



Primary Power System (PPS)

Primary power control for experimental and light-sport aircraft



Installation and Operating Manual

April 5, 2022
Rev. F1

Important Notice

This manual contains important information that may affect the safety of your aircraft. Do not fly the aircraft until you fully understand the installation and operating instructions, and all of the pre-flight checks have been successfully completed.

Read the Limited Warranty document (Limited Warranty - Vertical Power Products) available at www.verticalpower.com. There is information in the Limited Warranty that may alter your decision to install this product. **If you do not accept the terms of the Limited Warranty, do not install this product.** The product may be returned for a refund if you do not accept the terms of the Limited Warranty.

Astronics is not liable or responsible for a pilot's action or any situation that results in personal injury, property damage, missed commitments, lack of use of an aircraft or any expenses incurred due to: product failure, inaccuracy in displayed data or text files, display or display format issues, software bugs or problems, upgrade or customization issues, misinterpretation of the display, warning and/or limit settings, calibration problems, installation issues (leaks, mis-wiring, obstructions, damage to aircraft or components, incorrect installation of any parts, wrong parts, parts that don't fit, etc.) or any other issues related to the installation or operation of this product. All of the above are solely the pilot's and/or installer's responsibility.

The pilot must understand the operation of this product before flying the aircraft. The pilot will not allow anyone to operate the aircraft that does not know the operation of this product. The pilot will keep these Operating Instructions in the aircraft at all times. The ability for this product to correctly control electronic components and detect a problem is directly related to the pilot's ability to properly install the system, and the pilot's interpretation and observation skills.

By installing this product, the aircraft owner/pilot and installer agree to hold Astronics harmless and in no way responsible for monetary compensation, including punitive damages for any incident, harm and/or damage associated with this product (including but not limited to the ones listed above). If you do not agree to the above, **DO NOT INSTALL THIS PRODUCT.** The pilot, aircraft owner and/or installer may want to obtain an appropriate insurance policy before installing this product. If you do not have the skills, knowledge, tools, equipment or facility, to perform and determine the installation of this product is safe, reliable and accurate and to determine this product is operating properly after installation, **DO NOT INSTALL THIS PRODUCT.** If the aircraft owner/pilot and/or installer are unwilling to take the responsibility for the installation and operation of this product, **DO NOT INSTALL THIS PRODUCT.** This product may be returned for a refund by contacting Astronics.

It is possible for any system to fail thereby disabling electronic components or displaying inaccurate high, low or jumpy readings. Therefore, you must be able to recognize a system failure and you must be proficient in operating your aircraft safely in spite of a system failure. **IT IS THE BUILDER AND/OR PILOT'S RESPONSIBILITY**

TO DETERMINE THE APPROPRIATE LEVEL OF BACKUP AND REDUNDANT SYSTEMS NEEDED FOR SAFE OPERATION OF THE AIRCRAFT. If you do not have this knowledge or skill, contact the FAA, a certified aircraft mechanic, or a local flight instructor for training prior to building or flying the aircraft with this system. Before flying the aircraft verify the instrument markings displayed on the system are accurate with your POH for every function displayed. Verify that each electrical device is configured correctly and behaves appropriately. All data must be verified by the pilot before it is used.

Before starting the installation, make sure that your planned installation will not interfere with the proper operation of any controls. The installer should use current aircraft standards and practices to install this product. Refer to AC 43.13-2A, Acceptable Methods, Techniques, and Practices - Aircraft Alterations and AC 43.13-1B, Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair.

This is an experimental system limited to use in experimental aircraft or Light Sport Aircraft. These products are not approved for use in aircraft with FAA or foreign type certificates.

Limited Warranty

For warranty information, please refer to the Limited Warranty document (Limited Warranty - Vertical Power Products) available at www.verticalpower.com.

Copyright Notice

Copyright ©2022 by Astronics. Astronics' permission to copy and distribute this manual is for the purchaser's private use only and is conditioned upon purchaser's use and application with the hardware that was shipped with this manual. No commercial resale or outside distribution rights are allowed by this notice. This material remains the property of Astronics. All other rights reserved by Astronics.

Trademarks

Vertical Power is a registered trademark of Astronics. All other product names or trademarks are property of their respective owners.

Astronics

The home of Vertical Power products

12950 Willows Road NE

Kirkland, WA 98034

Phone: +1.425.328.1658

Email: info@verticalpower.com

Table of Contents

| | |
|---|----|
| 1. Introduction | |
| 1.1 PPS Overview | 5 |
| 1.2 Engine and System Incompatibility | 5 |
| 1.3 Reference Numbers | 5 |
| 1.4 Terms and Definitions | 5 |
| 1.5 Other Documentation | 6 |
| 2. Operation | |
| 2.1 Main Bus Contactor | 6 |
| 2.2 Alternator Contactor | 7 |
| 2.3 Main Starter Contactor | 7 |
| 2.4 Control / Status | 7 |
| 2.4a Control Inputs | 7 |
| 2.4b Status Outputs | 8 |
| 3. Electrical System Basics | |
| 3.1 Free advice on Designing your Electrical System | 9 |
| 3.2 Basic Concepts | 10 |
| 3.3 Alternator Options | 10 |
| 3.3a Wiring the B&C External Regulator with the PPS | 10 |
| 3.4 Wire Sizes and Circuit Protection | 11 |
| 3.5 Grounding - IMPORTANT | 11 |
| 3.6 Switch Nomenclature | 12 |
| 3.7 Current Sensing (Shunt) | 12 |
| 4. Installation and Test | |
| 4.1 Planning | 13 |
| 4.1a Tools and Supplies | 13 |
| 4.1b Wiring Diagrams | 13 |
| 4.2 Installation | 17 |
| 4.2a Mount the PPS | 17 |
| 4.2b Terminal Wiring | 19 |
| 4.2c Control/Status Wiring | 19 |
| 4.3 Ground Test | 20 |
| 4.3a Ground Test without engine running | 20 |
| 4.3b Start Mode Duty Cycle | 20 |
| 4.3c Ground Test with engine running | 20 |
| 4.4 Flight Test | 21 |
| 5. Maintenance | |
| 5.1 Do's and Don'ts | 22 |
| 6. Troubleshooting | |
| 6.1 Common Problems | 22 |
| 7. Specifications | |
| 7.1 General | 23 |
| 7.2 Circuit Ratings | 23 |
| 7.3 Environmental / Physical | 23 |

Change Log

| Change date | Rev | Change |
|--------------|-----|---|
| Oct 21, 2015 | | Initial public release |
| Mar 29, 2017 | | Updates based on product changes incl. new pinouts |
| Aug 24, 2017 | | Updated grounding instructions |
| Sep 25, 2017 | C1 | Updated grounding diagram and Table 4.2b |
| Jan 19, 2018 | C2 | Updated current values; added Start Mode Duty Cycle information; added GND stud and grounding updates to tables, diagrams and drawings; added maintenance recommendations. |
| Aug 5, 2020 | D | Updated temperature ranges, transient details; fixed errors in wiring diagrams; other minor updates. |
| Oct 29, 2020 | D1 | Clarified the function of pins 1 and 8 in the basic and comprehensive wiring diagrams on pages 15 & 16. |
| Feb 1, 2021 | E | Added LR3C external voltage regulator warning in Section 3.3 and wiring instructions in Section 3.3a. Updated Pin 1 and 9 functionality in comprehensive wiring diagrams in Section 4.1b. Update mounting template in Section 4.2a. |
| Jan 12, 2022 | F | Added 'Engine and System Incompatibility' to Introduction section. Added references to B&C LR3D voltage regulator. |
| Apr 5, 2022 | F1 | Updated VP-X manual reference in Section 3.3. |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

1. Introduction

This manual is the user’s guide for the Vertical Power Primary Power System (PPS). The PPS is a new and innovative way to simplify wiring on your aircraft. It replaces a host of mechanical components with solid-state circuits.

While the PPS makes life easier for the builder, it’s not simply a plug-and-play solution. The builder must still run wires to electrically-powered components and this wiring takes some careful planning. Please take the time to read and understand this manual before proceeding.

This manual describes the steps and techniques necessary to install and operate the PPS.

1.1 PPS Overview

The PPS controls power from the battery to the starter and the main bus. It also ties into the alternator b-lead(s) so that alternator power can both charge the battery and provide power to the main bus.



The Vertical Power PPS

The PPS works with a single-bus architecture. It supports a single battery and one or two alternators. Additional small backup batteries and E-Bus circuits can be tied into the PPS via the battery terminal.

It does not implement a true dual-bus architecture (two independent batteries, alternators, battery contactors, and a cross-tie contactor). Multiple PPS units can be used to implement a dual-bus architecture. Please contact support for more information on dual-bus installations.

The system also works with a remote-mounted battery, as shown in one of the wiring diagrams later in the manual.

The PPS is designed to ‘fit in’ with the way master switches and starter switches are normally wired. No special wiring or provisions are needed.

The PPS also includes fault outputs that show you when the alternator or main bus line have faulted.

