

QUEST FOR POWER

LITHIUM-ION TECHNOLOGY IS HERE AND READY TO ENERGIZE OFF-GRID ADVENTURES

Imagine a battery in your RV that has a 100-amp-hour rating, could be discharged to the full capacity of the battery and conditioned completely in as little as an hour. The battery would be a drop-in replacement for the existing flooded lead-acid (FLA) batteries, weigh half as much and last up to 10 times longer. It would not corrode or require any maintenance, and would withstand winter storage, which freezes and kills thousands of RV batteries each year. What's more, this battery, though representing a higher initial cost, would actually end up being cheaper per charge/discharge cycle than comparable FLA batteries — and thanks to the latest advancements in battery-

management systems (BMS), would be as safe as FLAs. If you guessed we're talking about lithium iron phosphate (LiFePO₄ or LFP) batteries, you're right on track.

While a long-lasting, quiet power source that would increase camping freedom is the holy grail for RVers, legacy battery technology has been a limiting factor. To secure true long-lasting off-grid power, most owners build large 6-volt battery banks. This not only consumes valuable storage real estate, but at 62 pounds per battery, these battery banks add a tremendous amount of weight to the rig. With cell watering, gassing and terminal corrosion, FLA batteries are mainte-

nance-intensive, and they also require adequate ventilation.

Until recently, lithium-battery technology wasn't a viable alternative. Early iterations were fraught with safety issues, not the least of which were fires as a result of runaway thermal events, often caused by cell crystallization or battery overload or overcharging.

Fortunately, the technology has advanced dramatically. LFP is the safest lithium-battery technology currently available, according to Sean Nichols, cofounder and chief operating officer of Dragonfly Energy, a Reno, Nevada-based Li-ion battery technology company that designs, manufactures and sells LFP batteries to the RV industry under the Dragonfly and Battle Born brands.

The company set out to design a drop-in LFP battery system that is safe and easy to use for the RV market. We tested these batteries, tethered to a Xantrex inverter-charger, and installed them in the new Torklift PowerArmor Max locking battery box, which mounts to the travel trailer's A-frame and allows room for system additions or upgrades.





For this install, the test trailer was previously fitted with a “green energy” project that used a Xantrex TrueCharge2 60-amp battery charger, a Xantrex Prowatt SW 2,000-watt inverter and two GC2 6-volt FLA batteries. These components were replaced with the new Xantrex Freedom XC 2,000-watt inverter and 80-amp charger system with a digital remote, and two Battle Born LiFePO4 12-volt batteries.

The Batteries

A few companies currently make LFP batteries, but most are battery packs that connect to an external BMS. Dragonfly’s packs are all-inclusive, combining the BMS and the cells in one sealed, user-friendly package that directly replaces a 12-volt battery. These batteries are designed to work with some existing converter/chargers on the market, including those from Progressive Dynamics, WFCO and Xantrex, although Nichols says that a charger with tweaked charge settings for LFP is ideal.

He adds that four-stage units (with equalization) can’t be used with LFP batteries unless the equalization stage can be turned off, and if users have any question about the charger, they should contact the battery manufacturer for assistance and guidance. Progressive Dynamics currently offers a full line of lithium converters, Nichols says.

For this installation, two Battle Born BBGC2 100-amp-hour, 12-volt batteries were installed. These

