

Wa-chur-ed Observatory

Power *Star*

USER MANUAL

Version 1.8, Dec. 4, 2020

Thank you for purchasing the Wa-chur-ed Observatory Power*Star (P*S). P*S integrates power control, data distribution, focus control, and dew heater control into a single, compact unit. The result is that most users will need only 2 cables going to the telescope; a 12V power cable and a USB data cable.

This document describes the system setup, software installation, and general use of the P*S.

WARNING

PLEASE BE VERY CAREFUL WHEN USING A BATTERY TO POWER P*S. EVEN A SMALL LEAD-ACID BATTERY CAN EXPLODE, CATCH FIRE, OR RELEASE STRONG ACID IF HANDLED INCORRECTLY. NEVER SHORT THE TERMINALS OR ANY WIRES CONNECTED TO THE TERMINALS OF A BATTERY. USE ONLY INSULATED TOOLS WHEN MAKING CONNECTIONS TO A BATTERY. IF YOU HAVE ANY UNCERTAINTY ABOUT THESE INSTRUCTIONS PLEASE CONTACT A QUALIFIED ELECTRICIAN.

The above warning relates to the greatest danger you will likely encounter in using the P*S system. Please refer to section 7 of this manual for additional precautions and more detailed information on safe use.

PLEASE READ SECTION 3 BEFORE CONNECTING ANY DEVICES TO Power*Star. IN PARTICULAR, SEE SECTION 3.3 REGARDING THE ENVIRONMENT SENSOR.

IF YOU DO NOT READ ANY OTHER PART OF THIS USER MANUAL, PLEASE REMEMBER THAT YOU SHOULD CLICK THE "DISCONNECT" BUTTON BEFORE REMOVING POWER TO PH. FAILURE TO DO SO WILL RESULT IN SOME VERY ANNOYING ERROR MESSAGES.

Table of Contents

- 1 Overview
 - 1.1 Introduction
 - 1.2 Features
 - 1.3 Not Included
- 2 Software Installation
 - 2.1 Preparation
 - 2.2 P*S Application Installation
 - 2.3 ASCOM Driver Installation
- 3 Hardware Set Up
 - 3.1 Power Connections
 - 3.2 USB Connections
 - 3.3 Environment Sensor
 - 3.4 Motor Connections
- 4 Mounting Power*Star on your Telescope
- 5 Using Power*Star
 - 5.1 Overview
 - 5.2 Power*Star Application
 - 5.2.1 Connecting and Configuring
 - 5.2.1.1 Setup Power*Star
 - 5.2.1.1.1 Power Ports
 - 5.2.1.1.2 USB Ports
 - 5.2.1.1.3 Multi-purpose Output
 - 5.2.1.1.4 LED Brightness
 - 5.2.1.1.5 Miscellaneous Preferences
 - 5.2.1.1.6 Automatic Dew Control
 - 5.2.1.2 Configure Focus Controller
 - 5.2.1.2.1 Backlash Compensation
 - 5.2.1.2.2 Preferred Direction
 - 5.2.1.2.3 Motor Current
 - 5.2.1.2.4 Step Period
 - 5.2.1.2.5 Max Position and "Set To"
 - 5.2.1.2.6 Temperature Compensation
 - 5.2.1.2.6.1 TC Coefficient
 - 5.2.1.2.6.2 TC Hysteresis
 - 5.2.1.2.6.3 Temperature Sensor Select
 - 5.2.1.2.6.4 ASCOM TC Available
 - 5.2.1.2.7 Behavior
 - 5.2.1.2.7.1 Reverse Motor
 - 5.2.1.2.7.2 Permanent Focus
 - 5.2.1.2.7.3 Lock Mode Braking
 - 5.2.1.2.8 Motor Type
 - 5.2.1.2.9 Motor Selection
 - 5.2.1.3 Firmware Update
 - 5.2.1.4 Power*Star Reset

5.2.2 Power*Star Application Tabs

5.2.2.1 Power Tab

5.2.2.1.1 Output Power Section

5.2.2.1.2 Monitor Section

5.2.2.1.3 Dew Control Section

5.2.2.1.4 Status section

5.2.2.2 USB Tab

5.2.2.3 Focus Tab

5.2.2.4 Status Tab

5.2.2.5 Fault Actions Tab

5.2.2.6 Graph Tab

6 Using the ASCOM Driver

6.1 ASCOM Chooser

6.2 ASCOM Setup

7 Safety Precautions

1 OVERVIEW

1.1 Introduction

Astrophotography often requires a significant amount of electronic devices, most of which are needed at or near the telescope itself, which can lead to a large number of wires and cables going from the telescope down to the ground or observatory floor. In the best cases this results in thick bundles of cables that are difficult to manage, and can impede the free movement of the mount. In the worst cases it results in a total mess that is confusing and potentially dangerous.

Almost all this cabling falls into 1 of 2 categories; power and data. Most astronomy gear that needs power uses either 12VDC or the 5VDC supplied by USB. Most data connections are made through USB. The base features of Power*Star are distribution of power and data. Two additional functions that are needed at the telescope and typically require cabling are focus motor control and dew heaters, so these are also integrated into Power*Star, along with an environment sensor that provides ambient temperature and humidity information.

1.2 Features

Starting from these base feature, P*S expands its capabilities to include control of power (the ability to turn power ports on or off), special types of power (variable voltage for non-standard devices such as DSLR cameras, and PWM output to control variable power devices such as flat calibration light panels and cooling fans), and monitoring of power usage. There are also extensive protection features, including self-monitoring of voltages and currents, with the ability to shut down either individual ports or the entire system when a fault is detected.

P*S also incorporates safety features, such as reverse polarity protection, ESD (Electro-Static Discharge) protection, and automatic dew control to help protect your equipment. Below is a list of the features included in Power*Star:

Protection Features:

- ESD protection
- Reverse polarity protection
- Over/under-voltage protection
- Over-current protection
- Per-port over-current protection
- Motor fault protection
- Internal fault protection

System configuration features:

- Selecting motor type
- Selecting Multi-purpose function
- Selecting fault protections
- User Preferences for program options
- User names for connected devices

Power control features:

Turning power ports on/off
Variable voltage output
Turning USB ports on/off
Automatic power up configuration

Monitoring features:

Incoming supply voltage
Total power consumption
Temperature, Humidity, and dew point
History graphs of the above
Per-port current draw
Per-port "no current" warning
Dew heater power consumption
Fast PWM power consumption
Export measurements to CSV file

Focus control features:

Direct drive of Starlight Instruments HSM and PDMS motors, and most other focus motor
ASCOT driver for control from other applications (including auto-focus)
User-defined motor parameters (with presets)
"Go To" and step in/out controls
Temperature and backlash compensation
"Permanent Focus" feature

Dew heater control features:

Setting the power level
Using automatic dew control

1.3 Not Included

What is NOT included in Power*Star is a processor capable of running all your astronomy/astrophotography applications. Some competitors provide this feature, and you may find it desirable, but we believe that separating the processor from the other functions makes a lot of sense for almost all cases because:

1. Computers are commodity products, so if we designed one specifically for this application it would not be cost-effective.
2. Computer technology evolves rapidly, while the functions of Power*Star are very well established and stable (the USB3 standard may become obsolete some day, but it is relatively young, and expected to be around for a long time). Most users will want or need to upgrade their computer several times before there is any reason to change the functions of Power*Star.

3. Although it is possible to run many astrophotography applications in low power/low cost processors, such a processor will limit your choices in software. When new versions of software come out they will almost certainly be available first for mainstream computers/operating systems. And there are many cases in which software you may want to use is not available for a low cost processor, or it may not be possible due to processor speed, memory size, or other constraints.

If you want to have your applications (including the P*S app) running on a processor mounted on the telescope, we recommend using a "headless" computer such as the Intel NUC and similar products from other companies. This minimizes size, weight, and cost without limiting your ability to run mainstream applications (including non-astronomy apps).

Also not included in Power*Star is regulation of the 12V outputs. While this would be a good feature to have, it is almost never worth the expense, and also wastes power. It is difficult to regulate an output voltage that is about the same as the input, since the regulation would have to be able to both reduce and increase the voltage (and switch between these 2 modes without introducing any variation in the output). Furthermore, it is rarely necessary to regulate the 12V outputs because any gear that needs a well regulated voltage will provide its own regulation, typically to a lower voltage such as 5V. This is necessary because astronomy gear is often powered with 12V batteries that have varying voltage over a wide range. Gear that IS affected by variations in the 12V supply are simple heating and cooling devices such as dew heaters, TEC devices, and fans. For these devices the amount of heating or cooling varies with the voltage, but can be compensated in other ways.

If you really need or want regulated 12V power, but must run off 12V batteries, the simplest way to achieve this is to connect a battery to an inverter to produce 120VAC, then use a regulated AC-DC power supply to generate the 12V to Power*Star. This has other benefits as well: You can use additional AC-DC power supplies to provide other voltages where needed, such as a mount that needs 48V (but DO NOT connect such voltage to Power*Star!). Furthermore, 120VAC power can be efficiently transmitted over long distances, so you don't need to have your batteries near the telescope. Such a system also reduces the danger of using 12V batteries by isolating it to a single connection (battery to inverter) that can be made permanent or semi-permanent.

2 SOFTWARE INSTALLATION

2.1 Preparation

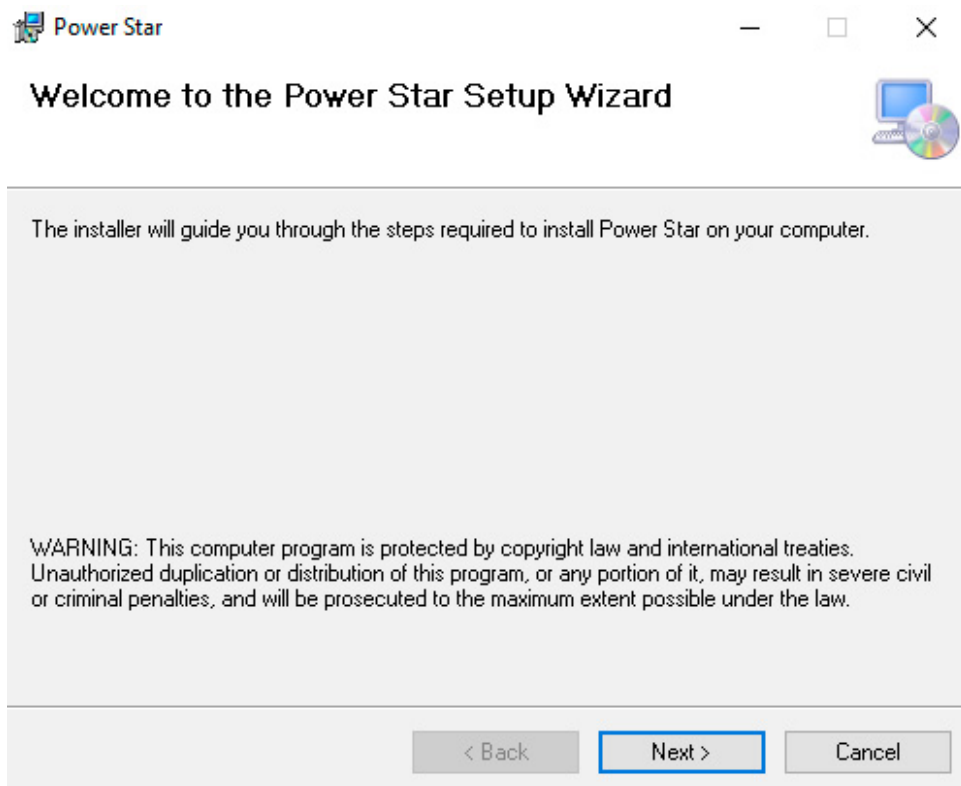
P*S is supplied with 2 essential software packages, the Power*Star app (a stand-alone program to control all aspects of P*S operation), and an ASCOM driver that allows you to control some (but not all) P*S features through other applications using the ASCOM platform.

To use the P*S ASCOM driver you must have ASCOM platform 6 (or higher) installed before installing the P*S ASCOM driver. If you do not have version 6 (or higher) of the ASCOM platform installed already, you can download it from <http://ascom-standards.org>.

2.2 P*S application Installation

If you have a CD containing the P*S software it should automatically run the Setup program when inserted. If it does not start automatically, simply navigate to the CD drive and double click on Setup.exe.

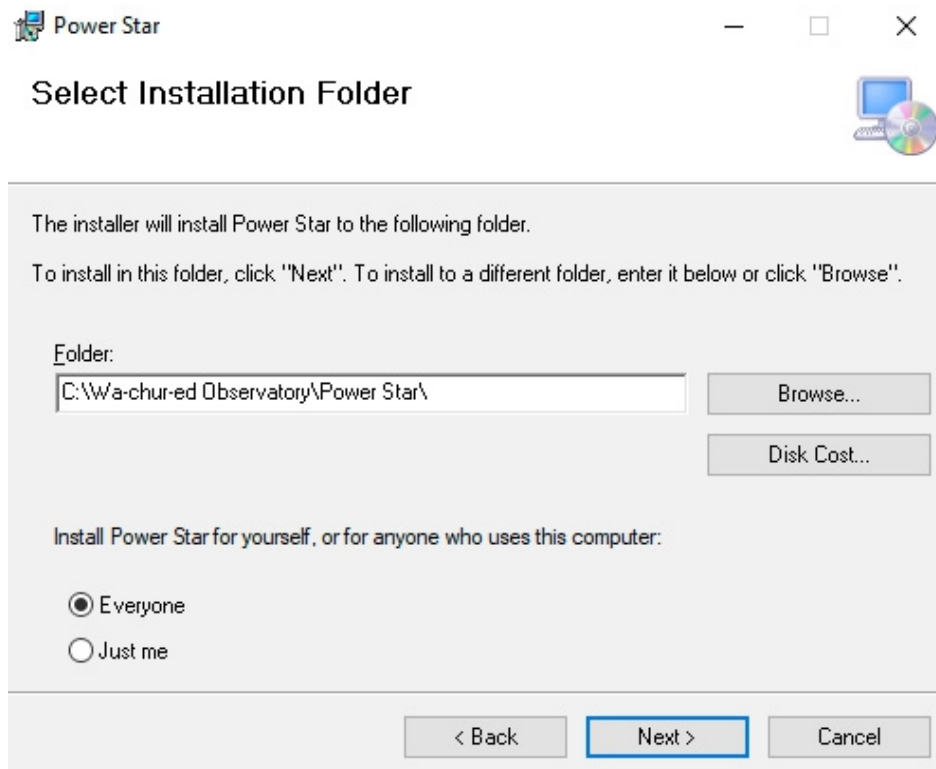
If you downloaded the files, simply double click the Setup.exe file. It does not need to be placed in any particular folder.



