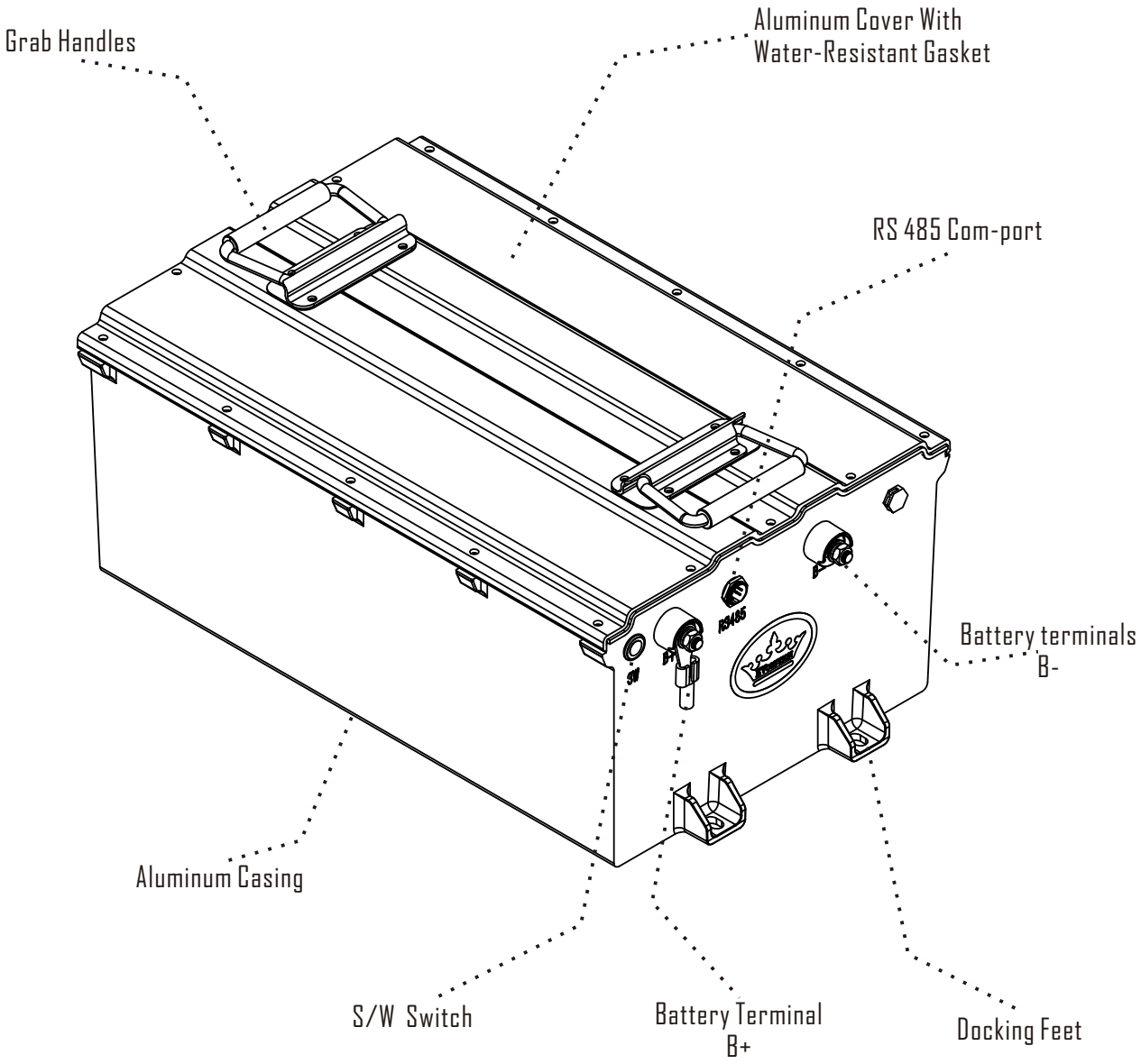
## 3.4Battery app connect

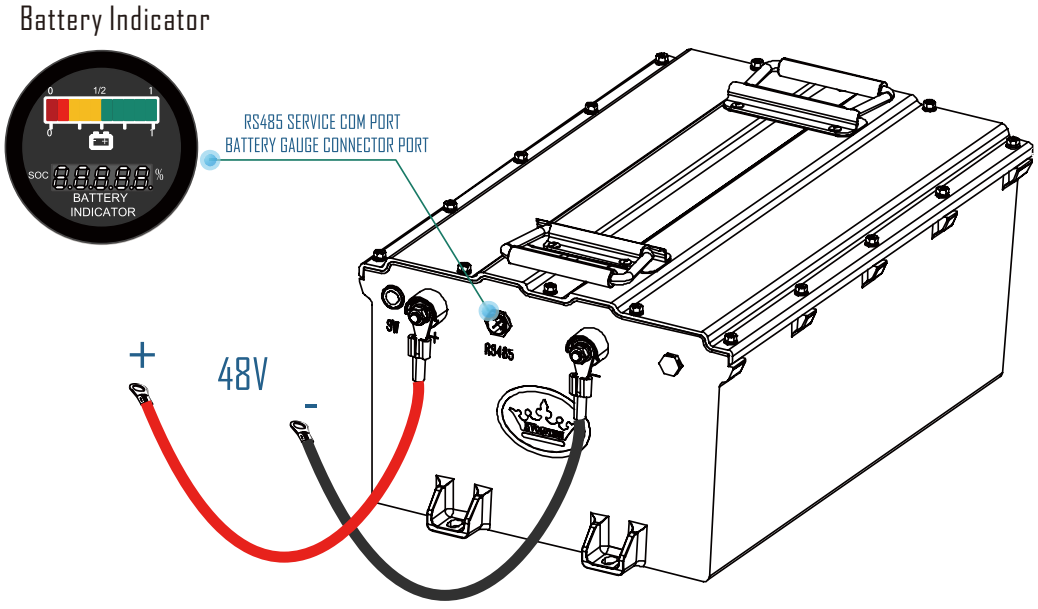
The battery is equipped with Bluetooth and uses this to communicate with the BBMS app. The BBMS app is used for reading out battery information, for making or changing battery settings, receiving alarms .,etc.

LITHIUM BATTERY SYSTEM

# 4.Lithium Battery System

## 4.1Evolution LFP battery pack system



LITHIUM BATTERY MODELS

## 5.Lithium Battery Models

*L series products are lithium-ion battery packs with integrated golf cart battery system.*
*They are designed to replace the lead-acid batteries, which are available for drop-in replacement in the Club Car, EZ-GO, Yamaha.,etc, vehicles easily.*

***SUITABLE FOR ALL TOP BRAND GOLF CARTS !***

## Product specification

| L series | L4860 | L48110 |
|---|---|---|
| Technical specification | | |
| Nominal voltage | 51.2V | 51.2V |
| Nominal capacity | 60Ah | 110Ah |
| Stored energy | 2.88kwh | 5.28kwh |
| Life cycles | >3500 times | >3500 times |
| Self discharge | max 3.2% per month | max 3.2% per month |
| Mileage (2 seat at 13mph) | 25-35miles/full charging | 40-55miles/full charging |
| Continuous charge current | ≤40A | ≤70A |
| Continuous discharge current | 100A | 100A |
| Maximum discharge current | 3C(30s) | 3C(30s) |
| Quick charging time | 1h | 1h |
| Standard charging time | 3-4h | 4-5h |
| Charge temperature range | 32°F to 110°F (0°C to 45°C) | 32°F to 110°F (0°C to 45°C) |
| Discharge temperature range | -4°F to 140°F (-20°C to 55°C) | -4°F to 140°F (-20°C to 55°C) |
| Storage temperature range | -4°F to 113°F (1month)(-20°C to 45°C)<br>32°F to 95°F (1year)(0°C to 35°C) | -4°F to 113°F (1month)(-20°C to 45°C)<br>32°F to 95°F (1year)(0°C to 35°C) |
| General specification | | |
| Cell combination | 16 in series circuit | 16 in series circuit |
| Cell assembly | 3.2V60Ah | 3.2V110Ah |
| Casing material | Aluminum Alloy | Aluminum Alloy |
| Weight | 56.8lbs(25.8kg) | 102.7lbs(46.6kg) |
| Dimension(L*W*H) | 13.5*12.8*9.4in | 23.5*12.8*9.4in |
| IP rate | IP66 | IP66 |

Note:

1. Only authorized personnel is allowed to operate or make adjustments to the battery.
2. Must to use Evolution original chargers and accessories with our batteries.
3. Specifications in this catalogue are subject to change without notice. Please contact EVOLUTION ELECTRIC VEHICLES,INC. for detailed information.

*The benefits of lithium-ion battery include lighter weight, shorter charging time, longer life, free maintenance and to save much electricity bill for you. Our battery has an integrated management system which includes an On/Off switch and a state-of-charge(SOC) gauge.*