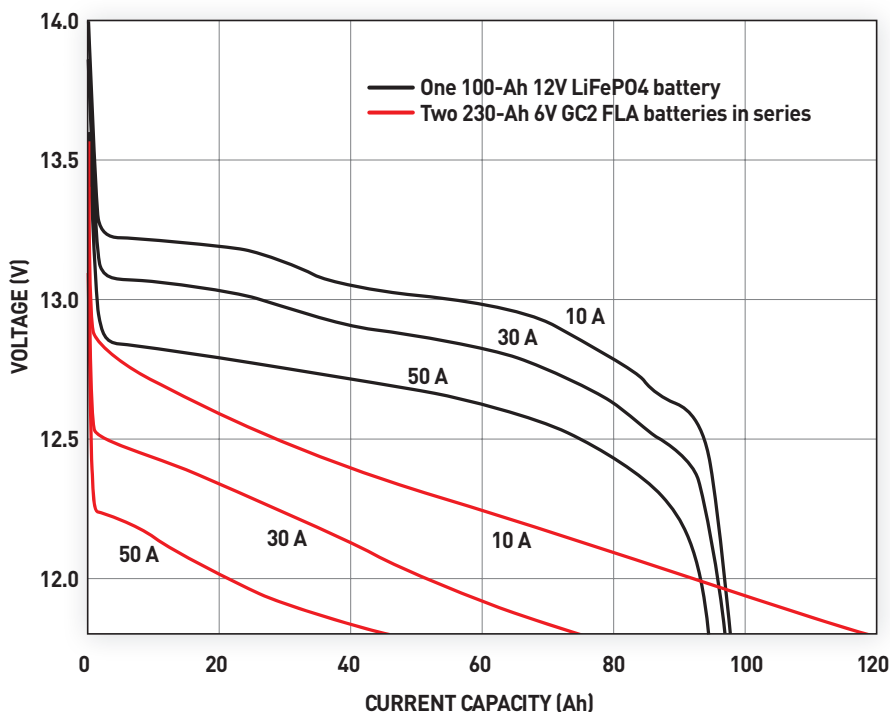
POWER PLAYERS

A) Two Battle Born BBGC2 100-amp-hour, 12-volt LiFePO4 batteries. **B)** Xantrex Freedom XC 2,000-watt pure-sine-wave inverter and 80-amp charger system. **C)** Xantrex Freedom X digital remote-display panel. **D)** Torklift PowerArmor Max aluminum battery box with diamond-plate sides and a sliding, lockable top.

batteries have a maximum surge rating of 200 amps for 35 seconds, and a maximum continuous current of 100 amps. They have the same footprint as standard 6-volt batteries, but while two BBGC2s have a 200-amp-hour capacity and two 6-volt batteries are rated at 220 amp-hours, the additional 20 amp-hours of power from the 6-volt batteries is not usable current because the voltage will be too low.

One of the true benefits of LFP is the power curve. LFP batteries maintain voltage far longer than FLA batteries discharging at the same rate,

which Dragonfly demonstrated during laboratory testing. Although an LFP battery can technically be discharged to 100 percent, it is better to discharge it to no less than 20 percent of capacity for longevity reasons. That said, an LFP battery can be discharged and left, with no detriment to the battery. By comparison, FLA batteries should never be discharged beyond 50 percent of capacity to prevent damage, and leaving one discharged for a lengthy amount of time will lead to sulfation and a reduction in available amp-hours. This means that LFP batteries provide



The graph on the right shows the power curve of the lithium iron phosphate (LiFePO4 or LFP) battery is higher and steadier than two flooded lead-acid (FLA) GC2 batteries. This results in a much longer discharge time.

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more usable power at a steady voltage for longer periods than conventional battery technology.

Another benefit of LFP batteries is weight. BBGC2 LiFePO4 batteries weigh 31 pounds, exactly half that of FLAs. In RVing, where every pound counts, this is a big difference.

Also, LFP charging is improved over FLA batteries, according to Nichols. "LiFePO4 can be charged faster than lead-acid batteries," he says. "Because of the lower internal impedance, Li-ion batteries spend most of the charge cycle in bulk mode [i.e., at the maximum current delivered by the charger], so they charge faster."

Nichols adds that LFP batteries can be charged as much as five times faster than FLA because of the reduced internal resistance inherent in an LFP battery pack. The charge voltage range for LFPs is 14.2 to 14.6 volts DC, with a float voltage of 13.6 or lower, which is why having a charger designed for use with the LFP batteries is ideal, though

not always required.

The terminal configuration on the Battle Born BBGC2 batteries is quite different from traditional batteries, in that the brass terminals stick out horizontally from the side of the pack and are each secured with a nut and bolt. This requires an additional amount of care when handling and setting the batteries in a box or compartment to ensure that the terminals don't short circuit on adjacent metal.

Since these are sealed packs, they can be mounted in any direction, provided there's adequate space above the battery for the terminals. For the test install, the batteries were mounted with the terminals facing up.

Battery Storage and Mounting

At a retail cost of \$949 to \$1,049 each, Battle Born BBGC2 LiFePO4 batteries are much more expensive than FLA batteries, so keeping them safe is essential. To secure them, Torklift's PowerArmor Max locking battery box

was chosen because it's virtually impenetrable. Torklift has been building these boxes for some years, including a model that integrates one or two 10-amp solar panels on top to help keep batteries charged while in storage. A smaller version was used previously on the test trailer to house the GC2 batteries, but it was quickly determined that the solar panel would not be practical for charging the LFP batteries.

