200407 Rev-

Installation & Maintenance Manual (IMM), ETX680-24-TSO Battery

Revision Log

Rev	Description	Date
New	Created New	11/6/2020

ICON KEY

Valuable information

Caution

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 Category I and II 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 ETX900-TSO Battery to be installed on 14 CFR part 23 Aircraft. Refer to AC 20-184 for full Aircraft installation guidance and requirements not the subject of this manual.

Failure to follow all application use, installation, charging, and storage instructions may result in battery damage and or fire!

Technology Inside

Battery Cells

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

Lithium batteries are fundamentally different than lead-acid batteries. A lithium battery voltage remains relatively constant while discharging, while voltage for a lead-acid battery decreases. As such, 16Ah lithium battery has the equivalent "useable" capacity. What do you mean here? Also, 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. 12V/24V lithium batteries are created by using 4 cells/8 cells in series (technically it is a 13.2V / 26.4 V battery). The typical full charge resting voltage is >13.3V for a 12V replacement battery and 26.6V for a 24V replacement battery. Another difference is that lithium cells are a dry cell technology, where the cells are packaged individually. As such, the individual cell's charge level will diverge with repeated charge/discharge cycles and age. This condition reduces the performance of the battery (reduces capacity), for the battery charge level is only as good as the charge level of the weakest cell.

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 (> 100Amps) and charge current (>10Amps) 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 it is drained to less than 3-5% remaining charge (an over-discharge condition). An over-discharged battery typically has a voltage less than 22V. 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" (engine cranking) to 10 -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.

In the event of a charging system failure where the voltage increases to above 32V, the charging current is blocked. The time delay for this feature is 2 seconds to allow the aircraft alternator's 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.

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.

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 with a ¼" quick connect terminal. The output is a "current sinking" type circuit (see diagram 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. 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 RS-232 Communications section of this manual for more details.

RS-232 Communications

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 (100^{th} 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 Warning
   Bit1=Cell to Cell Charge Level Mismatch Warning
   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 Warning
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. Below are the installation specific requirements and is not part of the TSO Part (LRU) specific certification under TSO-C179b:

- The maximum charge rating is 70 amps, so the aircraft alternator rated output must be <=70 amps or other means to limit battery charge current to 70 amps.
- 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 monitoring must be installed and tested.
- The battery vent system must be installed (see installation section of this manual).
- The battery must be installed in such a manner and or location to limit radiant and convection heating. The maximum short term environmental temperature of battery location should be less than 85°C.
- And other ratings as listed in the Specifications section of this manual.

The installation and maintenance must comply with the requirements of the Instructions for Continued Airworthiness (ICA), a separate document and any requirements of an accompanying STC.