1.2 Engine and System Incompatibility

Due to unique operating parameters, we do not recommend using the PPS with the following engines or systems:

- Rotax Engines
- UL Power Engines
- EFII System 32
- AeroVee Engines

1.3 Reference Numbers

For future reference, we encourage you to record the model number and serial number of your PPS product. You may wish to use the space provided below:

Model No: _____

Serial No: _____

1.4 Terms and Definitions

| | |
|-----------|---|
| Device | A user of electrical power. It may be a light, radio, GPS receiver, contactor, or EFIS, just to name a few. A device is wired to a power pin on the VP-X. |
| Pin | A pin refers to a physical pin on the connector. |
| ECB | Electronic circuit breaker. A solid-state, circuit protection module used inside the PPS. |
| Connector | The Primary Power System uses a 28-pin circular plastic connector for J1. It is made by TE Connectivity. A mating connector of the same brand is recommended for compatibility. |
| AWG | American Wire Gauge – a standard that describes the size of the wire. |

- Circuit breaker** While the PPS does not use conventional circuit breakers or fuses, the term is very common and herein is used to mean the maximum current a circuit will draw before faulting.
- Fault** The PPS protects the alternator b-lead and main bus wires. When a fault occurs, the PPS turn on the fault light. You can then reset or clear the fault, similar to resetting a circuit breaker.
- VP-X** The Vertical Power VP-X Electronic Circuit Breaker System is a separate and optional product that takes power from the PPS and intelligently distributes it to all the electrical devices on the aircraft, providing an unprecedented level of detail and control of your electrical system. More info: verticalpower.com

1.5 Other Documentation

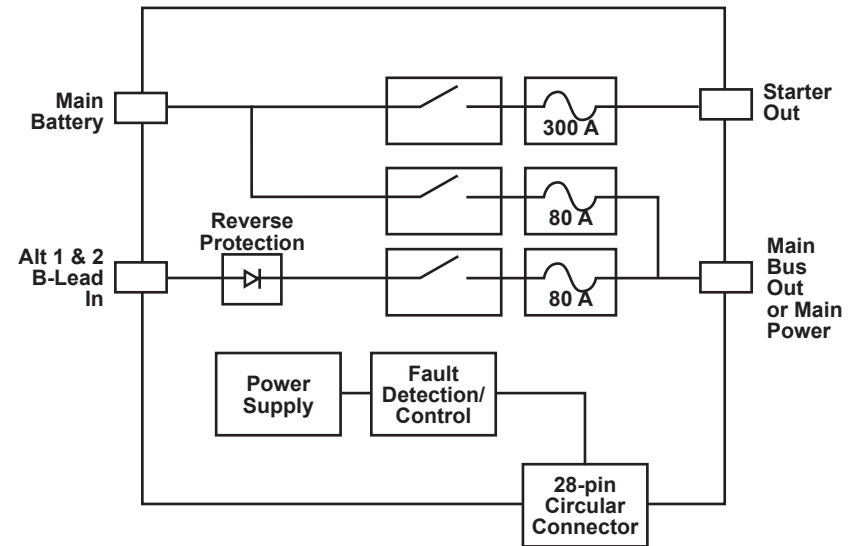
We provide other documents that should be used in conjunction with this manual to help you thoroughly plan a safe and effective electrical system for the type of mission you fly. The following documents are available on the Documents page in the Help section of the Vertical Power web site (www.VerticalPower.com), and should be reviewed in conjunction with planning your electrical system.

| Document | Description |
|------------------------|---|
| Contactor Wiring | Overview of the different types of contactors used in experimental aircraft, and step by step instructions how to wire them properly. |
| Device Amps | This document lists the electrical current draw of many popular radios, GPS moving maps, EFIS displays, lights, and other avionics. We maintain it, but contributions come from builders. |
| Top 10 Wiring Mistakes | A free, 12-page paper describing the most common wiring mistakes and how to get started wiring your aircraft. |

Additional documentation may also be available on the web site.

2. Operation

The functional block diagram of the PPS is shown below. The following sections explain in detail how each functional block of the PPS operates.



The Functional Block Diagram of the PPS

2.1 Main Bus Contactor

The main bus contactor allows current to flow to/from the main battery to the main power bus. This allows the battery to provide power to the main power bus loads and battery charging once the alternator is powering the main bus.

For the contactor to be closed, the master switch (MASTER) must be closed, the main battery (BATT DIST EN) must be enabled, and there must not be an active fault.

The main bus contactor will latch open and indicate a fault (BATT DIST FAULT) if the slow-trip current or the instantaneous maximum current of 160 amps is exceeded. The slow-trip current emulates the trip curve for a standard 80 amp slow-blow fuse.

The main bus contactor fault may be reset by either toggling the main battery (BATT DIST EN) or master switch (MASTER).

2.2 Alternator Contactor

The alternator contactor allows current to flow from the alternator(s) to the main power bus. This allows one or more alternators to provide power to the main power bus loads and battery charging if the main bus contactor is closed.

For the contactor to be closed, the master switch (MASTER) must be closed, the alternator (ALT DIST EN) must be enabled, and there must not be an active fault.

The alternator contactor will latch open and indicate a fault (BATT DIST FAULT) if the slow-trip current or the instantaneous maximum current of 160 amps is exceeded. The slow-trip current emulates the trip curve for a standard 80 amp slow-blow fuse.

The alternator contactor fault may be reset by either toggling the alternator (ALT DIST EN) or master switch (MASTER).

2.3 Main Starter Contactor

The main starter contactor allows current to flow from the main battery to the starter.

For the contactor to be closed, the master switch (MASTER) must be closed, the main starter (MAIN BATT START EN) must be enabled, and there must not be an active fault.

The starter active indicator (STARTER ACTIVE) will be active when there is voltage present at the starter output regardless of the main starter contactor or auxiliary starter contactor being closed.

The main starter contactor will latch open if the slow-trip current, the fast-trip current of 1200 amps or the instantaneous maximum current of 1500 amps is exceeded. The slow-trip current emulates the trip curve for a standard 300 amp slow-blow fuse.

The main starter contactor fault may be reset by toggling the main starter (MAIN BATT START EN) or master switch (MASTER).

2.4 Control / Status

2.4a Control Inputs

The inputs listed in the table below are inputs that control PPS operation and are intended to be connected to switches. The switch may be a toggle or momentary switch depending on the intended use. The switch should make connection to GND for Open/GND inputs and make connection to Bus voltage for BUS/Open inputs.

| Name | Description | Type | Switch State |
|--------------------|--|----------|---------------------------|
| MASTER | Turn on PPS | Open/GND | Closed = ON Open = OFF |
| MASTER ALTERNATE | Turn on PPS (Optional – redundant to MASTER) | Open/GND | Closed = ON Open = OFF |
| BATT DIST EN | Closes the Main Battery Distribution contactor | Open/GND | Closed = ON Open = OFF |
| ALT DIST EN | Closes the Alternator Distribution contactor | Open/GND | Closed = ON Open = OFF |
| MAIN BATT START EN | Closes the Main Battery Start contactor | Bus/Open | Closed = ON Open = OFF |

PPS Control input pins

The electrical characteristics for Open/GND inputs are listed below.

| Specification | Min | Max |
|----------------|--------|-------|
| Pin Voltage | 0 V | 36 V |
| Open Threshold | 500 kΩ | – |
| GND Threshold | – | 100 Ω |

Open/GND Input Electrical Characteristics

The electrical characteristics for BUS/Open inputs are listed below.

| Specification | Min | Max |
|----------------|--------|------|
| Pin Voltage | 0 V | 36 V |
| High Threshold | 7.8 V | – |
| Open Threshold | 500 kΩ | – |

BUS/Open Input Electrical Characteristics

2.4b Status Outputs

The outputs listed in the table below are status outputs from the PPS that indicate the operational and fault status of the PPS. BUS/GND outputs are intended to be connected to an LED indicator. Analog outputs are intended to be connected to equipment (e.g. analog gauges, electronic gauges, EFIS) that utilizes shunt resistors for current measurement. A positive output (CURRENT+ above reference) represents “forward current” (i.e. battery to loads). A negative output (CURRENT+ below reference) represents “reverse current” (i.e. battery charging).

| Name | Description | Type |
|-----------------|--|---------|
| BATT DIST FAULT | Latched Over-current fault indication | BUS/GND |
| ALT DIST FAULT | Latched Over-current fault indication | BUS/GND |
| STARTER ACTIVE | Starter Active indication | BUS/GND |
| BATT CURRENT+ | Main Battery current sense 1 mV/A relative to 7.5 V | Analog |
| BATT CURRENT- | Main Battery current sense 7.5 V reference | Analog |
| ALT CURRENT+ | Main Battery current sense 1 mV/A relative to 7.5 V | Analog |
| ALT CURRENT- | Main Battery current sense 7.5 V reference | Analog |

PPS output pins

The electrical characteristics of BUS/GND outputs are listed below.

| Specification | Min | Typ | Max |
|------------------------------|-----|-------|-------|
| Output Voltage | 0 V | – | BUS |
| Output Current (at VO=BUS/2) | – | – | 10 mA |
| Low Output Resistance | – | 10 kΩ | – |

BUS/GND Output Electrical Characteristics

The electrical characteristics of analog outputs are listed below. Analog outputs are protected against shorts to GND.

