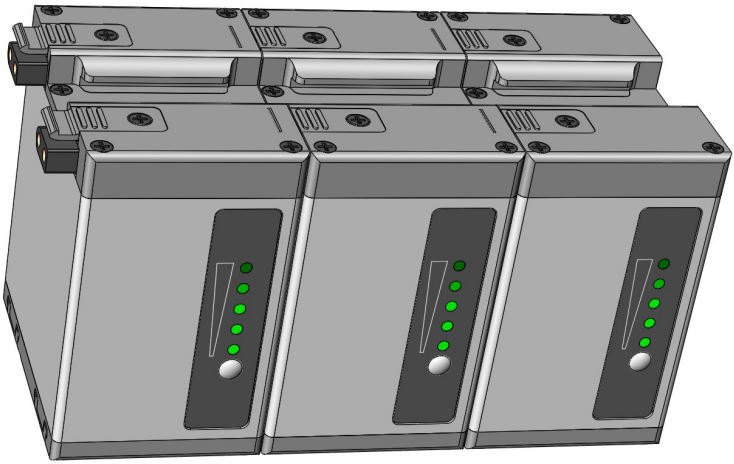
The LiGo 10X Battery Module

User Manual – Rev 1.1



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1 Introduction

The LiGo 10X is a modular 36V battery system designed to enable air travel with ebikes and other micro-mobility devices. The modules stack and lock together to create useful battery packs between 300-600 watt-hours and readily disassemble to individual 100 Wh bricks that can be transported with carry-on baggage aboard passenger aircraft.

2 Description

The LiGo module is illustrated in the Figure 1 with the core features shown.

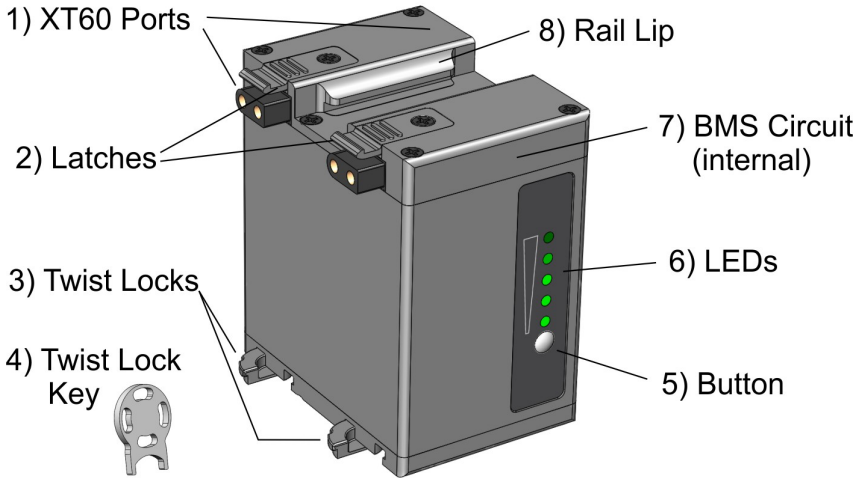


Figure 1: Summary of LiGo 10X Components.

1. **Connection Ports**: Each LiGo 10X has four XT60 connectors on the top, two male and two female, which can be used both for charging and discharging. These plugs mate with each other when the modules are stacked together.
2. **Push Latches**: Just above the XT60 connectors are a pair of plastic latches that click into place when the XT60 plugs are fully plugged into each other. These latches must be depressed by hand to pull the packs apart.
3. **Twist Locks**: There are four semi-circular captive latches on the bottom. They sit flush with the surface and are rotated 90 degrees to mechanically lock adjacent modules together.

4. **Twist Lock Key**: A small chainring key to easily rotate the twist locks when connecting or separating the packs from each other. Tweezers or needle nose pliers can work as well.
5. **Button**: A momentary button engages various battery functions like showing charge level, waking from sleep, or enabling Bluetooth. See section 4 for further details on the button behaviour.
6. **LED Strip**: A row of five multicolour LEDs on the side shows details on the state of the battery pack, including charge level and wireless connection status. See section 5 for a description of LED modes.
7. **BMS Circuit**: Potted inside the lid of the battery is an advanced battery management system (BMS) that protects the cells against overcharging, over-discharging, and excessive current. It can also communicate with external devices via Bluetooth.
8. **Rail Lip**: The top cap includes a slot with an overhanging lip that allows the LiGo modules to slide securely onto an optional rail system attached to the vehicle.

