Instruction Manual for $LiFePO_4$ Batteries

info@cycle9.com
919-636-5909
1-800-249-8098

Charge your new battery completely before using it.
Use a controller with a maximum current rating below the battery's rating.
Protect your battery from impact, weather, and vibration.
If anything unusual happens, discontinue use and contact us immediately.

Introduction
Your battery is built using the latest Lithium Iron Phosphate (LiFePO4) technologies. LiFePO4 is a battery chemistry ideally suited for electric vehicle uses, with its properties that combine: light weight, stability, safety, and long life. If treated properly (more on that below), LiFePO4 batteries can last for many years and for 1,000 charge/discharge cycles or more.

The battery is actually composed of individual LiFePO4 cells. Each cell is about 3.3 volts, which means that for a nominal "36V" battery, there are 12 cells, giving a typical operating voltage of 39.6V. For a nominal "48V" battery, there are usually 16 cells, giving an operating voltage of 52.8V. The reason the batteries are still called "36V" or "48V" harkens back to the days of lead acid cells, which typically come in multiples of 12V (even though they, too, are composed of smaller cells).

A typical electric vehicle controller can handle some range of voltages. The maximum voltage it can handle is determined by the ratings of the components and controller design. A typical "36V" controller may handle up to ~45V, and a typical "48V" controller may handle up to ~62V. At the other end, many controllers have a "low voltage cutoff" (LVC), which will cause the controller to cease operation below the cutoff voltage. This is to protect both the battery and the controller. Most batteries, including LiFePO4 can be damaged if over discharged. So a typical LVC for "36V" might be around 28-31V. Some controllers, such as the eZee, are designed for multiple voltages (36V and 48V), and in that case, when operating at 48V, the LVC is too low to protect the battery. In that situation, battery protection relies upon either operator care (monitoring the battery gauge or cycle analyst), or upon a so-called BMS.

The LiFePO4 batteries sold by Cycle 9 include a BMS, or "battery management system." These typically perform two functions:

1. Monitoring and protection for over-discharge of each cell. This is similar to the LVC, but built right onto the battery and monitoring every single cell.

2. Balancing the cell voltages during charging. With all lithium-ion based batteries, balancing is required for proper battery function, otherwise, some cells will end up "full" with others only "part-full".

A battery is the heart of an electric vehicle. If you treat your EV's heart gently, it will give you many years of great service.

Using your battery

Using the battery is straightforward. Most of our batteries are equipped with Anderson Powerpole connectors, red and black. These are plugged into the matching red and black Anderson Powerpoles on your controller. **Always make sure that red matches red and black matches black**. Please inspect your powerpoles each time you plug them in to make sure there are no signs of melting, corroded contacts, etc. They are easily replaced if they should ever become worn down. Also, for preventing corrosion in wet-weather, you can use dielectric "tune up grease" on the contacts. It will extend their life. This is a useful thing for all your electric bike contacts. The grease can usually be purchased at auto parts stores.

When you plug the battery in, there will often be a small spark. This is because most motor controllers have one or more capacitors, which are like little reservoirs for electricity. When you first plug it in, the electricity rushes in from the battery to fill up these reservoirs, and that is the source of the spark you see. Some battery packs have an integrated on/off switch which prevents that spark, provided the switch is in the “off” position when you connect the battery to the controller.

When mounting the battery on your vehicle, please make sure the wires are not pinched or overly bent. Some bending is ok, but a sharp 90-degree bend may damage them. If the charging/balance wires are located outside the pack (usually on non-hardshell batteries), make especially sure that these wires are protected, since they are thinner and more vulnerable than the discharge wires. If your battery did not include a specialized mounting system (such as a battery-specific rear rack), you will need to mount the battery securely, using vibration-dampening material between the battery and the bike (a padded, water-resistant bicycle trunk bag works well). The battery and wires must be protected from impact and moisture.