| Specification | Min | Typ | Max |
|----------------|-------|--------|--------|
| Output Voltage | 2.5 V | 7.5 V | 12.5 V |
| Scale | – | 1 A/mV | – |

Analog Output Electrical Characteristics

3. Electrical System Basics

This manual and the accompanying documentation on the Vertical Power web site are intended to provide enough detail to understand overall concepts and safely wire your aircraft. Should you want more information, additional resources can be found in a variety of books and texts, a few of which are shown here:

- FAA Advisory Circular AC 43.13, *Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair* available from www.faa.gov
- FAA Advisory Circular AC 23.1311, *Installation of Electronic Display in Part 23 Airplanes*, available from www.faa.gov
- EAA *Hints for Homebuilders* <https://www.eaa.org/Videos/Hints-for-Homebuilders>
- AeroElectric Connection book, available from www.aeroelectric.com
- https://www.eaa.org/shop/SAW/SportAir_Workshops.aspx
- Aircraft Wiring Guide, by Mark Ausman, more info at <https://www.aircraftwiringguide.com/>

3.1 Free advice on Designing your Electrical System

Many builders are new to electrical wiring and find it daunting. Even experienced electrical engineers may not be familiar with good practices specific to aircraft wiring. With that in mind, we've added lots of detail throughout this manual. Before we dig into those details, this section will help you to think about the big picture as you design your electrical system.

When designing your electrical system, there is a temptation to copy or do things the same way as your buddy did them when he built his plane. Avoid that temptation. Every experimental aircraft is different and is used in different ways. It may end up that your plane, when finished, is similar in certain ways to your friend's plane, but that should be because your requirements are similar and not because you blindly copied him.

We believe the most important free advice we can offer is the following:

CLARIFY YOUR MISSION

In this age of gadgets, it is all too tempting to add just one more enhancement, then one more again, until we lose sight of how and why we are building an airplane in the first place. Think about the most basic things first. What will your plane be used for? What type of weather will you be flying in? What do the worst-case scenarios look like?

The outcome of this decision drives not only how you wire your electrical system, but also what avionics and other equipment you put in the aircraft.

If you clarify your mission like this, determining not only what it is but just as importantly what it isn't, you will be ready to adopt our next bit of free advice:

COMMIT YOUR ELECTRICAL SYSTEM TO PAPER

It is surprising to us how many builders, after relying on many pages of detailed plans for their airframes, use little more than a napkin or a single sheet of copy paper to draw out their electrical system. Planning and researching your design and then committing every detail of that design to hardcopy before you buy equipment and run wires will pay huge dividends later on.

Whether you're comfortable with either a pencil or a keyboard, write and draw everything down, somewhere. Use whatever tools work best for you—paper, PowerPoint, AutoCAD, or spreadsheets. We cannot design your electrical system for you, but we can be a valuable sounding-board for your thoughts. We even have an on-line planning tool at planner.verticalpower.com that is a big step in the forward direction. After helping many different customers with many different designs, we've learned that it's much easier to erase than to rewire. Much cheaper too.

While you commit your design to paper, erasing and redrawing as many times as it takes to get it right, please keep in mind our last piece of free advice:

KEEP IT SIMPLE

As a basic rule, the more complex something is the more likely it is to break. For some reason, while most experimental airplanes are built as dependable but simple vehicles, their builders are enticed to attach every electrical bell and whistle they can find in a catalog. By adding more relays, busses, terminals, diodes, wires, and (let's face it) toys, you are actually adding more things that can fail and more things that make it harder to troubleshoot.

Before you delve into the details of designing your electrical system, please consider these three bits of advice. If you do so, the end result will be an electrical system and avionics package that meets your real needs when you get your project in the air.

3.2 Basic Concepts

An aircraft electrical system can be divided into three parts:

1. “Backbone” components: aircraft battery, alternator, voltage regulator, contactors and associated wiring. This is called the primary power distribution system. Contactors are just high capacity relays that are energized by low power signals but allow large amounts of power to pass through.
2. Busses, switches, smaller wiring, and circuit protection (fuses and/or circuit breakers). This is called the secondary power distribution system.
3. Users of power and the wiring to and from those users. Users may be lights, instruments, avionics, pumps, etc. The term device or load is used in this manual to generically describe all the users.

More on electrical system basics:

- The aircraft battery and alternator provide power to all electrically-dependent systems. Normally, the battery powers systems before and during starts and then the alternator takes over charging the battery and providing power to the electrical devices. A battery contactor, connects (or disconnects) the high-current wires between the battery and the main power distribution bus. The PPS functions as the battery contactor.
- Power typically runs from the battery/alternator to electrical busses behind the panel where power is split and sent to individual devices through circuit protection (fuses and circuit breakers) and switches. The VP-X assumes the role of busses, circuit protection, and a host of single-function modules. During construction, the VP-X greatly simplifies the task of wiring your aircraft.
- Wire size to each device varies and is determined by the current load (amps) of that device as well as the distance the current must travel. If a wire is too small for the load or distance, it will heat up and possibly fail. If the wire is too big, it will certainly carry the load but at the expense of added weight.
- To complete the electrical path, all electrical loads (such as radios, lights, etc.) must have a ground. This means connecting a ground wire to the metal aircraft structure (aircraft ground) or running a ground wire from each load to a central location such as a firewall grounding point.

3.3 Alternator Options

The alternator provides power to devices and also charges the aircraft battery. The voltage regulator continuously monitors the bus voltage and adjusts the output of the alternator. The regulator only works when it is powered from a bus through a wire called the field wire. Some alternators are internally regulated (the regulator is built in), and others have external regulators (a separate box located outside the alternator).


Today’s experimental aircraft are powered by either 14 volt or 28 volt systems. Often you may hear 12 volt or 24 volt systems. Why the difference? The reason is because the batteries are rated at either 12 or 24 volts. When the engine is running and the alternator is turned on, the alternator generates 14 volts or 28 volts, slightly higher than the battery voltage so it will keep the battery charged.

If you have a primary alternator and a secondary (backup) alternator only one alternator (field wire) should be powered on at a time. Therefore, we refer to one alternator as the primary and the other as the secondary. If both are on simultaneously, they do not equally “contribute” to powering the loads. The one whose voltage regulator is set to the highest voltage will draw all the current (sometimes called current hogging), possibly overloading the alternator.

When planning your electrical system, assume the alternator provides 80% of its rated output (in amperes), and therefore your total continuous load (don’t worry about trim or flaps or other transient loads) should not exceed 80% of rated alternator capacity.

3.3a Wiring the B&C External Regulator with the PPS

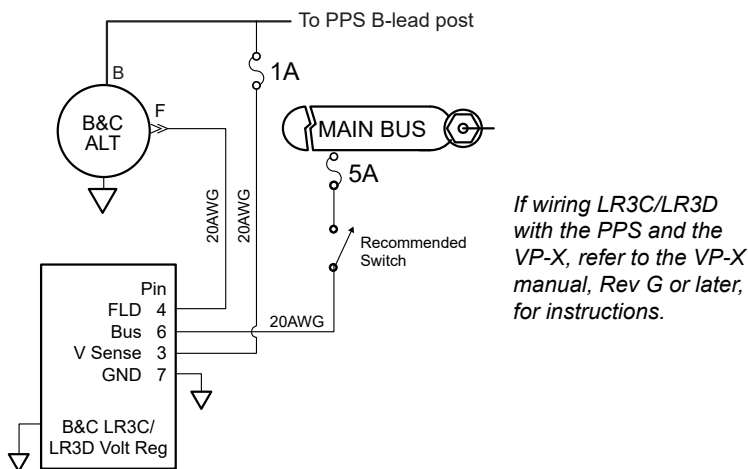
The B&C LR3C/LR3D voltage regulator can be used with several of the B&C alternators and other externally-regulated alternators. Do not use the SB1B regulator. The LR3C/LR3D requires a power wire for the field and the voltage sense wire, which senses the bus voltage in order to correctly regulate bus voltage. If using the PPS with the Vertical Power VP-X, refer to the VP-X manual for comprehensive wiring instructions. If using a traditional bus, use the instructions that follow.



When using the LR3C/LR3D external voltage regulator with the PPS, it is **IMPERATIVE** that you follow the wiring diagram below (for a traditional bus), or the wiring diagram presented in the VP-X Installation and Operating Manual, Rev G or later (if using the VP-X), or you will damage the PPS. Failure to wire the voltage regulator as shown will void the PPS warranty.

Follow the instructions below when using the B&C LR3C/LR3D external voltage regulator with the PPS on a traditional bus:

Wiring LR3C/LR3D with the PPS and a Traditional Bus



- Run 20 AWG wire from pin 6 on the LR3C/LR3D to a 5A breaker attached to the main bus. This is the alternator field wire.
- Run 20 AWG wire from pin 3 on the LR3C/LR3D to a 1A breaker and then to the PPS B-lead post. This is the alternator Vsense wire.
- Run a wire from pin 4 on the LR3C/LR3D to the field input on the alternator.
- Ground the LR3C/LR3D as per B&C installation manual.
- Run the B-lead wire from the alternator to the PPS B-lead post (no ANL fuse required). The B-lead is typically a 6 or 8 AWG wire.
- Follow the same procedure if using the LR3C/LR3D with a backup alternator.