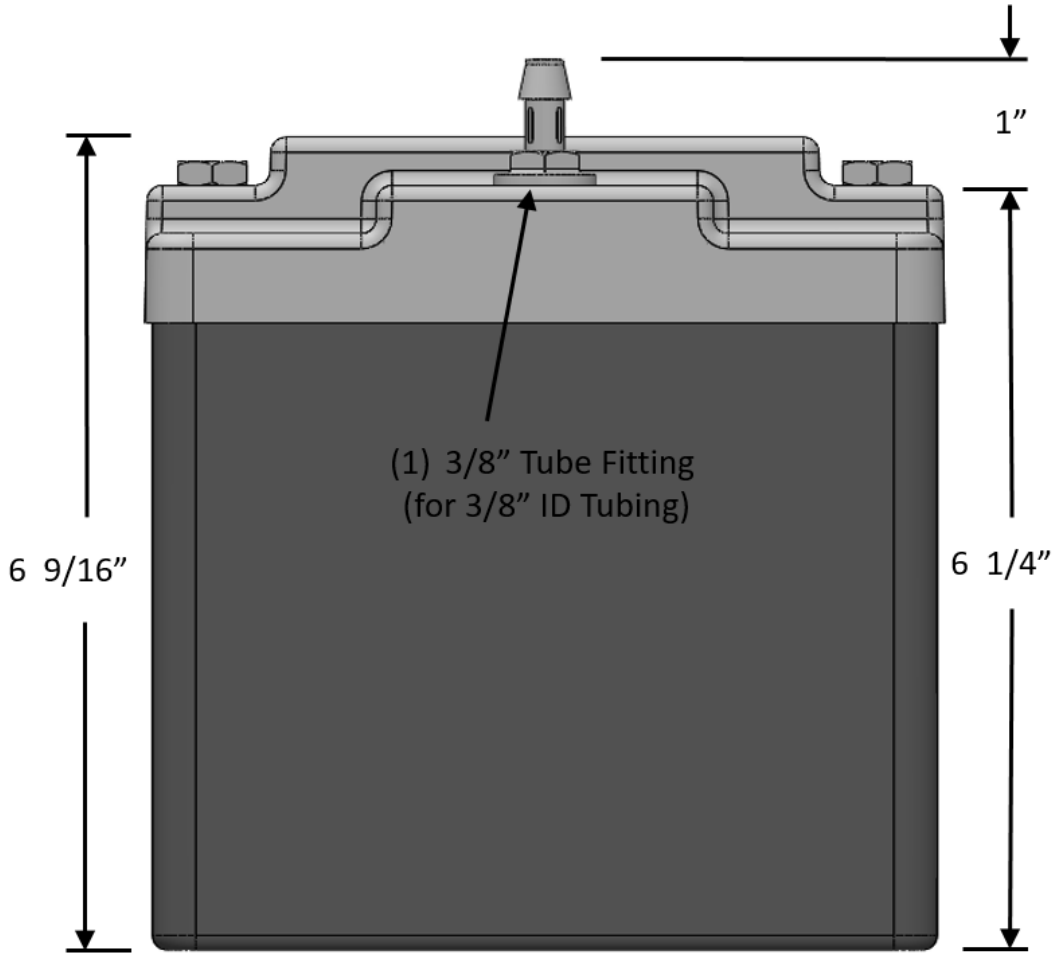
Specifications

Model: ETX680-24-TSO

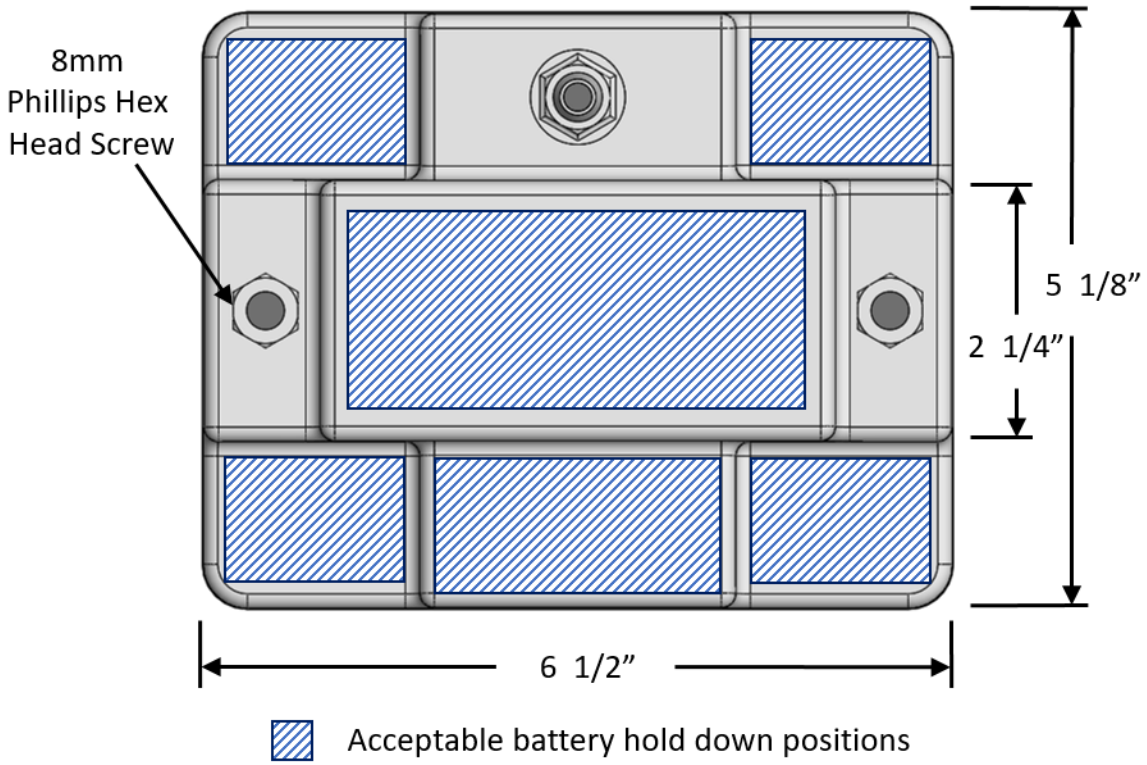
Voltage	26.4 V
Capacity (1C, 1hour rate at 23°C)	11.7Ah @ 1C rate (See below)
Capacity vs Temperature	25 °C = 100% 0°C = 97% -30°C = 95% (11.3Ah at this temperature)
Self-Discharge Rate	<3%/month @ 25°C
Peak Power (Ipp), 23/-18 °C	850 / 400 amps
Rated Power (Ipr), 23/-18 °C	500 / 250 amps
Max Continuous Discharge Amps (Discharging 100% of capacity)	24A
Standard Charge Voltage	27.6 – 28.8 V
Recommended Charger/Maintainer Amps	5 - 15A
Max Charge Amps	70A (from aircraft charging system)