LiFePO4 batteries have a “C” rating to indicate the maximum discharge current allowed. Your battery is rated to a maximum of 3C, or 3 times the Ah rating. Exceeding this number will dramatically reduce the lifespan of your battery, and void the warranty. To get the most life out of your battery, you should use a controller with a maximum current rating that is between 2 and 2.5C:

Ah	**Maximum Current**	**Ideal Controller Rating**
10	3C (3x10) = **30A**	2 - 2.5C = **20 - 25A**
15	3C (3x15) = **45A**	2 - 2.5C = **30 - 37.5A**
20	3C (3x20) = **60A**	2 - 2.5C = **40 - 50A**

Once you start using the battery on your vehicle, you may notice a few things, especially if you are monitoring your voltage using a device like the CycleAnalyst. The first is that the voltage will drop down a bit during use, then come back up when you stop use. This is called *voltage sag*, and is natural with all battery types, due to so-called *internal resistance*. Even new batteries will typically have a voltage sag of 3-5 volts at 20 amps current draw. If the sag becomes excessive (more than 5 volts drop at 20 amps), this may be a sign of a failing cell or other problem with the battery. Note that the higher the current, the more the sag, so at 20 amps there will be about twice the sag as at 10 amps. For very high current applications, it is important to use a battery system that has very little internal resistance and very little sag. This can be done by using a higher-capacity battery, or adding a second battery in parallel. If you want to add a second battery, we have a "parallel battery joiner" that can help with that.

Break in period

LiFePO4 batteries are new enough in the market that there is not a lot of good information available on how to maximize their lifespan. Our own experience indicates that a gentle break-in period for your battery will help make it happy and long lived. For the first 20 charge/discharge cycles, it is important to avoid over-discharging the battery (below 1/2 of its capacity), and to avoid prolonged, high currents (> 15 amps). This is just like breaking in a car. Just use it gently at first, and try to avoid sudden starts with it, or climbing long, steep hills at full throttle, until it has been broken in a bit.

Charging your battery

Precautions: while LiFePO4 is a reliable and stable battery chemistry, it needs to be charged in a location without flammables immediately nearby. If something were to go wrong during charging, parts may get very hot. Avoid leaving the battery unattended. If there are any signs of problems, please promptly unplug from the wall and contact us for further instructions.

The charger included with your battery is fully automatic. It will detect when all cells are balanced and charged, then turn itself off.

First, carefully plug the battery into the charger (leaving charger unplugged from the wall outlet). Make sure that the splines on the multi-prong connector are aligned, and plug it in straight. If you plug it in at an angle, you may short one or more pins and get a big spark (possibly damaging something too). If it won't plug in, don't force it - you may bend a pin, which is bad news. Just make sure everything is straight and aligned. If by chance you notice a pin that is bent and you want to straighten it, *do not use a metal tool to do so! Use a plastic or wood tool instead*. Otherwise you may short something out, and possibly start a fire. Always keep the charging pins for your battery covered when not in use.

After plugging the battery into the charger, plug the charger into the wall. The "power" LED should come on, and also the red "charge" LED. You may hear the fan blowing to

keep the charger cool. After several hours (depending on how much charging the battery needs), the green "charging" light will come on, and after a bit, charging will automatically stop. However, the battery is not necessarily at its fully charged and balanced state the first time the charging light turns green. The battery's BMS will turn the charger on and off several times, as it evens out the voltages on the individual cells. Therefore, you should leave the battery plugged into the charger as long as possible to ensure a full charge (overnight is best). It is safe to leave the battery plugged into the charger after a full charge, since the BMS will prevent over-charging. When you are ready to use the battery, you must first disconnect the charger from the wall outlet, then disconnect the charger from your battery (the reverse of the charging procedure).

Care and Maintenance

The charging and discharging connectors need to be kept clean and protected. **Please inspect all wires and connections before and after every use** for any signs of damage or wear. If there are any signs of damage to any of the wires, please discontinue use immediately and contact us for repair.

To maximize your battery's life, please treat it gently. The most damaging thing you can do to the battery is over-discharge, allowing any cell in your battery to fall below 2.0 volts. Some cells may become discharged to that point slightly before others. So you can't just wait until the overall battery voltage drops to 24V (for a 36V battery - 2.0V x 12 cells = 24V), since by the time the battery is that low, some cells are below 2.0V. It is better to play it cautiously. We recommend you don't let the battery fall below an average of 2.5v/cell, which for a 12-cell battery is 30 volts.

If you have an accurate voltage monitor like the CycleAnalyst, this is easy to tell. If you don't, you will still notice a substantial drop off in the battery's power at that time. The discharge curve of the battery's voltage is pretty flat until the battery starts running out, then it drops rapidly. So, if you feel like the battery is suddenly losing steam, then it is time to discontinue use and get it charged.