The PowerArmor Max box used for this installation sells for \$551.99 and measures 58½ inches long, 8⅞ inches wide and 13 inches high, which leaves ample room for expansion later. The box is made of aluminum with diamond-plate sides and a sliding, lockable top. It is vented so FLA batteries can breathe; however, that's unnecessary with LFP batteries.

The box is attached to the top of the trailer's A-frame and is available in multiple sizes to fit from one to as many as six batteries under integrated lock and key. Smaller boxes may fit on

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the rack where standard battery boxes would mount, with some modification.

Inside the box, the batteries were secured with battery straps and cushioned with foam-packaging blocks, which came with the batteries. The 2/0-gauge cable was brought into the box and connected to a 250-amp fuse, and cables were made to connect the two 12-volt batteries in parallel.

Charging and Inverting

Battle Born LiFePO4 batteries require special charging algorithms to function as designed. For that reason, the Xantrex Freedom XC 2000 was chosen. While the inverter-charger was a bit of work to install, the RV now has a single piece of hardware controlling all inverting and charging segments, and has AC power off the grid.

Retailing for \$775, the Freedom XC 2000 is a highly sophisticated pure-sine-wave inverter and battery charger designed for RV and marine applications. This system is ideal for LFP use, because

not only are the charging algorithms completely programmable, the unit is capable of conditioning a completely exhausted battery. Designed for AC efficiency, the charger is power-factor corrected—which leaves more current available for other loads—and has a power-share feature that prioritizes AC loads and reduces the charger current during peak loads to prevent overloading the breaker.

It also incorporates a built-in 30-amp transfer switch that automatically selects the proper AC power source for the circuits it feeds, from shorepower to inverter power. If the power goes out and the inverter controller is on, AC power to the inverter-connected circuits will go uninterrupted. This is especially important for RVs with residential refrigerators or critical medical equipment.

The Xantrex Freedom X remote digital panel (\$70 MSRP) was installed to provide complete control of the system from inside the RV.

The system comes set up for permanent AC wiring; however, an optional GFCI receptacle is available for the face of the inverter, so loads may be plugged directly into it. Installation is simplified with integrated spring-clamp terminals for the AC wiring and easy-to-reach studs for the battery connections.

Installation

RVers with experience in DC and AC wiring can certainly do this installation, but it requires planning, tools and equipment. All wiring must conform to applicable NFPA 1192 and NEC 551 codes. When installing an inverter system like this, plan on a sizable amount of DC and AC rewiring.

On the DC side, 2/0-gauge cable was routed from the batteries to the Freedom XC inverter. A heavy-duty crimping tool, the correct size (3/8 or 5/16 inch) copper terminals and heat shrink were needed to manufacture the battery cables. With cable this large, a bolt cutter or large cable cutter will be

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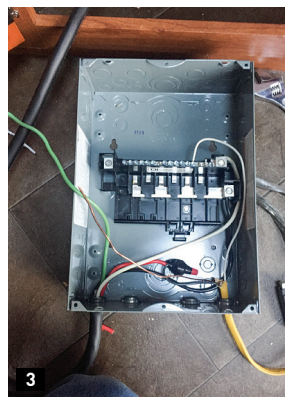
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required to size the cables.

A Blue Sea Systems e-Series battery-cutoff switch was mounted on the front cross member of the frame to allow the batteries to be isolated during storage. Battle Born recommends an automated cutoff relay to be used with its batteries, because the BMS will cut off the batteries internally if they fall below a predetermined voltage and will remain off until they are charged.

Battle Born recommends an automatic battery cutoff that activates at a voltage higher than the battery's internal cutoff. Since the Freedom XC can charge a completely discharged battery, the automatic cutoff was unnecessary.

The AC side was more complex with the addition of a subpanel and reorganization of the existing breaker panel for the installation. Xantrex outlines the requirements of the installation pretty well, but a review of NFPA 1192 codes is a good idea. These fire and safety

1) Beyond the Xantrex Freedom XC inverter-charger system and the Battle Born LiFePO4 batteries, supplies needed include 2/0-gauge battery cable with terminals and heat shrink, fuse, subpanel and GFCI breakers, Romex, wire nuts, electrical tape, junction box, spray-foam insulation and screws. **2)** For the AC wiring that runs up to the inverter and back to the subpanel, we used 10/4 GA SJE00W cable, which is well protected for use in the trailer's enclosed underbelly. **3)** We removed the two 15-amp breakers in the main box for the outlets and microwave, and replaced them with a single 30-amp breaker with 10-amp Romex to the new subpanel, where it was connected to the 10/4 cable to the inverter. **4)** The 10/4 cable was routed to a junction box in the forward compartment next to the Freedom XC, where it was converted over to Romex to link to the inverter's push connectors. **5)** The Freedom XC has convenient push connectors for the 120-volt AC connections, and two lugs for the 12-volt DC battery cables, which we made in-house. **6)** The completed subpanel has two circuits, for the front and rear receptacles, including the refrigerator and microwave. Code requires that the circuits being fed by the inverter are GFCI equipped.

standards are available to view for free at www.nfpa.org.