3.4 Wire Sizes and Circuit Protection

A table below shows wires sizes versus loads for a typical homebuilt-size airplane. The wire size can be larger than necessary but should not be smaller. Circuit breakers (and fuses) protect the wiring, not the device. If the breaker is too large, then the wire may overheat and fail. If too small, then the device may fault (breaker trips) because it draws too much current.

Most kit aircraft companies and avionics companies provide recommendations for sizing wires and breakers. You can use these recommendations. Or, you can borrow or purchase an ammeter (typically under \$50 at Radio Shack, etc.) measure the current draw of each electrical device and then determine the sizes yourself. When you know the current draw for each device, use the chart below to size the power wires. For simplicity, the wiring harnesses available from Vertical Power use the wire sizes in the table.

| Up to (amps) | Use wire size (AWG) |
|-----------------|---------------------|
| 5 A | 20 |
| 10 A | 18 |
| 15 A | 14 |
| 80 A | 4 |
| 300 A (starter) | 2 |
| Data signal | 22 |

Recommended wire gauges


3.5 Grounding - IMPORTANT

Many people think that the power, or positive, wire is the most important wire to provide electricity to a device. The electrical ground is just as important as electricity must flow the entire path from the power source to the device and back to the source. The ground wire must be the same wire gauge or a larger diameter (smaller gauge number) as the wire that provides power to the device.

A ground loop is when electricity takes two different paths, and each path has a different resistance. Ground loops are most noticeable in aircraft audio equipment, and can produce a variety of problems, most notably unwanted noise.


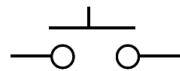
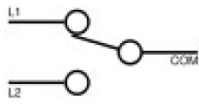
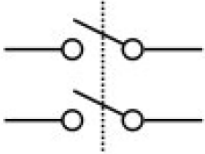
Several options for grounding your system are provided below. Choose the one that best fits your needs. Keep in mind that more wiring means more weight (although likely negligible). Also, note that in all the examples below the avionics grounds are kept together.

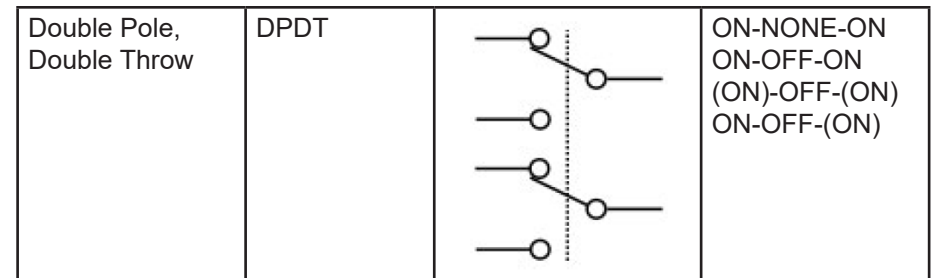
- **Option 1:** Run a ground wire from each and every electrical device back to a common grounding point, typically a ground bus on the firewall.
- **Option 2:** Run ground wires from all the avionics to an intermediate grounding point, then run a larger wire from the local ground bus to the firewall ground. Run wires from all the other devices to the firewall ground.
- **Option 3:** Run the ground wires from the avionics to the firewall ground, and run the other ground wires to a local ground (a metal part of the airframe located near the device).

| | |
|---|---|
|  | <p>The GND Stud connection to the PPS shall be $\leq 2.5 \text{ m}\Omega$. Failure to meet this requirement will damage the PPS and lead to an unsafe condition. 18 ga wire is sufficient.</p> |
|---|---|

3.6 Switch Nomenclature

The chart below shows the most common switch types. A parenthesis () around a switch position indicates it is a momentary, spring-loaded position.

| Switch Type | Designation | Symbol | Mechanism |
|---------------------------|-------------|---|---|
| Single Pole, Single Throw | SPST |  | OFF-ON |
| | |  | OFF-(ON) |
| Single Pole, Double Throw | SPDT |  | ON-NONE-ON ON-OFF-ON (ON)-OFF-(ON) ON-OFF-(ON) |
| Double Pole, Single Throw | DPST |  | OFF-ON OFF-(ON) |



PPS Control input pins

3.7 Current Sensing (Shunt)

When planning your aircraft electrical wiring you must consider whether to wire an ammeter (usually a shunt or hall effect sensor provided with the engine monitor) on the wire connecting the alternator(s) to the main bus. The ammeters indicate the amount of current the alternator is providing.

A shunt is not required to tell if the alternator is working. It is very easy to tell if the alternator is working correctly by simply looking at voltage. If you see 14 (or so) volts with the engine running then it is working. If you see 12 (or so) volts it is not working or not turned on or the devices are drawing more current than the alternator can provide (note, engine must be running). If you set your low voltage alarm on the EFIS at 13 volts, then you will get a low voltage alarm if the alternator fails.

The PPS provides the alternator current (shunt) output, which shows the amount of current the alternator is providing to power the devices and charge the battery. The VP-X total current reading shows the total amount of current the devices attached to the VP-X are using. The delta between the two is the battery charging current, which goes to zero after re-charging any loss from starting the engine or charging a run-down battery.

If the battery charging current is important to you, the PPS also provides a battery current (shunt) output as well. If not, then simplify your wiring and don't utilize this PPS output. Your call. And of course each builder's needs are different so there is no absolutely right answer.

The EFIS displays a VP-X page which shows individual device current as well as total current through the VP-X. The EFIS also has an 'Amps' gauge that is used to show the readings from the shunt. In some cases the EFIS 'Amps' gauge can be used to display total system current from the VP-X. Please check with your EFIS manufacturer for details.

If you don't use the PPS current outputs then the shunt wires on the engine monitor/ EFIS are not used.

4. Installation and Test

Installation of the PPS is accomplished in four main steps. Following these steps will increase the likelihood of a trouble-free electrical system. Taking time to plan your electrical system will pay big dividends later on.

- Planning
- Installation
- Ground Test
- Flight Test

4.1 Planning

It is a good idea to spend time on the planning stage whether you are installing a simple or a complex aircraft electrical system.

A wiring harness for the PPS circular connector is available to simplify the installation of electrical system.

The wiring diagrams in this section illustrate typical basic installations with traditional wiring and with the Vertical Power VP-X electronic circuit breaker system. Wiring diagrams also show alternate or advanced installation options that may or may not be needed for your installation.

Utilize this manual and the wiring diagrams to create a plan for your aircraft wiring prior to performing the installation.

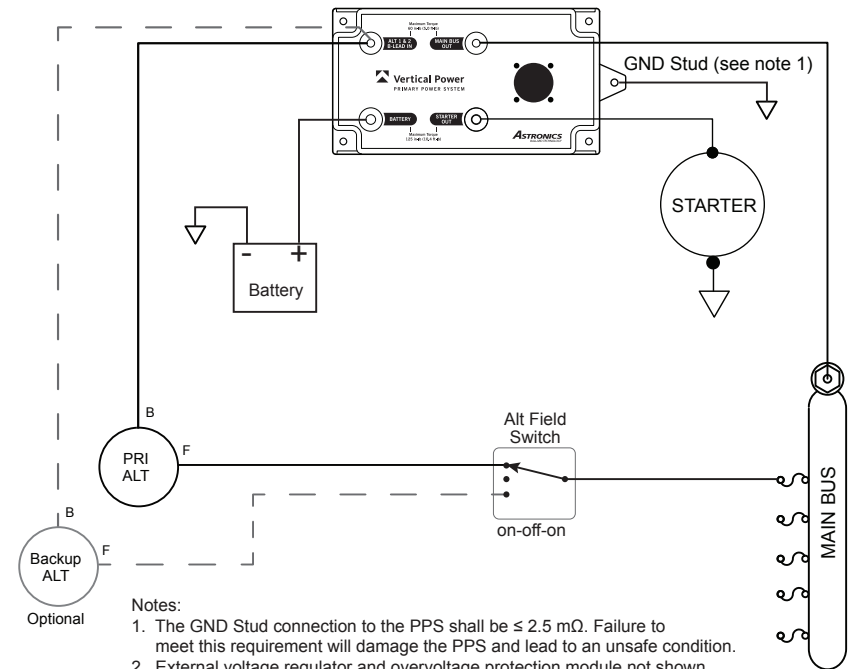
4.1a Tools and Supplies

This is a generic list of items to assist with planning. Some items may vary depending on the requirements of your specific installation.

- Crimper - insulated terminals 20 AWG
- Crimper - TE Connectivity Hand Crimper 601966-1 (or equivalent) and TE Connectivity Positioner 601966-5 (or equivalent)
- Crimper – terminals for 2 to 8 AWG wire
- Stripper – for wire 20 AWG
- Heavy gauge wire for “main” power runs
- Battery contactor (optional for remote mounted battery)
- Alternator(s) and voltage regulator(s)
- Switches
- Indicators

4.1b Wiring Diagrams

The following wiring diagrams provide an overview for wiring the PPS in traditional systems, systems with the Vertical Power VP-X, and in systems with a remote-mounted battery.

