ec 200407
RevA

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

# Revision Log

| Rev | Description | Date |
|---|---|---|
| New | Created New | 11/6/2020 |
| A | Revised to coordinate with ICA | draft |
| | | |

**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 battery. This manual is an accompanying manual to the Instructions for Continued Airworthiness (ICA) manual.

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 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, 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. 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 (> 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 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. EarthX requires having 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.

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 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 RS-232 Communications 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 ($100^{th}$ 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
   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 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/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. Note: Old CCA spec is Ipr at -18C.

- The capacity demand (storage requirement) should not exceed 23 Amps for 30 Minutes. Timely pilot identification and load shedding assumed per normal procedures. An Electrical Load Analysis (ELA) is required.

- 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 battery location should be less than 65°C. The maximum short term (30 minute) environmental temperature of battery location while the aircraft is on the ground shall not exceed 85°C. The battery's normal operating temperature is -30°C to 60°C.

- The battery should be secured in the existing battery box or battery holder as detailed in this manual or aircraft manufacturer's manual.

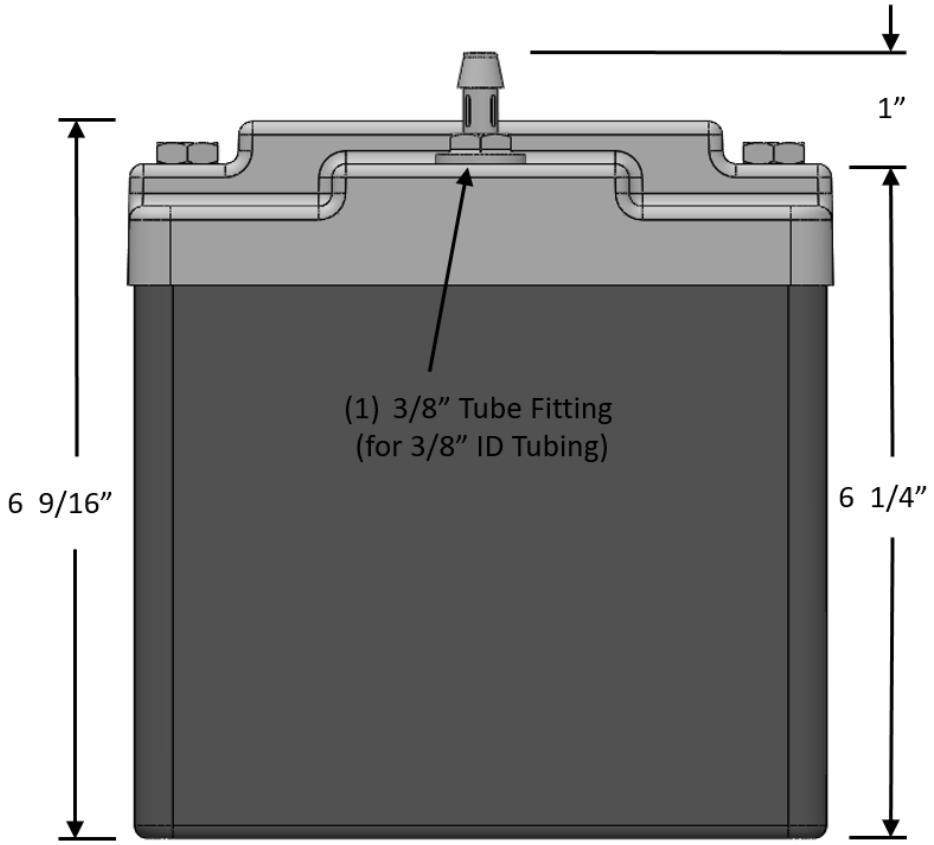
The maintenance must comply with the requirements of the Instructions for Continued Airworthiness (ICA), a separate document.

# Specifications

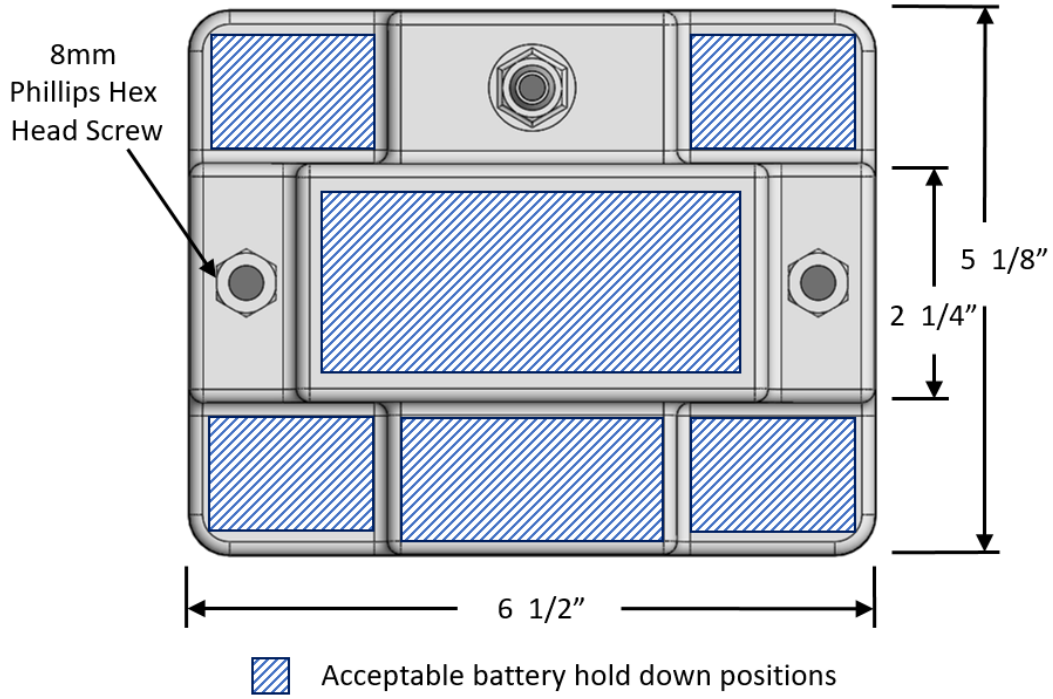
**Model: ETX680-24-TSO**

| | |
|---|---|
| Voltage | 26.4 V |
| Capacity (1C, 1hour rate at 23°C) | 11.7Ah @ 1C rate (See below) |
| Capacity vs Temperature | 25 °C = 100%<br>0°C = 97%<br>-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)<br>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)<br>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