Life (Charge cycles)	4000 cycles @ 1C discharge rate, 25°C (20% depth of discharge) 2000 cycles @10C discharge rate, 25°C (80% depth of discharge)
Life (Years)	Up to 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	50,000 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)

Back View



Top View

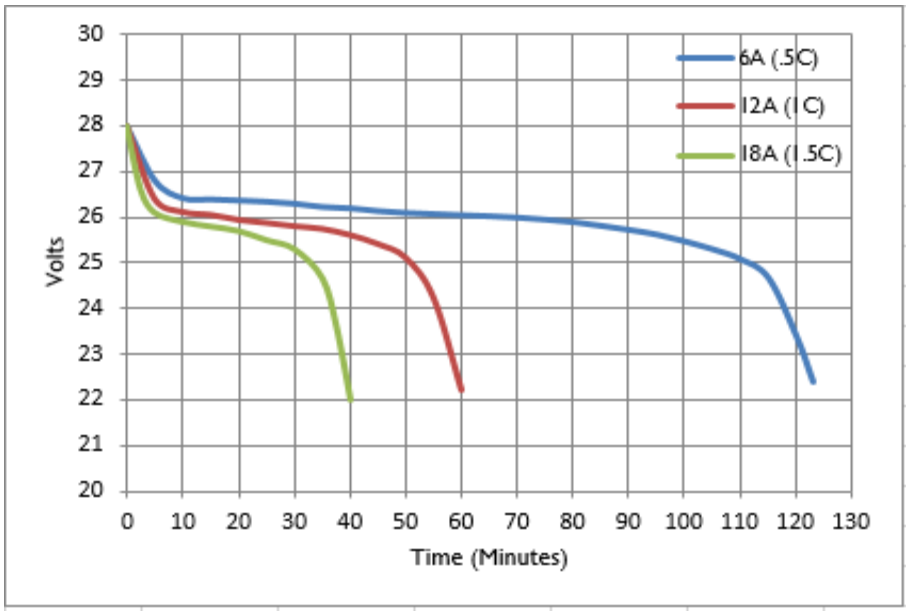


Discharge Curves

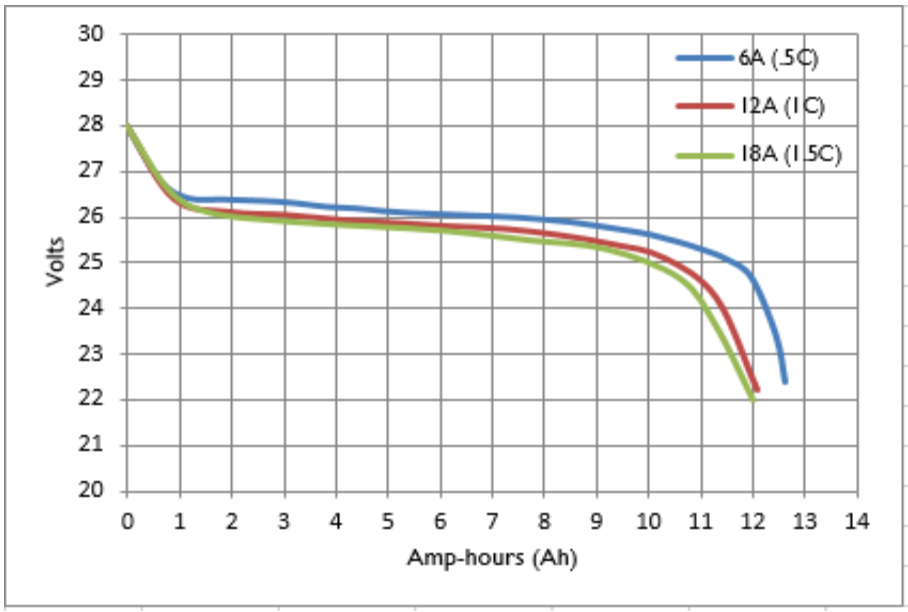
The first graph below shows the state-of-charge versus voltage at a 1C discharge rate. Typically, lithium batteries require advanced methods like current counting to track the charge level. As seen from the graph, the voltage only varies .8V for nearly 80% of the discharge cycle at 25°C. 26.8V is a good indication of full charge, while 25.5V is an indication of a deeply discharged battery at 25°C.