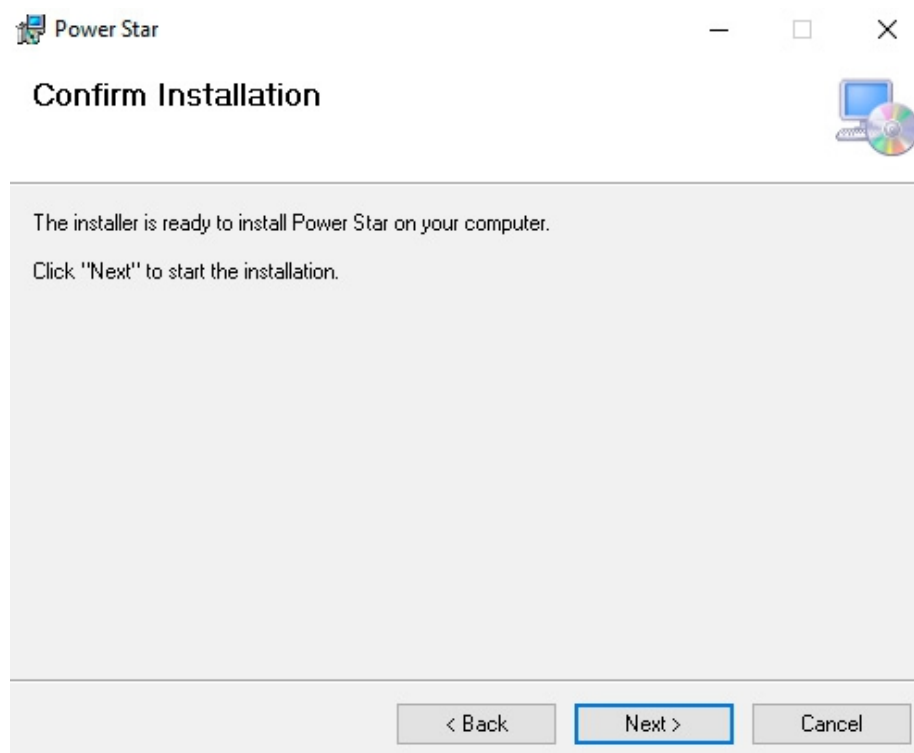
Just click Next to continue from this window.

When you click Next in this window it may produce a warning about making changes to your

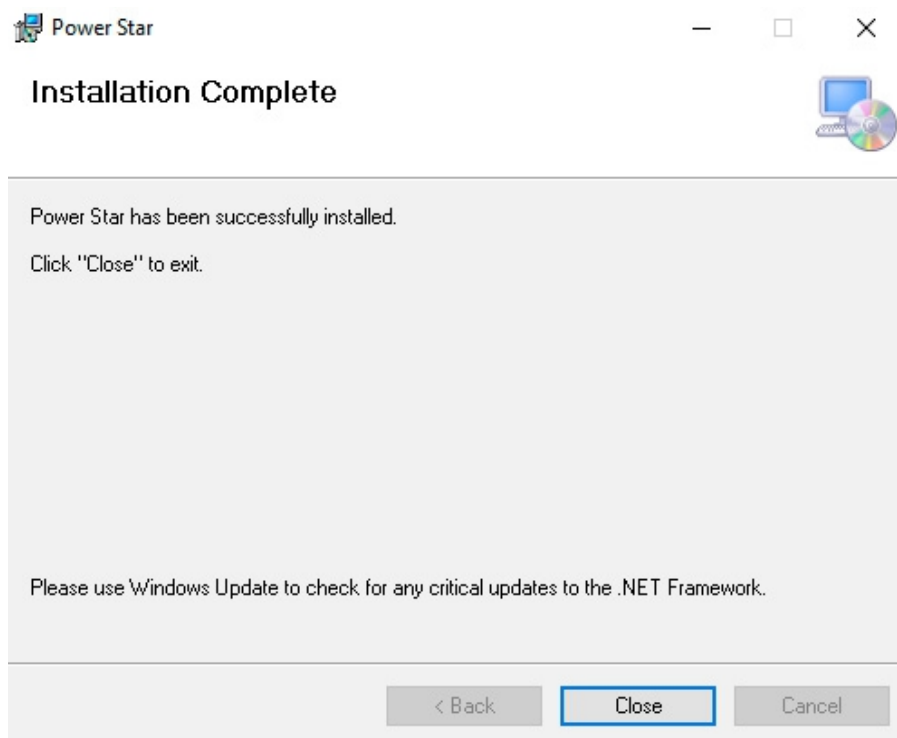
system. The appearance depends on the version of Windows you are using. Click Yes or OK to continue.



In this window you can change the location where the program will be installed, or just use the default location.



Just click Next to continue from this window. At this point Windows may ask you to confirm that you want to install the app. The format of this message varies, but you should click "OK", "Yes", or "Install" to install it.

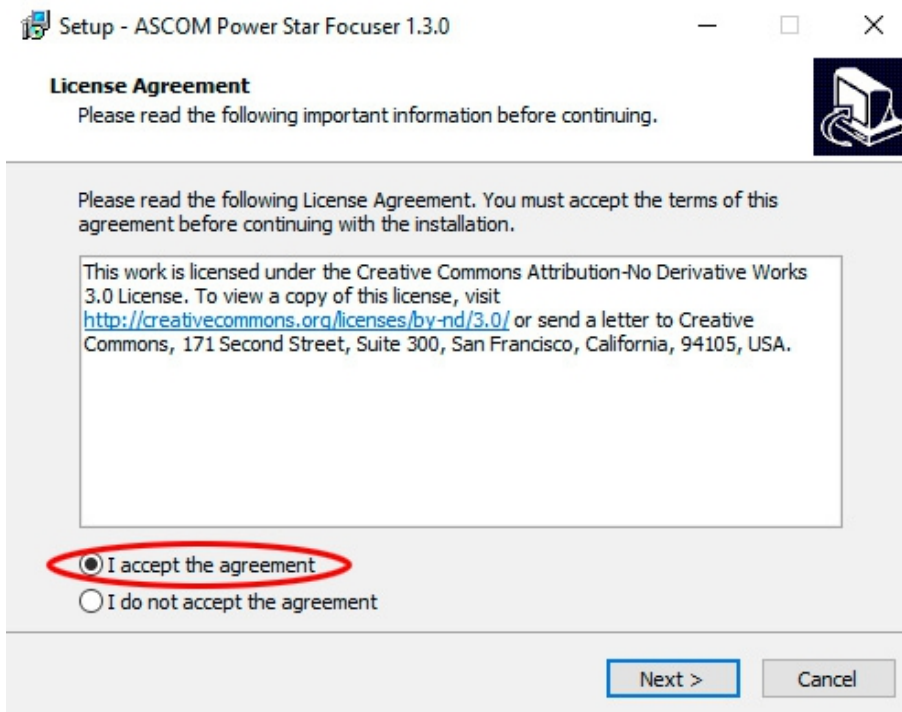


Finally, click Close to complete the installation.

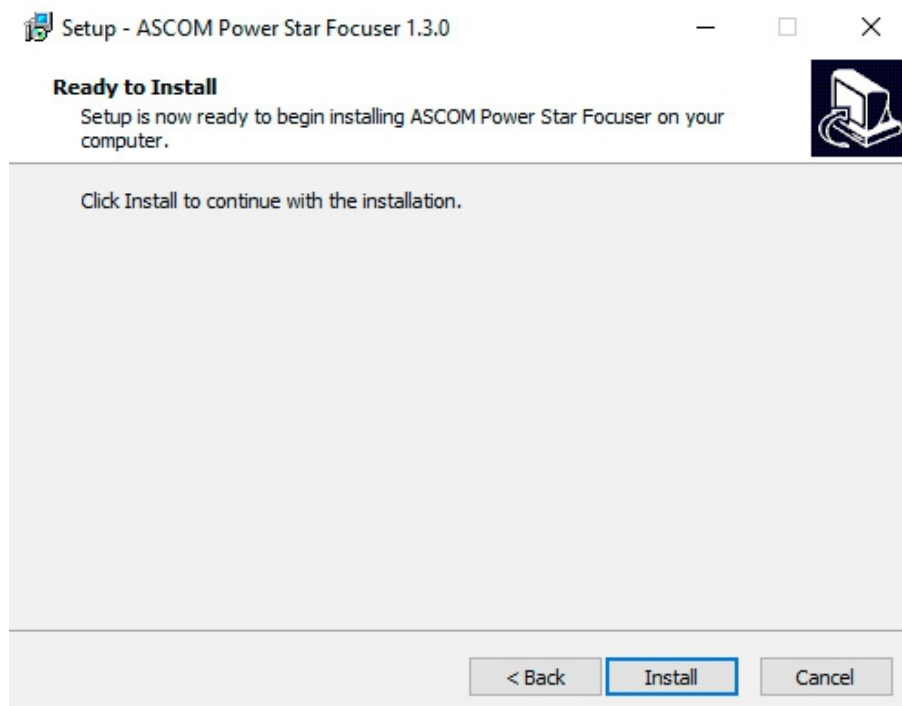
2.3 ASCOM Driver Installation

There are 2 different ASCOM drivers supplied with P*S, one for focus control and one for "observing conditions" (environment data). The installation procedure is the same for each, so the following instructions should be run for each driver you wish to use.

Once the ASCOM platform is ready, please install the P*S ASCOM driver by double clicking the Setup.exe for the desired driver and follow the on-screen instructions. You may get a warning about the program making changes to your system. The appearance depends on the version of Windows you are using. Click Yes or OK to continue.



In this window click the button to accept the license agreement, then click Next to continue.



In this window just click Install.



In this last window simply click Finish to complete the installation. Remember to repeat the above steps for each ASCOM driver you wish to use.

3 Hardware Set Up

3.1 Power Connections

The 12VDC power input port (jacks K1 and K2 in the diagram below) uses Anderson PowerPole™ connectors to provide high current capacity, and high reliability. This type of connector is growing in popularity for astronomy applications, and is especially important for the power input port, since it must carry the current for all the connected downstream devices.

Jacks K1 and K2 are internally connected together, and can be used in 2 different ways: It is possible to use 2 separate power cables, one connected to each of these jacks, to reduce the resistance of the cables, and thus reduce the voltage drop. Note that the source of power must be either the same device (battery or power supply) or 2 devices that may be safely connected in parallel. If starting from the standard single power cable of 14 gauge wire, it is probably better to go to a single 10 gauge cable than to use dual 14 gauge cables, except that the 10 gauge wire may be stiffer. The other purpose of the dual connectors is that one can be used for power input and the other as an unswitched, unmonitored power output. This is useful if you have gear that needs 12V power (especially if it consumes a lot of power), but does not need to be switched on or off through software. For example, a “headless” computer can be mounted on the telescope, powered through jack K1 or K2, and connected to P*S via the USB upstream port. In either scenario K1 and K2 are equivalent, and it doesn't matter which cable goes to one or the other. When K1 and K2 are used to “pass through” power to another device the theoretical current limit is 45 amps. However, this is pretty much always impractical due to power loss and voltage drop in the cables. 30 amps may be practical if you use 10 gauge wire on the input side (i.e., between the power source and P*S). Note that when using this “passthrough” mode of K1 & K2 there is no reverse polarity protection on the 2nd device connected, and its current draw is not seen by P*S. It is the same as if you used a Y adapter to connect both P*S and the 2nd device to the same power source.

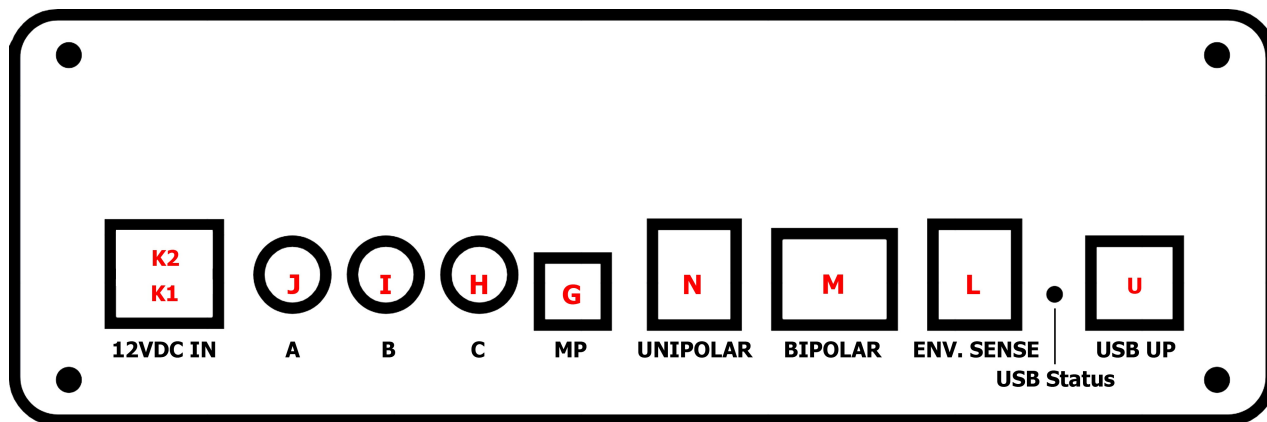


Diagram 1

P*S is supplied with a high capacity cable with PowerPole™ connectors at both ends. If possible, we recommend installing permanent PowerPole™ connectors at your power source. You can find adapters to various other types of power connectors online. You may use either

end of the supplied power cable to plug into the P*S.

If your power source is a 12V battery, please be aware that such batteries are capable of providing huge amounts of current that can be dangerous to both you and your equipment. Please refer to section 7, Safety Precautions, regarding use of batteries. In particular, you should have a fuse of suitable current rating installed near the battery.