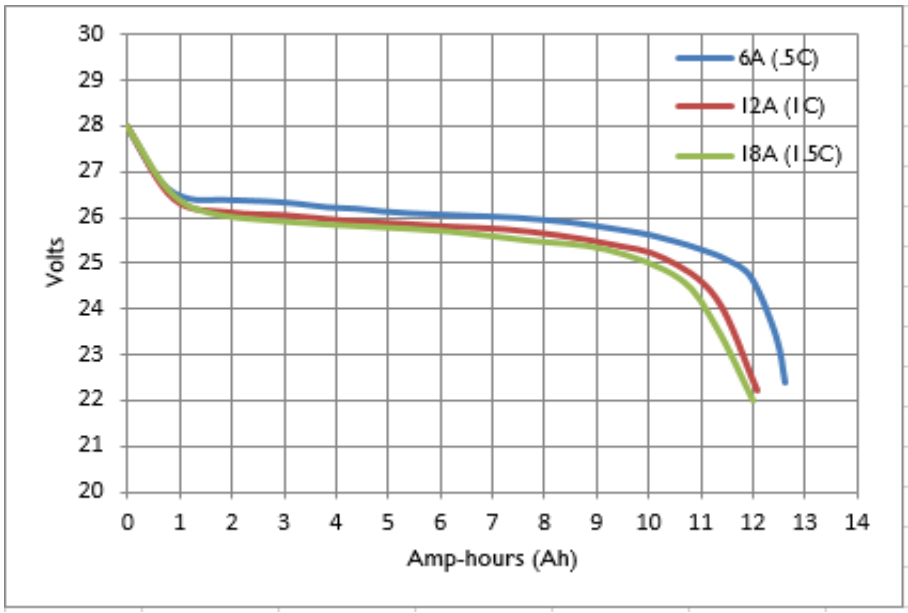


## Discharge Curves

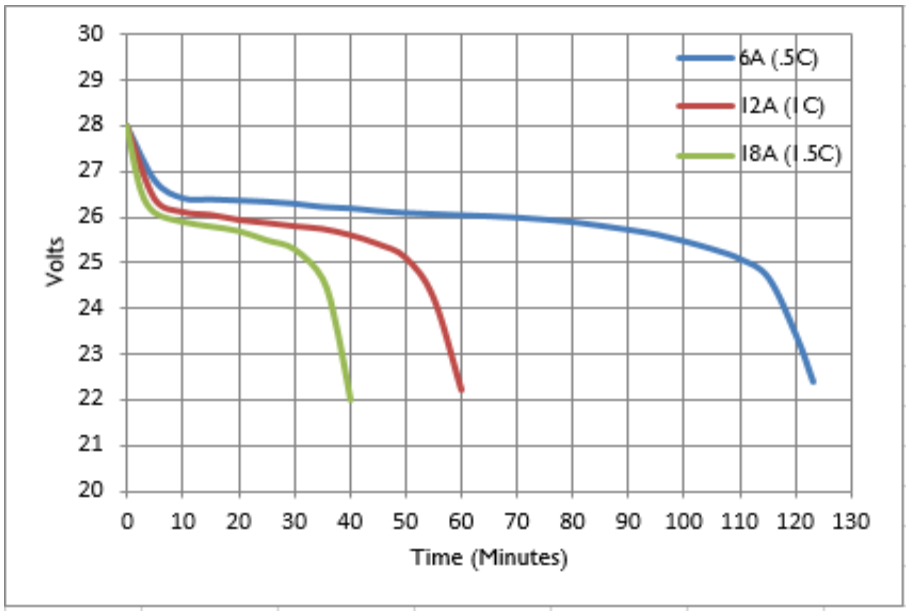
The first graph below shows the state-of-charge versus voltage at a 1C discharge rate. Typically, lithium batteries require advanced methods like current counting to track the charge level. As seen from the graph, the voltage only varies .8V for nearly 80% of the discharge cycle at 25°C. 26.8V is a good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