The graph below illustrate that usable Ah is nearly the same regardless of the discharge rate (discharge graph lines are nearly on top of each other), with the voltage remaining above 23V for most of the discharge cycle.

Like lead acid batteries, lithium batteries' discharge performance is lower as the temperature decreases, meaning the voltages and the Ah are lower. Note: there can be as much as a 15% decrease in Ah and discharge voltage at -30°C as compared to 25°C.



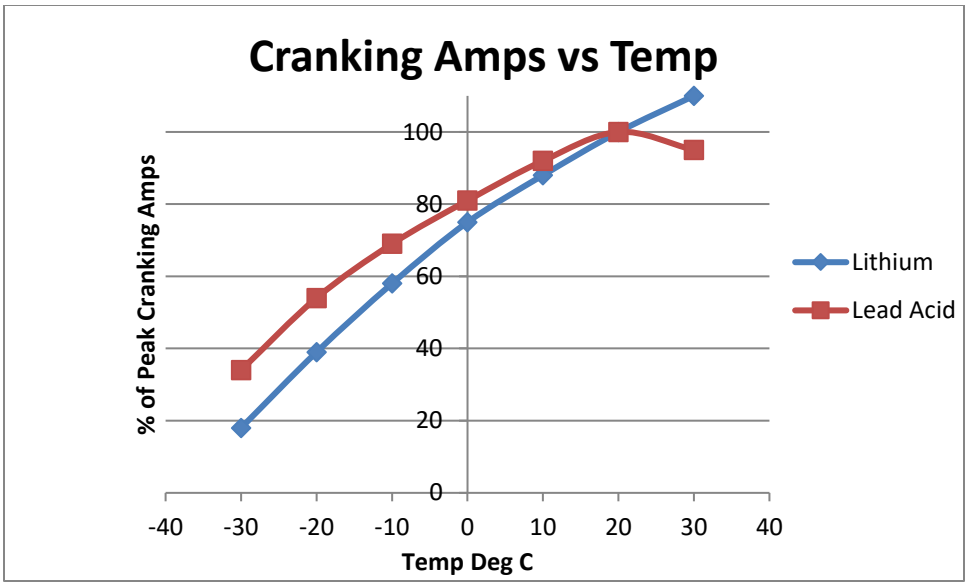
Discharge Time



Discharge Capacity

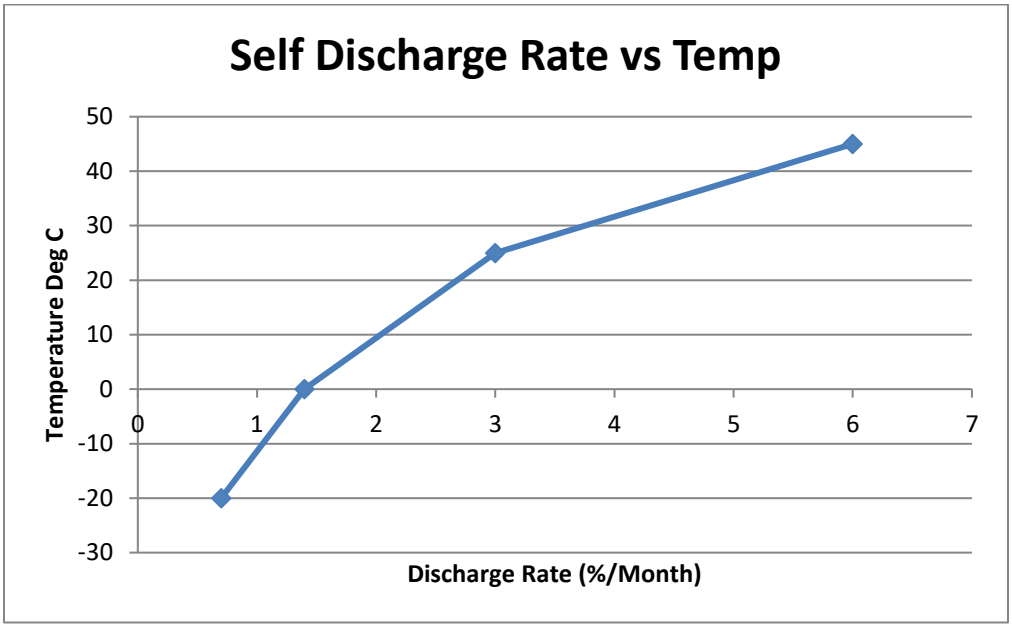
Discharge Versus Temperature

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 and is NOT the sole installation instruction for a particular aircraft. Appendix B has a block diagram of a typical installation. For a specific aircraft, refer to the documentation listed in the Appendix of the Instructions on Continued Air Worthiness (ICA) 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.

Battery Installation

Lithium Iron Phosphate batteries are very robust, but if mishandled or misused they can rupture and they can burn. Never disassemble the battery or disable the built-in Battery Management System (BMS). 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 ETX Lithium battery.

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 or the existing battery box with the approved spacer (see Appendix for specific instructions).