The power output ports include 3 different types of connectors; 2 PowerPole™ connectors, 6 barrel connectors (5.5 x 2.1mm), and 3 RCA jacks (for dew heaters). Barrel connectors are the most commonly used type for 12VDC power, and that is why they are the most prevalent type used in P*S. Note that some power functions are available on more than 1 type of connector (the same power signal is available on different types of connectors): DC Output 1 is available on both a PowerPole™ connector and a barrel connector, and a “multi-purpose” output is available on both barrel and RCA jacks.

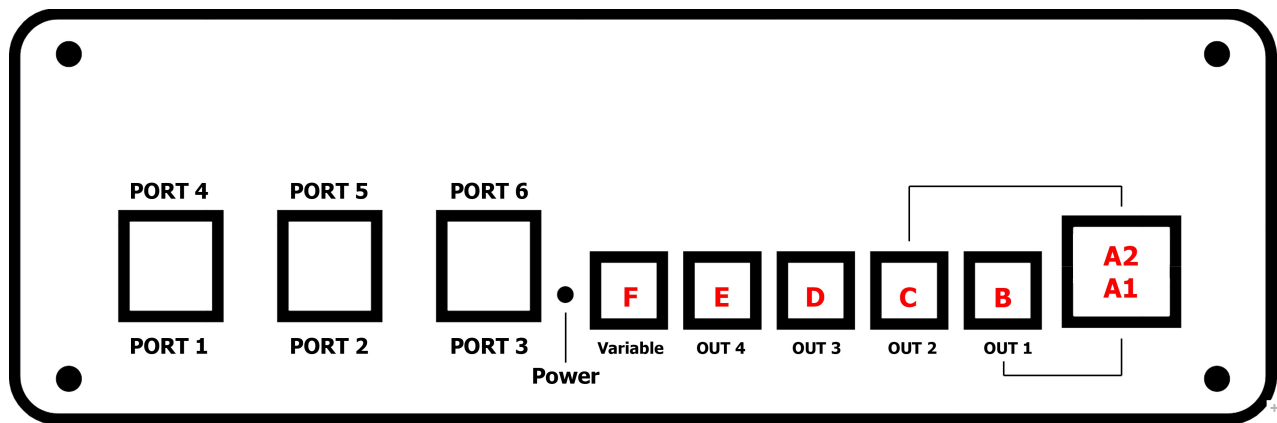


Diagram 2

Each power output channel is separately controlled, but where 2 types of connectors are available for the same power channel (DC Outputs 1 & 2, and the multi-purpose output) both outputs are controlled as one.

The table below shows the current limit for each jack.

Jack	Channel	Con. Type	Current Limit	Note
A1	Out 1	PowerPole™	15A	Jack A1 & B combined and jack A2 & C combined must not exceed 15A
A2	Out 2	PowerPole™	15A	
B	Out 1	Barrel	10A	
C	Out 2	Barrel	10A	
D	Out 3	Barrel	6A	Variable voltage: 3.0 to 10.0V Multi-purpose (see below) Multi-purpose (see below)
E	Out 4	Barrel	6A	
F	Var Out	Barrel	3A	
G	MP	Barrel	6A	
H	MP	RCA	5A	Power Input Power Input/Output
I	Dew B	RCA	5A	
J	Dew A	RCA	5A	
K1	12VDC In	PowerPole™	30A	
K2	12VDC In/Out	PowerPole™	30A	

Multi-purpose Output: This channel can be configured to be a standard DC output (switchable), a dew heater channel (Dew C), or a fast PWM output. Whichever function is selected, the same output is available on both jacks G and H. Although you may connect devices to both jacks G and H, the total current for the 2 connectors should not exceed 6A.

Note that current limits above are the lowest of several factors, including the current capacity of the physical connector. This is why there are different limits for each of the connectors in cases where the same signal appears on 2 different types of connector.

The dew heater channels use RCA jacks because this is the defacto standard for dew heaters. It is not a good choice for this use, but we have used a high quality part to provide the best possible connection for your dew heaters. Nevertheless, please do not exceed 5A (60 watts) for each connector. If you do not need the multi-purpose channel for other purposes and are able to modify your primary dew heater to use a 5.5 x 2.1mm barrel connector, we highly recommend connecting it to jack G.

All of the barrel connectors have multiple fingers contacting the outer barrel. This provides higher current capacity, greater retention, and improved reliability. These high-retention jacks will not release the plug so easily that the connection is unreliable, but provides a much better chance of protecting your gear by releasing the plug if there is a lot of force on the cable. Of course, cable snags are far less likely anyway when using P*S, since only short cables are needed to connect devices that all move with the telescope.

3.2 USB Connections

The upstream USB connector (going to the host computer) is a USB3 type B jack, shown above as port U. Use a good quality USB3 cable to make this connection. Note that USB3 cables must not be longer than 3 meters unless an active repeater is included in the cable.

The 6 downstream USB connectors are all capable of USB3 data rates, and are all type A connectors. However, they are not exactly equivalent/interchangeable: The lower row (ports 1 to 3) are preferred for USB3 devices because they have slightly better signal integrity (this is an inherent weakness of the upper row in any stacked USB connector, but it is really only significant for USB3 devices, and even then it is rarely a problem).

Also note that USB ports 2, 3, and 6 are switchable, while the others are not. If you have USB devices that you want to be able to disconnect (power off) via remote control, plug them into one of the switchable ports. The 3 switchable USB ports also have a higher current capacity of 2A per port. The other ports are limited to 0.9A, which is standard for USB3. Note that the current consumption for ALL USB ports in total should not exceed 5A. However, almost all USB devices use no more than 0.5A, since that is the standard for USB2. The higher capacity USB ports are generally used only for purposes such as battery charging or to power highly specialized devices, such as a Raspberry Pi or similar single-computer computer.

In addition to the above differences between the downstream USB ports, it is sometimes helpful to understand how a USB3 hub works when planning how to connect devices. In a USB3 cable and connector there are actually separate conductors for the USB3 “superspeed” signals and the standard USB2 signals. This separation of the channels goes all the way back to the host computer, so there really are 2 entirely separate data paths within a USB3 connection. Within each of these paths, all of the downstream devices share the bandwidth of the path. People often assume that USB2 devices connected to a USB3 hub have their data combined into a (much faster) USB3 path, and that would be great if it were true, but it's not. If you have a USB3 connection between the host computer and the hub, but all of the downstream devices are USB2 speed, there is no advantage to using the USB3 upstream connection, as all the data will go over the USB2 path, and the bandwidth will be limited accordingly. Similarly, when multiple USB3 devices are connected to a USB3 hub the available bandwidth in the USB3 upstream connection is shared between the devices. If they are all trying to transfer data at the same time, the throughput will be reduced for each. The hub cannot automatically shift data traffic to the USB2 path. However, you can force a device to use the USB2 path rather than USB3 by connecting it with a USB2 cable, which does not have the extra conductors for the USB3 data path. In some situations this can be a useful strategy.

3.3 Environment Sensor

Jack L in the diagram is a 4 pin modular connector for the included environment sensor. The sensor provides ambient temperature and humidity data. This information is displayed and logged by the P*S app, and is also used to control automatic dew heater operation and temperature compensated focus control.

The sensor resides in a small enclosure at the end of a 2 foot cable, which allows you to place it in a suitable location. It should not be placed near any source of heat, which is why we didn't just place the sensor inside the P*S enclosure. It should also be placed such that it

is exposed to free-moving air. We suggest securing it in place with a hook & loop strap.

WARNING: Jacks L and N are similar, but different sizes of modular jack. It is possible to push the plug on the environment sensor into jack N, the connector for a unipolar focus motor. Although it does not fit properly, the pins may make contact with the 12VDC power pin in jack N, resulting in damage to the environment sensor, so please pay attention and use the correct jack. If you are not using a unipolar focus motor you may want to put tape over jack N to avoid the possibility of this error.

3.4 Motor Connections

P*S supports PerfectStar and PerfectStar B focus motors from Wa-chur-ed Obervatory, the HSM and PDMS focus motors from Starlight Instruments, QuickSync motors from Optec, and most other brands and type of focus motors. PerfectStar B and the motors from Starlight Instruments and Optec are of the bipolar type, and connect using RJ-45 modular connectors (the same type used for Cat 5 or 6 ethernet cables). A suitable cable is provided with the motor (not included with P*S), and connects at jack M. These motors include a temperature sensor that can be monitored by the P*S app.

The “classic” PerfectStar focus motor and most motors from other manufacturers are the 12V unipolar type, and can be connected at jack N, a 6 pin modular jack. The table below shows the wiring diagram for the most common type of focus motor, using a DB-9 connector.

Jack N Pin	DB-9 Pin	Description
1	1	Phase 4
2	2	Phase 3
3	3	Phase 2
4	4	Phase 1
5	-----	(do not connect)
6	5	+12VDC

Although the DB-9 connector and the above wiring scheme is common, it is not universal, so please confirm the wiring for your motor. Because the DB-9 connector is not universal, and takes up a lot of space, we used the much smaller modular jack instead.

Note that some unipolar motors may use additional pins. If there are multiple pins for the +12V source, connect them all to pin 6 of jack N. If there are pins for GND (ground), +5V, or any other signals, leave them unconnected. Some unipolar motors may include temperature sensors, but these are not supported in P*S (and not needed, since you have the environment sensor), and the motor should work without these secondary signals.

4 Mounting Power*Star on your Telescope

The standard configuration for Power*Star includes a universal saddle attached to the bottom. This makes it very easy to attach P*S on top of your telescope, using either a Vixen or Losmandy D style dovetail bar. It mounts with the P*S enclosure parallel to the telescope tube, so the connectors are on the left and right sides. You may place it facing either direction.

The saddle also makes it very easy to adjust the position forward or back, either to optimize cable positioning or to help in balancing the 'scope.

If you ordered P*S without the universal saddle, it will come with a pair of threaded holes in the bottom (and top – see below) that you can use to attach P*S to a non-standard dovetail or other bar/rail. The holes will have short button-head screws in them to “plug” the holes. If you are attaching P*S to a fairly thin plate, such as 1/8” or less, you could use these same screws. Otherwise, you will need longer screws. CAUTION: Do not use screws that will extend into the P*S enclosure more than 1/4”.

Another alternative is the optional mounting flange available for P*S. This provides a tab at each end of the enclosure with a non-threaded hole. The distance between the 2 holes is roughly 7.5”. This spacing is fixed, so this is not a universal solution, but may be easier than using the threaded holes in the bottom. In particular, the bottom surface of the mounting flange is flush with lower edge of the front and rear panels, while the bottom surface of the enclosure itself is recessed about 0.15”.

There are also threaded holes in the top of the P*S enclosure that can be used to mount other devices, provided they are suitably small and light (no more than 2 pounds). These threaded holes have the same spacing and thread specifications as those in the bottom: M5 (5mm diameter, 0.8mm thread pitch), 35mm spacing.

CAUTION: When tightening screws into either the top or bottom of P*S do not over-tighten them. The material is aluminum, and only 1/8” thick on the bottom surface and 1/10” in the top. The use of M5 bolts provides a suitably fine pitch for such material, but it would not be difficult to strip the threads by over-tightening. You should hand-tighten only, not using a power tool.

5 Using Power*Star

5.1 Overview

Because P*S is typically mounted on or near the telescope, it does not have a handset or any manual controls – all operations are done through the USB interface to a host computer (which might also be mounted on the telescope and have either wired or wireless connections for remote control). However, P*S can perform a lot of functions that are independent of the host, including the safety features of reverse polarity protection, over-/under-voltage and over-current protection, etc. Less critical faults are also detected, and the user can notice such exceptions by the rapid flashing of the power/status LED (see diagram 2). When using the P*S application, and connected to a P*S unit, the user can control which faults will trigger this alarm (which is also displayed in the app). One such exception is the failure of the environment sensor, or (if enabled) the temperature sensor in a focus motor. Since these sensors take some time to acquire a valid reading, the power LED may flash for up to 10 seconds when first powered up, even though the sensor is connected and functioning normally. It may also flash again for a number of seconds if there is a disruption to either sensor. However, the user can select to “ignore” this fault, and the setting is remembered, so will not cause the status LED to flash the next time you turn it on.

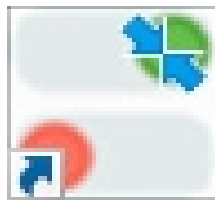
When the most critical operating limits are exceeded the P*S system will shut down some or all functions to protect itself and your connected equipment:

- * Each individual power output will turn off if the current draw exceeds safe limits or if the temperature of the output circuit rises to a critical level. The specific limits are not specified, but are far in excess of the rated limits. This feature is most likely to become active when there is a short circuit in the connected equipment.
- * Each USB port monitors the current drawn from the port (at 5 volts DC) and shuts off the supply if the limit is exceeded. This fault condition is passed on to the upstream USB host (if connected) and resetting the port can be done through the operating system of the host computer. Such faults are rare because USB devices are carefully designed to avoid excessive current draw. The 3 unswitched (always ON) USB ports (ports 1, 4, and 5) are limited to 0.9 amps each, which is the standard for USB3. The other ports, which can be controlled through the P*S software (ports 2, 3, and 6) will supply up to 2 amps each. Note, however, that the total current draw for all 6 USB ports should not exceed 5 amps.
- * If the 12VDC input voltage drops below approximately 10V or rises above approximately 15V, all outputs and functions of the P*S will turn off, including the switchable USB ports (ports 2, 3, and 6). The voltage is monitored by the internal processor, which remains active and connected to the host computer as long as the input voltage is high enough to run the processor (approximately 6VDC). While not as fast as the hardware protection on individual outputs, the processor checks operating conditions at least 5 times per seconds.
- * If the total current draw from the 12VDC input exceeds 30 amps, all outputs and functions of the P*S will turn off, including the switchable USB ports (ports 2, 3, and 6).