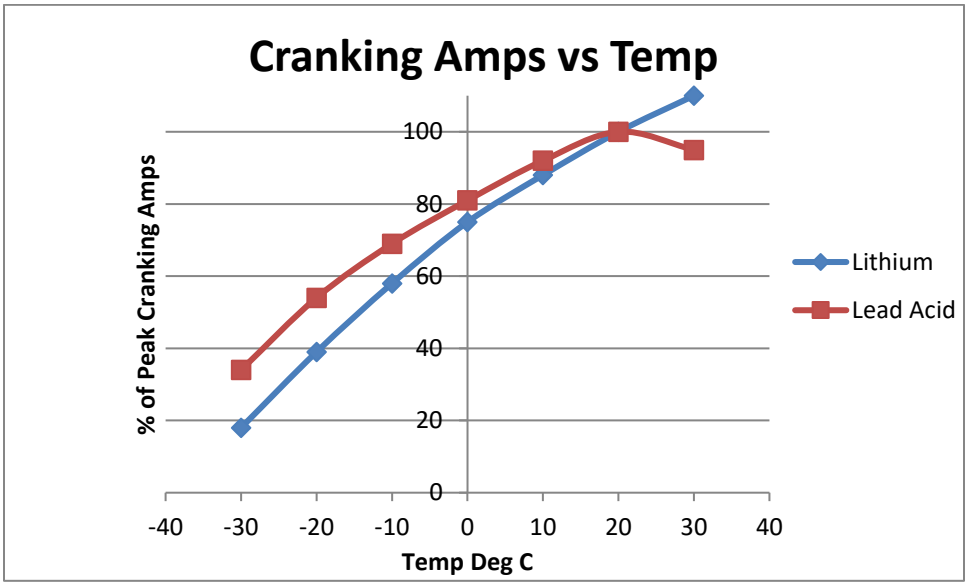

Discharge Capacity




Discharge Time

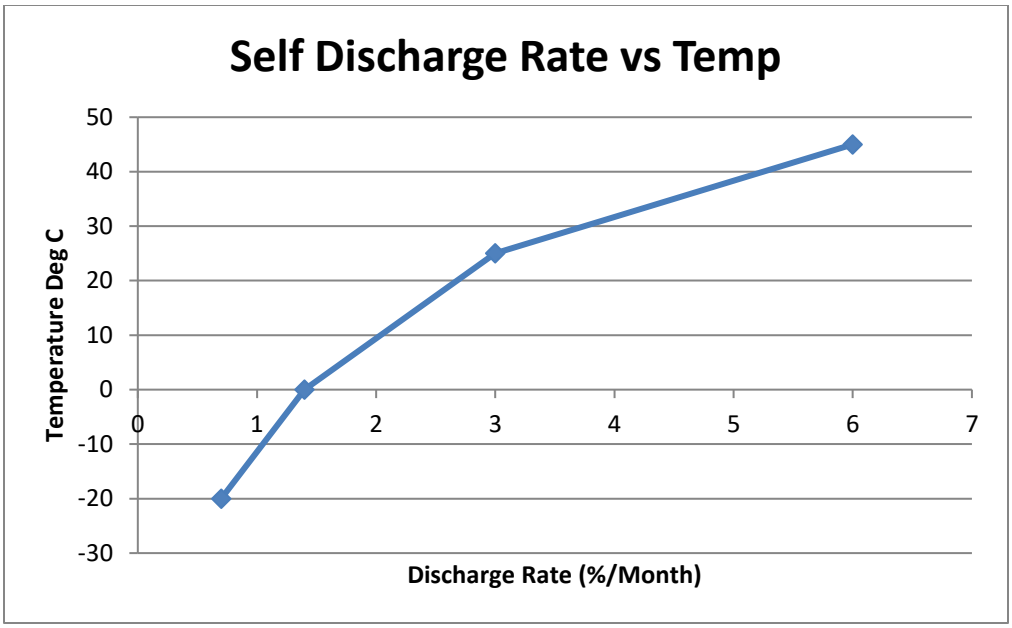
## Discharge Versus Temperature

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 documentation listed in this manual or aircraft manufacturer's 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

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 (see Appendix for specific STC instructions).
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.

## 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.
- 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).
- 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 elbow 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.

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

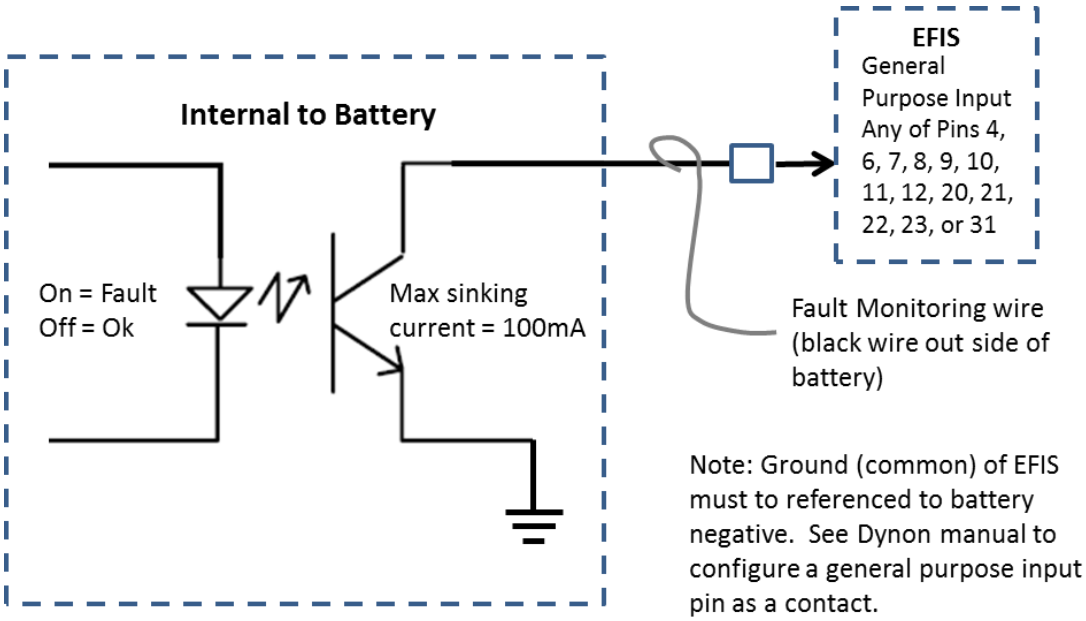
## Fault Monitoring Installation

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. 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 installation.

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

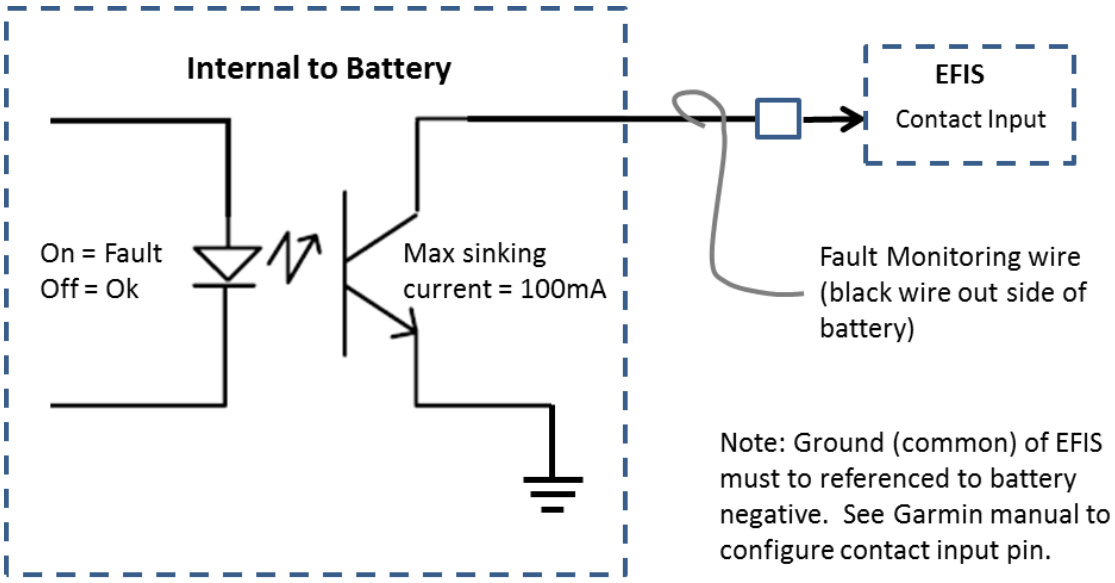
The discrete output for external fault monitoring is a single wire with ¼" quick connect terminal. The ¼" quick connect terminal is an insulated "female" type and should be compatible with most other manufacturers male ¼" quick connect terminals. The following two examples detail how to connect the fault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