4. Connect the positive (red) cable first. Make sure the Phillips screw is securely fastened (45in-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 with zip-ties or other fasteners. See specification section above for battery

dimensions and for recommended battery hold down bracket positions on the battery.

Be careful that the positive battery terminal does not or will not touch any metal parts of the aircraft.

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.
- Routing of vent tubes should include a 6" vertical section after exiting the battery and a downward slope so condensate drains to the outside of the aircraft.
- Secure the vent tubes within 12" of the battery and 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.
- Only EarthX supplied tubing should be used. The tubing is chemical resistant and rated for 500°F (Teflon 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. To install the supplied elbows, it is helpful to heat the tubing to a couple hundred degrees F before pressing them into the tubes. Be sure the entire barbed part of the elbow is completely inserted into the tubing.

 Installation of the battery in the cockpit requires the battery is properly vented over-board.

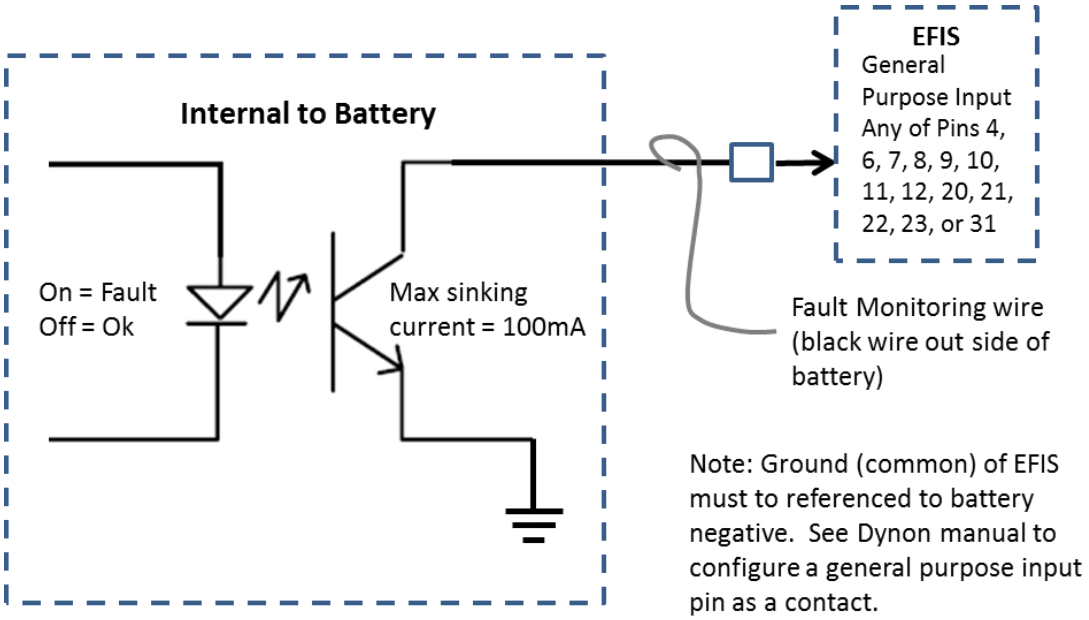
Fault Monitoring Installation

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. Alternately, RS-232 serial communication connection can be made to an EFIS. The diagrams below detail the required connections for each type installation. For specific installation instructions based on the type of aircraft and or battery mounting location, see the Appendix or refer to the instruction given in the STC.