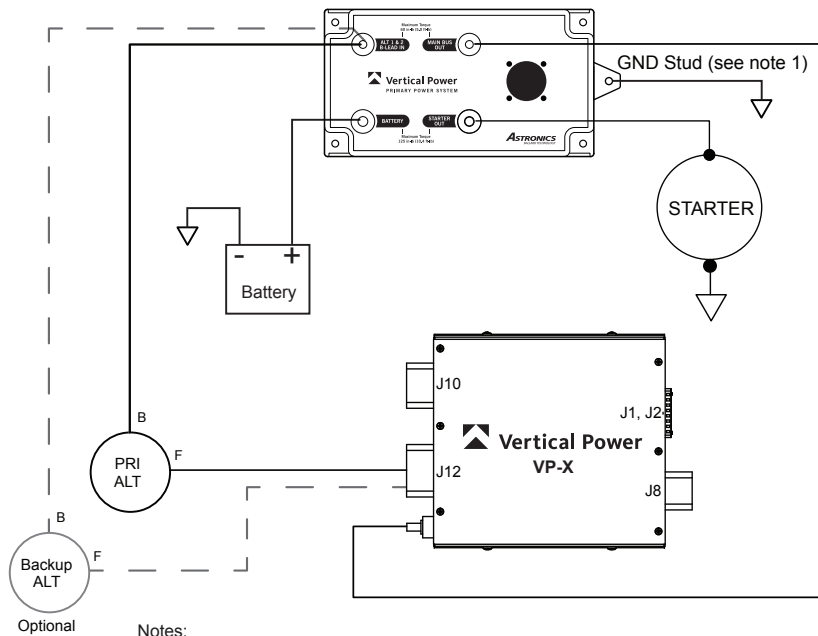


Notes:

1. The GND Stud connection to the PPS shall be ≤ 2.5 m Ω . Failure to meet this requirement will damage the PPS and lead to an unsafe condition.
2. External voltage regulator and overvoltage protection module not shown (may or may not be needed, depending on alternator)

PPS wiring overview with traditional wiring

Note: Alternator field switch shown for example purposes only. Other variants that achieve the same function electrically can be used, such as two individual switches, a split master/alternator switch, and other common variants.

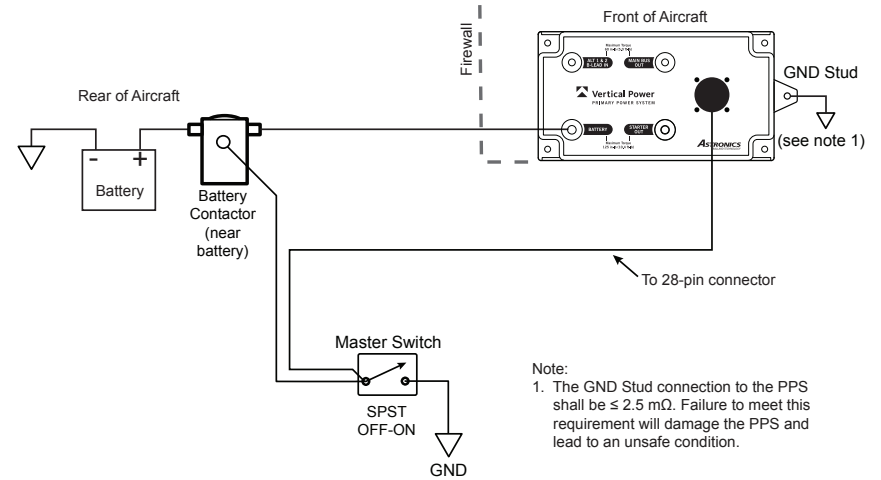


Notes:

1. The GND Stud connection to the PPS shall be $\leq 2.5 \text{ m}\Omega$. Failure to meet this requirement will damage the PPS and lead to an unsafe condition.
2. External voltage regulator not shown (may or may not be needed, depending on alternator)

PPS Wiring Overview with the Vertical Power VP-X

Aircraft with a remote mounted battery may require the addition of a battery contactor near the battery as shown in the following diagram:



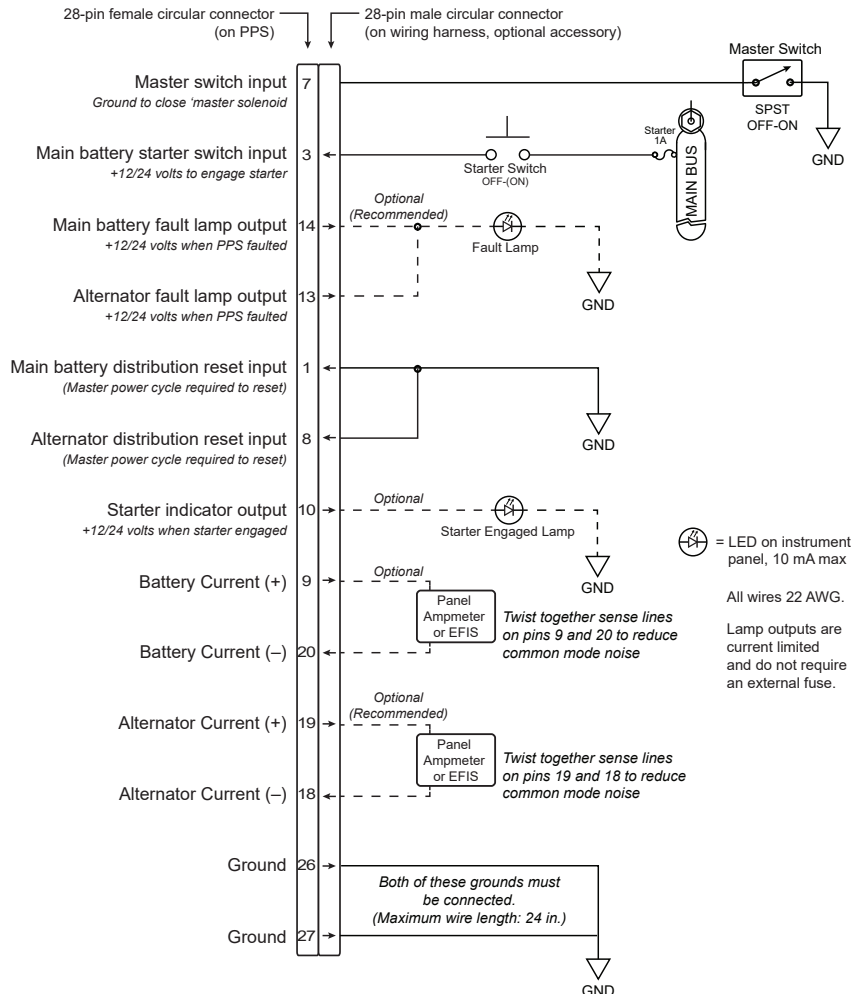
- Note:
1. The GND Stud connection to the PPS shall be $\leq 2.5 \text{ m}\Omega$. Failure to meet this requirement will damage the PPS and lead to an unsafe condition.

PPS with remote mounted battery

Depending on the level of control required two installation methods are available - basic and comprehensive. Basic installs minimize the number of switches and indicators needed and match well with existing panel wiring for retrofit applications. The comprehensive method requires more wiring, but allows individual reset control of faults.

Basic Installation with Traditional wiring

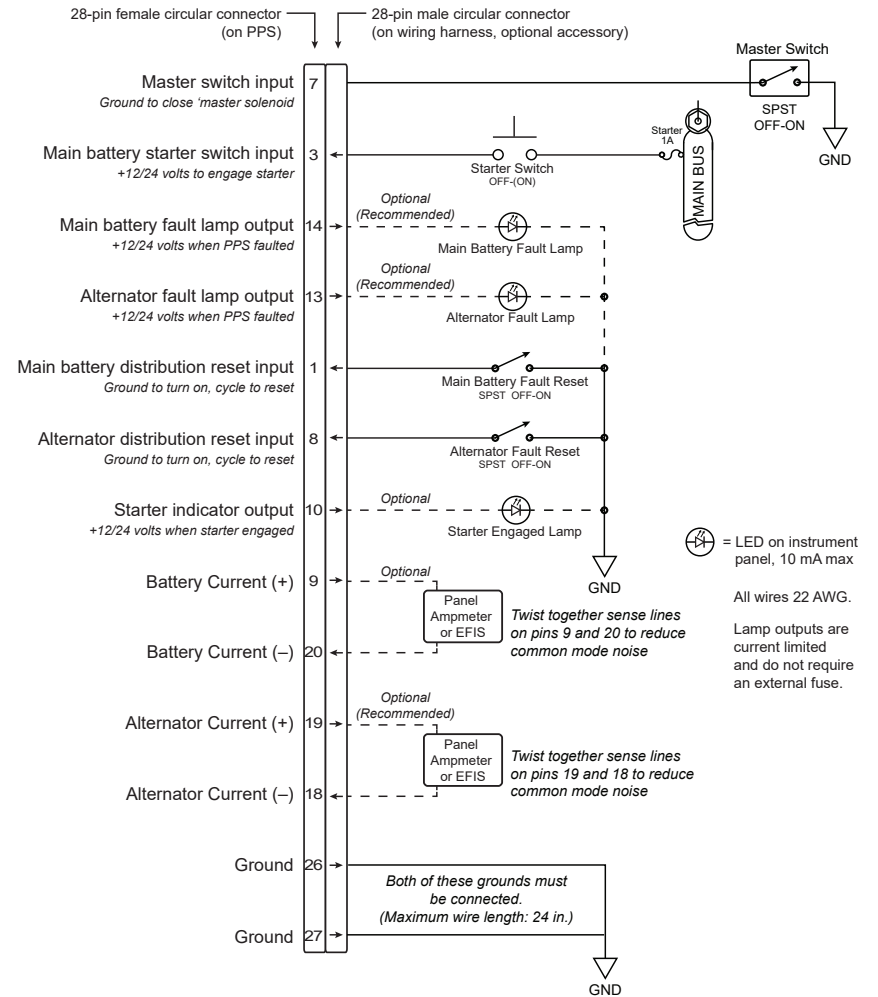
The image below details basic PPS connector wiring for an aircraft with traditional wiring:



PPS basic installation with traditional wiring

Comprehensive Installation with Traditional wiring

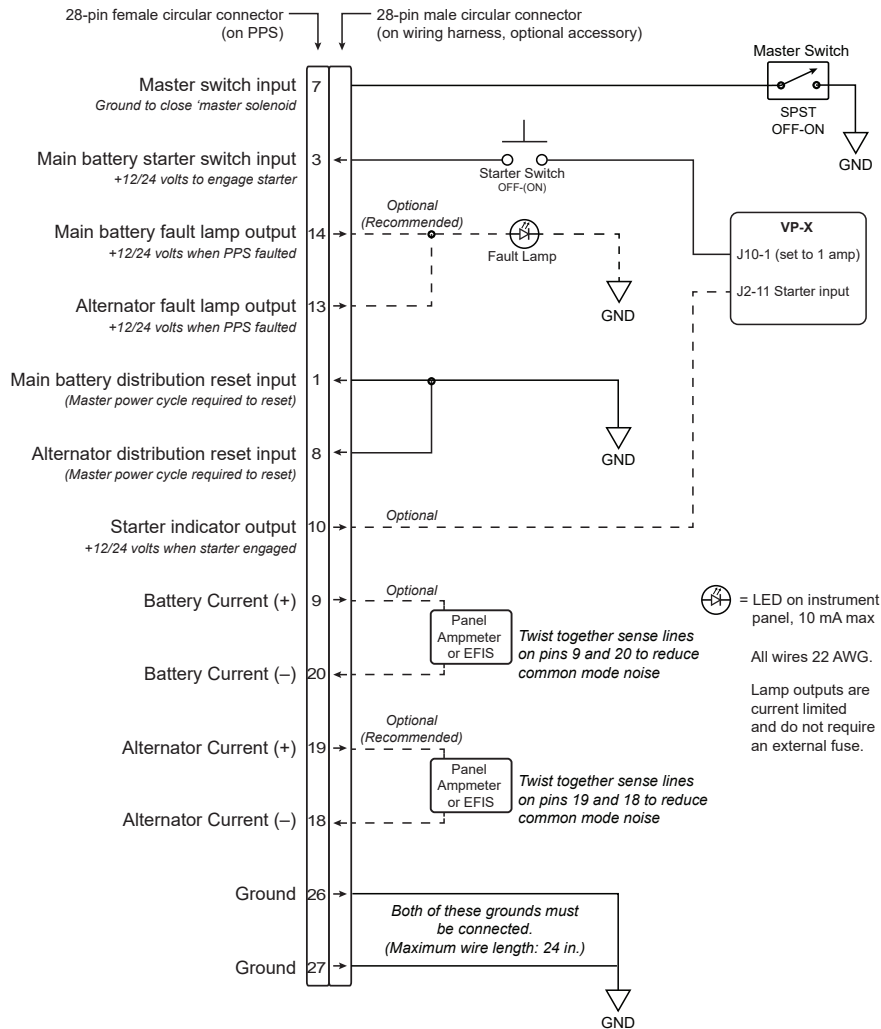
The image below details comprehensive PPS connector wiring for an aircraft with traditional wiring:



PPS comprehensive installation with traditional wiring

Basic Installation with the Vertical Power VP-X

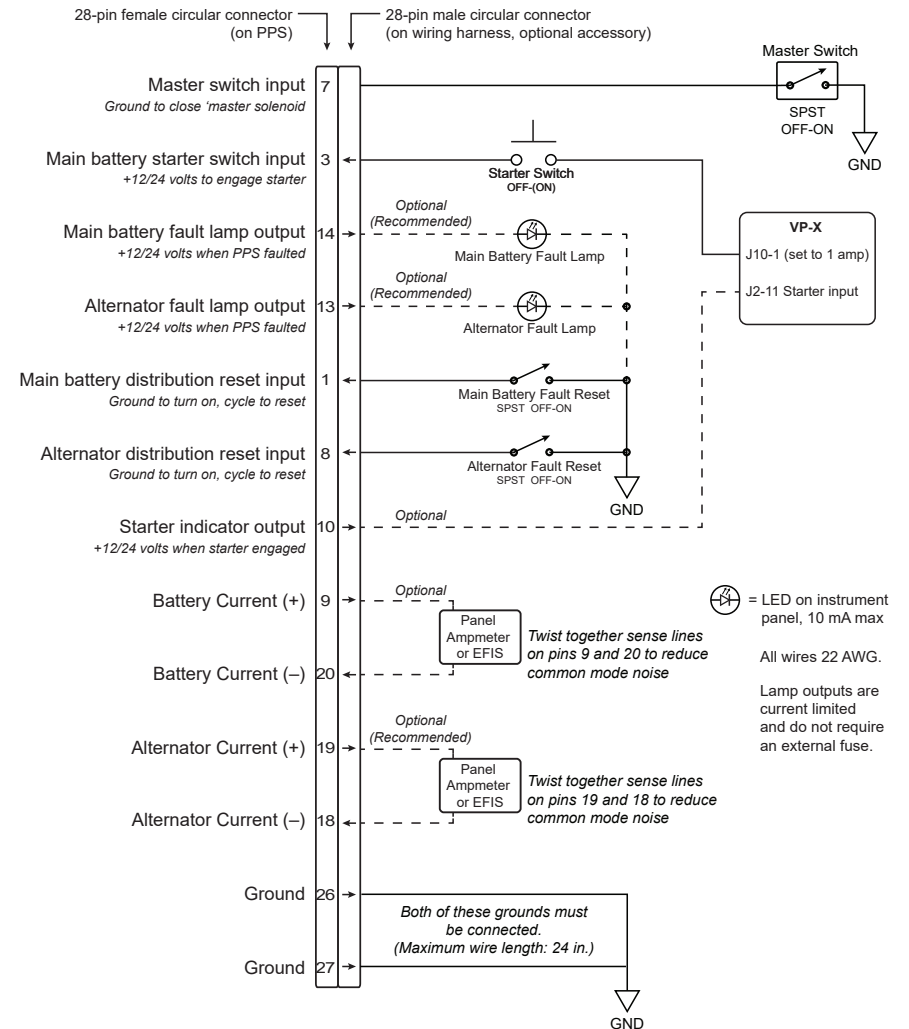
The image below details basic PPS connector wiring for an aircraft wired with the Vertical Power VP-X:



PPS basic installation with the Vertical Power VP-X

Comprehensive Installation with the Vertical Power VP-X


The image below details comprehensive PPS connector wiring for an aircraft wired with the Vertical Power VP-X:



PPS comprehensive installation with the Vertical Power VP-X

4.2 Installation


Prior to installation, be sure to review and understand your wiring plan.

| | |
|---|---|
|  | <p>During installation, the battery should NOT be connected until the wiring is installed and tested.</p> |
|---|---|