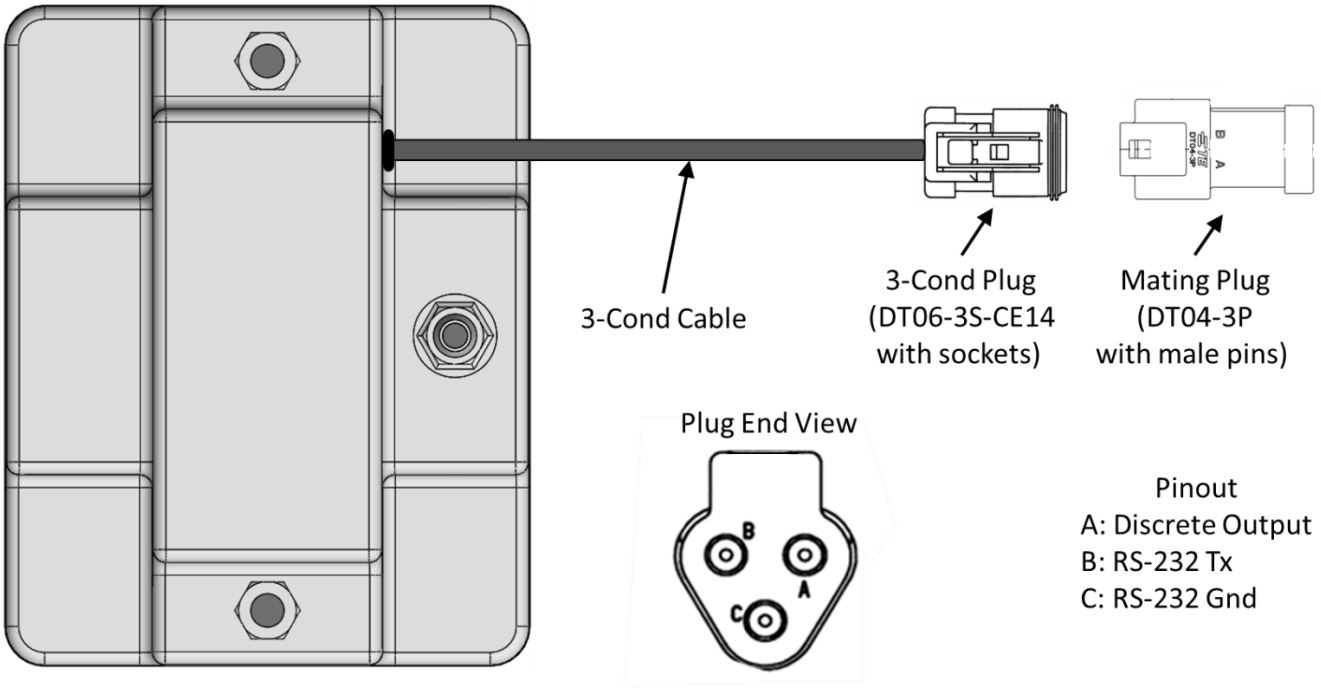



Configure the digital input (contact input) as "active low", "user defined alert" type.

**Fault/Status Connection to 24V 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 white wire to aircraft

ground. The black wire is to be connected to the battery's fault/status discrete output (Pin A of 3-Pin plug).




**RS-232 Communications Connection**

Connect EFIS RS-232 receive to Pin B and ground to Pin C (see figure above).

**Fault/Status Indicator (LED) Install Procedure**

A suitable location for the Fault/Status Indicator will be determined by the installer. One example is shown below, but aircraft will vary. Find an open area that will not interfere with other equipment and in plain view of the pilot. LED must be visible in all operating conditions. Follow shop best practice and/or AC 43.13 guidance.

1. Removed trim panel - drill a 7/16" hole in the panel.
2. Remove one panel nut from the LED housing, and feed the LED housing thru the hole from the back side of the panel.
3. Secure the LED in place with the panel nut removed in the previous step.
4. Secure the LED Placard (1" x 3") to the trim panel in close proximity to the LED.
5. Route the black wire from the LED to the battery box through main wire bundle; secure in place with zip ties. Follow shop best practices and AC 43.13 guidance. **See Appendix for wiring and routing diagrams.**
6. Cut the black signal wire to length leaving a few inches of service loop at the battery.
7. Attach the black wire to the 3-Pin Mating Plug. Then plug into the battery.
8. Behind the instrument panel, route the red wire (with inline fuse) to the instrument (or lights) circuit breaker (10A Typical); crimp (supplied) #6 ring lug to wire and secure to breaker.
9. Route the white wire to an adequate or available ground stud, crimp on (supplied) #6 ring lug and secure in place.

## 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 lens" 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 typical cruise loads and verify it is less than 23 amps. Alternately, configure aircraft for load shed load and verify it is less than 11 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.

## 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 |

### Replaceable Parts

There are no replaceable parts.

## Operating Instruction

While in flight the battery fault/status indicator should be monitored. The indicator can be monitored either by an LED or input to an EFIS where approved. The fault codes are considered cautionary or advisory only.

There are no special requirements for emergency procedures for this battery beyond the airplane PoH or AFM instructions. An in-flight loss of battery functions is indicated by aircraft current and/or voltage meters and is augmented by a battery fault/status light.

### Normal Operation

Under normal operating conditions the battery performs as any lead acid battery, storing energy from the charging system and suppling it when the charging system is off. Under normal operation the LED is OFF.

### Abnormal Operation

A battery fault in flight is categorized as ABNORMAL and the following conditions and actions then apply.