To test the internal LED and or external LED, touch the fault monitoring wire to battery negative.

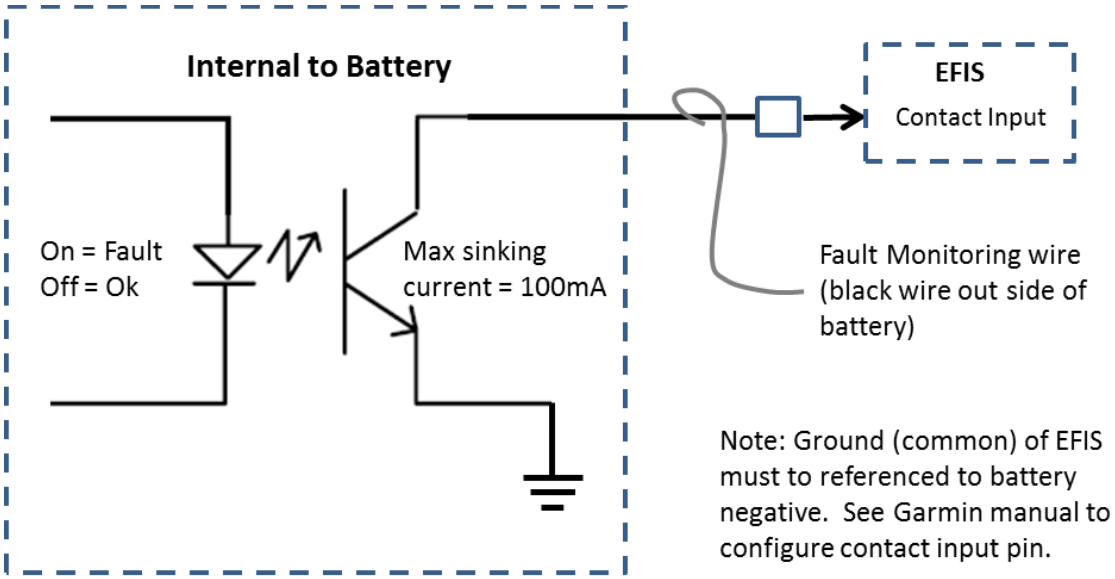
The discrete output for external fault monitoring is a single wire with ¼" quick connect terminal. The ¼" quick connect terminal is an insulated "female" type and should be compatible with most other manufacturers male ¼" quick connect terminals. The following two examples detail how to connect the fault 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 Dynon Avionics



Configure the input as "active low", "alarm" type. Note; when Dynon power is off the LED inside battery may be dimly lit (less than 120uA, too small to drain the battery).

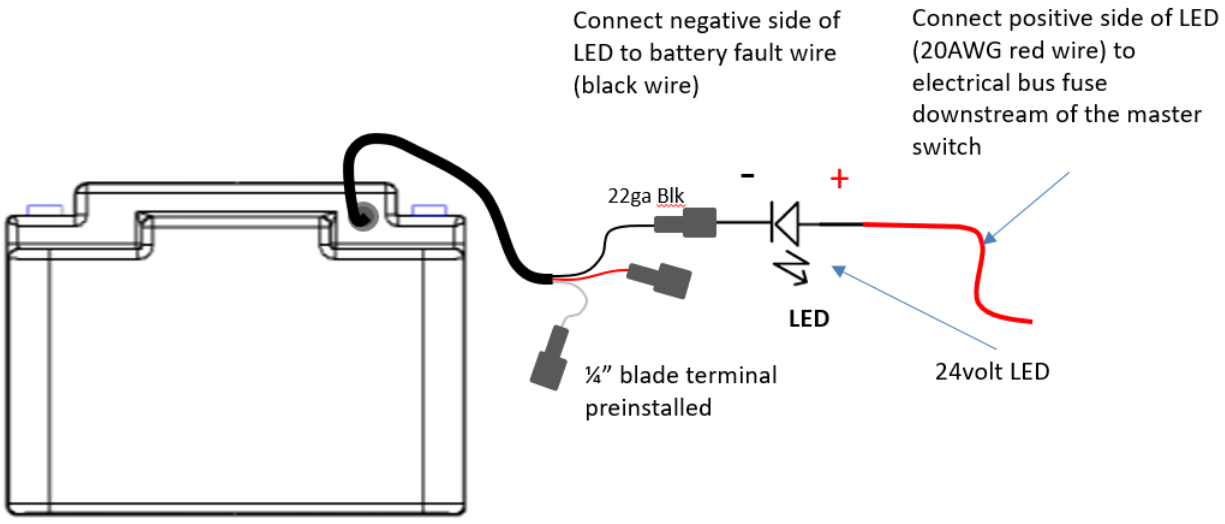
Fault Monitoring Connection to Garmin EFIS