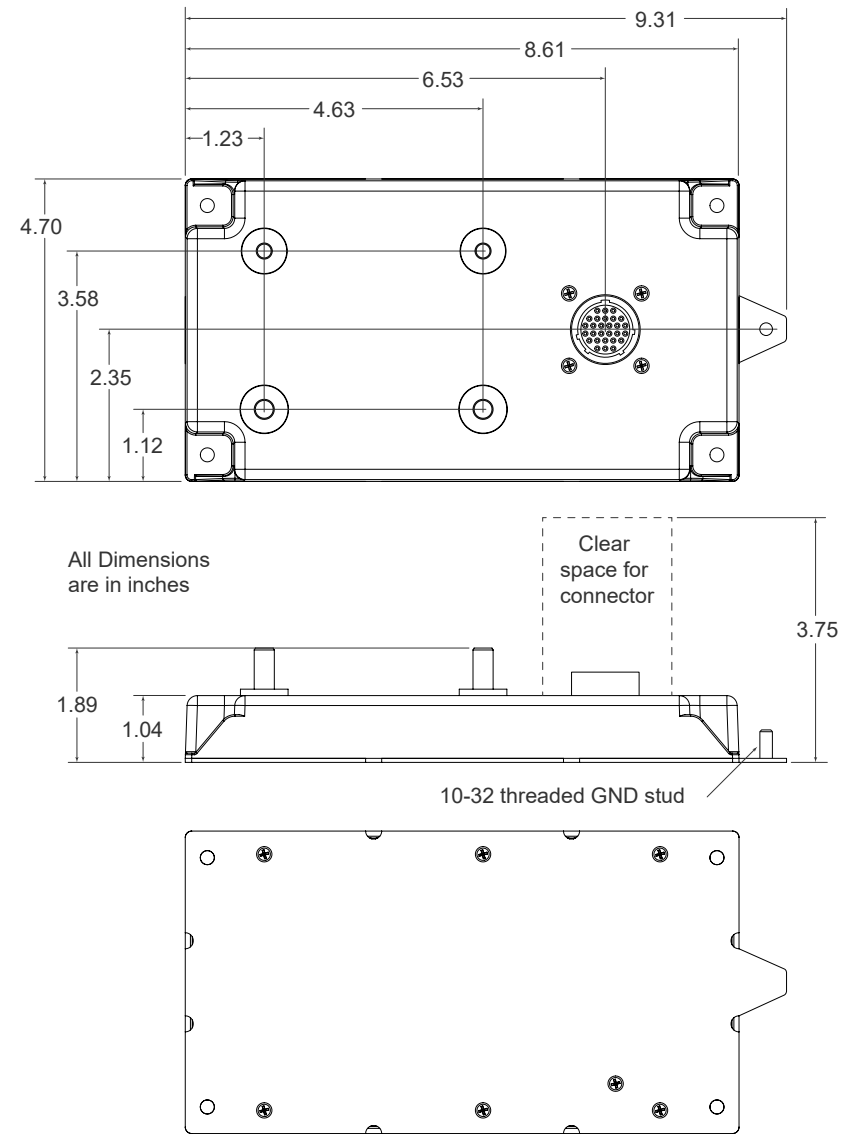
Tip: Disconnect the battery ground cable first, then the positive cable. When re-connecting, connect the positive cable first then the ground cable. Doing so ensures you won't spark the positive connection to the airframe.

4.2a Mount the PPS

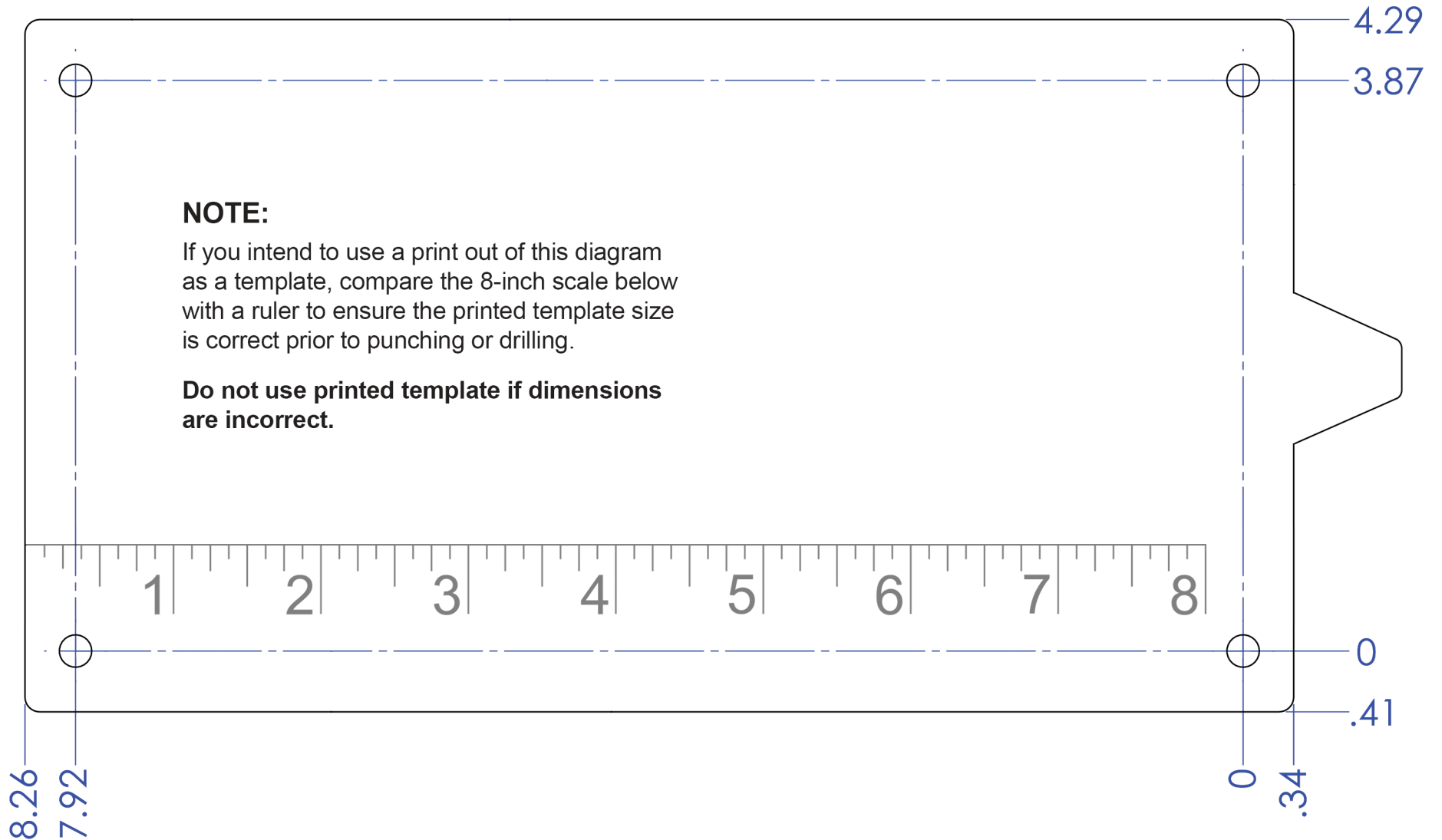
The PPS should be mounted to the firewall, or other desired location, using 4 #10 bolts (not included—use US recommended torque for #10 bolt). A drill/punch template is provided on the next page. You can print this as a guide for easy hole location (Important: prior to using, you must verify the dimensions of the printed template according to the instructions on the template).

| | |
|---|--|
|  | <p>When mounting the PPS to the firewall, a firewall sealant should be used around any penetrations as a barrier against the ingress of fire or fumes.</p> |
|---|--|

The interior components of the PPS are thoroughly encapsulated for complete sealing from the elements. The back panel includes “weep” holes to allow any excess moisture to escape. These are found around all sides of the exterior, allowing the PPS to be mounted in nearly any orientation where moisture can escape from the bottom of the unit. Do not mount the PPS with the connector side facing down as moisture would be impeded from escaping.



PPS Mechanical Diagram




PPS Mounting Template

4.2b Terminal Wiring

Per your installation plan, route wires and make connections to the terminals for the starter, main bus output, alternator b-lead(s) and battery. Use the included flat washer, lock washer, and nut to secure each connection and torque according to the table below.

| Terminal | Size | Minimum Torque | Maximum Torque |
|---------------------|----------|----------------------|----------------------|
| Main Battery | 5/16"-18 | 85 in-lb (7.1 ft-lb) | 90 in-lb (7.5 ft-lb) |
| Starter Out | | | |
| Alt 1 & 2 B-Lead In | 1/4"-20 | 40 in-lb (3.3 ft-lb) | 45 in-lb (3.7 ft-lb) |
| Main Bus Out | | | |
| GND Stud | 10-32 | 20 in-lb (1.6 ft-lb) | 25 in-lb (2.1 ft-lb) |

PPS Terminal Torque Table

| | |
|---|---|
|  | <p>When tightening terminal wiring to the appropriate torque, double-check that you are using the correct value for the tool you are using (in-lb vs. ft-lb) or you may damage the terminals.</p> |
|---|---|

Electrical anti-corrosion/corrosion inhibitor lube should be used on all power distribution cable connections (main bus, alternator, battery, starter and grounds).

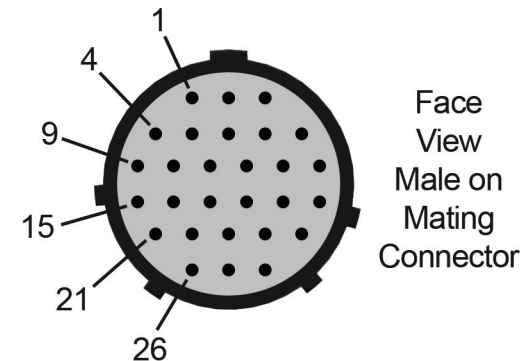
4.2c Control/Status Wiring

Per your installation plan, route wires for the switches and indicators. Crimp and install these wires into the circular connector.

