200407

ETX680-24-TSO Product Manual

Revision Log

Rev	Description	Date
IR	Initial Release	10/10/2024

ICON KEY

* Valuable information

 Caution

 Warning

Table of Contents

Overview

EarthX Lithium batteries are designed as a maintenance free replacement for the 24-volt lead-acid or lithium starter batteries. The Starting Battery (Function) is considered Primary in the electrical system for Part 23 Aircraft. The alternator charging system is considered secondary. Per 14 CFR 23.1309-1E and TSO-C179b, the Failure Condition Classification (FCC) for this TSO Battery is "Major" - unless other installations deem the analysis lessor or greater, dependent on the function in the particular installation Aircraft.

This manual covers the TSO Article (Part) installation aspects for the battery. This manual is an accompanying manual to the Instructions for Continued Airworthiness. For detailed operational information refer to the Aircraft Flight Manual Supplement (AFMS).

Failure to follow all application use, installation, charging, and storage instructions may result in battery damage and or fire! Never disassemble the battery or disable the built-in Battery Management System (BMS).

Technology Inside

Battery Cells

The batteries use cells made of Lithium Iron Phosphate ($LiFePO_4$). This chemistry has great performance and is the safest on the market today.

Lithium batteries have the same charging voltage as a lead acid battery, but there are other differences. The resting voltage (voltage of the battery when not in use) is slightly higher, 26.4 volt versus 25 volt. A lithium battery voltage remains relatively constant while discharging, while voltage for a lead-acid battery decreases more rapidly. As such, a lithium battery's cranking power is stronger, for the voltage while cranking is generally higher.

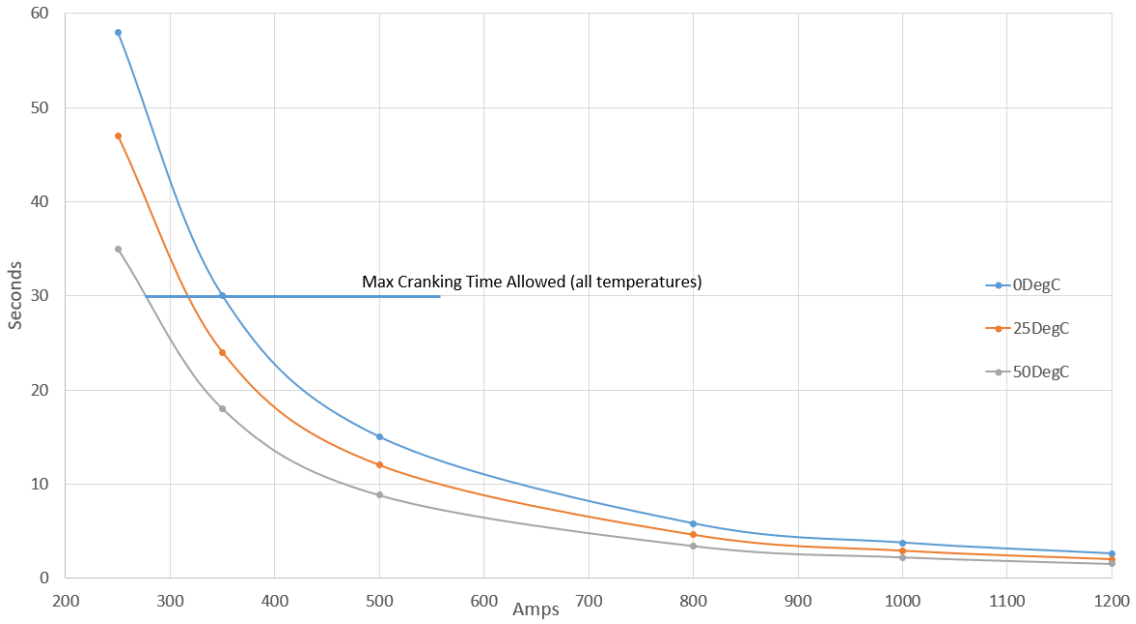
$LiFePO_4$ cells by the nature of their chemistry are 3.3 volt. 24V lithium batteries are created by using 8 cells in series (technically 26.4 V battery). Another difference is that lithium cells are dry cell technology, where the cells are packaged individually. Individual cell's charge level will diverge with repeated charge/discharge cycles and age. This condition reduces the performance of the battery (reduces capacity) without a Battery Management System to monitor, control and protect the cells.

BMS

EarthX's integrated Battery Management System (BMS) monitors each cell's voltage. If the voltage (charge) of a cell exceeds the others, the BMS circuits will work to reduce that cell's charge level. This ensures that the charge level of all the cells remains equal, even with the high discharge and charge current of your aircraft.

The BMS has the following additional protective features; over-charge protection, over-discharged protection (completely draining the battery), excessive cranking protection, high temperature protection and short-circuit protection. **The BMS was designed to Design Assurance Level (DAL), C (major).**

The BMS disconnects the battery from the load if 100% of the usable energy is consumed. The usable energy is the rated Ah of the battery (new battery at 25DegC, see the Specification section within). An over-discharged battery typically has a voltage less than 23V. If the BMS disconnects the battery, the voltage reading of the battery will be zero volts. Excessive cranking protection logic includes current, temperature and time monitoring to limit "high current use" (>100 amps) to 1 -30 seconds in any 60 second period. If the battery terminals are "shorted" (or a low impedance load is connected across terminals), which causes the battery volts to instantaneously drop to a very low level, the battery will disconnect from the load to protect the cells and BMS from damage (short circuit protection). If the BMS disconnects due to excessive cranking protection or short circuit protection, the BMS will automatically reconnect after a cooldown period (typically 1-3 minutes). The BMS is designed for short circuit protection > 1000 Amps.