**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. |
| | | |

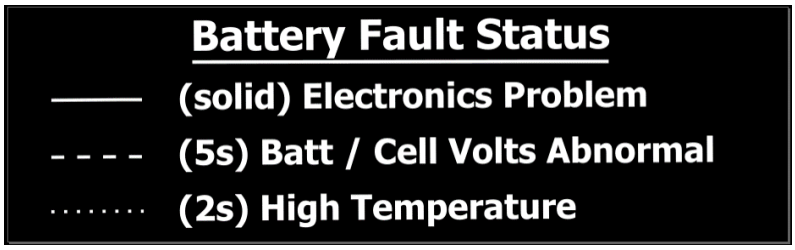
**The table below is a summary of the battery's fault codes (discrete output).**

| **LED Light** | **Airplane Voltage/Current** | **Battery Possible Cause** | **Recommended Action** |
|---|---|---|---|
| Slow Flashing (5s on/5s off) | 25.5-29V or current indicating normal charge or discharge | Cell to cell charge level imbalance. May come on briefly (less than 60 minutes) during or following periods of high current charging | No pilot action is required in flight. The pilot should report a battery problem to maintenance personnel when back on the ground. Do not dispatch aircraft. |
| Slow Flashing (5s on/5s off) | Less than 25.5V/ amp meter shows discharge / or alternator warning light on | Charging system is not functioning (battery is being discharged or at a low state of charge) | Pilot to follow POH procedure for faulty alternator. Do not dispatch aircraft. |

| | | | |
|---|---|---|---|
| Solid Light | Any voltage or current | BMS electronics problem | No pilot action is required in flight. Continue to monitor aircraft bus voltage and or current. The pilot should report battery problem to maintenance personnel when back on the ground. Do not dispatch aircraft. |
| Short Flashing (2s on/2s off) | Any voltage or current | High battery temperature (> 75°C / 167°F) | No pilot action is required in flight. The pilot should report battery problem to maintenance personnel when back on the ground. Do not dispatch aircraft until battery has cooled and fault cleared. |

Placard

A placard (P/N: 200208) is provided, and installed, adjacent to the Fault/Status Indicator LED (see image below).




A sustained fault can indicate a serious issue with the battery or aircraft charging system that requires attention. Discontinue use until the issue is resolved and the battery no longer indicates a fault. Continued use of a faulty battery can result in a cell rupture, and the release of flammable vapors, and or smoke (through vent system and to outside the aircraft).

## 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.

## Weight and Balance

A lithium battery is generally 25-30% of the equivalent lead acid battery weight, so weight and balance needs to be considered (see Appendix for more details).

## Charging

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

 **Never jump start from a battery 5 times the Amp-Hour or larger!**

If the battery fault/status indicator LED slowly cycles 5 second on then 5 seconds off and/or the aircraft bus voltage is less than 25.5 volts, or the aircraft will not start, or the battery seems low, 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 > 20 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 with 1-5 amps 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.

The battery 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!**

## Troubleshooting

The battery is an integral part of the aircraft electrical system and as such to is useful to know the aircraft electrical system voltage and or current at the time of the battery fault.

The Voltage/Current column in the table below lists the voltage/current level or condition that could correspond with the battery fault. For example, over-voltage is an electrical system problem and may be reported and addressed with other aircraft equipment.

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

| Health Status Bit | Voltage/Current | Possible Cause | Recommended Action |
|---|---|---|---|
| Bit0: BMS Hardware Problem | Any voltage or current | BMS electronics issue | Replace the battery. |

| | | | |
|---|---|---|---|
| Bit1: Cell to Cell Charge Level Mismatch | Normal bus voltage levels | Cell to cell charge level imbalance | Charge the battery with an approved charger and observe fault LED. If LED persists, charge the battery a second time with approved charger. If the LED fault persists, it is an early indication of a failing battery cell and the battery shall be replaced. |
| Bit2: High Temp Warning | Any voltage or current | High battery temperature (> 70°C / 158°F) | If the fault persists after the battery has cooled down, replace the battery. If the fault is the result of environmental temperatures, investigate causes of elevated temperatures. |
| Bit3=Over-charged Protection Activated | Greater than 31V / high charge amps/ high voltage warning light on | Over-charging (due to faulty charging system) | Verify aircraft charging system is functioning properly; could be faulty voltage regulator and or over-voltage protection device. |
| Bit4= Short-circuit Protection Activated | Any voltage or current | Aircraft electrical system short-circuit or engine cranking in extremely cold temperatures | Could be faulty starter or faulty battery/starter cable (worn insulation). Could be extreme low temperature starting (below 0 Deg F) causing false short circuit protection activation due to severe voltage dip during crank. |
| Bit5=Excessive Cranking Protection Activated | Any voltage or current | More than 15 seconds of engine cranking within any 1-minute period | No maintenance action needed if the battery reset within 1-2 minutes. This is a normal battery protective function. |
| Bit6= High High Temp | Any voltage or current | Battery internal temperature is greater than (> 85°C / 185°F) | If the fault persists after the battery has cooled down, replace the battery. |
| Bit7= Cell Over-charged Warning | Any voltage or current | Over-charging cell (due to internal battery cell problem) | Charge the battery with an approved charger and observe fault LED. If LED persists, charge the battery a second time with approved charger. If the LED fault persists, it is an early indication of a failing battery cell and the battery shall be replaced. |

| **Charge Status Bit** | **Voltage/Current** | **Possible Cause** | **Considerations** |
|---|---|---|---|
| Bit0: Battery Over-discharged | Voltage at low level (<25 volt) | Battery drained by aircraft load or parasitic load | The battery should be charged full with an approved charger. |

**The table below is a summary of the battery's fault codes (discrete output).**

| LED Light | Voltage | Possible Cause | Recommended Action |
|---|---|---|---|
| Slow Flashing (5s on/5s off) | Less than 25.5V | Battery over-discharged due to faulty charging system (alternator) not charging the battery. | Charge the battery. Verify aircraft charging system is functioning. |
| Slow Flashing (5s on/5s off) (> 1 hour) | 25.5-29V | Weak or failing cell | Charge the battery with an approved charger and observe fault LED. If LED persists, charge the battery a second time with approved charger. If the LED fault persists, the battery should be replaced. |
| Slow Flashing (5s on/5s off) | Greater than 31V | Over-charging (due to faulty charging system regulator) | Verify aircraft charging system is functioning properly; could be faulty voltage regulator and or over-voltage protection device. |
| Solid Light | Any voltage | BMS electronics issue | Isolate the battery from the aircraft (disconnect positive or negative cable). Disconnect the battery's fault wire from the aircraft's LED or EFIS. If the fault LED on the battery is not extinguished, the battery should be replaced. |
| Solid Light that turns off after 3 minutes | Any voltage | Short Circuit protection was activated | Verify normal voltage (25.5-29V) at the battery terminals. Battery can be returned to service. |
| Short Flashing (2s on/2s off) | Any voltage | Battery temperature very high (> 85°C / 185°F) due to environment or excessive discharge. | If due to excessive discharge amperage, let the battery cool down prior to cranking or charging. If environmental temperature is too high, engineer means to cool battery when in service. |