LITHIUM BATTERY MODELS

## *SUITABLE FOR ALL TOP BRAND GOLF CARTS !*

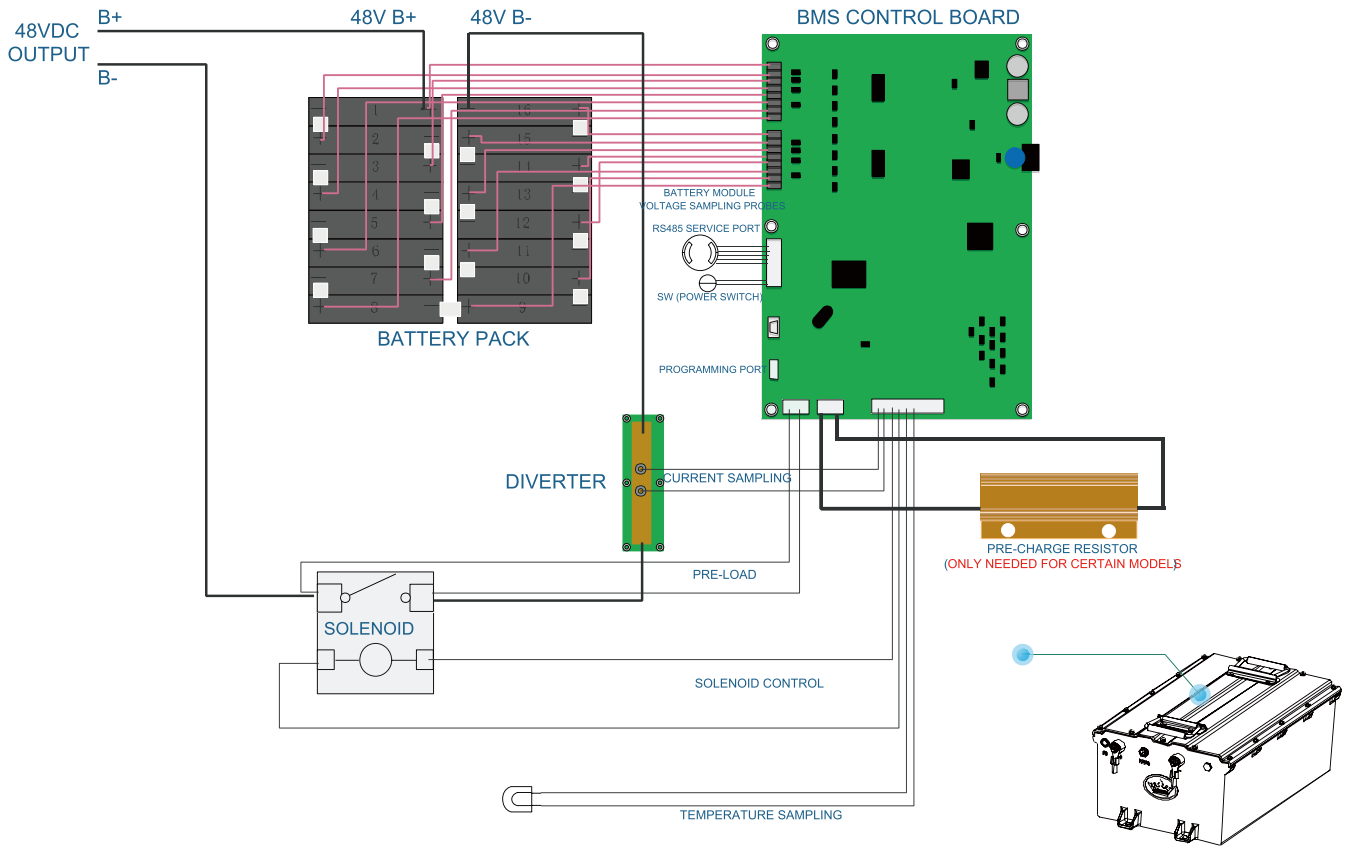
## Product specification

| L series | L48130 | L48180 |
|---|---|---|
| Technical specification | | |
| Nominal voltage | 51.2V | 51.2V |
| Nominal capacity | 130Ah | 180Ah |
| Stored energy | 6.24kwh | 8.64kwh |
| Life cycles | >3500 times | >3500 times |
| Self discharge | max 3.2% per month | max 3.2% per month |
| Mileage (2 seat at 13mph) | 45-55miles/full charging | 55-75miles/full charging |
| Continuous charge current | ≤75A | ≤126A |
| Continuous discharge current | 100A | 100A |
| Maximum discharge current | 3C(30s) | 3C(30s) |
| Quick charging time | 1h | 1h |
| Standard charging time | 4-5h | 4-5h |
| Charge temperature range | 32°F to 110°F (0°C to 45°C) | 32°F to 110°F (0°C to 45°C) |
| Discharge temperature range | -4°F to 140°F (-20°C to 55°C) | -4°F to 140°F (-20°C to 55°C) |
| Storage temperature range | -4°F to 113°F (1month)(-20°C to 45°C)<br>32°F to 95°F (1year)(0°C to 35°C) | -4°F to 113°F (1month)(-20°C to 45°C)<br>32°F to 95°F (1year)(0°C to 35°C) |
| General specification | | |
| Cell combination | 16 in series circuit | 16 in series circuit |
| Cell assembly | 3.2V130Ah | 3.2V180Ah |
| Casing material | Aluminum Alloy | Aluminum Alloy |
| Weight | 105.6lbs(47.9kg) | 158.5lbs(71.9kg) |
| Dimension(L*W*H) | 23.5*12.8*9.4in | 30.8*12.8*9.4in |
| IP rate | IP66 | IP66 |

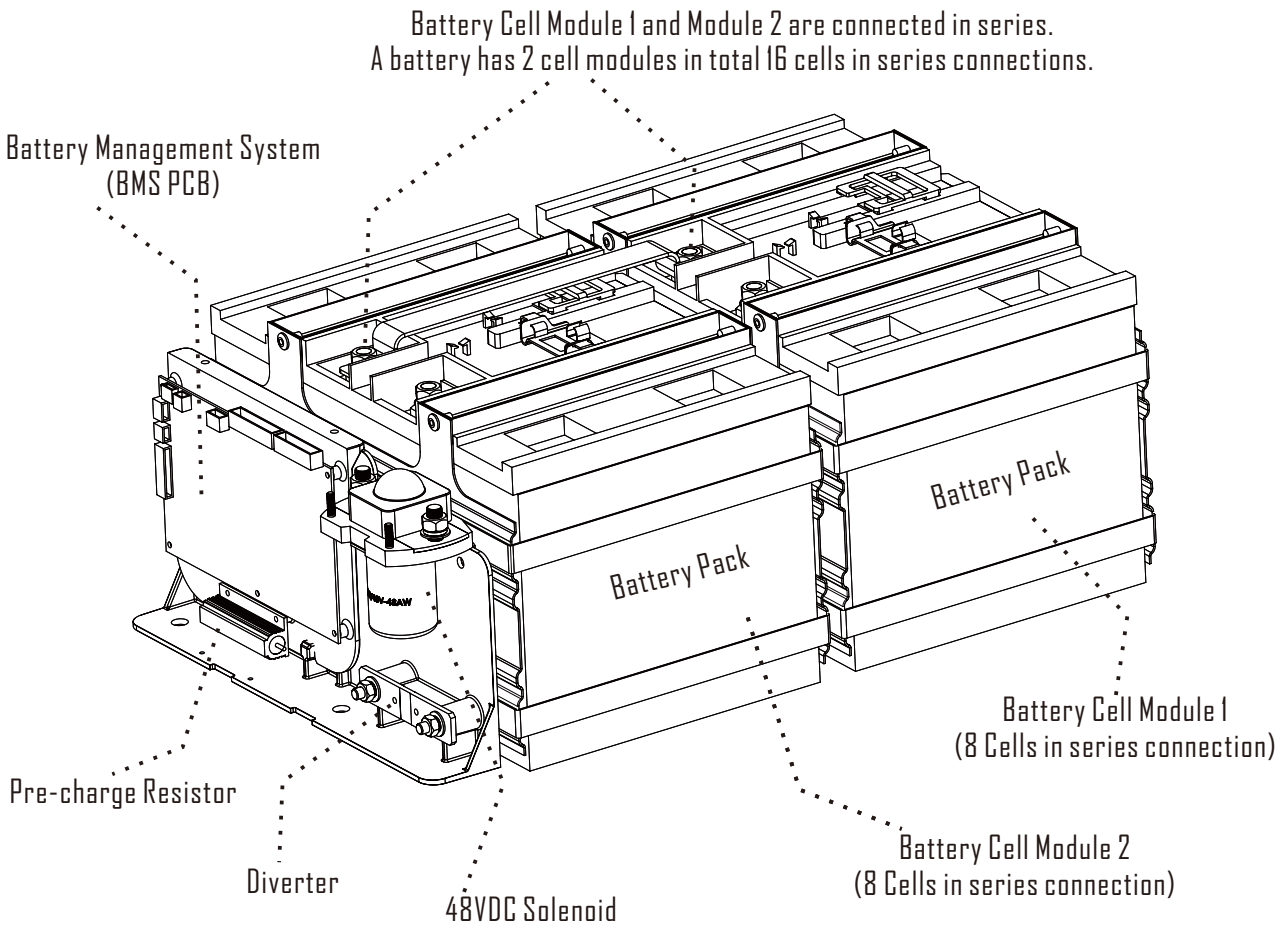
BATTERY STRUCTURE

# 6.Battery Structure

## 6.1 Inside battery



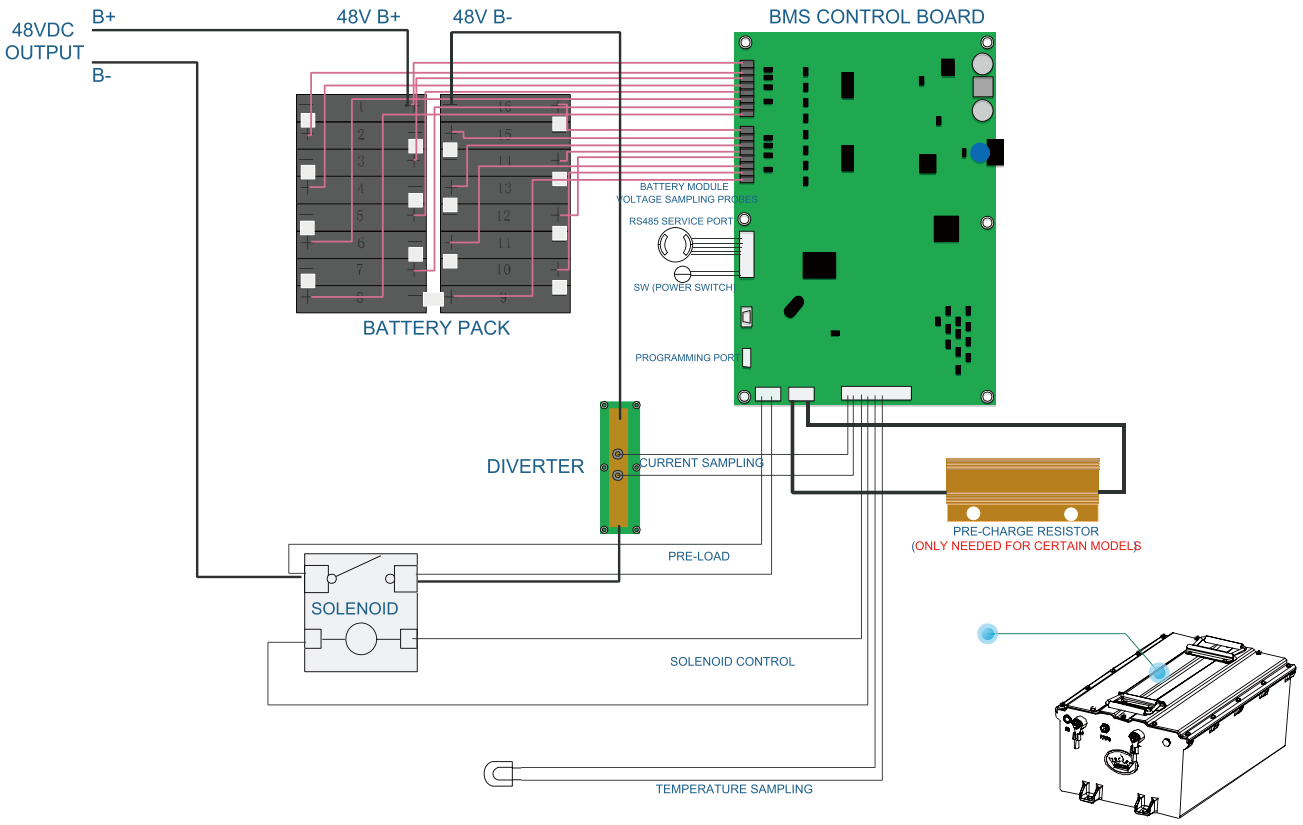

BATTERY INTERNAL CIRCUIT DIAGRAM




BATTERY INTERNAL COMPONENT LAYOUT

BATTERY STRUCTURE

## 6.2Evolution LFP battery pack system design




### .Battery Management System（BMS）Control Board

The battery cells in the Smart Lithium batteries are protected against over-charge, under-charge, charging at too low temperatures as well as charging at too high temperatures.As part of the protection the battery has an integrated Balancing, Temperature and Voltage control system. The Battery Management System, the BMS monitors each individual battery cell; it balances the cell voltages and in case of high or low cell voltage or in case of high or low cell temperature, it will generate an alarm signal. The alarm signal is received by the BMS and the BMS will turn off loads or chargers accordingly.A BMS is essential for a correct operation of the lithium battery. The lithium battery is not allowed to be used without one. In addition to this you will also need to ensure that the BMS correctly controls all loads and charge sources that are connected to the battery.

### .Battery Cells

Each Battery has 16 cells ,each cell is 3.2V (nominal voltage),16 cells are connected in series circuit.

### .S/W switch button

Allow user to manually switch on the battery.

### .Rs485 service port

Signal outlet for BDI display(battery SOC indicator) module.

### .Diverter

Capture & Sample real-time battery pack voltage and current values

### .Solenoid

A solenoid is a set of coiled wire which acts as an electromagnet when current is passed through it. It converts electrical energy directly into linear mechanical motion. Works as switch controls On/Off of circuit .

### .Pre-Charge Resistor

A pre-charge resistor is a device that slowly charges the capacitors inside a electronic circuit board(in this battery case it is for battery BMS board) before it is powered up. Without this resistor, closing the contactor would generate a large amount of inrush current causing the contacts to arc. This arcing can permanently weld the contacts in the "on" position.

### .Temperature Sensor Probes

A temperature sensor is a device that is designed to measure the degree of hotness or coolness in an object. The working of a temperature meter depends upon the voltage across the diode. The temperature change is directly proportional to the diode's resistance. The cooler the temperature, lesser will be the resistance, and vice-versa.The resistance across the diode is measured and converted into readable units of temperature (Fahrenheit, Celsius, Centigrade, etc.) .