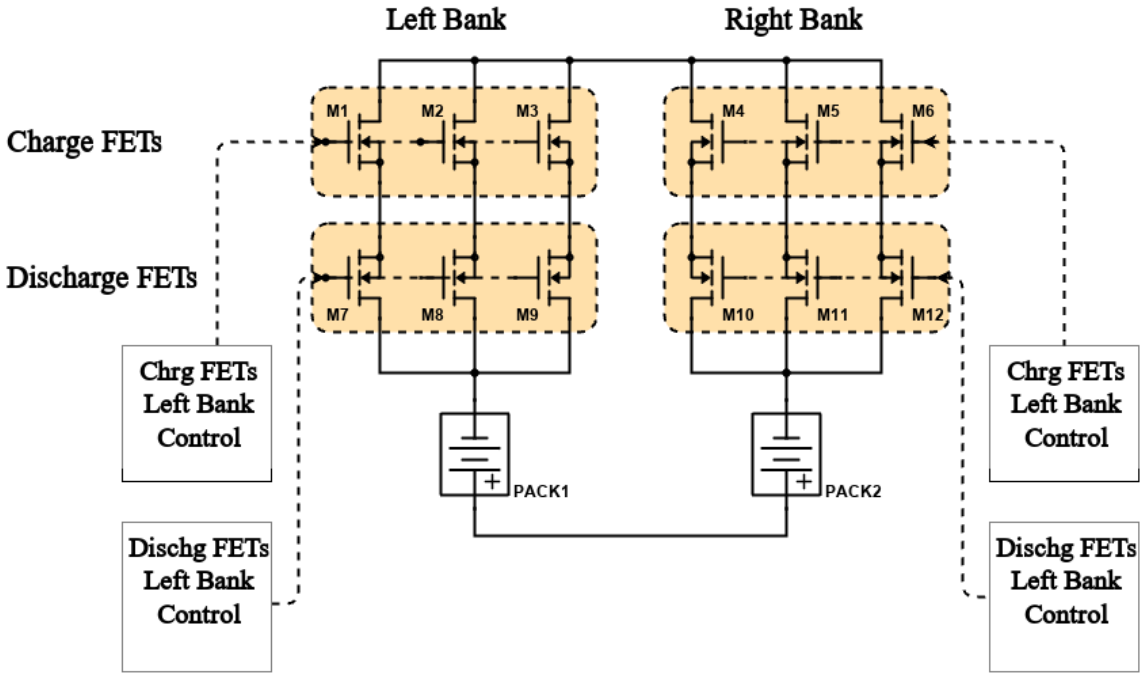


Excessive Cranking Time vs Temperature and Amps

In the event of a charging system failure where the voltage increases above 32V, the charging current is blocked. The time delay for this feature is 3 seconds to allow the aircraft alternators over voltage protection to activate first (typically less than 100ms). This design offers charge voltage protection greater than 100V. The discharge current (current out of battery) is unaffected in this situation. The circuit is like a diode, blocking flow in one direction (charge current into the battery), while allowing current to flow from the battery (discharge current). Once the alternator is shutdown or fails and the voltage returns to < 30 volts, the BMS's over-voltage protection automatically resets (allowing charge current). EarthX requires automatic over-voltage protection (crowbar or other means of shutoff) for alternator type charging systems.

All components associated with main electronic battery disconnect are redundant. The built-in redundancy ensures that no single point failure results in the battery unintentionally disconnecting. The battery also includes a thermal run-away containment system. The

design aligns with the requirements for a FAA approved lithium battery as per RTCA performance specification DO-311A and DO-160.



BMS Block Diagram of Redundancy

The battery's micro-controller monitors all failure modes, and reports failures with a built-in LED indicator, plus a discrete output and RS-232 communication link. The discrete output for external fault monitoring is a single wire connection. The output is a "current sinking" type circuit (see Installation section below) that can handle 100mA (connects the discrete output to battery ground if a fault is present). This output can be connected to an external 24V LED or general-purpose discrete input of an EFIS. The fault output has three states: fast flashing (2 seconds on/ 2 seconds off), slow flashing (5 seconds on/ 5 seconds off) or solid. The fast-flashing fault is an indication of high temperature; temperature exceeding the normal operating or storage limits of the battery (>75C). The slow flashing fault can indicate an improper state of charge or a problem with the cells internal to the battery. The solid fault indicates a BMS hardware failure. See the operating section of this manual for more details.

RS-232 Communications

For more details on the individual Health Status bits see the Instructions for Continued Airworthiness (ICA) manual 20408.

Physical Layer

The following defines the RS232 physical layer attributes:

- Baud Rate: 1200
- Parity: none
- Stop Bits: 1
- Data Bits: 8

Protocol Definition

The following defines the protocol message sequence periodically transmitted at every 5 seconds:

Byte Description
SYNC 1[A] =0xAA
SYNC 2[A] =0x55
DATA BYTES[B]
CHECKSUM [C]

A. Message begins with two synchronization bytes. A unique bit pattern to identify the beginning the message.
B. All data is sent in a Little-Endian format (data is sent least significant byte first and least significant bit first).
C. 8 bit Parity Word is computed on the data bytes of the message.

Data Definition

The following table describes the data bytes.