3 Joining Batteries

To connect two or more LiGo batteries together, simply slide the mating XT60 connectors into each other until there is an audible click from the latch. Then flip the module upside down and rotate the twist locks 90 degrees until they too click into the locked position.

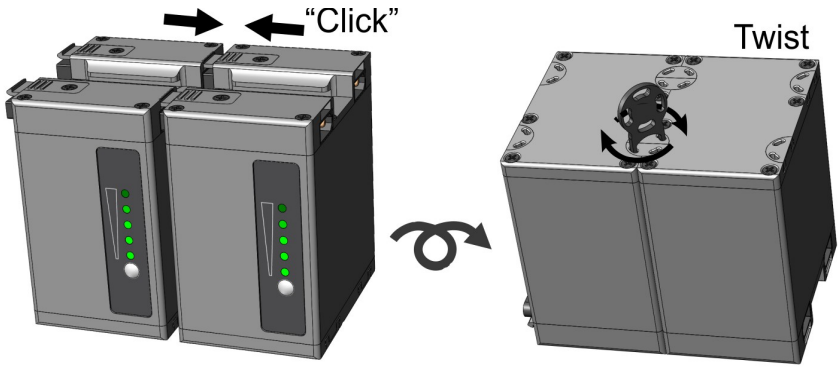


Figure 2: The top latches click on insertion, while the bottom twist locks are secured by rotating 90 degrees.

The LiGo modules are now hooked together at all four corners and act as a single larger battery. Up to 6 LiGo modules can be safely secured together this way to create a 36V 600 Wh (16.5 Ah) pack. Longer assemblies are

possible but not recommended as they may put undue strain on the connection points during rough handling.

To disassemble the batteries, reverse the process. First, rotate the twist locks until the seam lines up with the battery joint. Then depress the two push latches with your fingers while pulling the packs apart. It is important that both latches are pressed simultaneously for the packs to slide free.

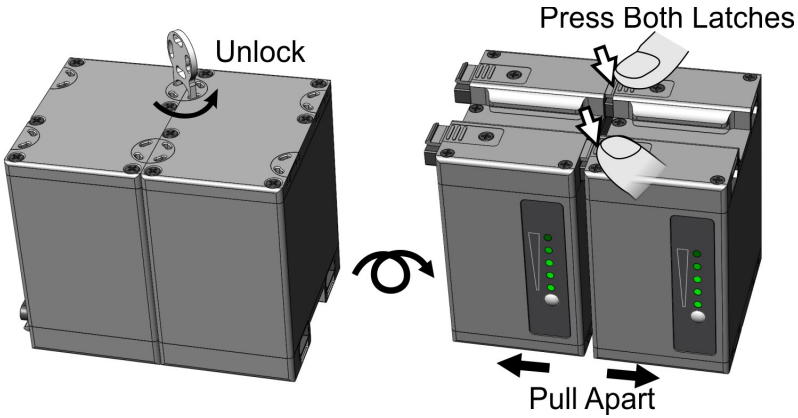


Figure 3: Separating the modules requires that both latches are pressed down simultaneously while the packs are pulled apart.

4 Button and Behaviour

The momentary push button allows a convenient physical control input to the battery.

4.1 Short Press

A brief button press will illuminate the LED light bar and show the current state of charge. The LEDs will stay lit up in 'heartbeat' pulse for several minutes and will then shut off again automatically to preserve charge if no active use of the battery is detected.

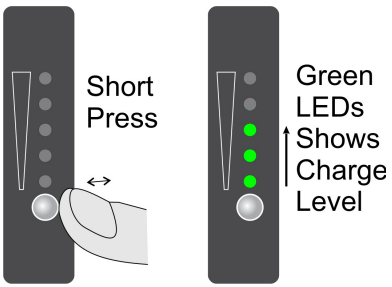


Figure 4: LEDs will remain lit up showing charge level while slowly pulsating. 3 LEDs = ~60% Charged.

4.2 Short Press (from Sleep)

If the LiGo battery is in shutdown/sleep mode (See section 9.4), then a short press will wake the battery from sleep and make it active again. In this situation, all 5 LEDs will simultaneously get bright together, followed by a heartbeat pulse showing the charge level.