The PPS uses TE Connectivity circular plastic connectors for J1. The mating TE Connectivity connectors are recommended for compatibility. Included in the table below are the recommended mating connectors and individual crimp pins.

| | J1 Connector |
|--------------------------|--------------|
| Positions | 28 |
| Contact size | 20 gauge |
| Mating connector | 206039-1 |
| Backshell, straight | 206070-8 |
| Backshell, right-angle | 1546349-2 |
| Crimp Contacts, stamped | 1-66506-0 |
| Crimp Contacts, machined | 205089-1 |

PPS Mating Connector Part Numbers



PPS Mating Connector View

If using the optional wiring harness, run each pre-crimped wire of the harness from the PPS connector to the switch/indicator location. Trim the excess length and terminate the wire to the switch/indicator. Insert the pre-crimped end of the wire into the circular connector.

| J1 Connector | | | |
|--------------------|---|----------------|-------|
| Name | Description | Type | Pin # |
| BATT DIST EN | Closes the Main Battery Distribution contactor | Open/GND Input | 1 |
| RSVD | Reserved (do not connect) | | 2 |
| MAIN BATT START EN | Closes the Main Battery Start contactor | BUS/Open Input | 3 |
| RSVD | Reserved (do not connect) | | 4 |
| RSVD | Reserved (do not connect) | | 5 |
| MASTER ALTERNATE | Turn on PPS (Alternate - redundant to MASTER pin 7) | Open/GND Input | 6 |
| MASTER | Turn on PPS (Redundant with pin 6) | Open/GND Input | 7 |
| ALT DIST EN | Closes the Alternator Distribution contactor | Open/GND Input | 8 |
| BATT CURRENT+ | Main Battery current sense 1 mV/A relative to 7.5 V | Analog | 9 |
| STARTER ACTIVE | Starter Active indication | BUS/GND Output | 10 |
| RSVD | Reserved (do not connect) | | 11 |
| RSVD | Reserved (do not connect) | | 12 |
| ALT DIST FAULT | Latched Over-current fault indication | BUS/GND Output | 13 |
| BATT DIST FAULT | Latched Over-current fault indication | BUS/GND Output | 14 |
| RSVD | Reserved (do not connect) | | 15 |
| RSVD | Reserved (do not connect) | | 16 |
| RSVD | Reserved (do not connect) | | 17 |
| ALT CURRENT- | Main Battery current sense 7.5 V reference | Analog | 18 |
| ALT CURRENT+ | Main Battery current sense 1 mV/A relative to 7.5 V | Analog | 19 |
| BATT CURRENT- | Main Battery current sense 7.5 V reference | Analog | 20 |
| RSVD | Reserved (do not connect) | | 21 |
| RSVD | Reserved (do not connect) | | 22 |
| RSVD | Reserved (do not connect) | | 23 |
| RSVD | Reserved (do not connect) | | 24 |
| RSVD | Reserved (do not connect) | | 25 |
| GND | Ground (must connect both pins 26 and 27 to GND - maximum wire length: 24 inches) | | 26 |
| | | | 27 |
| RSVD | Reserved (do not connect) | | 28 |

4.3 Ground Test

The ground test steps are performed in two parts: the first part without the engine running and the second part with the engine running.

4.3a Ground Test without engine running

Perform the following steps without the engine running. Prevent engine from starting during cranking by shutting off fuel and/or having mag switches in the off position. The battery will drain during testing, so have either a charger or ground power available.

- Turn on the master switch
- If installed, turn on the main battery enable switch
- Verify main bus power
 - Use a multi-meter or verify load device is operational
- If installed, verify the main bus current output.
- Verify starter cranking
 - Turn the starter switch to the on position for a few seconds
 - Verify the starter indicator if used.
- When installing with a VP-X, perform VP-X ground testing without engine running at this time.

4.3b Start Mode Duty Cycle

The PPS was designed to be more tolerant to overheating than most starters, but measures should still be taken to limit heat build up in the PPS. First and most important is to always follow your starter manufacturer's published duty cycle guidelines. In most cases, this will be adequate to prevent heat damage to the PPS.

For reference, here are the start mode duty cycle guidelines for the PPS:

- Each starting attempt must not exceed 20-seconds.
- After each starting attempt, there must be a 60-second rest time.
- After three (3) starting attempts, a 10-minute cool down period is required.

4.3c Ground Test with engine running

This section verifies the proper operation of the PPS with the engine running. If this is coincident with first engine start, be sure to integrate the kit manufacturer's first engine start safety procedures with the test plan below.

You may consider first verifying proper operation of the engine and once that is complete, begin the electrical system test.

Prolonged low-power operation of a new engine may adversely affect the engine. Be sure you understand the engine break-in requirements, and balance those against the time needed to test the electrical system.

The following tests should be used as a guideline. Follow the engine manufacturer's starting and safety procedures.

- Ensure that the battery is fully charged. If the voltage drops rapidly during engine start, then the battery is bad or not fully charged.
- Start the engine.
- Note the bus voltage. Then turn on the primary alternator. If installed turn on the alternator enable to the PPS.
- The voltage should increase to 14.2 volts +/- 0.3 volts (check with your alternator manufacturer for specifics)
- If installed, verify the alternator current output.
- If installed, verify the main bus current output. Current should show charging or zero current flow once alternator is operating.
- Verify the each alternator can be turned off and on.
- If installed, turn on the alternator enable to the PPS on and off. Verify correct operation.
- If installed, turn the main battery enable to the PPS on and off. Verify correct operation.
- Turn off all switches.

4.4 Flight Test

Prior to flight, make sure you understand how to operate the PPS and clear faults. This section provides a series of recommended steps which should be incorporated into the overall flight test plan as you deem appropriate. Review the ground test steps, as complete and thorough ground testing will mitigate the risk of trouble while airborne.



Do not fly the aircraft until you are comfortable everything operates correctly on the ground and you are knowledgeable about the systems and their proper operation.

It is the pilot's responsibility to develop a test plan that ensures a safe and productive first flight. Typically, the first flight is focused on verifying basic flight characteristics and proper engine operation. With that in mind, we recommend deferring complete electrical system tests until after you are comfortable that the engine and airframe are performing as expected, and you are comfortable flying the aircraft.

If you are installing the system as a retrofit, it is still important to complete as much of the testing on the ground as possible.

Once airborne, keep an eye out for traffic and obstacles during the test procedure. Carry a handheld radio as a backup in case of electrical system failure. If you encounter any difficulties in flight due to improper setup or unknown electrical system behavior, land as soon as practical or simply turn off the master switch.



Verify backup power is ON for ignition and required devices prior to turning off the master switch.

If you have completed a thorough check out on the ground, the chances of problems while airborne are greatly reduced.

Verify each of the following in flight:

- Verify the each alternator can be turned off and on.
- If installed, turn on the alternator enable to the PPS on and off. Verify correct operation.
- If installed, turn the main battery enable to the PPS on and off. Verify correct operation.

5. Maintenance

5.1 Do's and Don'ts

The PPS unit is maintenance free, but the following routine power system do's and don'ts are recommended:

- Do routinely check all the power distribution cable connection fastener torques on the interconnects to the PPS, alternator, battery, starter and grounds
- Do not expose the PPS directly to spray wash/fluids.

6. Troubleshooting

This chapter provides information to assist in troubleshooting the PPS installation. If the problem(s) cannot be resolved using the information in this chapter, please contact Customer Service.

6.1 Common Problems

Several common installation problems are listed below along with potential resolutions.

| Problem | Resolutions |
|---|---|
| Main Bus Voltage not present | Use multi-meter to verify bus voltage is present at Main Battery input terminal. |
| | Use multi-meter to verify that Master switch input (primary or alternate) voltage is ground (must be below minimum input voltage). |
| | Use multi-meter to verify that Main contactor switch input voltage is ground (must be below minimum input voltage). |
| | Verify that no fault is present. Use multi-meter to verify that Main contactor fault output is ground. |
| Main Bus Voltage is less than 13 V or 26 V when Alternator is enabled | Use multi-meter to verify bus voltage is present at Alternator input terminal and is above 13 V or 26 V. |
| | Use multi-meter to verify that Alternator contactor switch input voltage is ground (must be below minimum input voltage). |
| | Verify that no fault is present. Use multi-meter to verify that Alternator contactor fault output is ground. |
| Engine not turning over or starting | Disconnect starter from PPS and verify that starter circuit is operational. With the master on, enable the starter and verify either voltage is present at the starter output terminal or that the starter active indicator lights. |

Common Problems/Resolutions

7. Specifications

7.1 General

- Transient protection on all connections

7.2 Circuit Ratings

- Main Bus Output: 80 A maximum continuous
- Starter Output
 - 300 A maximum continuous
 - 1200 A maximum intermittent
- Alternator Input
 - 80 A maximum continuous
- Analog Current Monitor Outputs
 - Common-mode reference of 7.5 VDC
 - Scale: 1 mV/Amp
 - Short circuit protected

7.3 Environmental / Physical

- Component Temperature Range: -40°C to $+85^{\circ}\text{C}$
- Storage Temperature Range: -55°C to $+100^{\circ}\text{C}$
- Size: 4.7 x 8.65 inches
- Weight: 1.6 lb (0.72 kg)
- Operating Voltage: 8 – 36 VDC
- Low quiescent power: less than 1 mA at 14 VDC and 28 VDC
- Maximum power
 - 320 mA at 14 VDC
 - 140 mA at 28 VDC