Num of Bytes	Description	Valid Data Range	Units	Data Type
2	Voltage	0 – 6,000	Centi-volts (100th of volt)	uint16
2	Charge Level	0 - 100	%	uint16
2	Temperature	0 - 250	F	uint16
1	Health Status Bits[A]	n/a	Unit less	int8
1	Charge Status Bits[B]	n/a	Unit less	int8

A. Bit 0=BMS Hardware Problem
Bit1=Cell to Cell Charge Level Mismatch
Bit2= High Temp Warning
Bit3=Over-charged Protection Activated
Bit4= Short-circuit Protection Activated
Bit5=Excessive Cranking Protection Activated
Bit6= High High Temp Protection Activated
Bit7= Cell Over-charged
B. Bit0=Battery Over-discharged
Bit1=Spare
Bit2=spare
Bit3=spare
Bit4=spare
Bit5=spare
Bit6=spare
Bit7=spare

Installation Requirements

"This article meets the minimum requirements of technical standard order (TSO) C179b. Installation of this article requires separate approval." The article may be installed only according to 14 CFR part 43 or the applicable airworthiness requirements. Also, refer to AC 20-184 for full Aircraft installation guidance and requirements not the subject of this manual. Below are the installation specific requirements and is not part of the TSO Part (LRU) specific certification under TSO-C179b:

- The maximum voltage output from aircraft charging system shall not exceed 32 volts for greater than 100msec. Thus, an automatic over-voltage protection device (OVPD) is required on the aircraft charging system.
- The battery fault/status monitoring must be installed and tested.
- The battery vent system must be installed (see installation section of this manual).
- The cranking current demand should not exceed those listed in the Specification section below.
- The capacity demand (storage requirement) should not exceed the battery capacity listed in the Specification section below.
- The battery must be installed in such a manner and or location to limit radiant and convection heating. The maximum short term (30 minute) environmental temperature of the battery location shall not exceed the value listed in the specifications section below and the short term ground temperature shall not exceed 85°C. See the specification section for more information.
- The battery should be secured in the existing battery box or battery holder as detailed in this manual or aircraft manufacturer's manual.

The maintenance must comply with the requirements of the Instructions for Continued Airworthiness (ICA), a separate document.

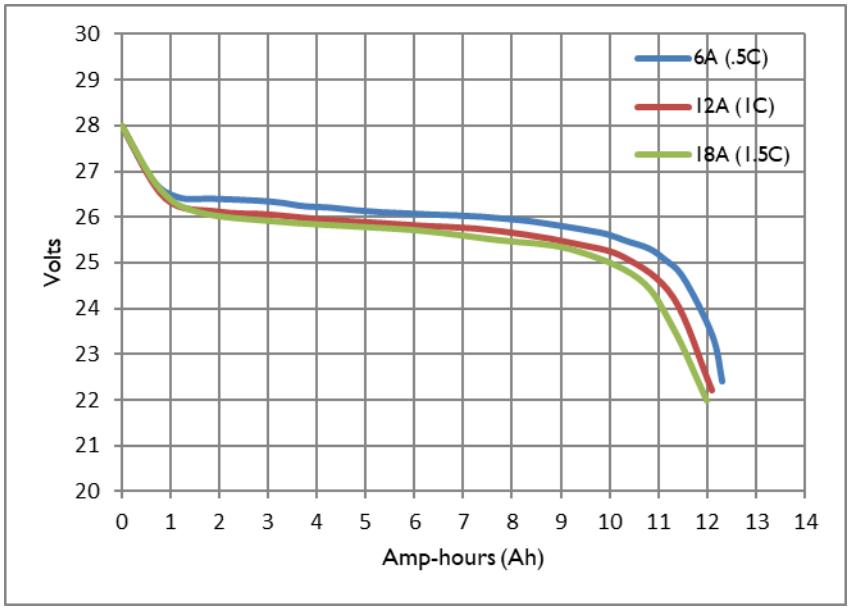
Specifications

Voltage	26.4 V
Capacity (1C, 1hour rate at 23 °C)	11.7 Amp-hour (Ah)
Capacity vs Temperature	25 °C = 100% 0°C = 97% -30°C = 95% (11.3Ah at this temperature) -40°C = 92% (10.7Ah at this temperature)
Self-Discharge Rate	<3%/month @ 25°C
Peak Power (Ipp), 23/-18 °C	850 / 400 amps
Rated Power (Ipr), 23/-18 °C	500 / 250 amps

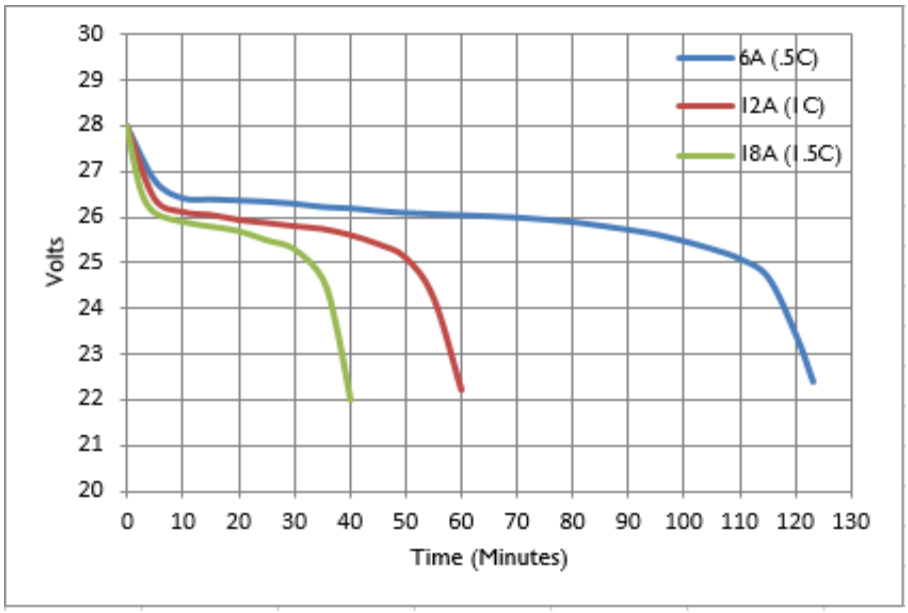
Max Continuous Discharge Amps (Discharging 100% of capacity)	24A
Standard Charge Voltage	27.6 – 28.8 V
Recommended Charger/Maintainer Amps	5 - 15A
Rated Life (recommended replacement time)	6 Years
Weight	7.2lb (3.27Kg)
Dimensions	6.5in (L) x 5.1in (W) x 6.6in (H) 166mm(L)x129mm(W)x168mm(H)
Environmental Rating (resistance to water intrusion)	IP 66 (wash down with a high-pressure washer)
Operating Temperature (short term)	-30 °C to +60 °C (+65 °C for 30minutes)
Storage Temp	-40 °C to +70 °C
Short Term Ground Survival Temp	85 °C (30 minutes)
Maximum Altitude	25,000 Ft
Shelf Life	1 year (without charging)
FAA Standard Order	TSO-C179b
Design Assurance Level (DAL)	C (major)
Flammability Rating (case and vent tube)	14CFR 25.853 (a)