Each Battery has 6 temperature sensor probes >

4 sensor probes in between battery cells .

1 sensor probe on solenoid .

1 sensor probe on BMS circuit board .

## 6.3System design

When designing a system with a lithium battery, a basic understanding of how the battery interacts with the BMS and how the BMS interacts with loads and chargers is required.

### .The Battery Cell Alarm Signal

The battery communicates with the BMS Control PCB board via its BMS cable harness.
The battery monitors its cells and it will send an alarm signal to the BMS in case of a:

- Low cell voltage alarm signal
- Low cell voltage pre-alarm signal
- High cell voltage signal
- Low temperature signal
- High temperature signal

⚠The BMS will act by turning loads and/or chargers off as soon it receives an alarm signal from one of the cells in the battery.

### .How BMS controls system On/Off ?

The main purpose of the BMS is to control the chargers and the loads. This is the way how Evolution battery do that:
. By physically connecting or disconnecting a load or a charge source from the battery, using a large contactor (48V solenoid).
The BMS is equipped with a “load disconnect”, a “charge disconnect”alarm contact .The BMS sends a “load disconnect” signal to loads in case of a low cell voltage alarm and it sends a “charge disconnect” signal to chargers in case of a high cell voltage or a cell temperature alarm. The loads or chargers can be controlled by the BMS directly .
>In the event of low cell voltage, the BMS will send a “load disconnect” signal to turn the load(s) off.
>In the event of high cell voltage or low or high cell temperature, BMS will send a “charge disconnect” signal to turn the charger(s) off.

### .Battery monitoring

The battery internals (temperature & cell voltages, as well as alarms and other parameters) can be monitored with the BBMS App. It connects to the battery via Bluetooth.

**.Download and install the APP**

The BBMS App is needed to communicate with the battery. The app can run on an Android, iOS or macOS device. Although there also is a Windows version of the app, it is not possible to use the Windows version of the BBMS App for the Smart Lithium batteries, as Windows Bluetooth is not supported by the BBMS App.

IOS Phones

Android Phones

### .Update the battery BMS firmware

Firmware for BMS PCB board can be updated in case there may be bugs or upgrades the firmware can be renewed with Specified tool(Firware downloader) , Consider this tool as essential service tool for servicing batteries .

# 7.Battery Installation/Commissioning

## 7.1Installation Prerequisites

When installing the system, avoid touching the battery terminal with any metal objects or human body. Evolution EV provides a safe source of electric energy when operated as designed. Potentially hazardous circumstances such as excessive heat or electrolyte leakage may occur under improper operating conditions, damage, misuse and abuse. The safety precautions and the warning messages described in section 1 must be observed. If any of the precautions are not fully understood, or if you have any questions,contact customer service for guidance. The Safety Section may not include all regulations for your region.

Make sure that the battery installation to vehicle meets the following conditions:

>The battery installation position is flat and level

>There are no flammable or explosive materials nearby

>The ambience is shady and cool, keep away from heat and avoid direct sunlight.

>The temperature and humidity stays at a constant level.

>There is minimal dust and dirt in the area.

>There is no corrosive gases present, including ammonia and acid vapor.

**⚠ Warning**

If the ambient temperature exceed the operating range, the battery module stops operating to protect itself. The optimal temperature range for the battery module to operate is 0°C to 45°C (when temperature is lower than 0°C,heating system is requested in order to allow battery to be functional ). Frequent exposure to harsh temperatures may deteriorate the performance and life time of the battery module.

## 7.2 safety gear

Installation and maintenance personnel must operate according to applicable federal, state and local regulations as well as the industry standards regarding the product installation personnel shall wear safety gears, etc. in order to avoid short circuit and personal injury.

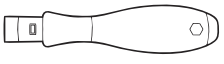
Insulated Gloves

Safety Goggles

Safety Shoes

## 7.3 Tools

These tools are required to install the Evolution EV battery system..

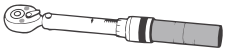


Torque Screwdriver

Phillips-head Screwdriver

Flat-head Screwdriver

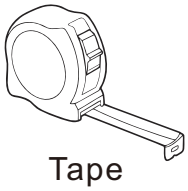
Insulated Wrench



Torque Screwdriver

Drill

Pencil or Marker Pen



Tape Measure

**⚠ WARNING**

>Always turn the key switch to 'OFF' and remove the key before disconnecting a live circuit.

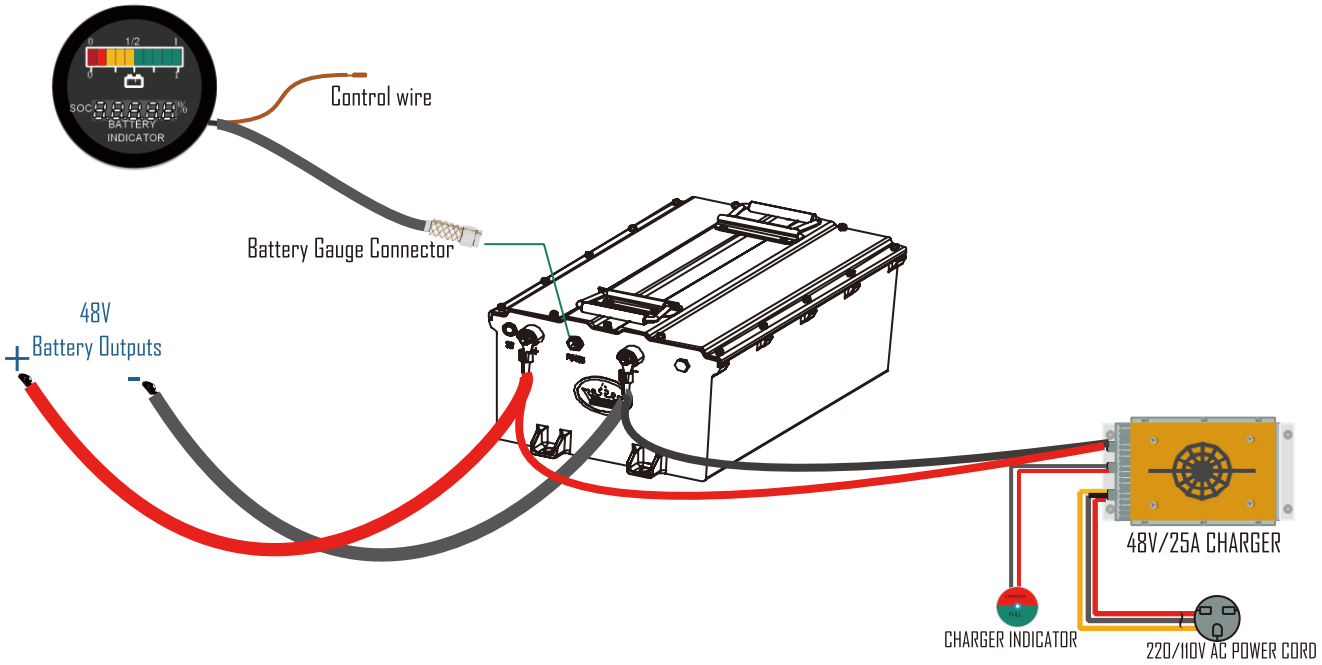
>When connecting battery cables, pay particular attention to the polarity of the battery terminals. Never confuse the positive and negative cables.

>If repairs are to be made that will require welding or cutting, the batteries must be removed.

## 7.4 System Connection


.Batteries are heavy. Use proper lifting techniques when moving them. Always lift the battery with a commercially available battery lifting device. Use care not to tip batteries excessively when removing or installing them;

.Wear Insulated gloves and Wrap wrenches with vinyl tape to prevent the possibility of a dropped wrench 'shorting out' a battery,which could result in an explosion and severe personal injury or death.




| |
|---|
| .Adaptive Installation Brackets & Hardwares |
| .Battery Pack |
| .Charger & Charger Hardwares |
| .Battery Indication Gauge |
| .Peripheral accessories |

## 7.4 Pre-installation inspection

### 7.4.1 Check for Transport Damage

Make sure the battery is intact during transportation. If there are some visible damages, such as cracks, please contact your dealer immediately.

### 7.4.2 Unpacking

Unpacking the battery package by cutting the packing tape and make sure theBattery modules and the relevant items are complete. See package items on the manual inside the battery package, please check the packing list carefully, if there's any item missing, please contact Evolution EV or your distributer directly.

**⚠ CAUTION**

According to regional regulations, several people may be required for moving equipment.

**⚠ WARNING**

Please strictly follow the installation steps. Evolution EV will not answer for any hurting or loss arising by incorrectly assembling and operation.

## 7.5 Installation

THE BATTERY PACK IS SUITABLE FOR ALL TOP BRAND GOLF CARTS. IN ORDER TO PROPERLY INSTALL THE BATTERY , EACH PACKAGES HAS ITS OWN MANUAL

>Follow the manual packed inside battery package for specific steps to install battery on specific brands / models .

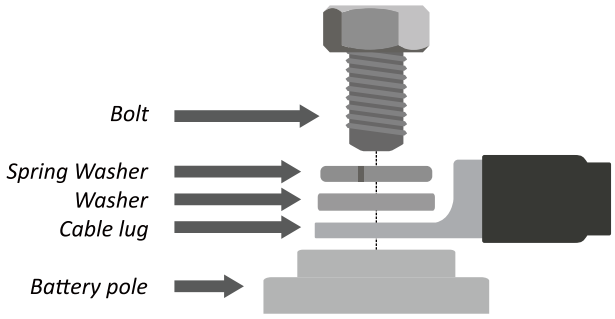
## 7.5.1 Installation /Commissioning Requirement

### .Mounting

The battery needs to be mounted in an upright position. The battery is only suitable for electric vehicle use and needs to be located in a specified location/Compartment.
>Batteries are heavy. When moving the battery into its destined location, use suitable handling equipment for transportation.
>Ensure adequate and secure mounting as the battery can become a projectile if involved in an accident.
>Batteries produce a certain amount of heat when they are charged or discharged. Keep a 20mm space on each side of the battery for ventilation purposes.

### .Connect the battery poles

The positive pole is indicated by a "+" symbol and the negative pole is indicated by a "-" symbol.
>Observe the battery polarity when connecting the battery poles to a vehicle system or to other batteries. Take care not to short circuit the battery poles.
>Connect the cables; place the cable's cable lug on the battery pole, place the washer, place the spring washer and then insert and tighten the bolt
>When tightening the bolt, use the correct torque and use insulated tools that match the batteries spanner size



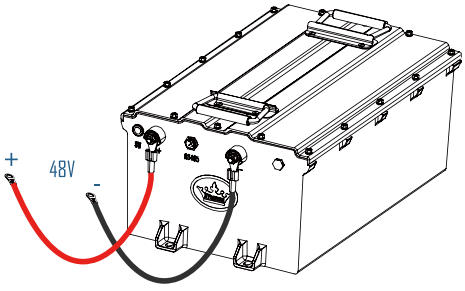

| Battery Model | Nut Size | Torque Moment |
|---|---|---|
| 51.2V 60AH | M6 | 10NM |
| 51.2V 110AH | M8 | 12NM |
| 51.2V 130AH | M8 | 12NM |
| 51.2V 180AH | M8 | 12NM |

### ..Cables used to connect batteries

Use battery cables match the currents that can be expected in the battery system. Batteries can produce very large currents; it is therefore necessary that all electrical connections to a battery match the expected maximum system currents.
>The battery maximum discharge rating is indicated in below table.

| Maximum Current Rating Lithium Battery | |
|---|---|
| Battery Model | Maximum current rating (Peak Current @30s) |
| 51.2V 60AH | 180A |
| 51.2V 110AH | 330A |
| 51.2V 130AH | 400A |
| 51.2V 180AH | 400A |