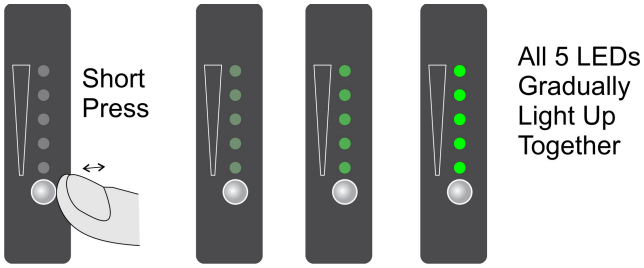


Figure 5: Short press will also wake up a LiGo 10X that was in sleep mode.

4.3 Triple Press (Bluetooth)

Pressing the button 3 times rapidly in succession will cause the battery to enter Bluetooth connection mode. The blue LEDs will fan outwards for two minutes while waiting for a connection to a Bluetooth device (See section 8 for more details). A momentary button press will exit broadcasting mode.

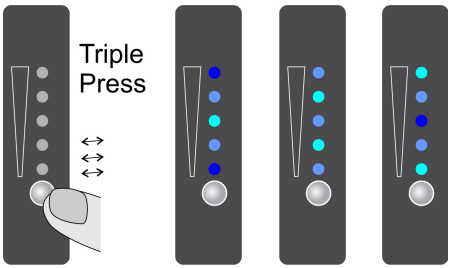


Figure 6: Bluetooth broadcasting is active for phone app connection.

4.4 Long Press – 6 Sec (Forced Sleep)

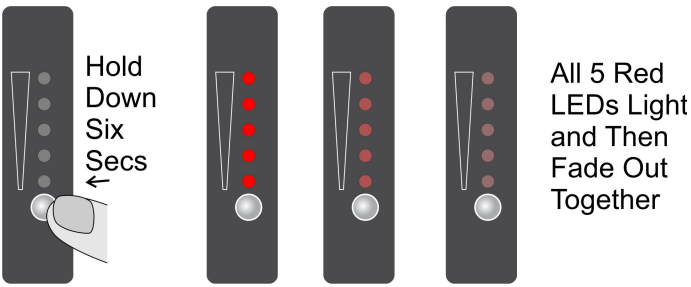


Figure 7: Forcing batteries into sleep mode through a long button hold is highly recommended before long term storage.

Holding the button down for over 6 seconds will force the LiGo 10X to enter shutdown sleep mode. All LEDs will go solid red and then fade out. Once in sleep mode, the LiGo module has almost no self discharge current and can can be stored for years without losing charge.(See section 9.4)

4.5 Medium Press – 2 Sec (On/Off Power Control)

By default, the LiGo battery output is always on. As long as the cells are not totally discharged, it will have voltage on the output pins and is ready to be used or recharged. The ebike system is turned ON and OFF via the vehicle's on/off switch while the battery itself remains energized. This is the simplest and the preferred option as there is only a single power switch to deal with.

Alternatively, you have the option to configure the LiGo 10X so that a 2 second press of the button also doubles as an on/off switch for the battery.

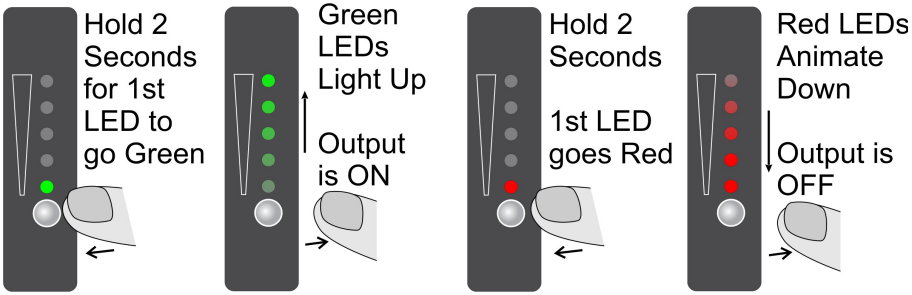


Figure 8: The ability to turn the LiGo output on and off via a 2 second button hold is useful in certain applications, but is best avoided with larger pack assemblies. Use a single primary on/off switch for the vehicle whenever possible.

This feature is not enabled by default but it can be turned on via the Bluetooth app. This is useful for systems that do not have their own built-in on/off switch.