Discharge Curves

The first graph below shows the state-of-charge versus voltage at 23°C. Typically, lithium batteries require advanced methods like current counting to track the charge level. As seen from the graph, the voltage only varies .8V for 80% of the discharge cycle (26.8V is almost a full charge, while 25.5V is an indication of a discharged battery). The graph also illustrates that usable Ah is nearly the same regardless of the discharge rate (blue, red and green discharge trend lines are nearly on top of each other), with the voltage remaining above 23V for most of the discharge cycle.



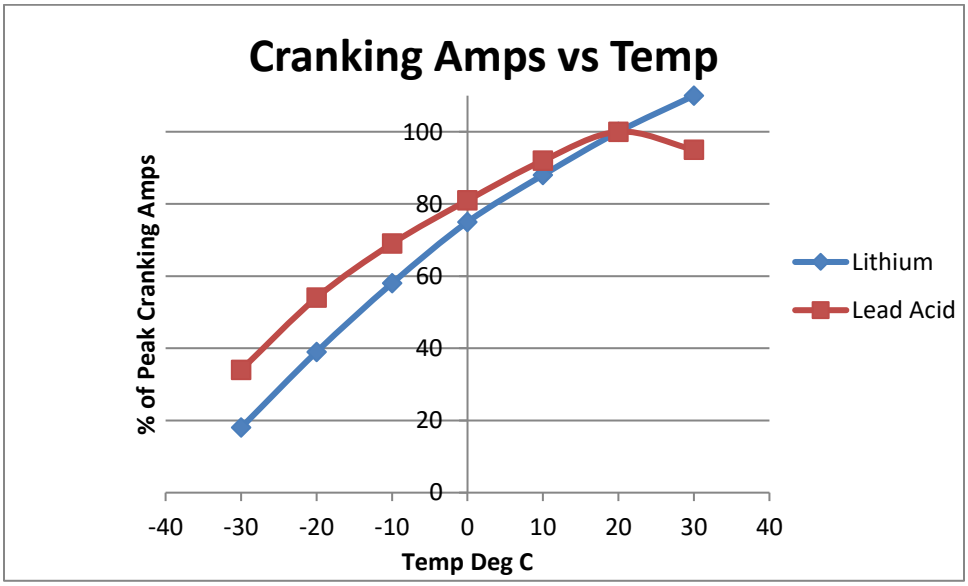
Discharge Capacity



Discharge Time

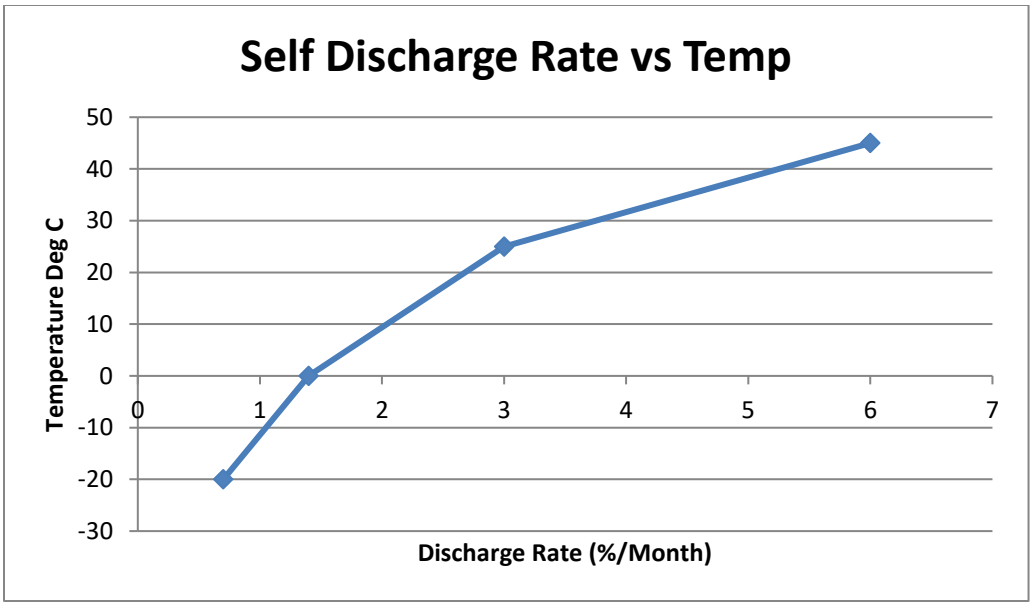
Discharge Versus Temperature

We use a similar Cold Cranking Amp test standard as the lead acid battery manufacturers (DO-311A IPP/IPR test performed at 0°F). As such, our battery with a similar cold cranking rating as a lead acid battery should provide the same cranking performance at 0°F. But, below 0°F an equivalent lead acid battery will outperform a lithium battery (see the graph below).



Self-discharge Rates

The self-discharge rate is dependent on temperature. At high temperatures (>25°C), the cell internal resistance decreases so the self-discharge rate increases. See the graph below for self-discharge rates (in % per month) versus temperature.



Installation

The instruction given here is generic. For a specific aircraft, refer to the installation instructions in the accompanying manual.