5.2 The Power*Star Application

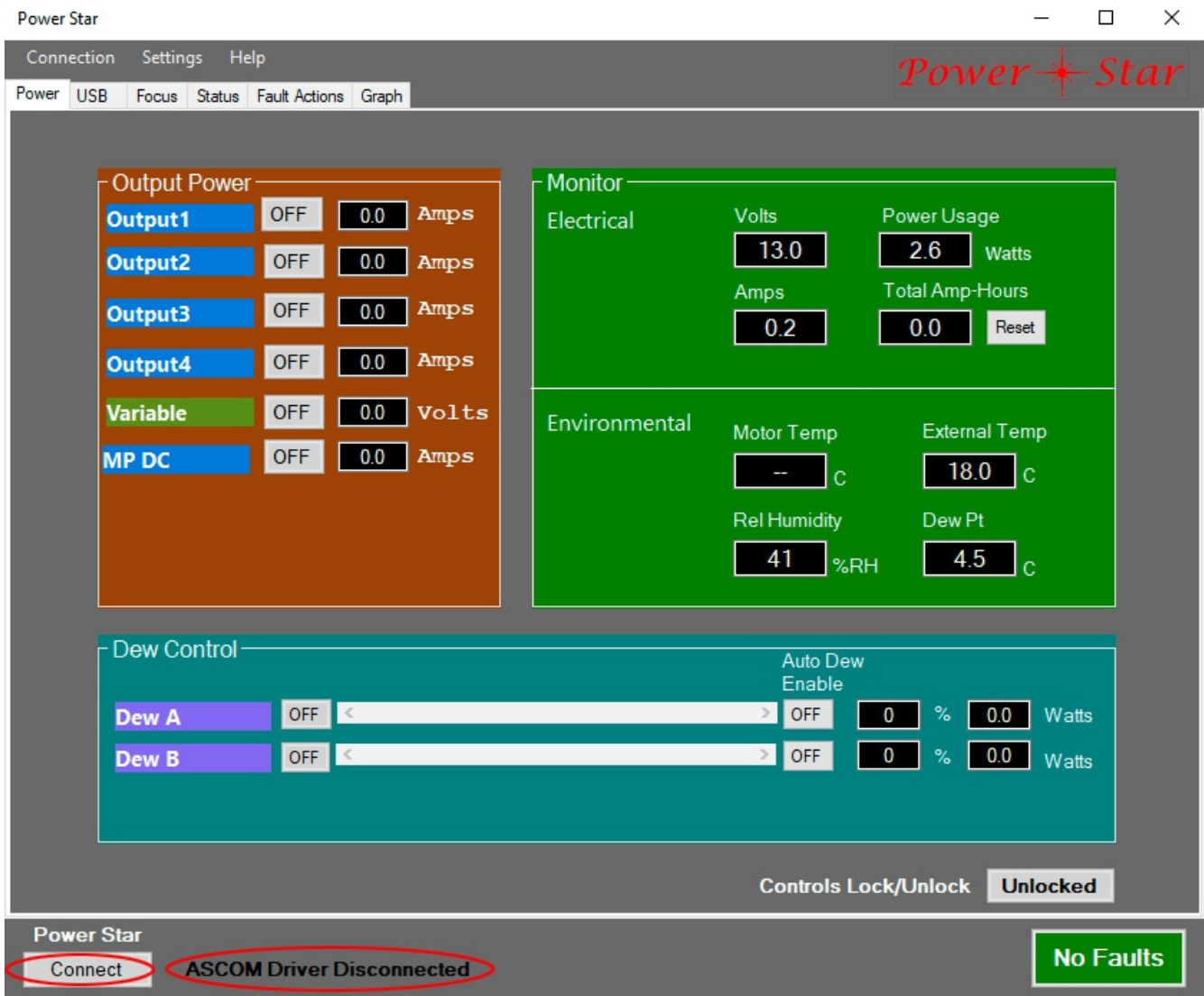
Power*Star is supplied with a stand-alone application program (also called “Power*Star” or “P*S app”) for Windows computers. It connects to the P*S hardware through a USB port (preferably a port that supports USB3, and using a USB3 cable). The P*S app allows the user to control each of the power outputs, including variable levels for the dew heater channels, the fast PWM output, and the variable voltage output. The user can also control power to 3 of the 6 downstream USB devices. A focus motor can also be controlled through the app, and the temperature and humidity at the telescope can be monitored. Third party applications that support ASCOM focus controllers can also control the focus and read the temperature (note that the P*S app must be running to use the included ASCOM driver). Extensive monitoring of power usage is also available. The following sections describe the use of the app in detail.

To start the P*S app, locate the icon on your desktop and double click it.



5.2.1 Connecting and Configuring

The computer running the P*S app must be physically connected via USB to the Power*Star before a logical connection can be established. To make the logical connection, click on the “Connect” button in the lower left corner, or select it from the “Connection” menu. The connection indicator at the bottom of the window will change to green when the connection is established. A few seconds later, the app will start displaying the various measurements it makes regularly. We'll take a closer look at them later.



If the P*S ASCOM driver has been used its status is displayed next to the connect/disconnect button. Note that P*S will not allow you to disconnect while an ASCOM client is connected.

5.2.1.1 Set Up Power*Star

Click on the Settings menu, then Setup Power*Star to configure the device to your needs. The Setup window is divided into 5 main sections; the Power Ports, the USB Ports, the Multi-purpose output, the Auto Dew control setup, and miscellaneous preferences.

Setup

Port Control

Power Ports

Connector	Change Name	Power ON at startup
Output1	Output1	<input type="checkbox"/>
Output2	Output2	<input type="checkbox"/>
Output3	Output3	<input type="checkbox"/>
Output4	Output4	<input type="checkbox"/>
Variable	Variable	<input type="checkbox"/>

Variable Set: Set
Current Value: 4.7 V

Dew A: Dew A ☐
Dew B: Dew B ☐

Reset All Names: Reset

LED Brightness

☐ Off
☒ 1/3
☐ 2/3
☐ Full

Miscellaneous

Reset Default PH Reset

OFF Verify Port Disables

ON Warn If Output Has Zero Current
ON Error Beep Enabled

Temperature: ☐ Celsius ☐ Fahrenheit
Ask Close Options: ☒
Export Charts To CSV: Export
Debug Level: Debug

USB Ports

Connector	Change Name	Power ON at startup
Port 1	Port1	<input type="checkbox"/>
Port 2	Port2	<input checked="" type="checkbox"/>
Port 3	Port3	<input checked="" type="checkbox"/>
Port 4	Port4	<input type="checkbox"/>
Port 5	Port5	<input type="checkbox"/>
Port 6	Port6	<input checked="" type="checkbox"/>

Multi Purpose

Configure As: DC PWM DEW

Change Name

Power ON at startup

Multi Purpose: MP DC ☐

Auto Dew

Temperature Trigger Adjust: < > 0.0 C

Dew Point: 10.1
Auto Dew Turn On: 10.1

Close

Changes made in this Setup window are applied immediately. Click the Close button when done.

5.2.1.1.1 Power Ports

The power ports section is used to configure the four primary 12VDC outputs, the Variable

Voltage output, and the Dew Heater channels. For each of these, the user can name the port by clicking in the Change Name field and typing the name you want. Typically, a port is named by the device attached to it. For example, a port used to power a camera might be named "ASI1600". However, any name you like can be used.

To the right of each of the DC output ports is a checkbox titled "Power ON at Startup". When you click on this box you are selecting whether or not the port will be automatically turned on when Power*Star is powered up. This selection also affects the options available to keep ports turned on when the P*S app is closed. This is covered in section 5.2.1.1.5.

Note that the Power ON at Startup works a bit differently for the dew heater channels and PWM outputs. Although these outputs have On/Off buttons like the standard DC outputs, it is really the level setting that controls the output, and it is this level that is saved in non-volatile memory when you disconnect the app from the hardware. Therefore, if you turn a dew channel or PWM output off before disconnecting, it will not come back on either by re-connecting or by powering the system off and back on. If you want a dew channel or PWM output to automatically turn on when the system is powered up, it must on (at the desired level) when you disconnect, and the "Power ON at Startup" option must be set. In contrast, a standard 12VDC output can be OFF when you disconnect, but will still turn back ON after a power cycle if the "Power ON at Startup" option is selected.

The variable voltage output can be configured to provide a DC voltage between 3.0 and 10.0 volts. It is typically used to power a DSLR camera, but can be used for any device that needs a voltage within this range (at up to 3 amps). Most DSLR cameras will work with a supply voltage of 8V, so that is the default setting. To change it, click the Set button and enter the voltage you want. Note that any value between 3.0V and 10.0V in 0.1V increments can be entered, but not every selectable increment is available in the hardware, especially at the high end of the voltage range. By design, the output voltage will be within 5% of the value you enter, usually much closer than that. However, there is also a +/-2% tolerance for the accuracy of the voltage measurement system, so it is possible (though unlikely) that the voltage displayed will be as much as 7% off from the selected value. If you need a very precise voltage, please check it with a volt meter and adjust the requested voltage accordingly. Most DSLR cameras do not need that precise a voltage (since they regulate their internal voltage) and the default setting of 8V will work great.

5.2.1.1.2 USB Ports

Each of the six downstream USB ports can be assigned a name, just like the DC power ports. Three of the six USB ports (ports 2, 3, and 6) can also be enabled to turn on automatically at startup. Unlike the power ports, the default setting for USB ports is "enabled", and the other three ports (1, 4, and 5) are always on.

Note the numbering of the ports on the Power*Star device (also represented graphically on the USB tab). The first three ports are on the lower row of connectors. Although all six ports support USB3.1 data speeds, the lower row of connectors have slightly better signal integrity,

so they are preferred for the most critical USB3 devices.

Also bear in mind that only three of the six ports can be switched off (ports 2, 3, and 6). These three ports can each provide up to 2 amps of current (at 5V) to connected devices, while the other three are limited to the 0.9 amps that is standard for USB3 devices. Because 0.9A is the standard, almost all USB devices will work with that much current, but there are cases where a device can make use of additional current. Such a device should be connected to one of the switchable ports, whether you intend to turn it off through software control or not. The other common use for turning a USB port off is to effectively “power cycle” a malfunctioning USB device. If you have a USB device that sometimes needs to be reset to restore proper operation, connect it to one of the switchable ports.

5.2.1.1.3 Multi-purpose Output

One of the Power*Star power outputs can be configured to operate in one of three different modes; as a standard 12VDC (switchable) port, as a 3rd dew heater channel, or as a “fast PWM” output. Dew heater outputs and the “fast PWM” output both use PWM (Pulse Width Modulation) to vary the power delivered to the connected device. In both cases the user has a slider to set the level. The difference is that the dew heaters switch the power at a very slow rate (once per second), while the fast PWM output switches 2,000 times per second. Switching slowly is more efficient, and minimizes the generation of electrical noise. This works great for heaters, since they naturally respond very slowly to the signal, generating heat that is proportional to the average “on” time. However, other devices, such as a light source or a fan, would switch very noticeably between being completely on and completely off at the slow rate. The fast PWM mode can drive such device without detectable variation. For example, a flat calibration panel (a light source) can be driven with the fast PWM output, and the user can then adjust the output to achieve the desired brightness. The fast PWM can also be adjusted to more precise levels, going from 0 (off) to 1023 (full On).

The Multi-purpose output can be named, just as with the other ports, and enabled for “Power ON at startup”.

5.2.1.1.4 LED Brightness

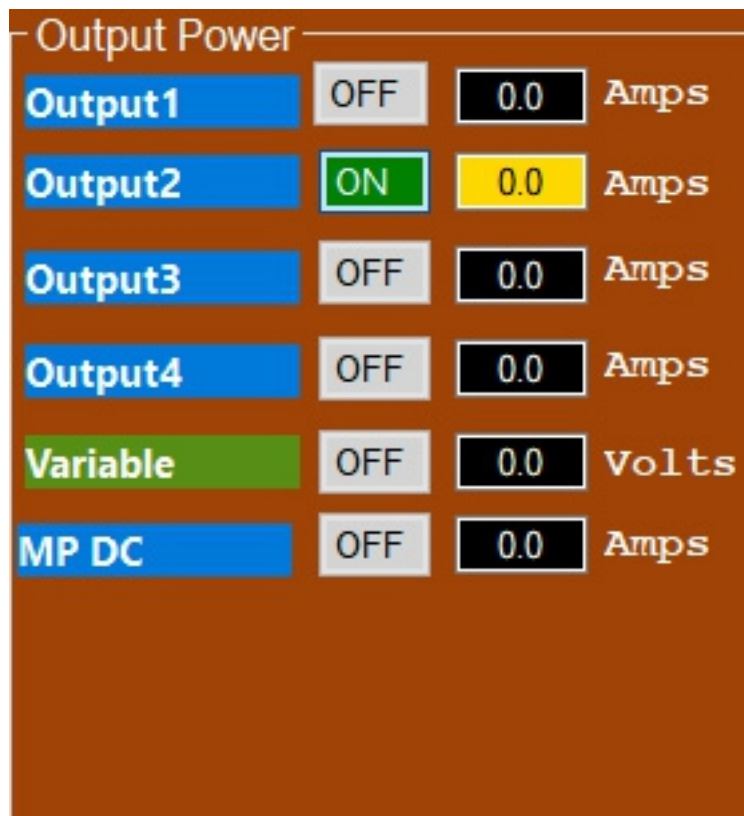
There are 2 LEDS in the P*S controller, one for power and general status, and another for USB status. The brightness of these LEDs can be controlled in the Setup menu. The “Full” setting is good for daytime use, but may be too bright for nighttime use, so the 1/3 or 2/3 brightness settings are typically used in normal operation. If desired, you can also turn the LEDs completely OFF. Note that the brightness setting applies to all uses of the LEDs, including all levels of fault detection. However, it does NOT apply while performing a firmware flash update. In this case the LEDs will always be at full brightness.

5.2.1.1.5 Miscellaneous Preferences

Default P*S Reset: Click this button to restore all configuration settings to factory default values.

Verify Port Disables: Clicking this button alternates between ON and OFF. When it is ON the port controls are protected from accidental turn-offs: When clicking a port control would cause it to switch from ON to OFF a dialog box pops up to confirm the action. Otherwise, the port turns off immediately. There is also a lock/unlock function available on the Power tab, which you may find to be a more convenient way to protect the on/off switches.

Warn if Output Has Zero Current: When this button is ON (default) any power output that is turned on, but has no current flowing through it, will generate a warning by changing the background color of the port's current measurement to yellow. This warning is helpful if a device has become disconnected, or if you accidentally turn on the wrong output. Note that power outputs 1 and 2 (which are capable of providing more current than the others) are less sensitive than the others in determining "no current", so they may give you a warning for a device that is drawing very little current. For example, in a camera that uses 12V power only for cooling (the camera circuitry itself is powered by the USB connection), if the cooling is turned off P*S might see it as drawing no current if connected to output 1 or 2, but not so when connected to one of the other outputs.