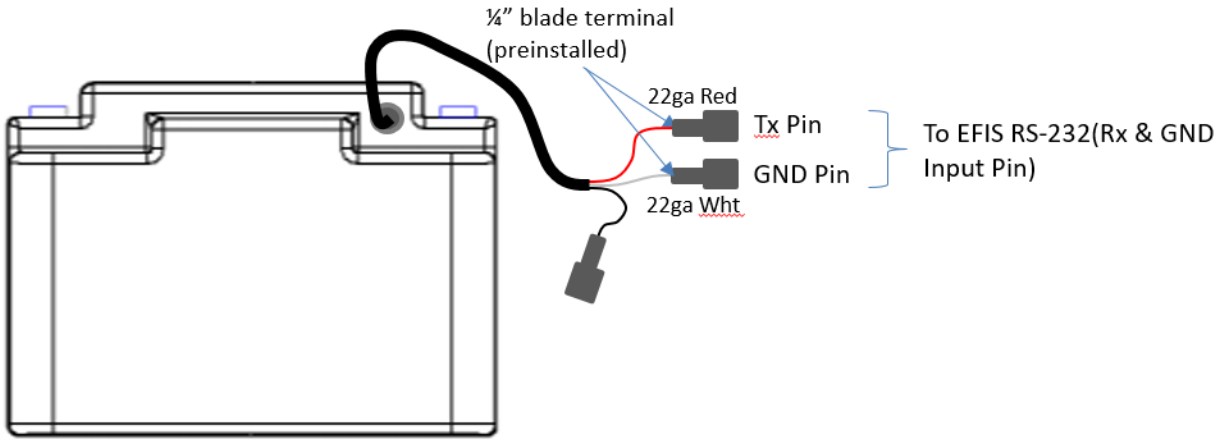
Configure the digital input (contact input) as "active low", "user defined alert" type.

Fault Monitoring Connection to 24V LED

Connect the LED's red wire 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 white wire to aircraft ground. The black wire is to be connected to the battery's fault output (black wire), using a male ¼" quick connect terminal.



RS-232 Communications Connection



Voltage Monitoring (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, and the normal resting voltage is 26.6V.

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
<25.5V	Low charge level warning

Accessory Parts

- Additional 3/8" Tubing: 5239K15_G12 (12 feet length)
- LED Kit: 11MM24

Replaceable Parts

There are no replaceable parts.

Installer Supplied Parts

- Vent port

- Hold down hardware

Operating Instruction

See the ICA for operating instruction, or for a specific aircraft, refer to the instruction given in the STC like an Aircraft Flight Manual Supplement (AFMS).

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 Instructions on Continued Air Worthiness (ICA) manual.

Charging

 **Failure to follow these instructions may result in damage to the battery!**

 **Never jump start from a car size battery or larger!**

If at any time the aircraft will not start, or the battery seems low, or the voltage is less than 26.4 volt, charge it for the recommended time and charge rates shown below and disconnect the charger when charging is complete. The recommended and maximum charge rate is specified on the top label of the battery. Never exceed the maximum charging amps for your battery.

This table shows typical charging times for the battery:

Model	Charging Amps	Charging Time
ETX680-24-TSO	5 amp	3 hour

Lithium batteries have a very low self-discharge rate which means the battery, if disconnected from the aircraft, could "hold its charge" for over a year. However, some aircraft may have systems that use a small amount of power with the "Master switch" off. In those cases, we recommend disconnecting a battery cable from the battery during long term storage (greater than 6 months).