Remove all metal objects from your person before handling the battery and use insulated tools for installation.

The power terminals are ALWAYS live. Do not short across the terminals. Use caution when handling the battery inside the aircraft around metallic structures.

Battery Installation Location

The battery is designed to be mounted in a variety of locations within the aircraft including the engine compartment, baggage compartment or cabin as long as the environmental condition in those locations do not exceed the battery's specifications (see the specifications section and environmental qualification section of this manual). The battery can be mounted upright or on its side.

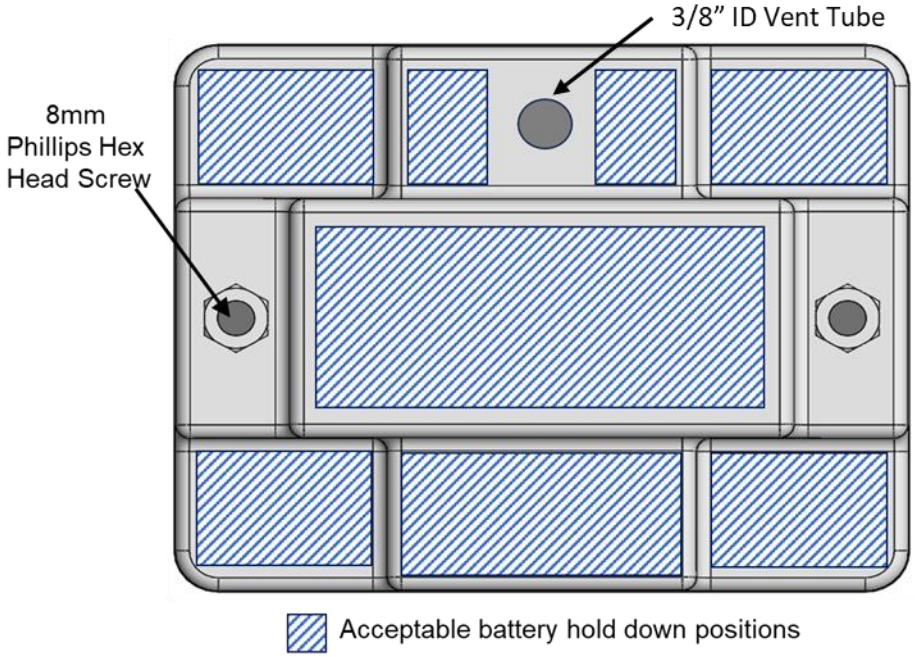
In the extremely improbable event of a battery thermal runaway the external surfaces of the battery and the vent gas tubing may reach 300°F. The battery and vent tube shall not be located near or touching aircraft structures that could be damaged by such temperatures.

Battery Installation

It is recommended you check the voltage before installing. If the voltage is below 26.4V, charge the battery before installing. Follow these steps to properly and safely install your new battery. Qualified personnel should inspect the box, connections and venting provisions in accordance with AC 43.13-1B Section 2. STORAGE BATTERIES (refer to 11-19). BATTERY MAINTENANCE (including d. Mechanical Integrity).

1. Remove the old battery, while paying attention to the routing and placement of wires, cables and protective covers.
2. Check the battery cables and connectors for corrosion or damage. Pay special attention to the positive battery cable (red cable), checking for cuts or wear marks in the insulation. Clean and or replace the battery cables as required.
3. Mount the battery in an approved battery box /hold down, or the existing battery box with the approved spacer.
4. Connect the positive (red) cable first. Make sure the Phillips screw is securely fastened (55in-lbs), but do not over-tighten. Next, connect the negative (black) cable. Do not connect the battery in reverse polarity (positive to negative or negative to positive).
5. Re-install the battery holder or strap and tighten securely. Re-secure all the wires and cables.

A battery holder or battery box can contact any part of the bottom and sides of the battery, and any area on the top of the battery as indicated in the figure below.

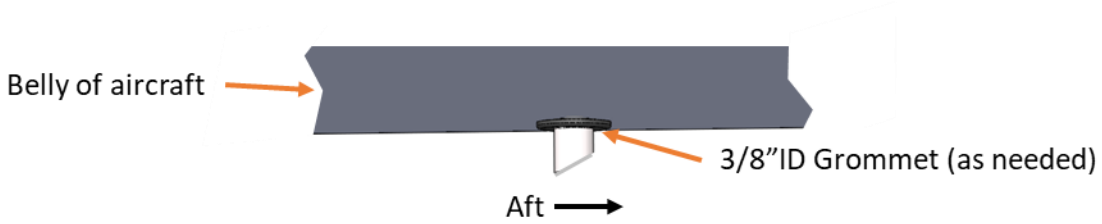


Battery Vent Installation

This battery includes a thermal run-away containment system. The containment system includes a vent tube designed to carry vapor or smoke to the exterior of the aircraft in the

event of a thermal run-away condition. There are no emissions during normal operation. For specific installation instructions based on the type of aircraft and or battery mounting location, see the Appendix. Plus, follow the below guidelines for properly installing the vent tubes.

- Route the vent tubes to the outside of the aircraft or a compartment sealed-off from the passenger cabin that is vented to the outside. Be sure emitted gases will not be directed to cabin air intakes. Vent tubes should use existing battery drain fittings on exterior of the aircraft if available. Leave at least 1" exposed on the outside of the aircraft. Cut the tube at a 45° angle towards the aft of the aircraft.