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

## 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 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. 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.**

## 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. |
| EFIS | Electronic Flight Instrumentation System |

| | |
|---|---|
| IEC | International Electro-Technical Commission on safety standards. |
| ICA | Instructions for Continued Airworthiness |
| LED | Light Emitting Diode |
| STC | Supplemental Type Certificate |

# 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<br>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's Specification: N/A
Manufacturer: EarthX

Revision & Change Number of DO-160: G, Dec8, 2010 Date Tested: Oct 30, 2020

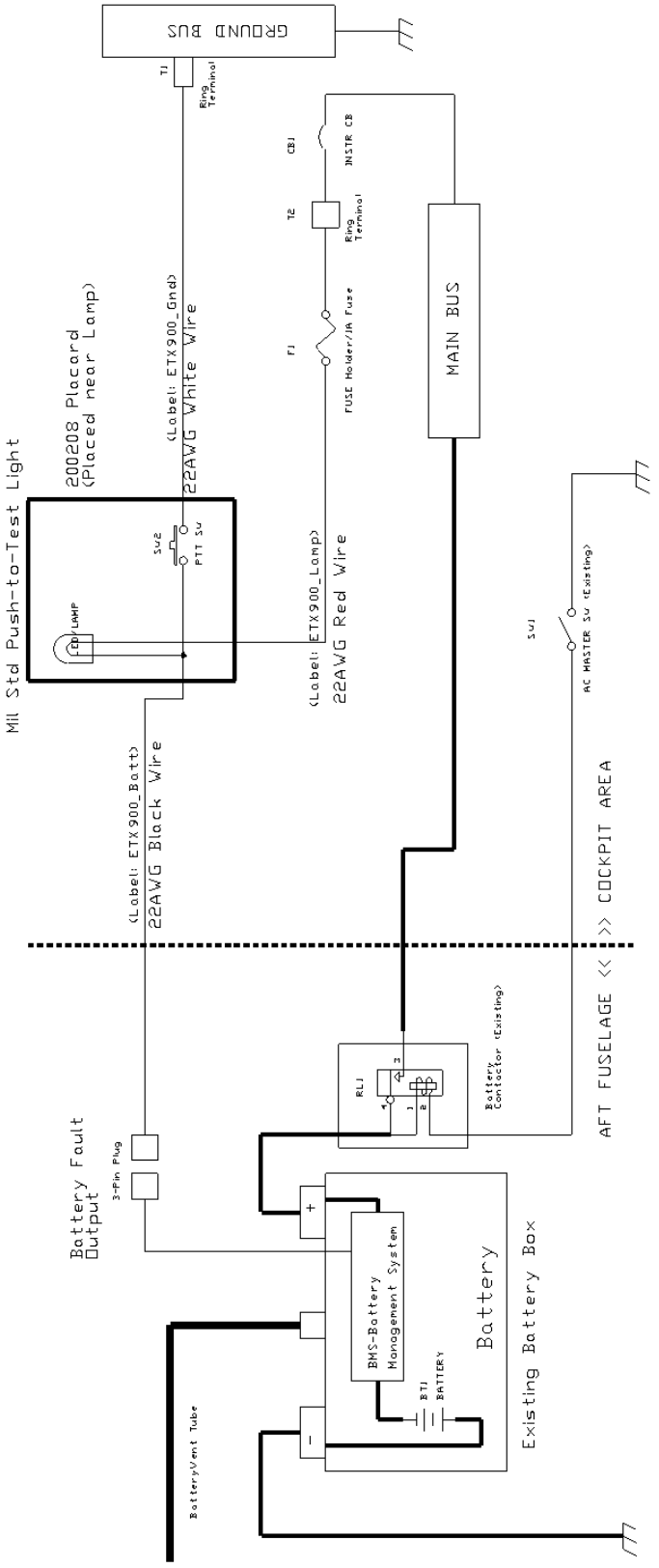
| Conditions | Section | Description of Tests Conducted |
|---|---|---|
| Temperature and Altitude | 4.0 | Equipment tested to Categories: |
| Low Temperature | 4.5.2 | B4, -30° C |
| High Temperature | 4.5.4 | B3 |
| Ground Survival | 4.5.1&4.5.3 | B3 |
| Loss of Cooling | - | Equipment Category X, 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<br>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.<br>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<br>- No critical frequency was identified.<br>-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 II: Typica Installation Wiring Diagram

## Wiring Diagram

Definitions:
CB=Circuit Breaker
AWG=American Wire Gauge
AR=As Required
EA=Each



# Appendix III: Model Evaluation Checklist (MEC)

This Model Evaluation Checklist is to document the applicability of the AML STC to a specific aircraft.

## ✓ 1. Identify the proposed Model for Installation Eligibility:

- ☐ Obtain the FAA Registry for the target Airplane at: registry.faa.gov/aircraftinquiry/NNum_Inquiry.aspx
  - ☐ Retain the information: Make, model and serial number for evaluation.
- ☐ APPLICABILITY: Is the installation candidate Model on the AML of the STC?
  - ☐ YES, proceed using AML STC data, installation is eligible.
  - ☐ NO, but do you want to add the Model?
    - ☐ Yes, contact EarthX, Inc. for additional update request, END this process.
    - ☐ NO, end this process checklist, Model not currently eligible.
- ☐ APPLICABILITY: Airplane certification level.
  - ☐ Certification Level: Level 1 - airplanes with a max seating configuration of 0 to 1 passengers.

  or Level 2 - for airplanes with a maximum seating configuration of 2 to 6 passengers.
- ☐ FUNCTION: Will this installation be for STARTING and STORAGE battery intended functions in the current electrical syster
  - ☐ YES, proceed. It is a replacement for the current battery using new technology.
  - ☐ No, incompatible, STOP. The installation may require further analysis and certification.

## ✓ 2. Evaluate the proposed Model serial number for addition:

- ☐ Using Qualified personnel, does the target airplane meet the min requirements for Required Systems & Equipment?

  A. Primary Electrical System - Alternator less than or equal to 80 Amps?
  - ☐ YES, proceed
  - ☐ NO, STOP -Airplane not eligible if it exceeds 80 Amps. I.E. - such as a 95 Amp alternator by STC.