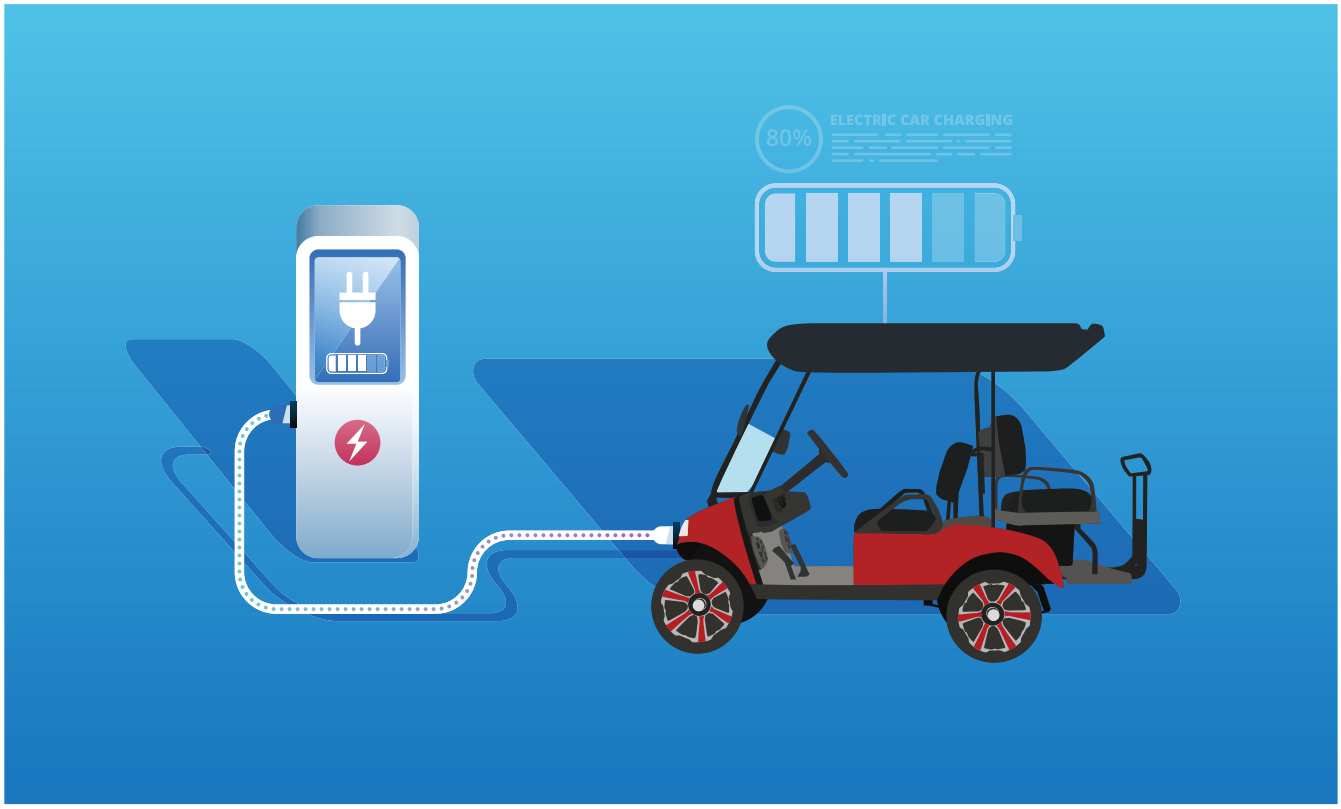
If the battery is located far away for cables to reach ,use optimal cables to avoid voltage dropping/cable melting ;etc .



## .Commissioning

Once all connections have been made, the system wiring needs to be checked, the system needs to be powered up and the BMS functionality needs to be checked.
These are how to do steps:

- Check polarity of all battery cables.
- Check cross sectional area of all battery cables.
- Check if all battery cable lugs have been crimped correctly.
- Check if all battery cable connections are tight (don't exceed maximum torque).
- Tug slightly on each battery cable and see if the connections are tight.
- Connect with BBMS app to each battery.
- Connect the system positive and negative DC cable to the battery (or battery bank).
- Check the main fuse rating.
- Check if all battery charge sources have been set to the correct charge settings.
- Turn on battery chargers and loads to verify the system functionality



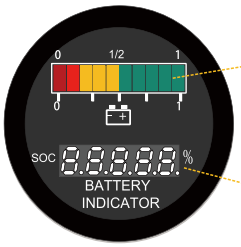
BATTERY OPERATION

## 8.Battery Operation

Once battery is in operation, it is important to take proper care of the battery to maximize its lifetime. These are the basic guidelines:
>Prevent total battery discharge at all times.
>Familiarize yourself with the alarm feature and act when alarm is active to stop battery discharge(battery is disabled in protection mode) .
>If the alarm is active, or if the BMS has disabled the loads, make sure that the batteries are recharged as soon as possible. Minimize the time the batteries spend in a far discharged state as much as possible.
>The batteries need to spend at least 2 hours in absorption charge mode each month to ensure sufficient time in balancing mode.
>When leaving the system unattended for certain time, make sure to either keep the batteries charged during that time, or make sure the batteries are almost full and then disconnect the DC system from the battery.

### .Monitoring

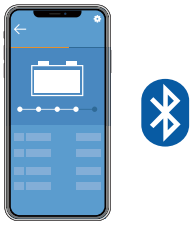
>For Basic battery SOC (state of charge) information ,check the battery level display module.

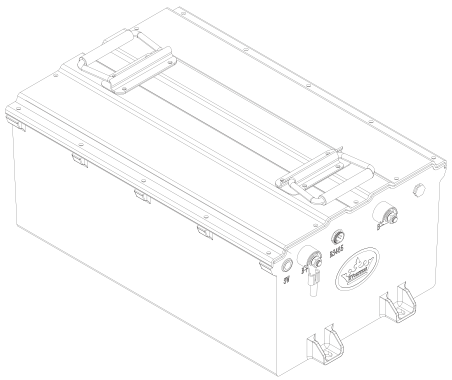



SOC indication in progress bar
1 means 100%
0 means 0%

SOC indication in percentage

>BBMS app can be used to monitor the battery via Bluetooth.
BBMS app will show the voltage of each cell, the battery temperature and if there are active voltage and/or temperature alarms. Alarm messages can only be seen or received when BBMS app is actively connected to the battery and the phone is actively showing the lithium battery screen.

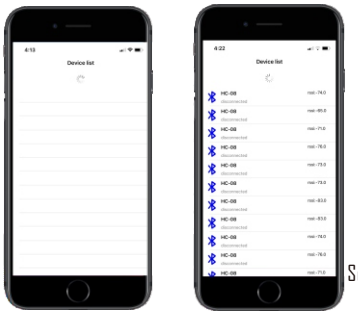




**BBMS App Connection Steps**
-Step 1. Install BBMS App on your cell phone .

BBMS App

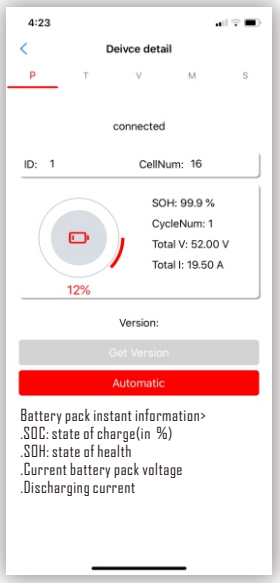
-Step 2. Enable Blue tooth allow the BBMS app to use blue tooth of your cell phone .Open the app to search the battery devices .



Refresh the available devices

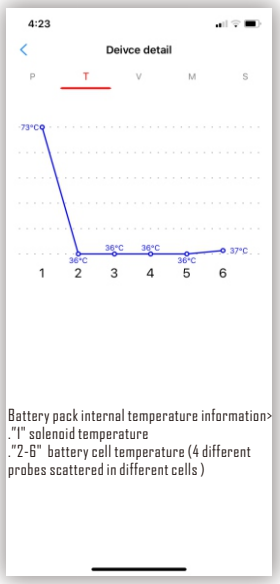
Select a device to connect

-Step 3.Check the battery status.



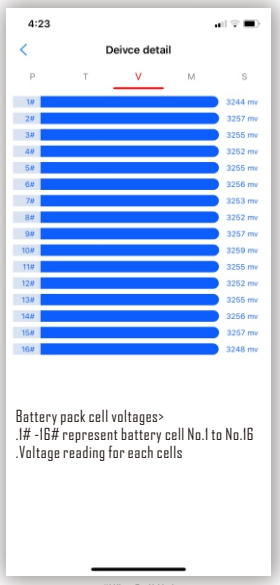

Battery pack instant information>
.SOC: state of charge(in %)
.SOH: state of health
.Current battery pack voltage
.Discharging current

Click "Automatic"to acquire the information
"P" = Pack info



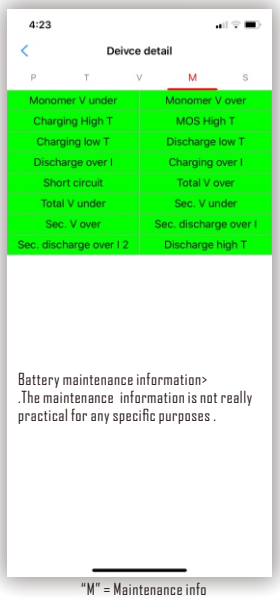

Battery pack internal temperature information>
."1" solenoid temperature
."2-6" battery cell temperature (4 different probes scattered in different cells )

"T" = Temperature



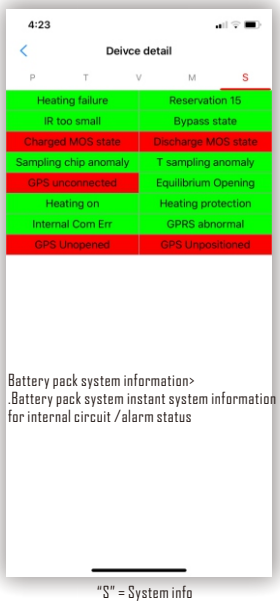

Battery pack cell voltages>
.1# -16# represent battery cell No.1 to No.16
.Voltage reading for each cells

"V" = Cell Volt




Battery maintenance information>
.The maintenance information is not really practical for any specific purposes .

"M" = Maintenance info




Battery pack system information>
.Battery pack system instant system information for internal circuit /alarm status

"S" = System info

## ⚠.Use the battery status info to detect Warnings and alarms.

These are the possible warnings and alarms that can be detected by checking status info of the battery.

**.Cell under voltage warning**

The voltage of one or more cells is becoming too low and discharging has been disabled. Detect the issue by checking the cell voltage information.

**.Under voltage alarm**

This alarm is generated when the battery has been deeply discharged and discharging has been disabled. To remedy this alarm ,recharge the battery as soon as possible. Detect the problem by checking the battery pack voltage reading from the app .

**.Over voltage alarm**

The voltage of the battery has become too high. Immediately disable all chargers and contact the system installer to check that all chargers are properly controlled by the "charge disconnect" contact on the BMS . When properly controlled, a high voltage situation is not possible, as the BMS disconnects all chargers well before raising the high voltage alarm. Detect the issue by checking the pack voltage information.

**.Under temperature alarm**

The battery has reached its low temperature threshold and charging/discharging is disabled. Detect the issue by checking the temperature information.

**.Over temperature alarm**

The battery has reached its high temperature threshold and charging/Discharging is disabled. Detect the issue by checking the temperature information.

**.Hardware failure alarm**

This alarm is generated when hardware has failed in the Battery. Contact your dealer or distributor to resolve this situation.

**.Other alert and errors**

In case of any of these alerts or errors, contact your dealer or distributor to resolve this situation.