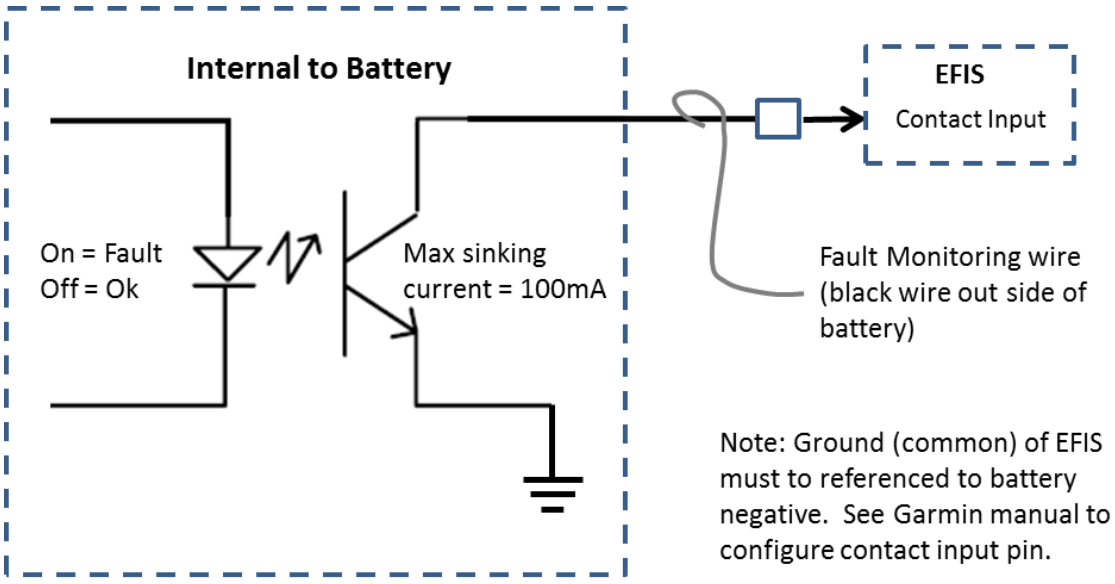
- Routing of vent tubes should include a 6" or longer or downward sloping section so condensate drains to the outside of the aircraft.
- Secure the vent tubes within 12" of the battery and or within 12" of the aircraft exit.
- Be careful not to crush or restrict flow through the tubing.
- The minimum bend radius is 3"; tighter bends could cause the tubing to kink.
- The vent tubing should be chemical resistant and rated for 500°F (i.e. EarthX typically supplies Teflon tubing).
- To install tubing to barbed fittings it is helpful to heat the tubing to a couple hundred degrees F.
- Be sure the entire barbed part of the fitting is completely inserted into the tubing.

If required 90° elbows may be used to make small radius corners. Fittings must be brass, stainless, Teflon or other material with at least a 400 °F temperature rating (i.e. nylon). Barbed fittings must not restrict flow.

Fault Monitoring Installation Options

The ETX-Hundred Series batteries have a discrete output that can be connected to many aircraft Electronic Flight Instrument System (EFIS) electronics or to a remote mounted LED. If a panel mount LED is used it should be yellow or amber in color. If an EFIS is used, the user defined alerts should also be yellow (caution). Throughout this document the text LED can be used to refer to either a physical battery fault/status LED or the EFIS alert text. The diagrams below detail the required connections for each type of installation.

The discrete output for external fault monitoring is a single wire (see connector pinout below). The following example details how to connect the fault monitoring output to an EFIS general purpose discrete input. The EFIS DC source negative must be referenced to the battery negative (this is the standard configuration).

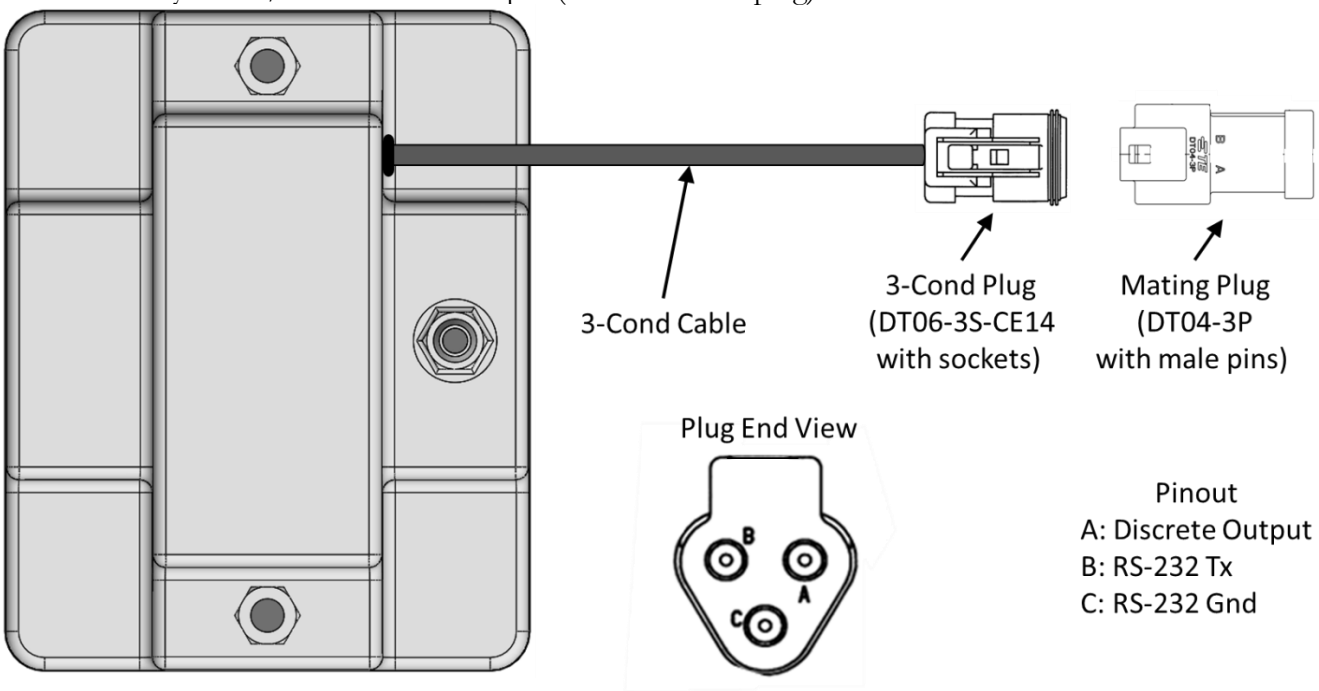


Fault Monitoring Connection to Garmin EFIS

Configure the digital input (contact input) as "active low", "user defined alert" type.