  B. Does the airplane electrical system have Over Voltage Protection?
  - ☐ YES,Proceed
  - ☐ NO, STOP - Airplane not eligible, or evaluate installation of an OVPD or OVPS.

    Is there an existing approval to install the required equipment?
    - ☐ YES, proceed to install equipment per approved data.
    - ☐ NO, incompatible, STOP

  C. Using qualified personnel, i.e. such as an A&P, DER or informed AET, evaluate the airplane Model for EBS requirement
  - ☐ ENVIRONMENT: Operating Temperature -30C to +60C (+65C, short term).
  - ☐ STARTING: Peak Power (Ipp): 800/390 Amps (+23C/-18C), Rated Power (Ipr): 600/365 Amps (+23C/-18C).
  - ☐ STORAGE*: 23 Amps for 30 Minutes. Timely pilot identification and load shedding assumed per normal proce

    * Either through Electrical Load Analysis (ELA) or Test, essential loads must be evaluated by qualified personn
  - ☐ CHARGE: 80 Amps maximum charging system.
  - ☐ WEIGHT: 7.2 Lbs. As the weight change is significant, a Weight & Balance Report (WBR) is required. 14 CFR 9
  - ☐ If yes to all, proceed. Else, further analysis and/or certification approval may be required. Contact EarthX.

## ✓ 3. Evaluate the certification basis for proposed Model:

☐ Does the installation CONTINUE to meet the requirements of the applicable rules, modifications and guidance?

A. Original AML STC remains applicable?

- ☐ YES, listed on the AML STC - meets the current regulations - Proceed.
- ☐ NO, STOP. Process END.

B. Are there any Model serial specific issues that would preclude the installation of the proposed equipment?

- ☐ NO, proceed. See list below.
- ☐ YES, evaluate the following:

  Inadequate location for Fault/Status indicator Light.

  Battery box not adequate for installing battery inside due to modifications.

  Other installation aspects or issues discovered that could affect functions or safety.

C. Does the installation manual still provide adequate detail to complete the installation?

- ☐ YES, proceed
- ☐ NO, contact EarthX, Inc. for further guidance on IMM updates or request improvements.

## ✓ 4. Issues

**Model specific issues and ELOS**

☐ ADs: Using qualified personnel, are current Airworthiness Directives complied with?

- ☐ YES, proceed
- ☐ NO STOP - Airplane is not eligible.

☐ STCs: Are currently installed STCs compatible with this installation?

- ☐ YES, proceed.
- ☐ NO, incompatible, STOP. Further analysis and certification may be required.

☐ COMPLEXITY: Does the installation remain simple? Installed into an existing location with no major modifications?

- ☐ YES, proceed.
- ☐ NO, contact EarthX, Inc. for further guidance.

# Appendix IV: Electrical Load and Capacity Analysis (ELCA)

## Load Definitions

**Normal Cruise Load, Pre-Load Shed (5 Minute):**

- Engine monitoring Instruments ON (Master ON)
- ALT ON – Alternator working per Ammeter
- Avionics ON
- Transponder and GPS ON
- Com/Nav 1, 2 and 3 ON (if so equipped)
- Autopilot ON
- Panel Lights ON
- Strobes ON
- NAV Lights ON
- Pitot heat ON
- Flood Lights OFF
- Landing Lights OFF

**Minimum Cruise Load (30 Minute):**

- Engine monitoring Instruments ON (Master ON)
- ALT ON – Alternator working per Ammeter
- Avionics ON
- Transponder and GPS ON
- Com/Nav 1 Intermittent
- Nav 2 and 3 OFF
- Autopilot OFF
- Panel Lights ON
- Strobes ON last 10 minute only
- NAV Lights OFF
- Pitot heat ON last 10 minutes only
- Flood Lights OFF
- Landing Lights ON last 3 minutes only
- Non-essential Lights OFF

## Battery Duration /Capacity Analysis

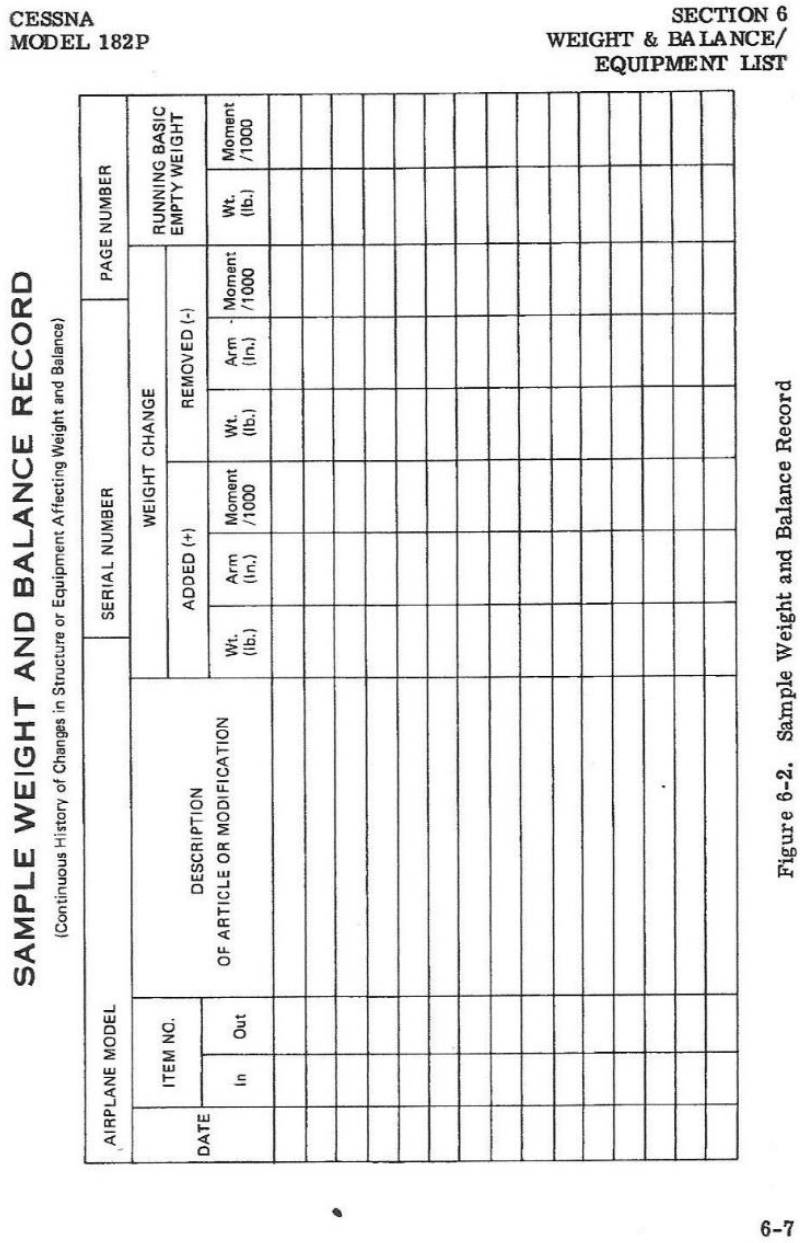
A conservative capacity for the battery is 75% of nameplate (.75x11.7Ah=8.8Ah). The A-min (amp x minutes) of this battery is (8.8Ah x 60min=528A-min). The calculated Capacity Used A-min in the table below must be equal or less than 528 A-min.