Two circuits from the main breaker box were relocated to a new Square D QO Load Center — one for the non-GFCI receptacles, which included the bedroom, living room and refrigerator, and the microwave circuit (15-amp circuits). A 30-amp breaker was installed in the main panel, and a 10/3 Romex cable was routed to a junction

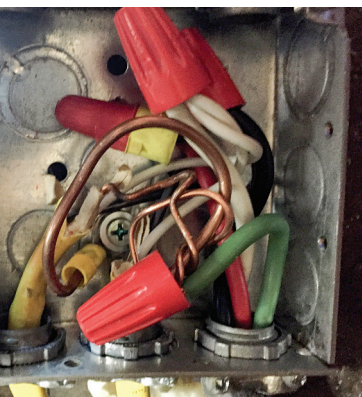
box where it was joined with a 10/4 SJE00W portable cord.

The cord is a heavy-duty, weather- and damage-resistant cable, capable of carrying 700 volts and 30 amps, which is suitable for the load, and running through the floor and under the trailer. This went to another junction box in the front compartment, where it was again joined with 10/3 Romex cable routed to the inverter.

Coming out of the inverter was another 10/3 Romex cable, which fed the second positive conductor in the 10/4 cord. This came back to the junction box and joined with another 10/3 Romex cable, which fed the subpanel.

7) Installed next to the RV control panel, the Xantrex Freedom X remote-display panel allows full control and programming of the inverter-charger. **8)** The Torklift PowerArmor Max battery box is an attractive way to secure the batteries. We installed a marine battery switch to isolate the batteries while the trailer is in storage. **9)** The batteries were wired in parallel and pass through the fuse before going to the Freedom XC. Straps and a movable divider in the box help secure them, and packing foam that came with the batteries was used to pad them.





The subpanel is equipped with two 15-amp GFCI breakers, which are required for inverter installations. Each of the circuits uses the original wiring, which was moved to the subpanel from the main breaker panel.

The Freedom XC was mounted in the front storage compartment on a 1/2-inch base that is screwed to the bed/compartment frame. A 2 1/2-inch hole saw was used to provide a passageway through the floor into the underside of the trailer at the front compartment; an existing plumbing pass-through under the kitchen cabinets was used to route the cables. Access was provided by dropping the trailer's underbelly in the front and opening an existing cutout panel by the freshwater tank under the trailer. Once the project was completed, the holes were sealed with spray-foam insulation.

The placement of the Freedom XC in the front compartment was the only real option to keep the unit safe and the battery cables as short as possible. The integrated control panel is on the top of the unit with an easy-to-activate power button; thus, it can be turned on and off unintentionally. Other Xantrex inverters have the control panel on the leading edge of the unit, but in this case, the control is of a size and complexity that requires it to be located on top. A guard needed to be installed to protect the control panel. We don't regularly need access to this panel because we installed the remote panel inside the RV, so providing a protective cover was of no concern.

Initial Programming

Once the system was completely

connected, we contacted Nichols at Battle Born to properly program the inverter-charger. This is an essential step. Unlike its automatic presets for FLA, gel and AGM batteries, Xantrex has not made a preset for LFP batteries because the algorithms will change based on the individual batteries. There are 23 programmable settings in the unit menus, from vehicle-ignition control (for motorhomes and trucks) to voltage and current values for each stage of charging, and so on.

Nichols worked closely with Don Wilson at Xantrex to determine the proper settings for this system. Once the programming was complete, the system was ready to run the trailer's appliances and accessories.

A setup like this should be built from the foundation up. Plan ahead and install cable, battery storage and AC distribution components that are capable of handling the calculated load and future additions. If you decide you need a larger inverter, for instance, or more batteries, you'll easily be able to add components without having to replace wiring or battery storage.

This system has greatly increased off-grid capability of the test trailer while saving weight in the process. When it comes to boondocking freedom, the future is here. 🚐

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