Fault Connection to LED

Connect the LED's red wire (positive) to a spare or existing fuse or breaker off the electrical bus. Use any .25 Amp to 2 Amp fuse or breaker. Connect the LED's negative to the battery's fault/status discrete output (Pin A of 3-Pin plug).



RS-232 Communications Connection

The battery's BMS can communicate to an EFIS like the G1000 over RS-232. The RS-232 link will report battery volts, battery temperature, battery State of Charge (SoC), and reports specific faults (see the communication specification below). Connect EFIS RS-232 receive to Pin B and ground to Pin C.

Return to Service Checks (Tests)

Follow these steps to check the battery operation prior to returning to or putting in service:

1. Verify the vent tube protruding for the aircraft can NOT be pushed up and into the interior of the aircraft with the force of an index finger.
2. Apply power to the aircraft via master switch, observe proper voltage, greater than 26V.
3. Verify the battery Fault/Status LED is off (no faults).
4. Press the LED "push-to-test" and observe the LED illuninates (if equiped).
5. At the battery, jumper the fault/status discrete output to battery negative terminal using a test clip and verify BOTH the panel LED and battery LED are lit.
6. Configure the aircraft for max typical cruise loads and verify it is less than 40 amps. Also, configure aircraft for load shed load and verify it is less than 11.5 amps. If either exceeds these values, conduct a complete Electrical Load and Capacity Analysis as detailed in the Appendix.
7. Verify engine starts as normal (if starter battery installation).

Aircraft Voltage Monitoring Equipment (if applicable)

The table below shows the recommended user alerts based on voltages when in flight. This pertains to existing equipment and is not applicable if existing low or high voltage alerts do not exist or are not adjustable.

The low charge level is very different from a lead acid battery, for a lithium battery is completely drained at approximately 23V.

Note: this table pertains to existing voltage level warning equipment and is NOT associated with the Fault monitoring LED.

Voltage	User Alert
>30V	High voltage warning
<27V	Alternator off-line alert
<25.6V	Low charge level warning

Operating Instruction

The battery has no manual operation; it is "plug and play". For details on battery status / faults, see the Aircraft Flight Manual Supplement (AFMS).

The table below is a summary of the battery's fault codes (RS-232 Communications).

Health Status Bit	Possible Cause	Considerations

Bit0: BMS Hardware Problem	BMS electronics issue	The pilot should report to maintenance personnel. Do not dispatch aircraft.
Bit1: Cell to Cell Charge Level Mismatch	Cell to cell charge level imbalance	The pilot should report to maintenance personnel (note how long the fault light was on). Do not dispatch aircraft.
Bit2: High Temp Warning	High battery temperature (> 70°C / 158°F). High environmental temperatures.	The pilot should report to maintenance personnel. Do not dispatch aircraft.
Bit3=Over-charged Protection Activated	Over-charging (due to faulty charging system)	The pilot should report to maintenance personnel. The over-voltage condition should be resolved; either by automatic operation like an over-voltage protection device or by the pilot (per aircraft flight manual). The pilot should make preparations to land prior to the battery's reserve capacity being depleted. Do not dispatch aircraft.
Bit4= Short-circuit Protection Activated	Aircraft electrical system short-circuit or engine cranking in extremely cold temperatures	The pilot should report problem to maintenance personnel. The battery's discharge current is shutoff and will automatically turn on when short is removed.
Bit5=Excessive Cranking Protection Activated	More than 15 seconds of engine cranking within any 1-minute period	The battery's discharge current is shutoff and will automatically turn on when battery cools down (typically 90 seconds).
Bit6= High High Temp	Battery internal temperature is greater than (> 85°C / 185°F)	The pilot should report to maintenance personnel. Sustain from cranking or charging until battery cools. This could be the result of very hot environmental temperatures. Do not dispatch aircraft.
Bit7= Cell Over-charged Warning	Over-charging cell (due to internal battery cell problem)	The pilot should report to maintenance personnel. Do not dispatch aircraft.

Charge Status Bit	**Possible Cause**	**Considerations**
Bit0: Battery Over-discharged	BMS electronics issue	The pilot should report to maintenance personnel.

Maintenance

This is a maintenance free battery with no internal replaceable components. Charging is only required as needed (see charging section in this manual).

Inspection and testing is required annually. For more details, see the ICA.

Warranty

EarthX, Inc. (Manufacturer) warrants its lithium batteries (hereafter referred to as Battery or Batteries) to be free of defects in material and workmanship for a period of two years. A dealer is not authorized to issue a replacement battery without prior authorization from EarthX, Inc.

The applicable Warranty period begins from the date of purchase on original receipt, or, if no receipt is available, from the manufacturing date on the battery. The warranty is non-transferable and for the original purchaser. Batteries determined to meet the conditions of this warranty will be replaced free of charge one time. For warranty replacement consideration, fill out the online warranty submission form located on the EarthX website. EarthX' s acceptance of any items shipped to EarthX for warranty replacement shall not be deemed an admission that the item(s) are defective. For international warranty returns, the customer will pay the shipping expenses. Batteries replaced under the warranty provisions will carry only the remainder of the original applicable Warranty period.