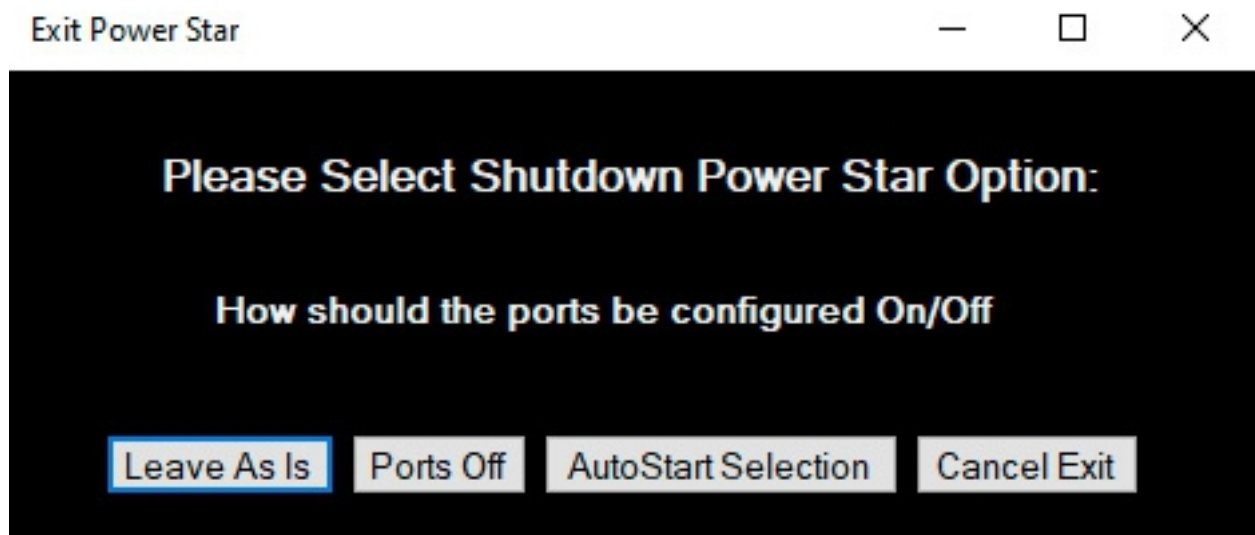


Error Beep Enabled: When turned ON, the program will generate an audible alarm when a fault is detected. The volume is dependent on the audio settings in your computer, so you

may want to test it. To generate a fault you can simply unplug the environment sensor (assuming that this fault is not set to "ignore").

Temperature: Select whether to display temperatures in degrees Celsius or Fahrenheit. Note that some parameters used in the focus controller are always specified in degrees Celsius, regardless of this setting.

Ask Close Options: When the checkbox is checked, each time you disconnect (or close) the P*S app it will ask you what you want to do with outputs. You can select to "Leave As Is", "Ports Off", or "Auto Start Selection". If the checkbox is NOT clicked, the program will use your most recent selection. If you have never made a selection the "ask" window will come up once, then future occurrences will use the same selection you make this one time. Note that "Ports Off" turns off the switchable USB ports as well as the power outputs. It's a good idea to set the "Auto Start" controls for all the outputs and USB ports you want to leave on all the time, then select "Auto Start Selection" as the disconnect/close action. Or, if you are prone to accidentally clicking buttons you didn't mean to, check the "Ask" option, since this gives you the option of canceling the disconnect before any action is taken.



Export Charts to CSV: Click this button to export the data collected in the current session for temperatures, humidity, dew point, voltage, and power consumption to a CSV file. The file can then be analyzed in a spreadsheet program.

5.2.1.1.6 Automatic Dew Control

P*S can automatically turn on your dew heaters when needed, based on the environment sensor. There are 2 parameters to dew control, the "trigger point", and the heater power. In this section we describe the trigger point. This point is defined as the difference between the current ambient temperature and the dew point (the temperature at which dew begins to form). Ideally, you want to apply heat only when necessary, so you would set the trigger to a

very small positive value (i.e., start the heat when the temperature is just slightly above the dew point). However, the sensor is less than perfectly accurate, this might not be completely effective. You can either “play it safe” by setting the trigger at 3 to 5 degrees C, or experiment with how your particular system behaves and set the trigger point accordingly. This is why a negative trigger value is allowed, even though it does not make sense in a theoretical, ideal implementation.

The other part of automatic dew control is specifying the dew heater level. Before getting into that, let's talk a bit about dew control via heaters. In a telescope with a front element (refractor or catadioptric telescope) there is typically a “dew shield” around the front of the 'scope (they are usually not included with a catastrophic 'scope, but should be added if you will be working in conditions that could produce dew on the front glass). A dew shield is surprisingly effective because it greatly reduces the flow of air directly in front of the glass, maintaining the temperature slightly above the ambient temperature. Many people place a dew heater strap on the tube directly around or slightly behind the objective or corrector plate, believing that the purpose is to warm the glass. This is not the most effective way to prevent dew formation, and can even result in optical distortion. Instead, the heater strap should be placed in front of the objective or corrector plate to warm the air in front of it. It only needs to be a few degrees C above the ambient temperature to prevent dew formation. The amount of power needed to produce a 3 degree temperature rise depends on the size, mass, and thermal conduction of the dew shield. However, for a given system, the amount of power (in watts) needed to produce a 3 degree temperature rise is constant. Calculating this number is complex for the general case, but you can experiment with your own system by setting a certain level with the dew heater slider (note that the resulting power consumption is displayed in watts) and measuring the difference between the temperature inside the dew shield and the ambient temperature. For example, my 132mm refractor takes about 8 watts to produce a 3 degree temperature rise.

Once you have determined the optimal level for each dew heater, click the “Auto Dew Control” button to the right of the slider, then set the slider to the level you want. The heater will then be enabled or not (at the set level) depending on the trigger setup.

5.2.1.2 Configure the Focus Controller

Power*Star has an integrated focus controller with a full set of features for motorized focus control. This controller supports both the bipolar motors offered by Starlight Instruments and the unipolar motors used by many other companies. It can also be configured to support a wide range of non-standard motors of either type. If you are unsure of how to set the motor parameters for your motor, please consult the manufacturer.

Note that although Power*Star has separate connectors (and driver chips) for the two types of motors, the system does not support using both motors at the same time. That is, you can change the configuration at any time, but doing so will cause the position and other information about the current focus motor to be lost. That is, the system only keeps track of information about one motor.

Also, the reason that P*S has separate driver chips for each motor type is not to support two motors simultaneously, but because the two types have different drive requirements. It is possible to drive a unipolar motor with a bipolar driver (as some competitors do), but the drive characteristics are not optimal. Using separate driver chips avoids this problem.

The settable parameters for each type of motor are slightly different, and these differences will be explained below for each parameter. However, there is another parameter that is NOT directly settable in the focuser configuration, but may be useful: Unipolar motors for focus control are typically designed for 12V operation, and require a +12V signal (it is provided on pin 6 of the unipolar motor connector). For unipolar motors designed for lower voltages, such as 5V, it is possible to simply connect the V+ supply lead (or leads) of the motor to either the variable voltage output or the the fast PWM output, and set that output to a suitable level. For example, when using a 5V motor you could configure the variable voltage output to 5V, or configure the multi-purpose output to PWM mode and set the PWM control to 430 ($430/1023 * 12V = 5V$).

Focus control configuration can be done either through the Settings>Configure Focuser menu, or by clicking "Configure" in the Focus tab.

Before delving into the details of focus motor control parameters, note that at the bottom of the Focuser Configuration window is a simple "Motor Selection" field. There is a good chance that the motor you use is included in the predefined sets included in this selection. If so, simply select that. You might still need to make some adjustments, such as backlash compensation, but most of the settings will probably be just right.

The focuser configuration window that comes up when you click the "Configure" button is the same as that used to set up the controller through ASCOM, so the following descriptions apply to both the P*S app and the ASCOM driver.

FocuserConfig

Motor Settings

Backlash/Preferred Direction

Backlash

Preferred Direction ☐ In ☒ Out

Motor Current

Idle

Drive

Motor Full Step Period

Period

Position

Max

Set To

Motor Selection:

Temperature Compensation

Coefficient (deg C)

Hysteresis

Temp Sensor Select

☒ Motor

☐ External

☐ ASCOM TC Available

Behavior

☐ Reverse Motor

☐ Disable Permanent Focus

Lock Mode Braking

☐ No Braking

☐ Low Power

☐ Normal Braking

Motor Type

Motor Type

☐ Bipolar

☐ Unipolar ☒ No Motor

Changes made in the Focuser Config window are not applied until you click Apply or Apply/Close. This is different from the P*S Setup window because some of the motor parameters work as a "set" and it could be inappropriate to change them one at a time. However, if you want to test a particular change you can click Apply, leaving the window open. You can then use the Focus tab in the main window to test the change.

5.2.1.2.1 Backlash Compensation

All mechanical systems using gears will have a certain amount of “backlash”, which is the additional movement required to take up the gap in gears when changing direction. The P*S focus controller can automatically compensate for this error in the mechanical system by applying a previously measured number of steps. The user must specify the amount of backlash (in units of single steps of the motor). The correct value can be determined by moving the focuser in one direction a significant distance (to ensure that any backlash has been taken up), then counting the number of single steps needed in the opposite direction before the focuser actually moves. Detecting this small motion can be tricky. A dial indicator or micrometer on the draw tube is ideal. The most general approach is to use a Bahtinov mask (ideally with 'Bahtinov Grabber' software) to observe the change in focus. After critically adjusting focus, move the focuser a significant distance in either direction, then back to best focus in the opposite direction. From there, again reverse the direction in single step moves until a change is detected. This is best done under excellent seeing conditions and with long exposures (>3 seconds) to average out the effects of seeing, or by using an artificial star.

Backlash compensation uses a “preferred direction” that is specified by the user (see section 5.2.1.2.2). When a move is requested in the preferred direction, the controller just moves the specified amount. But when movement in the non-preferred direction is requested, the controller moves an amount equal to the requested amount plus the backlash amount, then moves back in the preferred direction by the backlash amount, thus ending every request with a movement in the preferred direction. Therefore, it is always safe to use a backlash amount greater than the actual physical backlash – it simply takes more time to reach the final position when moving in the non-preferred direction.

Note that backlash compensation is NOT applied to focus adjustments made automatically by the temperature compensation feature. See section 5.2.1.2.6 for more information.

If for some reason you need to specify that the preferred direction is “out”, click the “Prefer Outward Movement” check box (see section 5.2.1.2.2). Note that the reported position is unaffected by backlash compensation. That is, steps taken to compensate for backlash are not included in calculating the new position. The “stop” button will not stop a backlash compensation movement and stopping in the middle of a movement in the non-preferred direction will still be compensated with a movement in the preferred direction.

Some applications include their own backlash compensation. You can use either the application's process, or Power*Star's, but do not enable both! We recommend using only Power*Star's backlash compensation, as it is more sophisticated than most applications.

5.2.1.2.2 Preferred Direction

In almost all cases the preferred direction is “in” (the default). This is because “in” is the direction in which the motor is working against gravity (assuming the telescope is pointed more “up” than “down”). But if, for some reason, you need to change it to “out”, simply click the “out” radio button.

5.2.1.2.3 Motor Current

The amount of current provided to the motor determines how much torque is applied to make the focuser move, and how much current is applied to hold the motor's position when it is not moving ("idle" state, or "braking current"). Obviously, more torque is generally a good thing, but there is a limit to the amount of current any given motor can withstand, so it is important to not set it higher than is appropriate for your motor. The settings for Starlight Instruments' motors in the Motor Selection presets are thoroughly tested and highly recommended if you are using this type of motor. When using the preset selections for SI bipolar motors the motor current selections will not go above about 150% of nominal. This is to protect the motor. However, you can select one of the "user" presets and set any values you like.

If the currently selected motor type is "unipolar" the "Drive" parameter is not programmable, as it is always driven to the maximum level (assuming the motor is designed for 12V operation, as most unipolar focus motors are). The "Idle" parameter is actually implemented as just 3 levels, but the user selection is still presented as 256 levels so that it is the same between the two motor types, and will also be the same should we change the system to allow for more choices of idle current in the future. When set to any value in the lower third of the range (0 to 85) the idle current is zero – the motor is simply turned off (see discussion below for more information). In the top third (170 to 255), the idle current is "maximum", which will definitely hold the position, but in many cases will result in a fairly hot motor. We recommend using the middle range (86 to 169), which uses a simplistic PWM method, turning the motor on and off rapidly, to cut the current in half. The "off" period is so brief that in most cases the motor will not move. Note that when using this setting the motor may "whine" while in the idle state. This is normal.

Both the Idle and Drive current fields are "unitless" numbers ranging from 0 to 255. Effectively, they select a fraction of the available (maximum) current that the driver can provide. For bipolar motors this maximum is 0.85 amps, and there is a minimum of 0.08A, so a setting of 64 yields $0.08 + (64/255 * 0.85)$, or 0.293 amps. This is the current per motor coil. For a bipolar motor there are effectively 2 coils, and both are driven simultaneously (in varying polarities) at all times, so the total current consumption is typically 2X the current setting. Once a motor movement is done a much smaller amount of current is needed to hold the position, and it is a good idea to set the idle current much lower, not only because it saves power, but because it reduces heat build-up in the motor. Some focus control systems (especially those using unipolar motors) do not provide any holding current. The idea behind this is that friction will hold the position, which is true to some degree (because there is typically a large gear reduction between the motor and the focus shaft), but this allow the rotor in the motor to "spring" back from the tension in the gears. When the motor is then re-energized, it will not be in exactly the same rotation that it was. Although this error is usually quite small, it will accumulate over time with each start/stop operation of the motor, thus defeating the purpose of an absolute-positioning focus motor.

5.2.1.2.4 Step Period

Stepper motors require a certain amount of time to move from one “step” position to the next, and this limits how quickly the motor can move. The timing is controlled by the focus control system, based on the parameter specified here (in milliseconds). If the step period is set very low the motor will not move at all. As you gradually increase the step period you reach a point where the motor will move, but has limited torque. Usually it takes only a little bit greater step period to achieve good torque. Setting the step period too high makes the motor run slowly, of course, but can also result in apparent “roughness” in running. This is not necessarily detrimental to torque, but may sound bad.