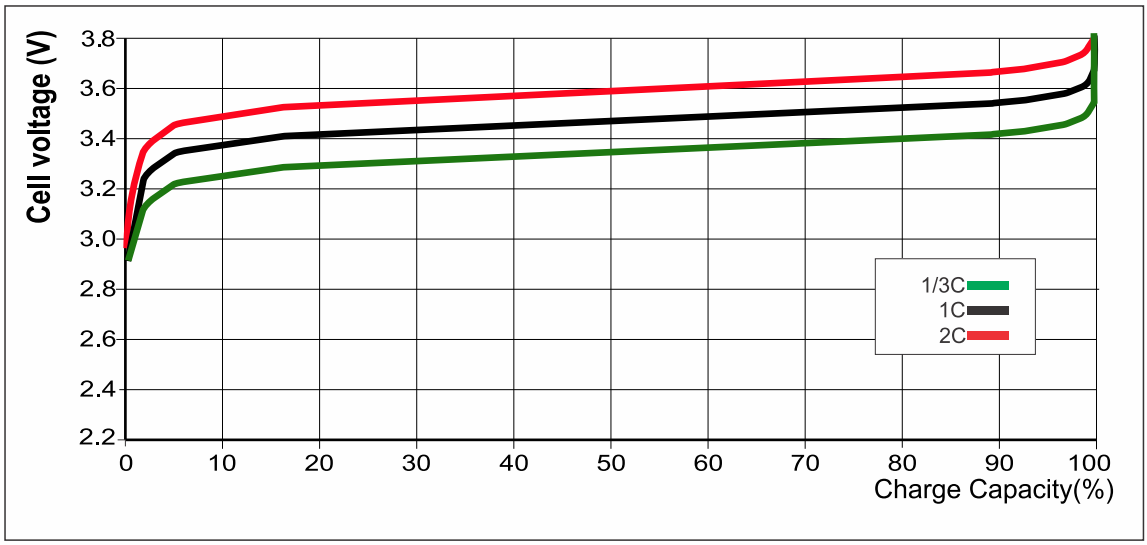
# 9.Battery Charging and Discharging

**This chapter describes the charging, discharging and cell balancing process in more detail for those who are interested in the technical background.**

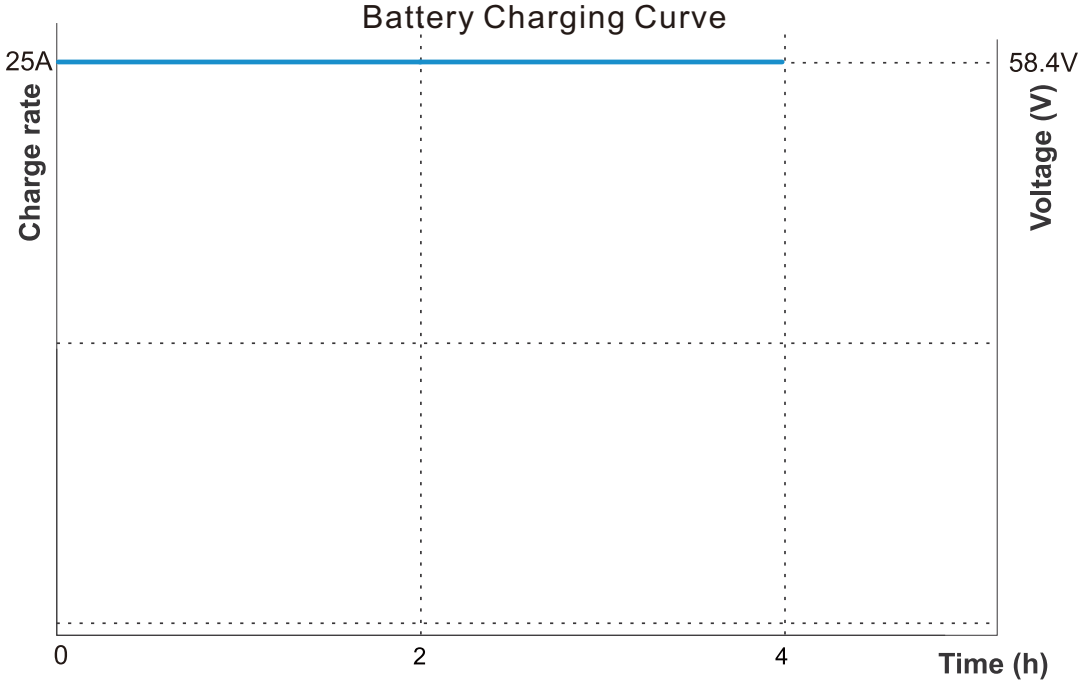
## 9.1 Charging

Lithium batteries are easier to charge than lead-acid batteries. The charge voltage may vary anywhere from 56V to 58.4 V for a 48 V lithium battery , as long as no cell is subjected to more than 3.62 V. Lithium batteries will become permanent damaged if they are over-charged.
Should a cell reach 3.62 V, impossible on a properly installed system, all charge into that cell will be dissipated as heat.

We use a charge current of 25A . This means that if the battery is completely empty, it will take 2 - 8hours(depends on battery model) to charge the battery . The maximum charge current is 1C, for a 60 Ah battery this is 60A. This will charge the battery in an hour. But be aware that the batteries will produce more heat when high charge currents are used. More ventilation space is needed around the batteries and depending on the installation, hot air extraction or forced air cooling might be needed.




Battery Charging Curve




Battery Charging Time Curve (varies from 2-8 hours for different models)

### .Lithium battery charge graph

The BMS will turn off all charge sources as soon as a battery cell voltage reaches 3.62V .
⚠ If the battery temperature drops below 0°C or increases above 45°C. This means that all charge sources that are connected to the lithium battery will be controlled /cut off by the BMS .

## 9.2 Cell Balancing

The lithium battery consists of 16 lithium cells that are connected in series for the 51.2V battery (48V battery system ) .

Though carefully selected during the production process, the cells in the battery are not 100% identical. Therefore, when cycled,some cells will be charged or discharged earlier than the other cells. The differences will increase over time if the cells are not regularly balanced.

The same happens in a lead-acid battery, but that self-corrects without the need for electronics: a small current will continue to flow even after one or more cells are fully charged. This current helps to fully charge the other cells that are lagging behind, thus equalizing the charge state of all cells. The current through a lithium cell however, when fully charged, is almost zero, and lagging cells will not be charged further.

Cells will not get damaged if they have different balance levels, but rather the imbalance will manifest itself in a (temporary) reduced battery capacity.

To keep all cells in balance, the Evolution lithium batteries have built-in active cell balancing. Each cell is equipped with monitoring and cell balancing electronics. The lithium battery measures the voltage of each cell and, when required, moves energy from the cell(s) with the highest voltage to the cells with a lower voltage. It will keep doing this until the voltage difference between the cells is below 50mV . This process is called active balancing.

At what voltage the balancing starts depends on the imbalance. In case of significant cell imbalance, the cell balancing process starts as soon as the first cell reaches 3.3V during charge. The cell balancing continues while the battery is being charged further. And, due to the flat voltage curve of lithium chemistry, cell voltages need to be 3.50V (fully charged voltage is 3.62V)or higher to correct smaller differences in balance.

Above explanation is the reason why a 2-hour fixed absorption period is recommended for lithium batteries: that is to allow the electronics to equalise all the cells. During absorption, the voltage is 51.2V, equalling 3.62 V per cell in case of a fully balanced battery.

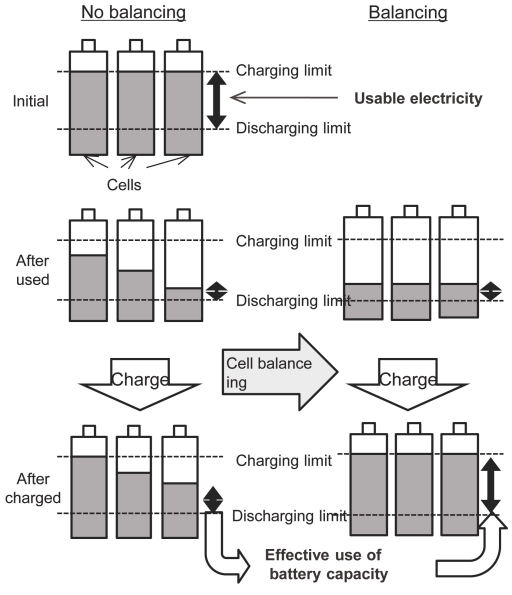
It is important to regularly fully charge the battery (once a month).

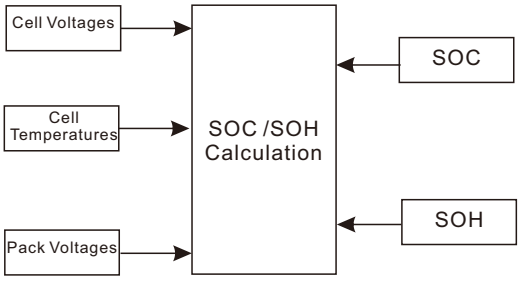
If the system is intensively used and has charge/discharge cycles each day or a few times per week, or the system is deeply discharged, more absorption (cell balancing) time per month is needed.

Please note that a higher charge voltage will not speed up the cell balancing process. Battery cells are charged by current and not by voltage. Feeding current into a cell will cause the voltage to increase over time, but this is a fixed process and applying more voltage will not speed this process up. In addition to this, the speed of balancing is determined by the maximum rated power of the active and passive balancing circuits and not by charge voltage.

There are some applications in where the battery cells will become quicker unbalanced than usual. In these cases, a weekly full charge needs to be performed:

- Systems with series connected batteries
- Systems with high discharge currents
- Systems with short charge periods or low charge voltages



## 9.3 Discharging

Nearly the whole available battery capacity can be used, with exception of the approximate last 3% of remaining capacity. Lithium batteries will become permanently damaged if they are discharged too deeply.

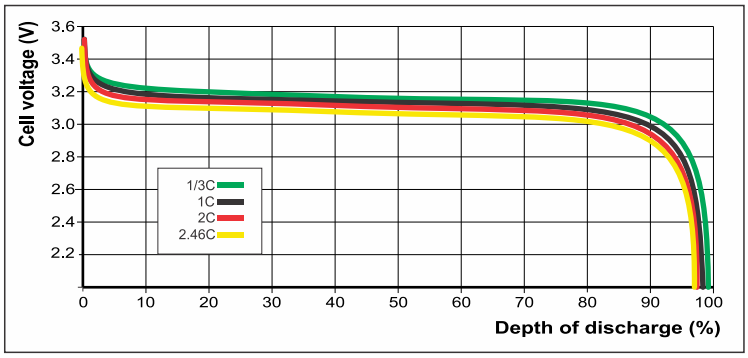
Lithium batteries can be discharged with high currents. The maximum discharge of the lithium battery is 3C(only for 30 s ). For a 60Ah battery this means a 180A discharge current. However, we recommend not to discharge above a 1C rate. A 1C rate means that the battery is discharged in 1 hour. For a 60Ah battery this is a discharge current of 60A.

When using a higher discharge rate, the battery will produce more heat than when a low discharge rate is used. More ventilation space is needed around the batteries and depending on the installation, hot air extraction or forced air cooling might be needed.

Also, some cells might reach the low voltage threshold quicker than the other cells. This can be because of a combination of heat and ageing.

To be able to tell if a battery is too deeply discharged you will need to look at the individual cell voltages. As the battery is being discharged, the cell voltage drops. This is indicated in below discharge graph. When the battery is almost empty, the voltage will drop faster. This is the sign that the battery is almost empty. This happens at around a cell voltage of 2.60V to 3.62V. Further discharge needs to be prevented, otherwise the battery will get damaged. So as soon as one of the cells has reached this voltage the BMS will disable all DC loads.

The under voltage shutdown threshold is configurable, if it is set to a higher voltage the reserve capacity is greater than if it is set at a lower voltage. It is set by default at 3.62V and the range is 2.6V to 3.62V.




Discharge graph showing cell voltage at various depths of discharge for different discharge rates

The BMS will turn off all loads as soon as a battery cell voltage drops below the low voltage threshold.

Although a BMS is used, there are still a few possible scenarios where the battery can be damaged due to over discharge. This can occur if small loads, such as: alarm systems, relays, standby current of certain loads, back current drain of battery chargers or charge regulators, slowly discharge the battery when the system is not in use.