Only an $LiFePO_4$ battery charger shall be used; such as Optimate TM-281 (5 amp).

If the battery has been over-discharged and "disconnected", the voltage at the battery terminal should be near zero volts if the battery still has a load on it. If the battery is disconnected from the load it will automatically reconnect and the terminal voltage return to > 18 volts (remove the load by removing the positive or negative cables from the battery). In this case, simply connect the battery to a charger to restore charge (charge for 20-30 minutes), and then re-check the voltage. If the voltage is 25V or greater and holding a charge, the battery should be ok and can be fully charged. If the battery does not automatically reset when removing any and all load, connect the Optimate TM281 to the battery, then press and hold the "Reset" button on the charger for 20 seconds. The charger should start charging in the "Save" mode. It may require several attempts. If the battery still will not charge, contact EarthX tech support.

If using a Ground Power Unit (GPU), the current rating or current setting SHALL NOT be more than the max charge rate stated on the battery label or in this manual. It is recommended that a warning label is placed next to the GPU plug stating the max current allowed.

 **Never charge a faulty battery (a battery that will not accept a charge or hold a charge).**

 **Never use the de-sulfate setting on your charger.**

 **If the battery gets hot while charging, discontinue charging and use.**

 **Do not charge battery in temperatures above 140 degrees F (60C), or in direct sunlight.**

 **When charging a battery, place it on a non-flammable surface, and remove any flammable items nearby.**

 **For maximum battery and starting system life, do not crank an engine for more than 15 seconds within any 1 minute period.**

Storage

If the Aircraft is to be put in storage for an extended period of time (> 6 months), disconnect the battery cable to eliminate drain from the Aircraft's electrical system. A fully charged battery can be put in storage for up to a year without charging, but should be charged and inspected annually.

Our batteries can be stored at temperatures between -40°C to +70°C. Our batteries have no liquid inside and will not freeze.

 Do not incinerate or expose to open flames!

Part Number Revision

Part Number	Revision	Configuration (Release Date)
EXT680-24-TSO* BMS Part # Rev: BMS_HP**	A	0 (Initial)

* Design Assurance Level, C (major)
** Airborne Electronic Hardware

Warranty

EarthX, Inc. (Manufacturer) warrants its ETX 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 with 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, customer will pay the shipping expenses.

See our website at www.earthxbatteries.com **for details.**

Troubleshooting

The ETX Lithium battery is an extremely reliable battery with a longer useful life than comparable lead-acid batteries.

Despite the high reliability, you may encounter situations where the battery does not operate as expected. Go to www.earthxbatteries.com and review the FAQ section for the most up to date comprehensive troubleshooting information.

Regulations / Standards

The ETX Hundred Series battery, is designed and tested to the following safety regulations as outlined in:

- FAA Technical Standard Order – TSO-C179b
- RTCA DO-311A, RTCA DO-160, DO-254
- IEC 62133-2
- CE — EU consumer safety, health and environmental regulations.
- UN 38.3

These standards set the level of safety required for lithium batteries. The standard addresses normal and abnormal operating conditions.

Lithium batteries have special requirements for transportation (shipping) per UN 38.3 and Title (part) 49 of the Code of Federal Regulations or CFR's. Title 49 CFR Sections 100-185 of the U.S. Hazardous Materials Regulations (HMR).

Terminology

The following table describes the terminology used in this document.

Ah	Amp-Hour is a unit of measure of charge that can be stored in a battery.
BMS	The Battery Management System refers to the collection of electronics responsible for monitoring and controlling the cell charge level, providing over charge protection and over discharge protection
Cell	A single encased electrochemical unit (one positive and one negative electrode) which exhibits a voltage differential across two terminals.
OEM	Original Equipment Manufacturer
STC	Supplemental Type Certificate
IEC	International Electro-Technical Commission on safety standards.

Appendix A

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:
Manufacturer's Specification: N/A
Manufacturer: EarthX
Address: 955 Merchant Ct, Windsor, CO 80550

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	B4, -30° C
High Temperature	4.5.4	B3
Ground Survival	4.5.1&4.5.3	B3
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 A
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 Q and for radiated susceptibility to Category Q
Radio Frequency Emission	21	Equipment tested to Categories P
Lightning Induced Transient Susceptibility	22	Category A3C3XX. Equipment tested to pin test waveform set A, level 3. Cable bundle test waveform set C, level 3.
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.		

Appendix B

Block diagram of a typical installation.