Note that unipolar motors generally move more slowly than a bipolar motor, which means that the step period must be set to a larger value for a unipolar motor. You will see this in the default values for the predefined motors.

The typical 12V unipolar motor used by other manufacturers has a torque range that varies considerably with the step period. The preset parameters for a 12V unipolar motor include a step period of 5mS, which is something of a compromise value providing moderate torque and speed. Torque will increase somewhat by increasing the step period to as much as 10mS, but beyond that there is no advantage. Decreasing the step period will result in faster movement, but torque decreases, eventually reaching a point where the motor can't move at all. For bipolar motors such as the SI HSM and PDMS the torque range is more narrow, so there is little (if anything) to be gained by using a larger or smaller step period than the preset values.

5.2.1.2.5 Max Position and “Set To”

The maximum position is a limit on the position applied by the P*S hardware. That is, the focuser will not be allowed to move to a position beyond the specified value. It is usually not necessary to change this from the default value of 100,000 steps. However, if you need more than 100,000 steps to reach the full travel of your focuser you may want to increase it. Another situation is that you want to prevent the controller from trying to move past the maximum position that the focuser can reach to prevent mechanical strain on the motor or focuser. In this case, you should determine the correct value by setting the position value to zero with the focuser racked all the way in, then carefully move the focuser out to find the maximum position you want to allow.

Note that there is also a “minimum” position of zero. That is, neither the software or the hardware will allow the focuser to move to a negative position. Although it is not necessary, many people like to set up the focus control system such that the zero position corresponds to the focuser being at the “full in” position. There are two ways to achieve this: You can move the focuser to the full in position before attaching the motor (or with the motor disengaged), then use the “Set To” parameter to define this position as zero, or you can use the “Set To” parameter to define the current position to be some large value so that you can then use the focus controller to (carefully) move the focuser to the full in position, then use

"Set To" again to change the current position to zero. We recommend the former method when using our focus motors, since it is very easy to disengage the motor and move the focuser manually. Be careful not to attempt to move the focuser past the full in position using the motor. Setting the zero position at full in (or even a little "out" from there) prevents accidentally going too far inward because the controller will not allow the motor to move beyond the zero position.

Likewise, you may want to define the maximum position at or slightly "in" from the most outward position of the focuser. After setting the zero/full in position, use the focus controller to move the focuser to its maximum outward position. Note the current position at that point and copy it to the "Max" position field. From then on (until you change the "Max" position) the controller will not allow the motor to drive beyond this point.

For an observatory installation, where it is never necessary to move the focuser all the way in (such as to put the telescope in a carrying case) and the elements in the image path never change, the minimum and maximum position settings can be used to limit travel to the amount that focus shifts with temperature change and filter changes. For example, we might set the 0 position (minimum) at 1,000 steps IN from the average focus position and the maximum to 1,000 out from the average focus position (by definition, this would be at 2,000 steps).

The "Set To" field, as mentioned above, is used to define the current position to any arbitrary value between zero and the maximum position.

5.2.1.2.6 Temperature Compensation

This section describes parameters that determine how the focuser responds to temperature changes.

Temperature compensation (TC) is possible because Power*Star comes with a temperature/humidity sensor. Focus motors from Starlight Instruments also have a temperature sensor built into them, and either sensor can be used to control TC. You can enable TC at any time (using the on/off button in the Focus tab), but it does not become active until a valid temperature reading is available.

Note that TC movements are calculated based on the "reference point" established when you turn TC on. That is, the current position and temperature are saved at that time and used for all TC calculations rather than simply calculating the change from the most recent event. The latter method is imprecise because of the accumulation of rounding errors. The reference position is automatically updated if the position is changed by user-driven movement. Therefore, although it may be necessary sometimes to "tweak" the focus while TC is enabled, this will not cause errors in the calculation of TC corrections.

Backlash compensation is not applied to TC movements. That is because TC may require moving the focuser OUT as the temperature drops, while the preferred direction is usually IN.

If backlash compensation were used it could result in relatively large movements of the focuser in the middle of an exposure. It is recommended that TC be used only with systems having backlash of less than half the size of the critical focus zone.

TC also involves a heated philosophical debate, if you'll pardon the pun. The issue is whether corrections to compensate for temperature changes should be reflected in the reported position. The argument against including TC adjustments in the position report is that the actual position (the distance from the telescope objective to the image sensor or eyepiece) does NOT change because TC is holding it constant by increasing the draw tube extension as the OTA dimension shrinks, for example. In fact, under this philosophy the position value DOES change with temperature if TC is NOT enabled. This might make a lot of sense if the reported position were actually the focal length of the telescope (perhaps in millimeters). The argument is further complicated by the fact that TC makes corrections for optical changes from temperature as well as the mechanical dimensions (the effective focal length of both lenses and mirrors changes slightly with temperature). We think that the opposing philosophy is preferable: P*S reports the number of steps out from a user-defined zero point, including any adjustments made for temperature compensation.

5.2.1.2.6.1 Temperature Compensation Coefficient

You can set the coefficient and hysteresis parameters at any time. Note that the initialization of the temperature sensor can take a minute or two after turning on the Power*Star and connecting a motor. After that, the temperature is updated frequently.

The temperature coefficient is the number of steps needed to compensate for a 1 degree Celsius change in temperature. In traditional terms, a falling temperature requires moving the focuser "out" as the length of the telescope tube shrinks. Therefore, positive values of the temperature coefficient produce increasing position with decreasing temperature. In case you need the opposite, simply enter a negative value for the coefficient. In the real world it is very common to have a telescope with a negative temperature coefficient. What it means is that temperature changes effect the optical elements to a greater degree (and in the opposite direction) as compared to changes in the physical length of the OTA.

A coefficient of zero disables temperature compensation.

To measure the temperature coefficient, critically adjust the focus and record the position and temperature at that time. When the temperature has changed a significant amount (5 to 10 degrees C, preferably), critically adjust the focus again and note the final position and temperature. Calculate the change in position divided by the change in temperature, rounding off to the nearest tenth of a step. Ideally, the temperature will have been fairly stable for a long time before making the critical focus adjustments (for both temperature/focus points).

5.2.1.2.6.2 Temperature Compensation Hysteresis

The hysteresis value defines how large a change in temperature is allowed before a correction is applied to the focus position. Setting it to 0 means that a new position is calculated every time that the temperature is measured (approximately every 5 seconds). However, if the resulting position change is less than 1 step no action is taken.

Normally, the hysteresis is set to something larger than 0 because it is not necessary to make such small changes, and moving the focuser unnecessarily is a risk. Every time the motor is activated there is a very slight vibration created. This vibration is generally too small to have any effect, but there is no point in risking it when the adjustment will not improve anything.

To determine the optimal value for hysteresis, use this formula:

$$\text{TC hyst} = ((\text{CFZ} / \text{SS}) / 4) * (1/\text{TC coef})$$

where CFZ is the "critical focus zone" for your telescope, SS is the linear step size for your focuser and motor (the distance the focuser actually moves for a single step of the motor), and "TC coef" is the temperature coefficient determined in the previous section (ignore the sign of the coefficient – enter a positive value). CFZ and SS must be in the same units (typically microns), TC coef is steps per degree C, and hysteresis is in degrees C. The idea here is that no correction should be made until the resulting movement is at least a quarter of the critical focus zone. For example, if CFZ = 100 microns, SS = 5 microns per step, and TC coef = 10 steps per degree, the suggested TC hyst value would be:

$$\begin{aligned}\text{TC hyst} &= ((100 / 5) / 4) * (1/10) \\ &= 0.5 \text{ degrees}\end{aligned}$$

Setting the hysteresis value to zero will result in a correction for every change in measured temperature. This is not recommended because there will always be some small change that is not meaningful. On the other hand, setting hysteresis to too large a value (greater than the change in temperature that actually occurs) will prevent temperature compensation from working.

If you are using a Feather Touch focuser and motor, the step sizes are:

$$\begin{aligned}\text{HSM20 (2" FT crayford focuser)} &= 1.31 \text{ microns/step} \\ \text{HSM30/35 (2.5", 3", or 3.5" focuser)} &= 1.04 \text{ microns/step} \\ \text{SI-PDMS (2.5", 3", or 3.5" focuser)} &= 2.23 \text{ microns/step}\end{aligned}$$

If you are using a PDMS unit with a non-FT focuser the exact step size depends on the characteristics of the focuser, but is typically similar to the SI-PDMS value of 2.23 microns/step.

5.2.1.2.6.3 Temperature Sensor Select

Temperature Compensation can be controlled by either the environment sensor, or the temperature sensor in the motor (if using a Starlight Instruments HSM or PDMS motor). Click the button for the sensor you want to use.

5.2.1.2.6.4 ASCOM TC Available

If this box is checked before an ASCOM client program connects to the P*S focus controller, the client program will be informed that TC is available, which may allow control of TC through the 3rd party program. This setting should not be changed while an ASCOM connection is active because the change will not be passed on to the 3rd party software. The setting is only checked when the program establishes the connection.

We recommend leaving the checkbox unchecked and using only the P*S app to control TC.

5.2.1.2.7 Behavior

This section contains parameters that affect how the system responds to user actions.

5.2.1.2.7.1 Reverse Motor

Stepper motors turn in a direction defined by the sequence of coil activations and the direction can be reversed by changing the sequence. By default, the motor turns such that IN and OUT are correct when the motor is attached to the right side of the focuser (on a refractor). Note that when you look at the motor (off the telescope) you will usually be seeing it from the opposite perspective, so the motion appears to be backwards. Since this relationship may be different depending on the specific focuser used and on which side the motor is attached, it may be necessary to use this check box to get the proper relationship between IN and OUT in the P*S application and the physical movement of the focuser.

5.2.1.2.7.2 Disable Permanent Focus

The Permanent Focus Feature is a special case of Temperature Compensation. Normally, if TC is enabled when you shutdown P*S (i.e., when you click the Disconnect button) the parameters for TC (including the reference position and temperature) are saved in non-volatile memory, along with a flag that tells the system to automatically restore the reference data and enable TC during initialization of the next session. If TC is disabled at Disconnect, the flag is cleared and the next session will begin without TC. However, if the Disable Permanent Focus checkbox is checked the flag will not be set, regardless of the state of TC at Disconnect.

Permanent Focus means that the focuser position is always adjusted for temperature. Even

when the system is powered down, as long as the focuser is not disturbed, when the system powers up again it will check the temperature, calculate the corrected position based on the saved parameters and move to that position. Theoretically, this means that the telescope can always be in perfect focus. In practice, focus changes depending on the filter used, so it is a good idea to use filter offsets if that is supported in the software you use for image capture. In that case the TC system adjusts for temperature changes and the filter offsets adjust for difference between filters. However, when the filter offset operation adjusts the focus, the TC system has to establish a new reference point, since it has no way of knowing that the adjustment is just compensation for filter differences rather than a normal adjustment of focus. Since the filter offset adjustment can only work in full steps there will be a very small rounding error in this calculation, and after doing that many, many times, the accumulated error can become significant. This effect can be minimized by limiting the number of times you change filters (e.g., by shooting all of the sub-exposures for 1 filter before switching to the next). However, there are other reasons you might prefer to capture an exposure with each filter before going back to the first. An even better solution to the problem is to use filters that are sufficiently parfocal that you can use all of them without adjusting focus. Although most filter sets claim to be parfocal, the truth is that it depends on the CFZ of your system, which depends entirely on the focal ratio: A very fast telescope will likely show differences between filters that are undetectable on a slower system. It should also be noted that in refracting telescopes the chromatic aberration (even on a true apochromatic telescope) may very well contribute more to the focus shift between filters than does the characteristics of the filters themselves.

If you do not use TC there is no need to disable Permanent Focus, as it will never be activated. If you use TC, but do not want the telescope to automatically adjust focus at start-up, check the Disable Permanent Focus checkbox.

5.2.1.2.7.3 Lock Mode Braking

When you click the “disconnect” button in the P*S app it enters a “lock mode” in which the motor will not move, either from commands sent to the controller or from temperature compensation. By default, the amount of current used to hold the motor in lock mode is the same as in normal operation, and this is the default selection, “Normal Braking”. However, since the telescope may be parked in a position that does not require as much power, you can also select “Low Power” (the lowest possible motor current), or “No Braking”, which completely shuts down the motor driver chip. Note that “No Power” reduces power consumption, but may allow a small amount of motion, even if the telescope is horizontal and the focuser is physically locked. Over multiple cycles, the resulting position error can accumulate to the point that it becomes noticeable. This is usually not a problem, and reducing power consumption can be much more important. If the P*S will be turned off between sessions there is no point in trying to maintain the position accurately, so “No Braking” is then appropriate.

5.2.1.2.8 Motor Type

As mentioned earlier, P*S supports both bipolar and unipolar motors, using a separate connector for each. Click the "radio button" selector for the type of motor you are using. Starlight Instruments motors (HSM and PDMS) are bipolar motors. If you are unsure of what type of motor you have, please consult with the manufacturer.

If you are not using the focus control features of P*S you can select "No Motor" to disable both motor drivers.

5.2.1.2.9 Motor Selection

The "Motor Selection" drop down menu allows you to select one of several preset motor types (including "No Motor"), which will then fill in all the corresponding parameters that relate to the motor specifically. Clicking on one of the predefined entries (the top 4 choices) will load the parameters associated with that name. Clicking on one of the the bottom 4 entries allows you to define the parameters for another motor. You can name it by clicking the Rename button and typing in the new name (the Rename button only appears when you have selected one of the bottom 4 slots).

You can modify any of the parameters for any motor preset. When you have selected one of the predefined motor definitions a Restore button will appear. Clicking this button will restore the parameters for the selected preset to its default values.

When you have finished setting the focuser configuration, click on "Apply" to save them (leaving the window open for further changes), "Apply/Close" to save the changes and close the window, or "Cancel" to close the window without saving changes.

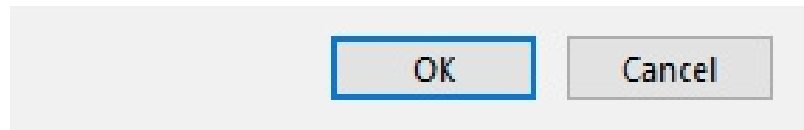
5.2.1.3 Firmware Update

This menu item is used to update the firmware in the P*S controller. This would only be used if there is a newer version of the firmware released. To perform a "flash update", first download the new firmware (a .hex file) from www.starlightinstruments.com, and place it in a convenient folder on your computer. With P*S powered on and connected to the computer via USB, select "FW Update" from the Settings menu. This will bring up a window to confirm that you want to continue with the update.