In case of any doubt about possible residual current draw, isolate the battery when the system is not in use. Do this by disconnecting the battery negative cable.

A residual discharge current is especially dangerous if the system has been discharged completely and a low cell voltage shutdown has occurred. At 2.8V cell voltage there is approximately 3% remaining capacity and at 2.6V there is about 1% remaining capacity.

After shutdown due to low cell voltage, a capacity reserve of 1% corresponds with 1Ah left in a 110Ah capacity battery. The battery will be damaged if the remaining capacity reserve is drawn from the battery. A residual current of 10mA for example may damage a 110Ah battery if the system is left in discharged state during more than 4 days (100 hours).

If all cells are 3.4V, this means that the battery pack terminal voltage is 54.4V and if all cells are 2.6V the battery terminal voltage is 41.6V . Be aware that the BMS will turn the loads off as soon as **one cell drops below the low voltage threshold**.

This might not necessarily correspond with the battery terminal voltage. So, if investigating low voltage scenarios, always use BBMS app to look at the actual cell voltages and do not just rely on the battery terminal voltage.

BATTERY TROUBLESHOOTING

# 10. Battery Troubleshooting

## 10.1 ESSENTIAL SERVICE TOOLS

.Insulated Gloves

.Insulated Wrench

.Socket&Ratchet set

.Clamp Ammeter

.Multimeter

.Lithium Battery Firmware Downloader

.Smart Phone With BBMS app

.Hand-handle Crane

## 10.2 BBMS App Connection Issues

### **10.2.1** BBMS APP Connection issues

**Cannot connect with the BBMS App .**

It is highly unlikely that the Bluetooth interface in the battery is faulty. These are some pointers to try before seeking support:

• Is the battery a Smart Lithium battery? The older non-Smart Lithium batteries do not support Bluetooth.

• Is the battery voltage still high enough? The batteries Bluetooth module is turned off as a precaution as soon as the battery terminal voltage drops below threshold. The Bluetooth module will power up again once the battery is charged. When recharging the battery after a low voltage event, use the low voltage charge procedure as described in paragraph: “Battery very low terminal voltage”.

• Is there already another phone or tablet connected to the battery? Only one phone or tablet can be connected to the battery at any given time. Make sure no other devices are connected and try again.

• Are you close enough to the battery? In open space the maximum distance is about 10 meters.

• Are you using the Windows version of the BBMS App? The Windows version cannot use Bluetooth. Use an Android,iOS instead.

• Does BBMS have an issue? Try to connect to another Evolution product, does this work? If that also does not work, then there probably is an issue with the phone or tablet.

### Interrupted firmware update

• This is recoverable, just try to update the firmware again.

## 10.3 Battery Issues

### **10.3.1** Battery Cells Out Of Balance

Imbalance between the cells reduces the usable capacity of a battery. It does not cause permanent battery life reduction.

There are a number of reasons that can cause cell imbalance:

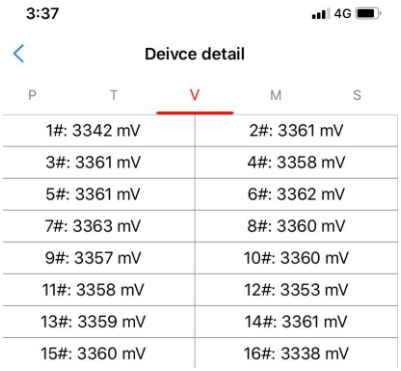
• The battery has not spent enough time in the absorption charge stage. A certain amount of imbalance will always arise, due to differences in self-discharge between cells as well as difference in internal resistance.

• The battery is old and near its maximum cycle life.

• The battery has been too far discharged and one or more cells in the battery have been damaged. This is not covered by warranty and also be aware that this might not be recoverable.

**How to recognise cell imbalance**

The indication of imbalance is that the BMS frequently disables the charger. On a well-balanced battery the charger would not be disabled – not even once the batteries are fully charged. More details can be seen with the BBMS App. Be aware that checking the cell balance can be done only near the end of a charge cycle. It’s best to wait for the battery voltage to reach 58.0V, and then check the individual cell voltages. They should all be between 3.50 and 3.60V. And over time they will all become equal at 3.55V. By that time the battery will be completely charged and balanced.




The screenshot Above shows a balanced battery（Not Fully charged）.

**How to re-balance a battery**

〉To re-balance, fully charge the battery once more. The balancing occurs at the end of the charge cycle. This is when the charger is in the “fixed“ 2-hour length absorption stage.

〉Once all cells show with voltage difference between cells less than 50mV, the battery is properly balanced again.

>Restart the charger in case the charger already finishes its absorption stage before the cell balance is restored.

## 10.3.2 Less Capacity than expected

**If the battery capacity is less than its rated capacity these are the possible reasons for that:**

• The battery has a cell imbalance, causing premature low voltage alarms, which in turn cause the BMS to turn loads off. Pleaserefer to paragraph “Charge battery before use”.

• The battery is old and is near its maximum cycle life. Check how long the system has been in operation, check how many cycles the battery has gone through and to what average depth of discharge the battery has been discharged? A way to find this information is to look at the history of a battery monitor (if available).

• The battery bas been too far discharged and one or more cells in the battery are permanently damaged. These bad cells will have a low cell voltage faster than the other cells and this will cause the BMS to turn loads off prematurely. Has the battery perhaps been through a very deep discharge event?

## 10.3.3 Battery very low terminal voltage

〉If the battery has been discharged too far, the voltage will fall way below 48V . If the battery has a voltage of less than 40V or if one of the battery cells has a cell voltage below 2.5V, the battery will have permanent damage. This will invalidate the warranty. The lower the battery or cell voltage is, the bigger the damage to the battery will be.

If the voltage has dropped below Threshold, the battery will not communicate via Bluetooth anymore. The Bluetooth module is turned off when the battery terminal voltage drops below threshold or if a cell voltage drops below threshold voltage.

You can try to recover the battery by using the below low voltage recharge procedure. Be aware that this is not a guaranteed process, recovery might be unsuccessful and there is a realistic chance that the battery has permanent cell damage resulting in a moderate to severe capacity loss after the battery has been recovered.

• Make note of the initial battery terminal voltage and battery cell voltages.
• Start the charger.
• The BMS might turn the charger off, then on again for a short time and then off again. This can occur many times over and is normal behaviour in case there is a significant cell imbalance.
• Make note of the voltages at regular intervals.
• The cell voltages should increase during the first part of the charge process. If the voltage of any of the cells does not increase in the first half hour, consider the battery as unrecoverable and abort the charge procedure.
• Check the battery temperature at regular intervals. If you see a sharp increase of temperature, consider the battery as unrecoverable and abort the charge procedure.
• Once the battery has reached 48V the charger will increase voltage to and increase the charge current to 25A.
• The cell voltages will increase more slowly, this is normal during the middle part of the charge process.
• Leave the charger connected for hours.
• Check the cell voltages, they should all be within 50mV between each other. If one or more cells has a much bigger voltage difference,consider the battery as damaged.
• Let the battery rest for a few hours.
• Check the voltage of the battery. It should comfortably sit above 48V or higher. And the cell voltages should still be within 50mV different between each other.
• Let the battery rest for 24 hours. Measure the voltages again. If the battery voltage is below 48 V or if there is a noticeable cell imbalance, the battery is unrecoverable damaged.

>If the battery has been damaged internally or has active alarms , the system is being disabled for protection ,the solenoid has been dis-engaged to cut off the circuitry . Need to eliminate system alarms before system resume back to normal .

**Refer to Session 6 for the circuitry information !**

### 10.3.4 Battery is close to end of cycle life or battery has been mis-used .

>If the battery has been discharged too far, the voltage will fall way below 48V . If the battery has a voltage of less than 40V or if one of the battery cells has a cell voltage below 2.5V, the battery will have permanent damage. This will invalidate the warranty. The lower the battery or cell voltage is, the bigger the damage to the battery will be.

If the voltage has dropped below Threshold, the battery will not communicate via Bluetooth anymore. The Bluetooth module is turned off when the battery terminal voltage drops below threshold or if a .cell voltage drops below threshold voltage.

**To check if the battery is close to its cycle life:**
• Find out how many charge-discharge cycles the battery has been subjected to? Battery lifetime is correlated to the number of cycles.
• How deep has the battery been discharged on average? The battery will last for less cycles if deeply discharged, compared to more cycles if discharged less deep.
• For more info on the life cycle see **session 5** for the technical data.

**To check if the battery has been misused:**
• Is the BMS connected and functional? Use the BBMS app to validate the connections .
• Is there mechanical damage to the battery, its terminals or the cables. Mechanical damage voids the warranty.
• Has the battery been mounted upright? The battery can only be used in an upright position.
• Is the battery soaked in water ?
• Is there an indication the battery has been charged with too high voltage? check the maximum battery voltage and the high voltage alarms .

## 10.4 BMS Issues

### **10.4.1** The BMS frequently disables the battery charger

A well-balanced battery does not disable the charger, even when the batteries are fully charged. But when the BMS frequently disables the charger, this is an indication of cell imbalance.In case of moderate or large cell imbalance it is an expected behaviour that BMS frequently disables the battery charger. This is the mechanism behind this behaviour:
As soon as one cell reaches 3.62V the BMS disables the charger. Whilst the charger is disabled the cell balancing process still continues, moving energy from the highest cell into adjacent cells. The highest cell voltage will drop, and once it has fallen below 3.6V the charger will be enabled again. This cycling typically takes between one and three minutes. The voltage of the highest cell will rise again quickly (this can be in a matter of seconds) after which, the charger will be disabled again, and so forth. This does not indicate a problem with the battery or the cells. It will continue with this behaviour until all cells are fully charged and balanced. This process might take several hours. It depends on the level of imbalance. In case of serious imbalance this process can take up to 12 hours. Balancing will continue throughout this process and balancing even takes place when the charger is disabled. The continued enabling and disabling of the charger can appear strange but rest assured that there is no problem. The BMS is merely protecting the cells from over voltage.

10.4.2. The BMS is prematurely turning chargers off
This could be because of a cell imbalance. One cell in the battery has a cell voltage above 3.62V. Check the cell voltages of all the batteries that are connected to the BMS.

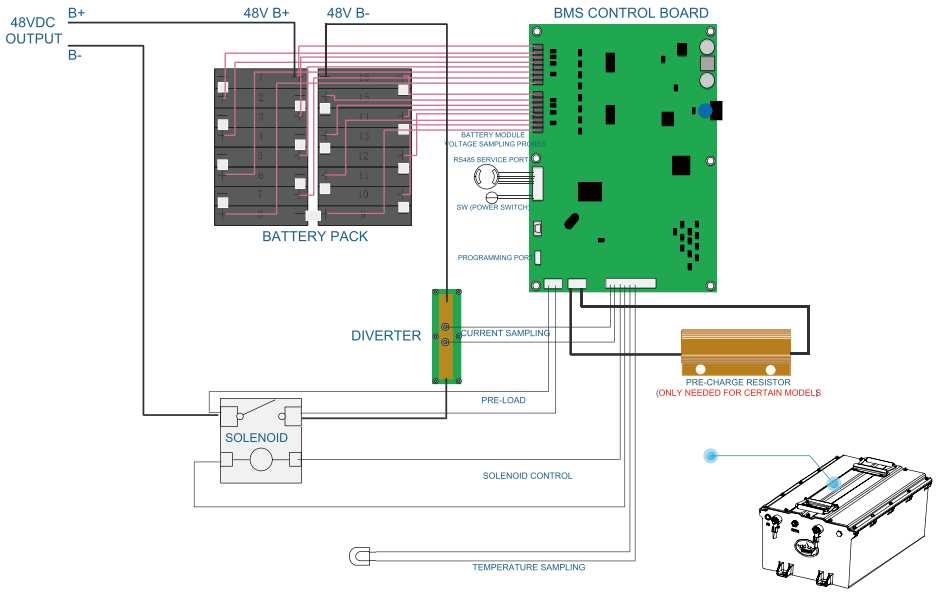
10.4.3. The BMS is prematurely turning loads off
This could be because of a cell imbalance. One cell has a cell voltage below 2.6V. Check the cell voltages with BBMS App the batteries. Once the loads have been turned off due to low cell voltage, the cell voltage of all cells need to be 3.2V or higher before the BMS will turn the loads back on.