When using a large pack with on/off control enabled, each LiGo module must be individually switched on before use. Any modules left off will result in those LiGos not contributing to the battery output, giving a reduced capacity for the battery pack as a whole.

The battery can still be charged and connect over Bluetooth when it is in an OFF state, making it quite different than being in sleep mode. If a charger is connected while OFF, it will accept a charge as usual and show the charging animation.

Note that all XT60 plugs will have charger voltage present while the charger is attached, which can result in the vehicle turning on in some cases. Once the charger is removed the output voltage will go low again.

5 LED Blink Codes

The LEDs are also used to convey the state of the LiGo battery and any faults conditions that have disabled the charge or discharge ports.

Ramping Green – Charging: During charging, the green LEDs will repeatedly animate from zero to full, with a short pause at the end of each cycle to show the current charge level.

Pulsing Green – Heartbeat: When the LiGo battery is actively in use or has recently had the button pressed, the green LED's will pulse in a slow blinking heartbeat pattern at the current charge level. This heartbeat display will stop after a user-settable time and can also be disabled in the app.

3X Yellow Flash – Short Circuit: In the event that a short circuit is detected, all yellow LEDs will flash 3 times in succession. The output will be disabled as long as a load remains across the output.

3X Orange Flash – Excessive Discharge Current: If the discharge current out of the module exceeds the BMS maximum (but not an actual short), all LEDs will blink 3 times in orange and the output will be disabled. The output port will automatically turn on again after the load is disconnected or several seconds of time has elapsed.

3X Green Flash – Excessive Charge Current: If the LiGo module is charged faster than the maximum allowed charge current, the LEDs will flash green 3 times and the BMS will block any further charge current. The charge port will remain blocked from charge current until the charger is disconnected, or several seconds of time has elapsed.

3X Red Flash – Under Voltage: If the LiGo 10X is fully discharged to the low voltage cutoff, then the red LEDs will blink 3 times and the output will be disabled until some amount of charging has taken place or the voltage recovers sufficiently on its own. If it is not charged within several weeks, it will automatically go into sleep mode, at which point it will have to first be woken from sleep with a button press before it can be charged up.

3X Teal Blue Flash – Under Temperature: If the battery is connected to a charger when is too cold to charge safely, LEDs will all blink 3 times in a light frosty blue colour. Either reduce the charge current on your charge to a bare trickle, or warm the battery up so that it can safely charge at a standard rate.

Red / Orange / Yellow – Over Temperature: If the battery is too hot to be charged or discharged, it will animate in a persistent flaming red/orange/yellow pattern resembling a fire. This is a sign of potentially unsafe conditions for battery operation. The battery must be allowed to cool to allowable temperatures before it can be used.

6 Installation and Rail

The assembled LiGo 10X battery pack can be easily strapped to your vehicle in a soft padded bag, with an XT60 terminated cable harness connected to the motor controller. This often works well for small packs of 2-4 modules and looks discrete as no external pack is visible.

6.1 Rail

Alternatively, Grin produces a metal mounting rail option with tabs that slide into the LiGo Lid and spring latches that hold it in place. These are available in 4 lengths and attach to the bicycle tubing through waterbottle eyelets or hose clamps. A 2-6 pcs LiGo battery assembly slides on and off the rail in one go, you do **not** individually add each module to the rail one at a time.

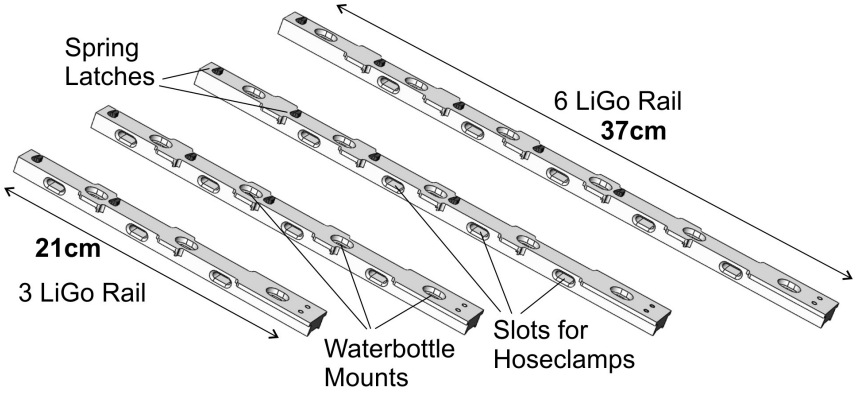


Figure 9: Illustration of 3, 4, 5, and 6 piece LiGo rails. Spring latches retain LiGo pack assembly on the rail, and are positioned so you can secure from 2 to the