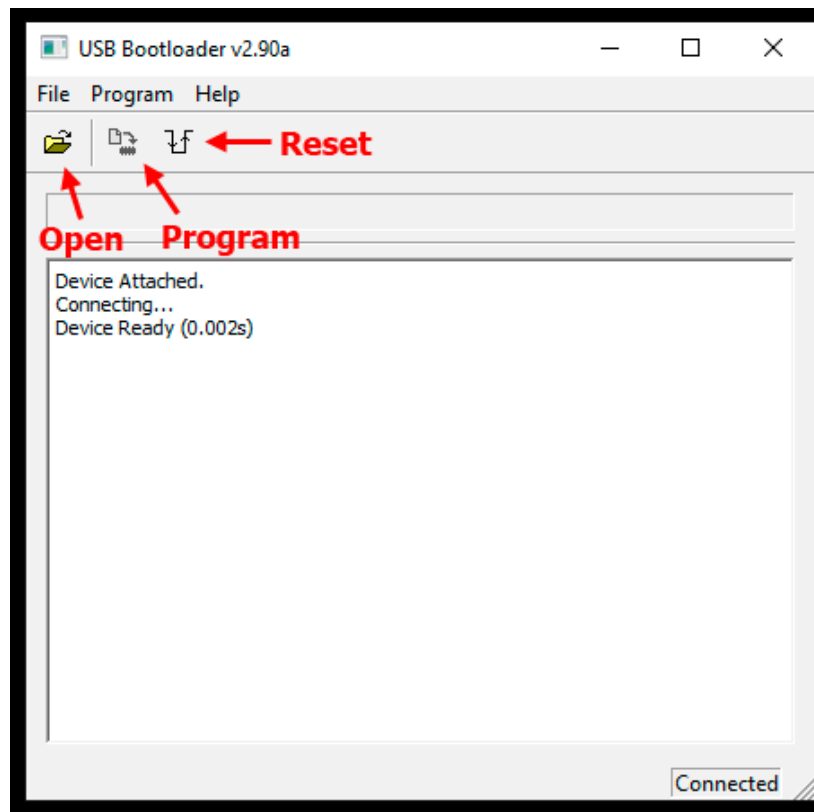
Power Star FW Update



Press OK to update firmware, else Cancel to exit



Click OK to continue. The P*S app will then disconnect from the controller and launch the update utility program. This program allows you to open the .hex file and program it into the controller. These steps can be done using either the menus or icon buttons in the utility program.



WARNING: The program might be able to load “.hex” files intended for other devices, but attempting to update the controller with such a file will almost certainly not produce a good result, including the strong possibility of overwriting the code that allows firmware updates. If that happens the controller will be completely non-functional and will need to be sent back to Wa-chur-ed Observatory to be reprogrammed. The firmware files for Power*Star will be named as “PowerHub_vX_Y.hex”, where X.Y is the version number.

Once the program and verify are complete, click the “Reset” button or select Reset from the Program menu, then close the Utility program. This will return control to the P*S app, which will ask you to confirm that the controller has been reset. You may then click the Connect button and go to the Status tab to confirm that the firmware version has changed to the new version. If you forget to click the “Reset” button P*S will remain in the firmware update mode and you will have to go through a power off/power on cycle to resume normal operation.

If the P*S firmware becomes corrupted (such as by turning off power to P*S or disconnecting the USB cable while in the middle of a firmware update), it might still be possible to restore the firmware. This requires a special device that can be obtained from Wa-chur-ed Observatory when needed.

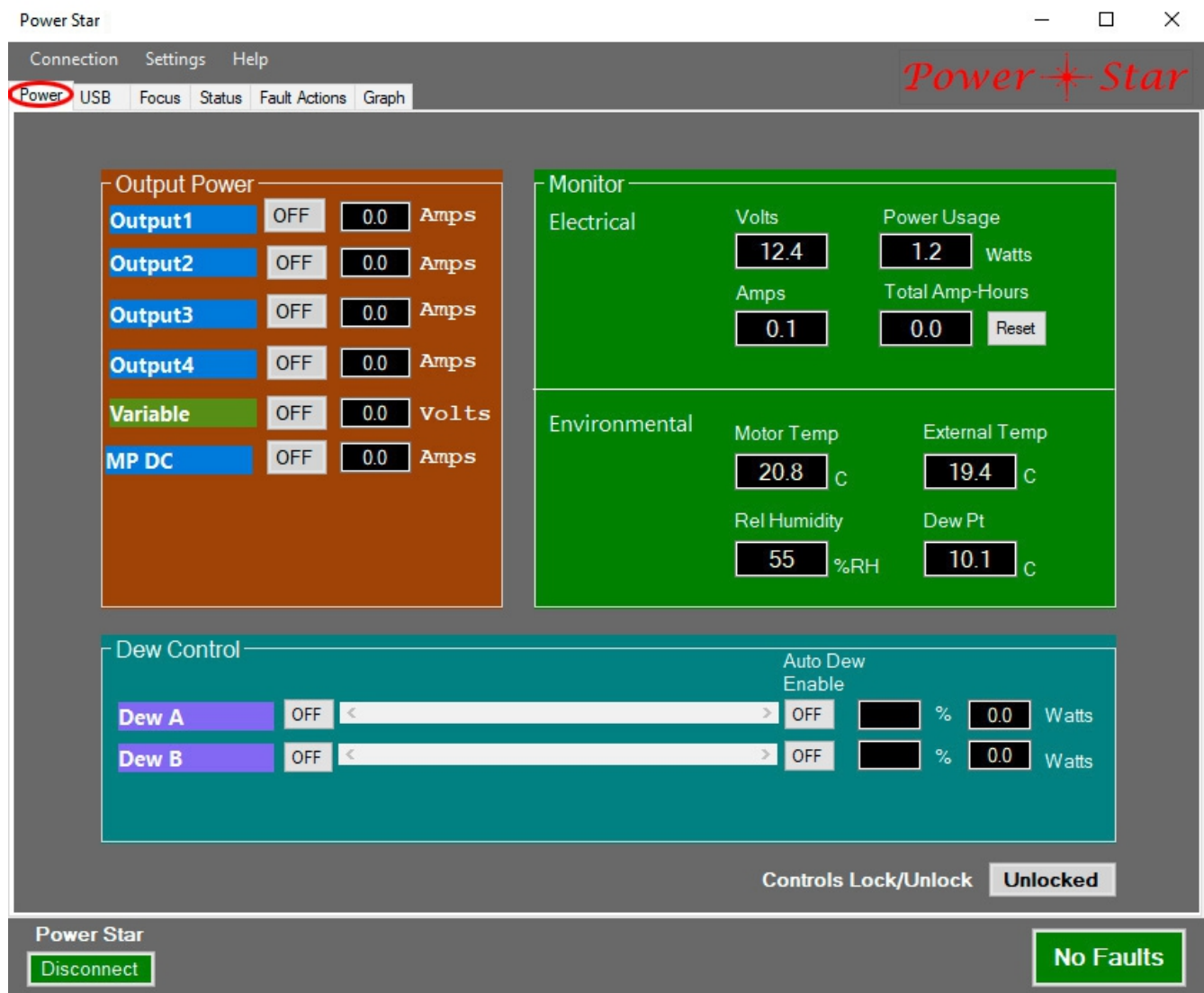
5.2.1.4 Power*Star Reset

While it is unlikely that you will ever need to use it, this menu item allows you to force a hard reset to the P*S controller. It will look essentially the same as simply disconnecting from the controller, but actually performs a reset after the disconnect. You may notice that your computer “chimes” to indicate that a USB device has been disconnected, and then re-connected, since the reset also affects the USB hub in P*S.

5.2.2 Power*Star Application Tabs

The main section of the Power*Star window is divided into 6 tabs, which allows you to quickly access various information and controls in logical groups. There is also a global status section at the bottom of the window (visible regardless of which tab is selected) that indicates the “connect” status of the Power*Star and the focus controller within Power*Star. If a fault is detected (see section 5.2.2.4) a warning will flash in red in the lower right corner, and is otherwise green. This is a “latched” indicator, so even a momentary fault will cause it to start flashing and it will continue to flash until the fault is reset. The following sections describe each tab.

5.2.2.1 Power Tab



The Power tab is used to control each of the power outputs, including the switchable 12VDC outputs, the variable voltage output, the Multi-Purpose (MP) output, and the dew heater channels. The tab also displays information about the input voltage, the current draw for

each output, the total current draw, the ambient temperature, humidity, and dew point.

5.2.2.1.1 Output Power section

In the upper left corner is the Power Output section. Each of the four 12VDC outputs, the variable voltage output, and the MP output (except when MP is configured to be a dew heater channel) are displayed with the name you assigned in Settings>Setup Power*Star. Next to the name is an OFF/ON button, which is gray when OFF, and green when ON. Next to each OFF/ON button is a small information box. For most outputs this box displays the current being drawn from the port. If an output is ON, but there is no current flow, the measurement will be shown with a yellow background (if this feature is enabled in Settings>Setup Power*Star). This serves to warn you that the device may have become disconnected, or that you turned on the wrong output. Note that the warning is displayed when the current measurement is an absolute zero. Since the display has a resolution of 0.1A, it may show a reading of "0.0" but not be at absolute zero. Outputs 1 and 2 have higher current capacity, but less sensitive current measurement. Therefore, a device that draws very little current might trigger the "no current" warning when connected to output 1 or 2, but not when connected to other outputs. For example, many CMOS cameras power the actual camera circuitry through the USB cable, and use the 12V supply only for cooling the camera. If the cooling is turned off the current flow to the 12V port will be very low and trigger the warning if it is on output 1 or 2, but there might be enough leakage current to avoid the warning on other outputs. If you are getting false warnings you can ignore them, disable the warning, or switch the device to a more sensitive output.

The variable voltage port does not have the ability to measure its current draw, but it does display the measured voltage. This voltage will normally be very close to the level set in P*S Setup. However, if the load on the port is too great (more than 3 amps), the voltage will "sag", and this will be reflected in the displayed voltage. If it sags by more than 6% a 1st level fault will be indicated, and if it sags more than 12% it is a 2nd level fault, which will cause the port to be turned off.

If the MP output is configured as a standard 12VDC output, it will be displayed in the same format as the others. If it is configured as a PWM output a slider control will appear at the bottom of the Power Output section. To the left of the slider is an OFF/ON button that works very much like the standard outputs, except that when first turned on the slider goes to just 1%. By clicking and dragging the slider you can adjust the duty cycle of the output from 0 to 1023 (10 bit resolution). You can also adjust it incrementally by clicking the left and right arrows at either end of the slider. The PWM output is adjustable to 1024 levels (0 to 1023), although depending on the device being powered, you may observe that some number of steps near either end of the range appear the same – completely off or completely on.

The PWM output is different from all the others in that the system cannot accurately measure the average current flowing to the connected device. Instead, it must measure the current while the output is set to 1023 (full ON), remember this measurement, and multiply it by the currently set duty cycle percentage to calculate the current. The current calculation is then

multiplied by the input voltage measured to calculate and display the power being used in watts. Both the number of watts and the percentage setting of the slider are displayed. When the PWM output is first turned on (each time the program is launched) a pop-up message will appear, reminding the user of the need to measure the current at 100%. If it is OK to turn on the output at 100% for 2 seconds, click OK. Otherwise, click cancel. The PWM output will work the same either way, but if the output is never set to 100% the power measurement will be unknown and displayed as "--". You can reset (calibrate) the full-scale current measurement at any time by briefly setting the PWM output to 1023.

5.2.2.1.2 Monitor section: Electrical

The Monitor section contains information about the electrical power passing through Power Hub. This includes momentary measurements of the power (in watts), the input voltage (volts DC), and current (in amps). There is also a display of the accumulated amp-hours, with a reset button to zero it and start over. The amp-hour display is useful in monitoring battery charge if you are using batteries to power the system.

Note that the current and power usage numbers are the total of all uses at the 12VDC input. This includes all the outputs (whether they are separately measured or not), such as the USB ports, and a small amount of power used internally. The current measurements for 12VDC outputs are not as accurate as the total current measurement, especially when the current is relatively low. This, in combination with the fact that some ports are not measured, means that the total will rarely equal the sum of the displayed output currents.

5.2.2.1.3 Monitor section: Environment

This section displays the temperature, humidity, and dew point. When using a focus motor from Starlight Instruments (HSM or PDMS) the temperature measured from the motor is also displayed. The two temperature measurements will often disagree, and sometimes more than you might expect. There are several reasons for this, but a very significant one is that the environment sensor is measuring the air temperature, while the sensor in the motor is measuring the temperature inside the motor enclosure. Since it is not directly exposed to the air, its temperature will change more slowly as ambient conditions change.

Any measurement not available will be displayed as "--".

When auto dew control is enabled for any dew channel the trigger temperature is also displayed.

5.2.2.1.4 Dew Control section

Below the Output Power section is the Dew Control section. Each of the dew heater channels is shown in a format similar to the PWM output. If the MP output is configured as a dew heater channel there will be three sliders displayed, otherwise two.

Unlike the PWM output, the dew heater outputs can be measured regardless of the slider

setting (although at very low settings such as 1 or 2% it may take a few seconds to get a measurement).

The dew heater outputs are “phased” to even out the power usage. That is, using the same switching period, channel A is on for the first X% of the period (where X is the slider position), and channel B is on for the last X% of the period. If the MP output is configured as a dew heater channel, its timing is the same as channel A.

To the right of each dew channel slider is a button to enable the channel for automatic dew control. The trigger point for automatic dew control is covered in section 4.2.1.4. To enable a channel for auto control, first click the Auto Dew Enable button then set the slider to the desired level (see section 4.2.1.4 for information on determining the proper level). The heater will then turn on or off to the set level based on the temperature and dew point.