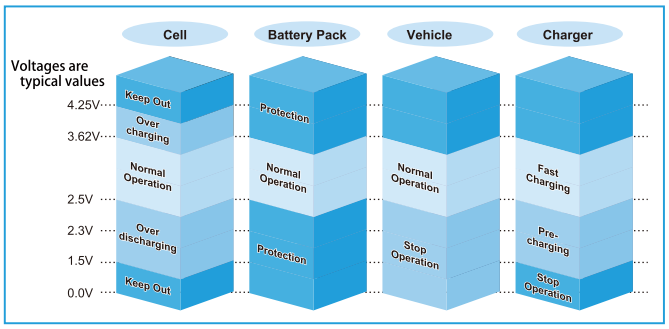
10.4.4. BMS is turning loads/chargers off while all cell voltages are within range
A possible cause is a loose or damaged BMS cable or connector(The wiring harness loom between BMS board and cells). Check all BMS cables and their connections.
First rule out that the cell voltages and temperature of all connected batteries are in range(use the BBMS app to check the data ). If they are all in range, then also consider that once there has been a cell under voltage alarm, the cell voltage of all cells need to be increased to 3.2V before the battery clears the under voltage alarm.

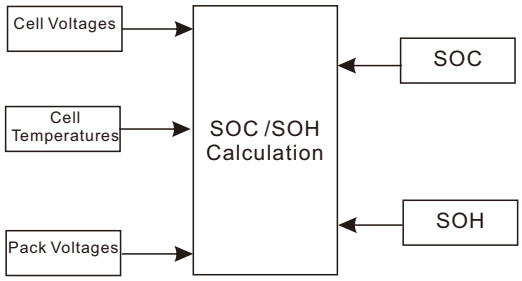
BATTERY TROUBLESHOOTING

## 10.5 Battery Pack Troubleshooting

### 10.5.1 System explaination.




### .Battery System

.The battery cells >Power Source
.BMS board > Protect/Control Power Source, the whole battery is essentially controlled by this BMS.
.Diverter> For constant Voltage/Current Sampling
.Solenoid >Work as a switch to engage or cut off the circuit ,with the control signals from BMS board .
.S/W Switch >To manually turn on the battery .

### .What is battery system protecting/prevent from ?

.Prevent battery cell from under voltage discharging
.Prevent battery pack from under voltage discharging
.Prevent battery pack from over voltage charging
.Prevent battery from under temperature charging/discharging
.Prevent battery from over temperature charging/discharging
.Prevent battery from continuous working while battery suffering from setting data corruption or hardware failure .
.other alert and errors

### .What will trigger the protection / failure mode ?

.Battery cell voltage reach “under voltage discharging” threshold
.Battery pack voltage reach “under voltage discharging” threshold
.Battery pack voltage reach “over voltage charging” threshold
.Battery pack voltage reach “under temperature charging/discharging” threshold
.Battery pack voltage reach “over temperature charging/discharging” threshold
.Battery pack has “setting data corruption” or “hardware failure”
.other alert and errors

### .What are Measurements battery will take in case of alarm/Failure

.Battery disables DC loads
.Battery frequently disable DC loads
.Battery disables charger (battery can not be charged)

### .Methodology for troubleshooting

1.When battery has issues always use BBMS app on your mobile devices first to validate the voltage/current values ,detect any abnormal cells if presented .
2.Check the physical connections make sure all the wiring harness /connectors are tight . no loose wiring pins popped out from connectors .
3.Check battery internal compartment for possible water/ foreign object contamination .

BATTERY TROUBLESHOOTING

## Troubleshooting List

| Possible Issues | Possible Causes | Possible Solutions |
|---|---|---|
| 1.Battery stops the discharge prematurely .<br>(milege is too short) | .Check the actual cell voltage data using monitoring software and see if there is a cell voltage reading significantly higher/ lower than other battery cells. If so, *cell is with voltage i*mbalance issue. | .Change the wiring harness between BMS board and cells<br>recharge the battery for few rounds to blance the battery cells |
| 2.Battery gauge stays on all th time ,even when you turn off the Key switch | .Check the internal compartment of battery pack for signs of water contamination . | .Change the diverter<br>.Change the BMS board if needed after changing diverter<br>.Change the wiring harness if needed after changing the diverter |
| 3.Battery pack voltage is very low (0-15V | .Check the cell voltages.<br>.Check the Solenoid.<br>The terminal voltage is too low probably because the battery was kept in storage with any charge or there are active alarms / hardware failure the BMS disabled the solenoid to break off circuit | .Change the wiring harness<br>.Change BMS board<br>.Change the diverter<br>.Change the solenoid |
| 4.Battery stops the charge prematurely .<br>(battery can not be charged fully) | .Check the actual cell voltage data using monitoring software and see if there is a cell voltage reading significantly higher/ lower than other battery cells. If so, cell is with voltage imbalance issue.<br>.Check the other active alrams. | .Change the wiring harness between BMS board and cells<br>recharge the battery for few rounds to blance the battery cells<br>.Change the BMS and diverter if needed |
| 5.Battery works intermittently . | .Check the actual cell voltage data using monitoring software and see if there is a cell voltage reading significantly higher/ lower than other battery cells. If so, cell is with voltage imbalance issue.<br>.Check the other active alrams.<br>.Check the connections and wirings. | .Change the wiring harness between BMS board and cells<br>recharge the battery for few rounds to blance the battery cells<br>.Change the BMS and diverter if needed |
| 6.Battery charge drops too fast . | .Check the actual cell voltage data using monitoring software and see if there is a cell voltage reading significantly higher/ lower than other battery cells. If so, cell is with voltage imbalance issue. | .Recharge the battery for few times<br>.Change the wiring harness between BMS board and cells<br>.Change the BMS/Diverter if needed |
| 7.Other issues /alarms /malfunctions | .Always use BBMS app to check the battery status of current , voltage.,etc first.<br>.Always check the tightness of connections.<br>.Always check the internal compartment for detecting possible water,foreign object contamination. | .Recharge the battery pack<br>.Change the wiring harness<br>.Change BMS board<br>.Change the diverter<br>.Change the solenoid |

BATTERY STORAGE

# 11.Battery Storage

## 11.1 Battery Storage(shelf storage , not installed in vehicles)

### Self Discharge

Self-discharge (which occurs in all batteries) determines the "shelf life" of a battery. The figure blow shows typical self-discharge rates for the three chemistries, exact values will vary with manufacturer( **For Evolution battery the self discharge rate is lower than 3.2% per month**).

In general, **Li-Ion is the best of the lot**, while Ni-Cd and Ni-MH are fairly comparable to each other. Ni-Cd is typically a little better than Ni-MH, but this may even out as Ni-MH manufacturing technology matures.

It is important to note that self-discharge is highly **dependent on temperature**, increasing as the battery temperature is increased. Another unpleasant characteristic is that the discharge rate is extremely non-linear. A battery which loses 30% in a month may lose 15 to 20% in the first few days .

| CELL TYPE | NI-MH | NI-CD | LI-ION |
|---|---|---|---|
| SELF-DISCHARGE @ 20° C (%/MONTH) | 20-30 | 15-20 | 5-10 |

**>Initial state of charge calculation before you put battery in storage .**
The right level of charge must be defined by taking into account:
- The storage period
- The maximum consumption of electronic devices
- The self-discharge of the cells (the higher the state of charge, the higher the rate of the self-discharge).

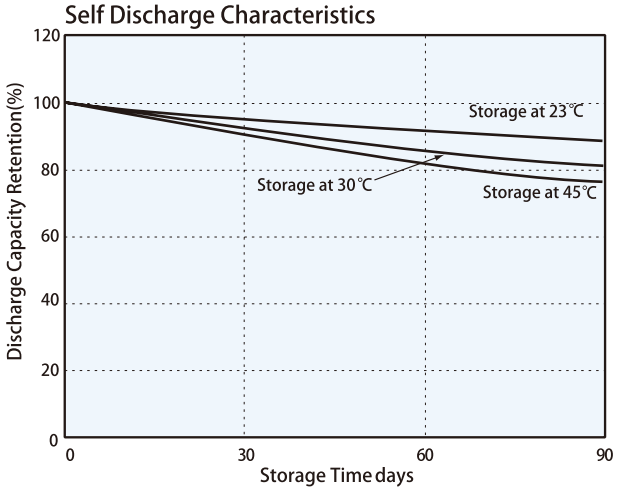
Depending on the storage duration, the Initial state of charge of batteries before storage must be at least between 15% and 50% of initial capacity, Typical cell self-discharge during the first year at 20°C is less than 5% per month , for a state of charge between 15 and 50%. For others condition, please consult Evolution.

**>Minimum state of charge under storage.**
A minimum state of charge of 5% is required at the end of the storage period to avoid any further 'Over-discharge state'.
Note: Overdischarge ("cell under 2.5V") may seriously and definitively affect the performances.

**>Warnings .**
If after storage, the battery voltage is low or even at 0V, the battery protection circuit has probably gone into 'sleep mode'. In such a case, the battery must be charged up as soon as possible in order to avoid the voltage of one or more cells to fall below a level where the cell may be damaged. Therefore, try to wake up the battery with an appropriate charger.
If the battery doesn't take the charge, means the voltage of one or more cells has dropped below a level where it is forbidden to recharge and where the electronics protects the battery.

**>Temperature**
Recommended conditions for storage are: from 0°C to +35°C(one year storage) or -20 °C to +45°C(if only store for one month), in a dry and clean surface, and preferably in its original packaging.

Short excursions from -40°C up to +50°C are possible.
Excursion between +50°C and 60°C may result in **higher self-discharge**(as can be seen from the figure below ,the higher the temperature the higher the self-discharge), lower performances and swelling of inner cells.



BATTERY STORAGE

## 11.2 **Proper Way To Store a battery together with vehicle (battery installed in vehicle)** .

### >TWO WEEKS PRIOR TO THE STORAGE

- For Lithium Battery)Make sure the vehicle battery is plugged in for full charging for few rounds prior to storage period.

### JOBS TO BE DONE PRIOR TO THE STORAGE

>Put golf cart under shelter, keep the golf cart in dry and ventilated space .Optimal ambiet temperature 14°F to 95°F (-10°C to 35°C) . Maximumstorage temperature should not be higher than 122 °F (50°C).

>Turn the key switch to the OFF position, remove the key and leave the forward/reverse switch in the NEUTRAL position during storage.

>Power down all accessories.

>Clean the battery packs, tops and terminals using a battery acid neutralizer (1 cup baking soda per 1 gallon water).Check, clean and treat battery terminal connections with a battery terminal protector spray.

>Disconnect batteries per owner manual ensuring that the cables do not come into contact with a terminal (Disconnect the 48V Main power outlet cables from battery pack ,insulate the cable ) .

>Connect Battery cables back to system , charge the battery to full state every 1-3 months to keep battery alive without damages caused byself discharge/over-discharge ;etc .

>Check Tire pressure and inflate the tires to standard pressure level as values presented on tires .

>Perform all semi-Annual Lubrications .

>Thoroughly clean the front and rear body ,seats ,battery compartment and underside of the vehicle.

>DO NOT engage the park brakes , but secure the golf cart from rolling. Chock the wheels with wheel stopper or something similar .