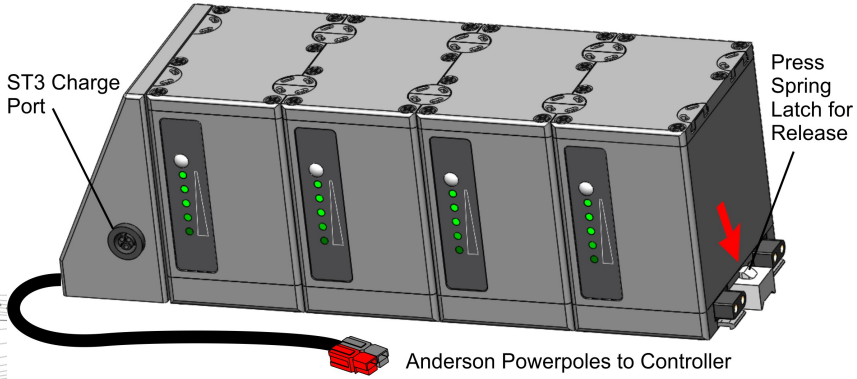


Figure 10: Four LiGos mounted on rail with

6.2 Dock Options

At the back of the rail there are two docking options, either with or without Grin's Baserunner controller mount. Both include an ST3 port for charging using Grin's existing charge plug standard. The Basic Dock is plastic and has a flat DC cable terminated with Anderson Powerpoles for an external controller connection. The Baserunner version is made from sheet metal and includes a machined heatsink to fit in a concealed Baserunner motor controller. This allows for a neat overall installation.

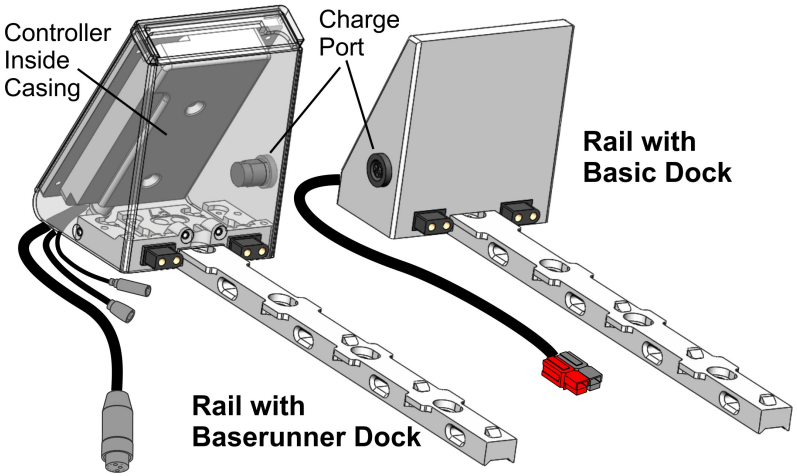


Figure 11: Baserunner Dock is made of metal to aid controller cooling, while Basic Dock is smaller and hooks to an external controller

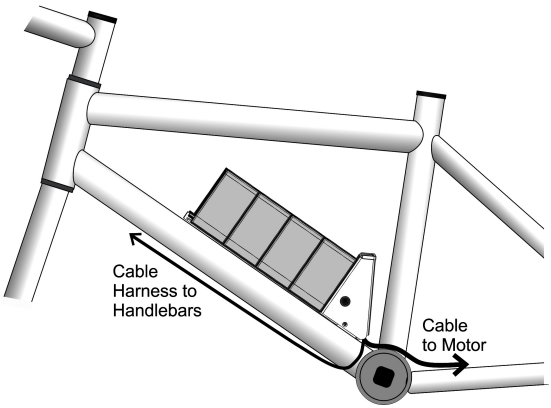


Figure 12: Example of a typical mount to downtube waterbottle eyelets. Wiring is minimized with controller integrated in the dock.