If you need to store the battery for long periods, start by fully charging it up, and then make sure to charge it at least once a month to keep it topped up. These batteries will discharge themselves a bit during storage, since the BMS draws a small amount of power to maintain cell balance. If you don't occasionally charge them, one or more cells may fall below the 2.0V per cell critical threshold, permanently damaging the battery and voiding the warranty.

Do not ever short-circuit the charge or discharge terminals. Do not ever damage the insulation on the wires. Do not puncture or incinerate battery. Fire may result.

Troubleshooting

1. There is no power from the battery. First, check to make sure that the discharge connectors (usually Anderson Powerpoles) are clean and in good shape. Second,

check the fuse (if applicable) to make sure it has not blown. Check the fuse on your charger as well, in case the battery has simply not been getting charged. Third, check the rest of your system to make sure there is not a problem somewhere else (e.g. controller). If you have access to a voltmeter, measure the discharge terminal voltage. For a fully charged 36V battery, it should be 41-42 volts. For a discharged battery it should be around 34-36V.

2. Charging won't start. First, reset the charger. Unplug the battery and the AC cord, and wait 60 seconds. Then, plug the battery back in, and plug the charger into the wall. Make sure that the battery is plugged in correctly and securely to the charger. Make sure your outlet is supplying power. If these steps fail, please contact us.

3. Cell going bad. This doesn't happen often, but occasionally one cell in a battery may fail prematurely (this can be replaced). You may notice that the battery seems to be losing steam early (not full capacity). If this is happening, please contact us to explore repair/replacement options.

Specifications
Series configuration, 12 or 16 cells, LiFePO4 chemistry. 8+ amp hours, measured at 0.2C discharge rate. Anderson Powerpoles and multi-pin connector for charging. Fully automatic balancing charger with 120VAC wall cord. Absolute maximum discharge rate of 3C (30A for 10Ah battery); recommended discharge rate 2-2.5C.

Warranty

Batteries and battery chargers have traditionally been our largest source of warranty support. The manufacturer’s warranty period is 1 year from the date of purchase, and it covers things like:

- Faulty BMS circuits that trips below rated current or cause premature pack cutout
- Pack that delivers less than 80% of its nominal capacity at a 1C discharge rate
- Internal cell tab weld coming loose

Warranty does not cover:

- Batteries that have self discharged below 2V/cell from being left on the shelf for an extended period of time
- Cells that have been over discharged below 2V/cell, either by cycling the power system (turning the battery off and then back on when it stops providing power), or by removing or bypassing the BMS
- Water damage, which can lead to unreliable BMS circuit behavior, including burned leads/components, damaged cells, or complete battery failure
- Damage from the battery being dropped, punctured, or subjected to impact, whether accidental or intentional
- Use of the battery outside the specified parameters
- Modification of the battery or charger

- Battery damage as a side-effect of damage to other parts of the ebike system

Lithium batteries are liable to self-discharge over time because the BMS circuit itself draws current from the battery pack. Although the amount of current is usually small (< 1mA typically) it is still enough to kill a battery in 1-2 months, especially if it is stored in an initially flat state. If you plan to store a lithium battery, be sure to top it up with a charger at least once a month.

Often, we get issues that are wiring related, such as a fuse holder that starts to melt from being loose, or a connector that gets corroded. In these instances, we will send or replace just the wiring part. Do not modify or replace any part of the battery, wiring, or connectors unless specifically instructed by us to do so.

Please see our full warranty and return policies, posted on our website, for more information.

Further, the battery manufacturer and Cycle 9, LLC will not be responsible for any damages to anything beyond the battery itself. Before using the battery, you are acknowledging your understanding that the battery carries a large amount of energy that may cause sparks or fires. You will carefully monitor battery during both charge and discharge for any signs of deformation, heating, or other damage, and immediately discontinue use if you observe a problem. The battery can carry as much energy as a stick of dynamite - so it must be treated with similar respect. Cycle 9, LLC will not be held liable for any damages arising from misuse, intentional or otherwise.

Now, after all that necessary legalese: Cycle 9 may *at its own discretion*, extend the warranty in some instances beyond the manufacturer's warranty. Upon any problem or failure of the battery, we will assess the likely causes and solutions, and at our option, we may repair or replace the battery if determined to be due to manufacturing defects.