**⚠ WARNING**

INCORRECT STORAGE CAN CAUSE BATTERY DAMAGE, PERMANENT LOSS OF BATTERY CAPACITY, OR CAUSE THE BATTERY TO BE UNSERVICEABLE. A FULLY DISCHARGED BATTERY PUT IN STORAGE WILL MAKE THE BATTERY PERMANENTLY UNSERVICEABLE. PUT THE BATTERY ON CHARGE DURING EXTENDED STORAGE. DO NOT EXCEED THE STORAGE TEMPERATURE LIMITS. DO NOT PUT A FULLY DISCHARGED BATTERY IN STORAGE. INCORRECT STORAGE WILL VOID THE BATTERY WARRANTY

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## 12.Battery Disposal


**B**atteries are considered hazardous because of the metals and/or other toxic or corrosive materials they contain. Batteries are potentially a valuable source of recyclable metal.Hazardous waste regulations designate a category of hazardous wastes called "universal waste." This category includes batteries, fluorescent lamps, cathode ray tubes, instruments that contain mercury, and other items .Unlike alkaline batteries, lithium batteries are reactive and contain hazardous materials. For this reason, you should not put them in the trash. To dispose of lithium batteries, you'll need to take them to a recycling center, which is easy to find online .All batteries must be recycled or taken to a household hazardous waste disposal facility, a universal waste handler (e.g., storage facility or broker), or an authorized recycling facility.

### Where to Recycle or Safely Dispose Batteries?

#### Local Solutions

- **Rechargeable Battery and Cell Phone Drop-Off Locator.** Find where to recycle used rechargeable batteries from the Call2Recycle website.
- **Earth911.com.** Or call 1-800-CLEANUP (1-800-253-2687), a service of Earth 911, to find the nearest recycling center. The website includes information about most recyclable household waste, including household hazardous waste collection centers.
- **CalRecycle E-Waste Disposal Search Directory.** Find an E-waste collector or recycler near you to recycle electronic devices that contain embedded batteries.
- **Where Can I Recycle My**... Call 1-800-CLEAN-UP (253-2687) or enter a ZIP code at this website to find the nearest recycling center. Information about most recyclable household waste, including household hazardous waste collection centers, is included.
- **Local Governmental Household Hazardous Waste Agencies**. See the website for local governmental household hazardous waste agencies.

#### Other Solutions

- **The Big Green Box.** The Big Green Box™ is a national program that offers companies, consumers, municipalities, and other generators, a low-cost, easy, and flexible way to recycle batteries and portable electronic devices. Once The Big Green Box™ is purchased, all shipping, handling, and recycling fees are included. The Big Green Box™ includes a UN-approved, pre-labeled container, pre-paid shipping to and from the recycling facility, and of course, all recycling fees.
- **Battery Solutions.** Battery recycling solutions for businesses, governmental agencies, and consumers.
- **Retriev Technologies Inc.** This company recycles most types and sizes of batteries including alkaline, lithium, mercury, NiCd, lead, and others.
- **Kinsbursky Brothers Inc.** A U.S. EPA-permitted battery-recycling facility in California.
- **Aqua Metals.** This company recycles lead acid batteries via aqua refining.

NOTE: CalRecycle provides this list of battery recycling options for informational purposes only. Neither CalRecycle nor the state of California endorses the companies listed or the technologies they employ in recycling batteries.

#### Find More Information About Lithium-ion Battery Recycling Regulation

https://www.epa.gov/environmental-topics/land-waste-and-cleanup-topics
https://www.calrecycle.ca.gov/ReduceWaste/Batteries/

BATTERY MAINTENANCE CHECK LIST

# 13.Battery Maintenance Checklist

## 13.1 MAINTENANCE CHECK

The battery system components are designed to be free of regular maintenance. Regular inspection of components and power connections are recommended to ensure proper performance. Scheduled checks of the battery system are recommended but not mandatory for optimal performance. Refer to Operation Status for the battery system's operating conditions.

13.1 Daily Checks
Following is a list of items to be checked daily.
>Cell voltage differences should be within 50mV.
>There must be no alarms or faults.
>Check ambient temperature and humidity according to the range of operation.

13.2 Monthly Checks
Personnel should visually inspect the battery system monthly and review log data about the battery and its operating environment.
>Battery should have no visible damage (rust, bent structure, damaged or missing cables or busbars, etc.)
>Check the recorded data of the battery system for the voltage and current readings.
>Check the date and time of charge and discharge cycles.
>Check whether any alarms or faults have been triggered.

13.3 Annual Check
A trend analysis of the recorded data (battery and environment) is recommended.

**13.4 Maintenance Checklist（Conducted by authorized technician only）**
Refer to the following checklist template for scheduled checks. Detailed recordings may be necessary depending on the level of maintenance required by the user.

| Items | Criteria | Perform Location | Result |
|---|---|---|---|
| Battery Status | 1. Battery voltage<br>a) Pack voltage check<br>b) Cell voltage check (max/min difference)<br>2. Alarm or faults: No alarms or faults set | On Site | |
| | . Alarm or protection: No alarms or protections set | On Site | |
| | . Visual Inspection: check for physical damages<br>(rust, bent structure, damaged or missing cables, etc.) | On Site | |
| Environment | .Ambinent temperature | On Site | |
| | .Ambinent Humidity | On Site | |
| Recorded Data | 1. Recorded voltage and current<br>2. Date and time of charge and discharge cycles<br>3. Number of alarms and faults recorded<br>4. Record of temperature and humidity | On Site | |

## 5 YEAR LIMITED WARRANTY

Evolution electric vehicles ("the Manufacturer") warrants each Evolution Lithium branded Lithium Iron Phosphate (LiFePO4) battery ("the Battery") sold by Evolution Electric Vehicles or any of its authorized distributors or dealers, to be free of defects for a period of 5 years ("the Warranty Period") from the date of sale as determined by either the customer's sale receipt, the shipping invoice and/or the battery serial number, with proof of purchase. Within the 5 years of the Warranty Period, subject to the exclusions listed below, the Manufacturer will credit, replace or repair, if serviceable, the Battery and/or parts of the Battery, if the components in question are determined to be defective in material or workmanship by manufacturer technicians or authorized technicians, and the Manufacturer deems the components to be repairable, the Battery will be repaired and returned. If the Manufacturer deems the components to be not repairable, a new, similar Battery will be offered . The offer will be valid for a period of 30 days after the date of notification.

The Warranty period of any repaired Evolution Lithium battery product or its replacement is the remaining term of the Limited Warranty Period.

This Limited Warranty does not cover the labor cost of installation, removal, repair, replace or re-installation lithium battery pack or its components.

## NON-TRANSFERABLE

This Limited Warranty is to the original purchaser of the Battery and is not transferable to any other person or entity. Please contact the place of purchase regarding any warranty claim.

## THIS LIMITED WARRANTY MAY BE EXCLUDED OR LIMITED AT THE SOLE DISCRETION OF COMPANY IF THE FOLLOWING PROBLEMS ARE FOUND (INCLUDING BUT NOT LIMITED TO):

- shows indications that it has been altered or modified in any way from Company specifications, including but not limited to alterations to the lithium-ion battery pack, battery management system and the system electric circuit.
- shows indications that the failure is caused by installer error such as reverse polarity or misuse of system wide equipment or inaccurate programming of all ancillary equipment attached to lithium battery pack.
- shows indications that the battery charger has been modified to charge lithium battery not approved for the charger.
- shows indications that the battery pack was disassembled, opened, or tampered in any way without a company formal approval.
- shows indications that attempts may have been made to intentionally reduce the battery pack life;
- contains lithium battery packs that are not paired with the battery management system as supplied by the company;
- Extended storage without recharging or repairs done by an unauthorized person or modification.
- Damages resulting from an accident or collision, or from the neglect, abuse battery pack system.
- Environmental damage; inappropriate storage conditions as defined by the Manufacturer; exposure to extreme hot or cold temperatures, fire or freezing, or water damage.
- Damage due to improper installation; loose terminal connections, under-sized cabling, incorrect connections ( series and parallel) for desired voltage and AH requirements, reverse polarity connections.
- Battery that was used for applications other than which it was designed and intended for including repeated engine starting or drawing more amps then the battery is rated to continually discharge in the specifications

- Battery that was used on an over-sized inverter/charger (any inverter/charger that is rated to 10K Watts or greater) without the use of a Manufacturer-approved current surge limiting device
- Battery that was under-sized for the application, including an Air Conditioner or similar device having a locked rotor startup up current that is not used in conjunction with a Manufacturer-approved surge-limiting device
- Battery that has not been charged for over one year (batteries need to be charged regularly to allow for a long life span)
- Battery not stored in adherence to the Manufacturer's storage guidelines, including storage of the Battery at low state-of-charge (charge your battery fully before storing!)

**This Limited Warranty does not cover a Product that has reached its normal end of life due to usage which may occur prior to the Warranty Period. A battery can deliver only a fixed amount of Energy over its life which will occur over different periods of time depending on the application. The Manufacturer reserves the right to deny a warranty claim if the Product is determined, upon inspection, to be at its normal end of life even if within the Warranty Period.**

## WARRANTY DISCLAIMER

This warranty is in lieu of all other express warranties. the Manufacturer will not be liable for consequential or incidental damages. We make no warranty other than this limited warranty and expressly exclude any implied warranty including any warranty for consequential damages. This limited warranty is not transferable.

## LEGAL RIGHTS

Some countries and/or states do not allow limitation on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations may not apply to you. This warranty gives you specific legal rights, which may vary from country to country and/or state to state. This warranty shall be governed by and interpreted in accordance with the laws.This warranty is understood to be the exclusive agreement between the parties relating to the subject matter hereof. No employee or representative of Manufacturer is authorized to make any warranty in addition to those made in this agreement

## NON-EVOLUTION LITHIUM WARRANTIES

This Limited Warranty does not cover Battery sold by the Manufacturer or any authorized distributor or dealer to an Original Equipment Manufacturer ("OEM"). Please contact the OEM directly for warranty claims regarding such Battery.

## NON-WARRANTY REPAIRS

If outside of the Warranty period or for damage not covered under the Warranty, customers may still contact the Manufacturer for battery repairs. Costs will include, shipping, parts, and $65 per hour labor.

## SUBMITTING A WARRANTY CLAIM

To submit a warranty claim, please contact the original place of purchase. The Battery may be required to be shipped back to the Manufacturer for further inspection.

# EVOLUTION BATTERIES

## LITHIUM-ION BATTERY CLAIM FORM

PHONE:909-393-6800 EMAIL: INFO@EVOLUTIONELECTRICVEHICLE.COM

Please fill out the Evolution Lithium-ion battery Warranty Claim Form COMPLETELY and return with the product and copy of Purchase Receipt shipped back to

**Evolution Electric Vehicles 4552 Brickell Privado,Ontario CA 91761 , USA**

IT IS AGAINST THE LAW TO SHIP DEFECTIVE LITHIUM BATTERIES VIA MAIL. IF YOU BELIEVE THE BATTERY TO BE DEFECTIVE CONTACT US BEFORE SHIPPING!

It will be the Customers responsibility for all shipping to Evolution EV, we will not be held responsible for lost or damaged products in shipping. Evolution EV will test the product and if found defective due to workmanship, or components Evolution EV will provide shipping cost back within the USA only. Outside of the USA shipping to and from Evolution EV will be the Customers responsibility.

Evolution EV will warrant the Evolution Battery Products that are purchased from an AUTHORIZED DEALER ONLY, to be free from Manufacture and Material defects for the period of 5 years prorated. Warranty is void if product is not used as directed. Please see Warranty for all specific terms

NAME:_____ PHONE:_____ EMAIL ADDRESS:_____

MAILING ADDRESS:_____ CITY:_____ STATE/PROV: _____

COUNTRY: _____ POSTAL CODE: _____

Model of Evolution Battery:_____ Date of Purchase:_____ Serial #_____

Place of Purchase:_____

Brand of Vehicle:_____ Model of Vehicle:_____ Year of Vehicle:_____ Motor Size:_____

Main use of Vehicle :_____

What is the issue and when and how did it start occuring? Explain completely so we can best determine the issue with the product.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ _____

NAME DATE

Please include this form with the product you are returning and a copy of the receipt!

**We will NOT accept or warranty product without a valid receipt.**