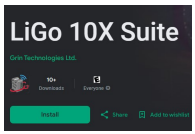
7 Charging

The LiGo 10X modules can be charged with any generic 36V lithium battery charger (42V full charge output) that is terminated with the appropriate mating connector. For the sake of cell longevity, we do not recommend charging at more than 3 amps (~1C) per module. So if there are 4 modules connected together the maximum charge current would be 12 amps.

8 Bluetooth Connection

The LiGo 10X enters wireless broadcasting mode from 3 or more quick button presses as explained in section 4.3.

This allows connection of an individual module to either a smartphone or a laptop computer and enables the interrogation of the LiGo BMS over Bluetooth. A LiGo Suite app is currently available for Android and iOS:



[LiGo 10X Suite on Google Play]

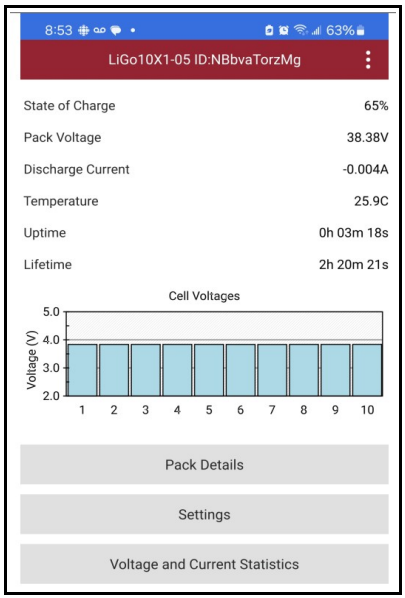
[LiGo 10X Suite on App Store]

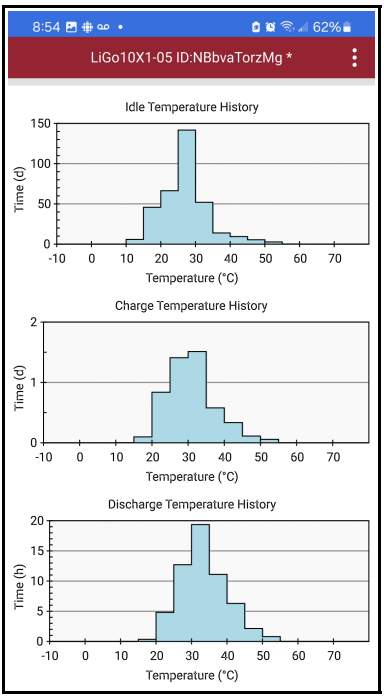
Once connected, the LiGo 10X can report details such as:

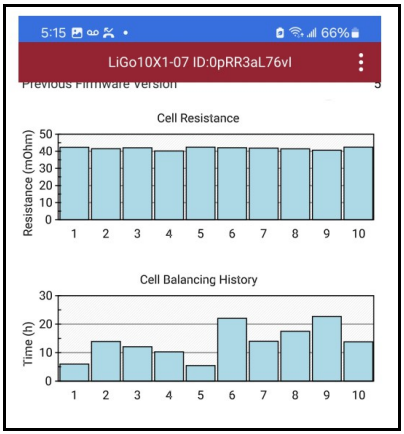
- All individual cell voltages.
- The current and historic internal resistances of the cells.
- The instantaneous charge or discharge current.
- The lifetime kWhr of energy in and out of the pack.
- The history of temperatures exposure while charging, discharging, and idle.
- The historic exposure to different tiers of charging and discharge current level.

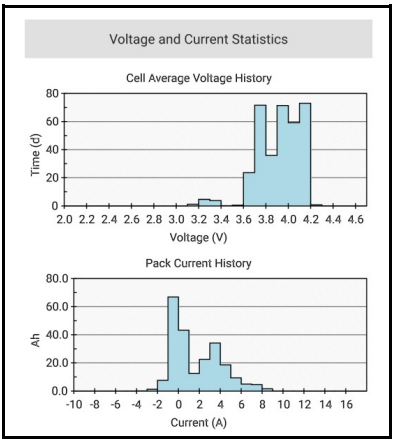
Please note that you must connect to the LiGo module from within the app itself. If you connect to the battery via your phone's general bluetooth connections, nothing will happen.

Below are some examples of the historic pack usage data and individual cell data available from the LiGo app.









There are also various BMS settings that can be adjusted through the application, such as:

- Duration of heartbeat animation.
- The intensity of the LED light indicator.
- Whether the battery is always on, or can be turned on and off via a medium button press.
- Custom high voltage and low voltage cutoffs to allow optimization for cycle life or maximum capacity.