| ASTM F2490 – 20 Capacity Calculation | | | | |
|---|---|---|---|---|
| **Load** | **Min** | **A** | **A-min** | **Notes:** |

| | | | | |
|---|---|---|---|---|
| Normal Cruise, Preload Shed | 5 | | | Measure the total amps, and put number in A column; calculate A-min by multiplying minutes and amp and put in A-min column |
| | | | | |
| Minimum Cruise | | | | |
| 20 Min (prior to approach/landing) | 20 | | | Measure the total amps, and put number in A column; calculate A-min by multiplying minutes and amp and put in A-min |
| 10 Min (approach) | 10 | | | Measure the amps for strobes and pitot heat only, and put number in A column; calculate A-min by multiplying minutes and amp and put in A-min |
| 3 Min (landing) | 3 | | | Measure the amps of landing lights only, and put number in A column; calculate A-min by multiplying minutes and amp and put in A-min |
| | | | | |
| **Capacity Used (A-min):** | | | | Take sum of A-min for all rows and put in the A-min column |
| | | | | |

# Appendix V: Weight and Balance Supplement (WBS)

The ETX680-24-TSO is a significant change in weight from a Lead-Acid battery. As such, a Weight & Balance Record change is required. The Operator / Pilot must determine the change in weight and balance per the aircraft's Pilot Operating Handbook (POH) and document it on the Weight and Balance Record (WBR). Below is an example of a WBR for a Cessna



CESSNA
MODEL 182P

SECTION 6
WEIGHT & BALANCE/
EQUIPMENT LIST

SAMPLE WEIGHT AND BALANCE RECORD

(Continuous History of Changes in Structure or Equipment Affecting Weight and Balance)

AIRPLANE MODEL | SERIAL NUMBER | PAGE NUMBER

| DATE | ITEM NO. In | ITEM NO. Out | DESCRIPTION OF ARTICLE OR MODIFICATION | WEIGHT CHANGE ADDED (+) Wt. (lb.) | ADDED (+) Arm (in.) | ADDED (+) Moment /1000 | REMOVED (-) Wt. (lb.) | REMOVED (-) Arm (in.) | REMOVED (-) Moment /1000 | RUNNING BASIC EMPTY WEIGHT Wt. (lb.) | RUNNING BASIC EMPTY WEIGHT Moment /1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

Figure 6-2. Sample Weight and Balance Record

6-7

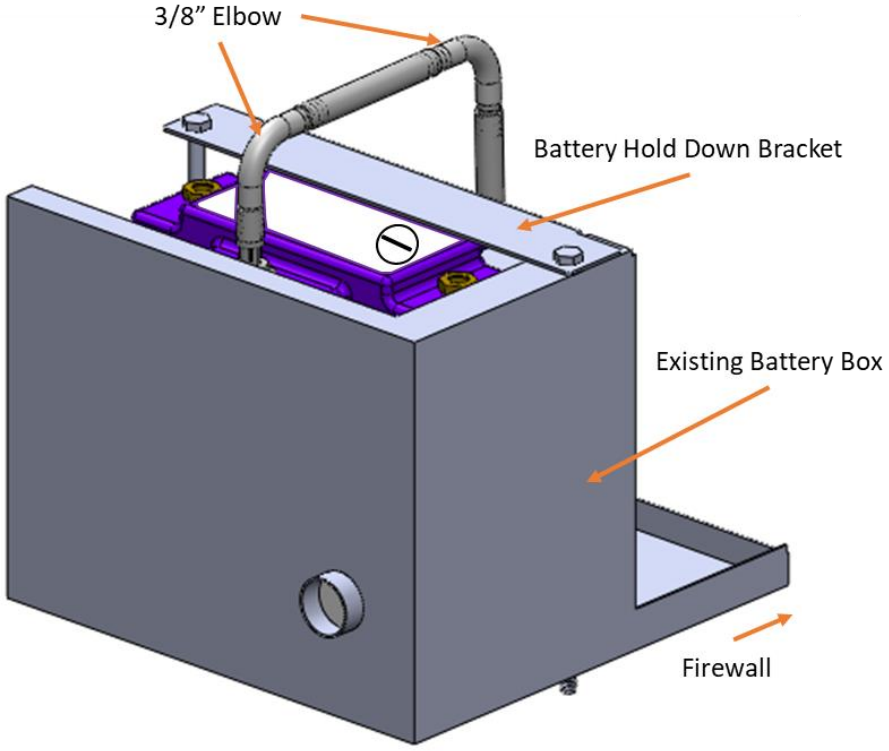
# Appendix A: Cessna 172 Install

**Install Parts Kit:**
ETX680-24-TSO-25-KIT

**Typical Wire Routing**
As required, protecting wire has it passes through the firewall.

**Battery and Vent Tubing**

1. Remove the existing battery and battery vent.
2. Place the ETX680-24-TSO EarthX battery into the battery tray. Place the new battery hold down bracket into the battery and battery tray side wall (see figure below). Re-install the existing hold down bolts.




3. Use the supplied 3/8" tubing and two 3/8" elbows to route the battery vent to the belly of the aircraft (use exiting tubing clamps to hold tubing in place).
4. Then cut exhaust tube to length; at least 1" should be exposed on the outside of the aircraft. Cut the tube at an angle towards the aft of the aircraft.