See our website at https://earthxbatteries.com/ **for details.**

Appendix I DO-311a and DO-160 Testing

DO-311A Test Summary

Test Description	Section	Reportable Information
Physical Examination	2.4.4.1	Passed functional performance per DO-311A, Section 2.2.1.1
ATP	2.4.4.2	Passed functional performance per DO-311A, Section 2.2.1.2
Insulation Resistance	2.4.4.3	Passed functional performance per DO-311A, Plastic non-conductive lid, no heaters
Handle Strength	2.4.4.4	N/R, no handle on battery
Capacity	2.4.4.5	Passed functional performance per DO-311A, Section 2.2.1.5
Capacity at Low & High Temperatures	2.4.4.6	Passed functional performance per DO-311A, Section 2.2.1.6
Constant Voltage Discharge for High-Rate Batteries	2.4.4.7	Passed functional performance per DO-311A, Section 2.2.1.7
Charge Acceptance	2.4.4.8	Passed functional performance per DO-311A, Section 2.2.1.8

Charge Retention	2.4.4.9	Passed functional performance per DO-311A, Section 2.2.1.9
Cycle Test for High-Rate Batteries	2.4.4.10	Passed functional performance per DO-311A, Section 2.2.1.10
Rapid Discharge at Short Time Operating High Temperature	2.4.4.11	Passed functional performance per DO-311A, Section 2.2.1.11
Short Circuit with Protection Enabled	2.4.4.12	Passed functional performance per DO-311A, Section 2.2.1.12
Overdischarge	2.4.4.13	Passed functional performance per DO-311A, Section 2.2.1.13
Overcharge	2.4.4.14	Passed functional performance per DO-311A, Section 2.2.1.14
Short Circuit of a Cell	2.4.5.1	Passed functional performance per DO-311A, Section 2.2.2.1
Short Circuit without Protection	2.4.5.2	Passed functional performance per DO-311A, Section 2.2.2.1
Over discharge without Protection	2.4.5.3	Passed functional performance per DO-311A, Section 2.2.2.2
Single Cell Thermal Runaway Containment	2.4.5.4	N/R, this test is not required when thermal runaway containment testing is done with two or more cells in thermal runaway
Battery Thermal Runaway Containment	2.4.5.5	Passed functional performance per DO-311A, Section 2.2.2.4
Explosion Containment	2.4.5.6	Passed functional performance per DO-311A, Section 2.2.2.5
Drop Impact Test	2.4.5.7	N/R, this battery is not for a portable device
Remarks There is no deviation to the test requirements. If test is marked N/R, it is not required due to the battery construction or battery energy category.		

DO-160 Environmental Qualification Form

The following table is the DO-160 testing Environmental Qualification form.

Nomenclature: Rechargeable Lithium Battery System
Model: ETX680-24-TSO
TSO Number: TSO-C179b
Manufacturer: EarthX
Revision & Change Number of DO-160: G, Dec8, 2010 Date Tested: Oct 30, 2020

Conditions	**Section**	**Description of Tests Conducted**
Temperature and Altitude	4.0	Equipment tested to Categories:
Low Temperature	4.5.2	B3, -30DegC, Short Term -45 DegC
High Temperature	4.5.4	B3, 60 DegC, Short Term 70 DegC
Ground Survival	4.5.1&4.5.3	B3, -45 to 85 DegC
Loss of Cooling	-	Equipment Category X, no auxiliary cooling
Altitude	4.6.1	Equipment tested to Cat. B3
Decompression	4.6.2	Equipment tested to Cat. A3, 50,000ft
Overpressure	4.6.3	Equipment tested to Cat. A3, -15,000ft
Temperature Variation	5	Equipment tested to Categories B

Humidity	6	Equipment tested to Categories B
Operational Shock and Crash Safety	7	Equipment tested to Categories B
Vibration	8	Equipment tested to Category R, S, and U aircraft zone 1 and 2 for fixed wing turbojet engine aircraft, fixed wing unducted turbofan engine aircraft, helicopters, and fixed wing reciprocating/turbojet engine aircraft (multi or single engine) less than 5,700kg using vibration test curves B, B1, C, C1, G, G1, L, M, R and F
Explosive Atmosphere	9	Equipment identified as Category X, no test performed
Waterproofness	10	Equipment tested to Categories R
Fluid Susceptibility	11	Equipment tested to Categories F Equipment spray tested
Sand and Dust	12	Equipment identified as Category X, no test performed
Fungus	13	Equipment identified as Category X, no test performed
Salt Fog	14	Equipment tested to Categories S
Magnetic Effect	15	Equipment tested to Categories X, no test performed
Power Input	16	Equipment tested to Categories B(RX), loss of power or low voltage tests not applicable for the equipment is a power source
Voltage Spike	17	Equipment tested to Categories A
Audio Frequency Conducted Susceptibility	18	Equipment tested to Categories B
Induced Signal Susceptibility	19	Equipment tested to Categories B(CX)
Radio Frequency Susceptibility	20	Equipment tested for conducted susceptibility to Categories R and for radiated susceptibility to Category G (100MHz – 1GHz) and D (1GHz -18GHz).
Radio Frequency Emission	21	Equipment tested to Categories P
Lightning Induced Transient Susceptibility	22	Category B4K3L3. Equipment tested to pin test waveform set B, level 4. Cable bundle test waveform K3L3.
Lightning Direct Effects	23	Equipment identified as Category X, no test performed
Icing	24	Equipment identified as Category X, no test performed
Electrostatic Discharge	25	Equipment tested to Categories A
Fire Flammability	26	Equipment identified as Category X, no test performed.
Other Tests: Flammable Material		Fire resistance tests were conducted on battery case and vent tubing in accordance with FAA regulations Part 25, Appendix F
Remarks - No critical frequency was identified.		

-Fluid susceptibility test was conducted with the following fluids: piston engine fuel, synthetic hydraulic fluid, mineral based lubricating oil, isopropyl alcohol solvent, ethylene glycol, and insecticide.