Full usage details of the LiGo App and LiGo Software will be provided in respective manuals for those products and is not covered here. As well, the complete LiGo BLE communication protocol is available for study by OEMs who want to integrate a LiGo 10X battery into their device.

9 Additional Details

9.1 Matching Charge Levels

We recommend that you connect LiGo 10X modules when they are at least in a somewhat similar state of charge, generally within 2-3 volts of each other. In that scenario the flatter modules get charged up from the more charged modules for a short period of time until all the voltages are equalized. Nonetheless, if you do happen to connect fully charged modules to flat ones, don't worry - the batteries will protect themselves.

A flat module connected to a fully charged pack assembly will detect the excessive charge current and isolate itself until the rest of the packs are discharged to a similar state, at which point they would all charge and discharge together again.

Conversely, a fully charged LiGo 10X module connected to a bank of mostly flat modules will detect the excessive discharge current then isolate itself from the rest of the pack. This module will stay isolated until the rest of the batteries are charged up to a similar voltage, at which point all the LiGo modules will operate in unison.

9.2 Connecting with Other Lithium Batteries

In general, the LiGo 10X modules can be safely connected in parallel to other 3rd party 36V ebike batteries as a booster pack to increase range. The protections described in section 9.1 will apply in the same manner.

9.3 Voltage on Ports when OFF

Even when the battery is turned off or in sleep mode, you may still measure a voltage present on the output pins using a multimeter. Depending on the impedance of your source, it could be anywhere from 5 to 25 volts. This will drop to zero the moment any current draw is attempted, or even if you just touch the terminals with your finger. It is not a measure of the actual voltage of the cells inside the pack.

9.4 Quiescent Current and Sleep Mode

All BMS circuits draw a certain amount of power to monitor and protect the cells, and this current itself will slowly drain the battery flat even if no external load is hooked up. Many lithium batteries are susceptible to permanent damage if they are put in long term storage in a flat state, as the small internal current will fully drain the cells below a safe recovery point.

The LiGo 10X BMS draws ~250 uA of current when the battery is active. That is insignificant over the course of a few days or weeks, but it will drain about 1 amp-hour every 5-6 months. A battery that is put away fully charged in the fall will be only half charged in the spring, and flat the next year.

When the LiGo 10X battery is in sleep mode, the quiescent drain is much lower at approximately 1uA, and it would take many years or even decades for the cells to discharge an appreciable amount.

The LiGo 10X BMS circuit will automatically enter into sleep mode if it sees itself at a low charge level and not used for a certain length of time. That allows it to be stored almost indefinitely.

The LiGo 10X can also be forced into sleep mode at any point by holding down the button for 6 seconds. In sleep mode, the circuitry is entirely turned off and it cannot accept any charge current either. It will have no functionality until the button is pressed to wake it.

9.5 Cell Balancing

Most BMS circuits only balance cells when the battery is fully charged, by 'bleeding off' a small amount of current when cells exceed 4.2V each. This gives a limited time window for cell balancing, and it does not work at all if the battery is deliberately not charged to 100%.

The LiGo 10X modules employ a smarter cell balancing strategy. Instead of balancing at the end of charging, they are balanced any time the battery is over 60% charged and is sitting idle. This gives a larger window for balancing to to be active, and it ensures that the cells stay balanced even in usage scenarios where the pack is only partially charged for cell longevity.

9.6 Regen Current

Although the maximum recommended charge current is 3 amps per module, LiGo 10X batteries can handle short duration charge currents at up to 10 amps per module as experienced during regenerative braking. The BMS circuit can detect based on the current profile if the charging current is coming from a conventional battery charger or from regen. This ensures that the BMS circuit is less likely to suddenly trip from transient over-charge current or cell over-voltage during regen and cause a loss of vehicle braking.

We strongly recommend setting a max regen voltage in the motor controller to 42V to ensure a smooth rollback behaviour with charged packs.

9.7 Cold Weather Behaviour

LiGo 10X batteries come with intelligent charge current cutoffs that automatically adjust based on cell temperatures. Under freezing conditions, they will only allow charging at very low currents.

However, it is best to avoid letting the battery get extremely cold when you plan to use it. Not only does this result in higher internal resistance and more voltage sag under load, it also prevents charging at meaningful rates due to the risk of lithium plating. If you ride in a sub-zero climate, we recommend keeping the LiGo 10X modules indoors when not in use, and to thermally insulate them with some kind of wrap on the vehicle. The battery will generate its own heat during use and that, combined with some external padding, will normally keep the battery temperature reasonable over the duration of your trip.

9.8 Water Exposure

Each LiGo 10X is sealed and potted to provide protection from water ingress and associated damage. It is no problem to expose the LiGo battery to the splashes and rainfall that are part and parcel of being on a vehicle.

That said the battery is not at all submersible. If the entire XT60 connectors are surrounded in water, the high DC voltage will rapidly dissolve the positive connector pin from electrolysis. Avoid storing or installing the battery in any scenario where water could pool up around the connectors.

10 Regulatory CAUTION

The following required blurb is brought to you by EN62133 and EN15194 and is technically incorrect on several points but we digress:

1. *Please read these specifications carefully before testing or using the battery as improper handling of a li-ion battery may result in loss of functionality, heating, ignition, electrolyte leakage, or explosion.*
2. *While testing the battery by charging or discharging, please use test equipment specifically designed for li-ion cells.*
3. *When charging or discharging the battery or integrating them into equipment, reversing the positive and negative terminals could result in overcharging or over-discharging of the battery. This could lead to serious loss of functionality or danger.*
4. *Do not solder or weld directly to the battery or enclosure.*
5. *Do not put battery in containers together with metal products that could connect the positive and negative battery terminals, as this could result in a short circuit of the battery.*
6. *Do not puncture, throw, or crush the battery, do not put the battery into washing machines or high pressure containers. When cleaning the battery, use a cloth or brush and avoid submerging the connectors.*
7. *Keep the battery away from heat sources such as fires and heaters. Do not store battery in locations where the temperature exceeds 60°C, as this may lead to damage. Only charge the battery when it is within the specified charge temperature window.*
8. *Do not leave battery wet or immerse in water. When not in use, store in a cool and dry place.*
9. *This battery does not require maintenance and is internally potted. Please do not disassemble.*
10. *If during use, testing, or storage the battery becomes hot, emits a smell, changes in colour, deforms or shows any other abnormalities, please stop using or testing immediately, isolate it and keep it away from other batteries.*

The following required blurb is brought to you by FCC and RED (Radio Equipment Directive):

- This device contains transmitter FCC ID:X8WBM832 IC: 4100A-BM832
- Bluetooth Version: BT 4.0 (GFSK)
- Frequency Range: 2402-2480MHz
- Transmit Power: 5.44dBm

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

Changes or modifications not expressly approved by Grin Technologies Ltd. Could void the user's authority to operate the equipment.

***Note:** This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation.*

If this equipment does cause harmful interference to radio or vintage television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

This device contains licence-exempt transmitter(s)/receiver(s) that comply with Innovation, Science and Economic Development Canada's licence-exempt RSS(s). Operation is subject to the following two conditions:

- *This device may not cause interference.*
- *This device must accept any interference, including interference that may cause undesired operation of the device.*

11 Specifications

11.1 Electrical

Nominal Voltage	36V
Default Voltage Range	32V - 42.0V
Pack Capacity	2.75 Ah
Pack Energy	99 Wh
Cell Manufacturer	LG Chem
Internal Resistance	350-400 mOhm
Discharge Current	6A Continuous, 10A max
Charge Current	3A Max Recommended, 10A trip

11.2 Protections

BMS Trip Current	15.5A (5C)
Quiescent Current (active)	250 uA
Quiescent Current (sleep)	<1 uA
Standard Charge Temp	0C to 45C
Standard Discharge Temp	-20C to 60C
BMS Cutout Topology	Common Charge / Discharge Port
Output Impedance When Off	3 Megaohms

11.3 Mechanical

Dimensions LxWxH	55 x 78 x 89 mm
Weight	640g
Connectors	Amass XT60 M / F
Material	Aluminum extrusion, GFN end caps

11.4 Regulatory Compliance

UN38.3	Yes
EN15194	Yes
EN62133-2	Yes
FCC / IC / CE	Yes
EMC / EMI	Yes
UL2271	No*

Certain UL2271 requirements don't make much sense in a small module like this. Nonetheless provisions are in place for a UL2271 variant in the future.