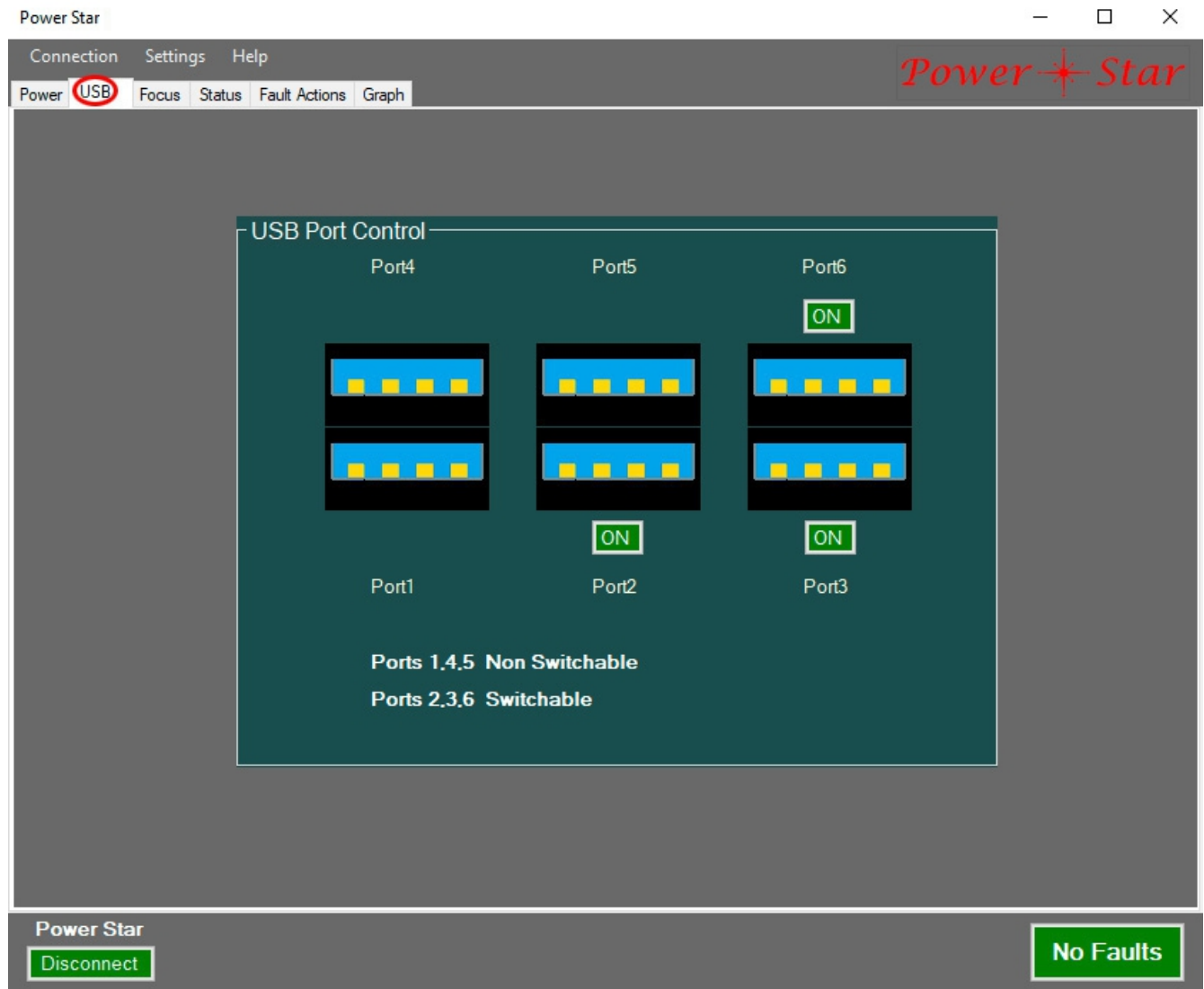
When auto dew control is enabled for any channel, the calculated trigger temperature will be displayed in the Status section at the bottom of the Power tab. You can (usually) tell when a dew heater is ON because the “Watts” display will be greater than 0.0, but you can also simply check whether the external (ambient) temperature is below the dew point trigger.

While a dew channel has Auto Dew enabled the ON/OFF button on the left will always show “OFF”. To force the channel ON you must turn off the Auto Dew Enable.

5.2.2.1.5 Lock Control

In the lower right corner of the Power tab is a lock/unlock toggle button. After you have set the on/off switches as needed for an imaging session you can set this control to “Locked” to prevent accidentally turning something off (or on). If you attempt to change any of the on/off switches while the lock is engaged a warning message pops up to remind you that it cannot be changed unless you first unlock the controls. There is also an option in the Settings>Setup Power Hub menu to require confirmation to switch from on to off. These are 2 different methods to accomplish roughly the same thing, but you might prefer one over the other. Or you could be a “belt and suspenders” type and use both!

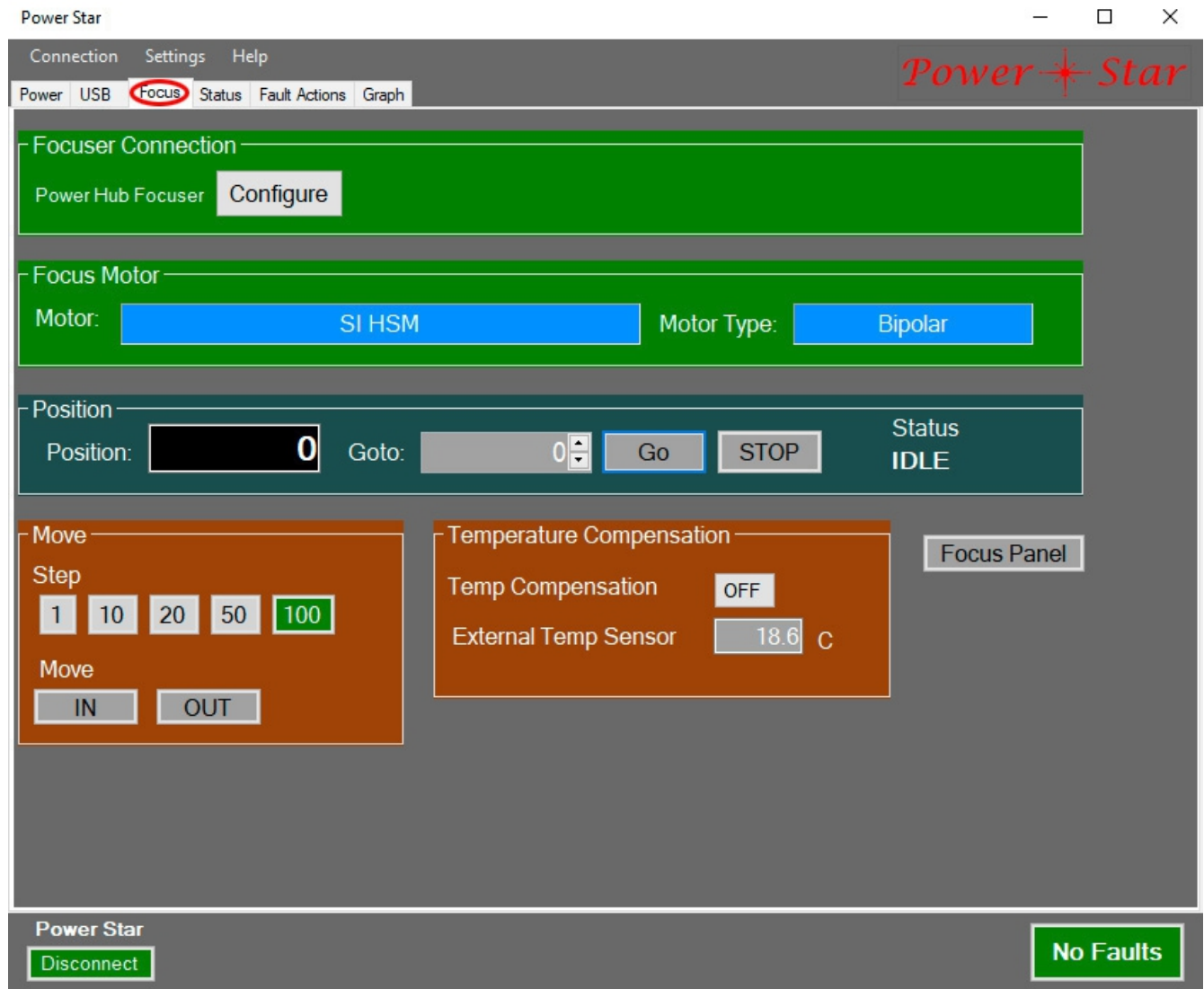
5.2.2.2 USB Tab



The USB tab shows the status of each USB downstream port. The six icons represent the ports as they are arranged on the front panel of Power*Star. The name you assigned to each port is displayed above or below the icon.

Three of the six ports have power switches, using the same OFF/ON button as the power ports.

5.2.2.3 Focus Tab



The top section of the Focus tab shows a Configure button, which takes you to the same window as the Settings>Configure Focuser menu item (see section 5.2.1.2). To the right of this button a message may appear to indicate that the focuser is currently connected through the ASCOM driver.

Immediately below the connection section is information about the currently selected motor configuration. The predefined or user-defined name for the motor is displayed, along with an indication of whether it is a unipolar or bipolar motor (and thus, which motor connector on the rear panel is being used).

Below that is the Position section, which shows the current position (in steps) on the left side. To the right of the position display is a Goto field. By entering a numeric position in this field and clicking the Go button, the focus controller will move the focuser to that position. On the right side of the Position section is the status of the motor, IDLE or MOVING.

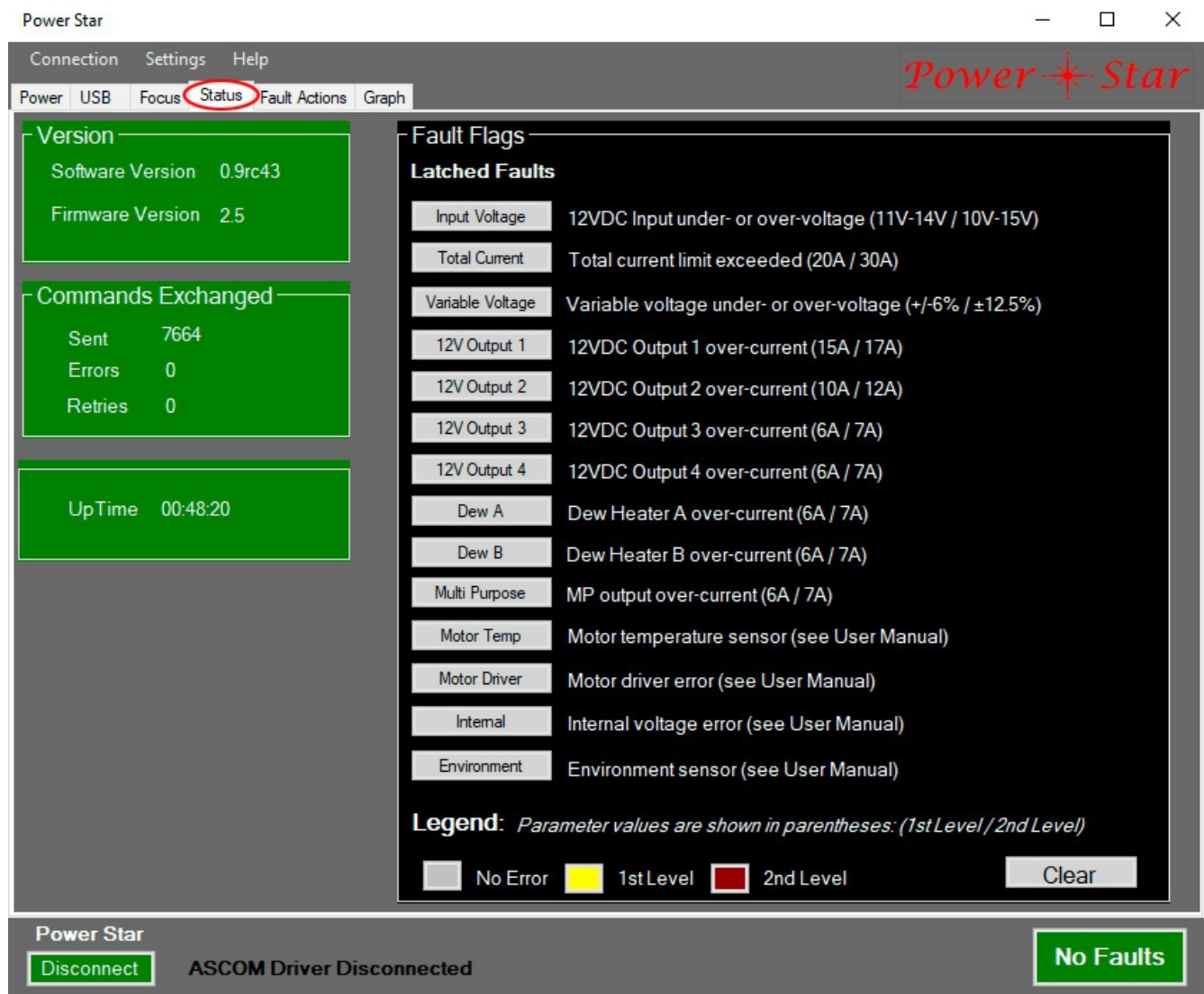
Below the Position section and on the left is the Move section, which provides a simple way to make incremental adjustments to the focus. Click one of the Step Size buttons, then click the IN or OUT button to move the focuser the selected number of steps in the selected direction.

To the right of the Move section is the Temperature Compensation section. See section 5.2.1.2.6 for details on setting up and using TC. The control here is simply an OFF/ON button for TC. There is also a display of the current temperature. Since TC can operate from either the environment sensor or the motor's temperature sense (if available), the display indicates which temperature reading is being used.

In the lower left corner of the Focus tab is a button labeled Focus Panel. Clicking this button will bring up a compact version of the focus controls described above. This small panel can be placed anywhere on your desktop, and used to adjust focus at any time, even if the Power*Star app is minimized.

If you attempt to move the focuser beyond the specified maximum position, or to a negative position (more "IN" than the zero position) a warning message will pop up. This applies only to the P*S app itself, not to other apps connected to P*S through the ASCOM driver.

5.2.2.4 Status Tab



The larger portion of the status tab (on the right) shows a list of the 14 fault conditions that the Power Hub monitors. For detailed information on each fault, please refer to section 5.2.2.5 Fault Actions Tab. The following is an overview of the fault detection and reporting system.

There are 14 fault conditions that are detected and reported by P*S, each represented by a "Latched Fault" button in the Status tab. The buttons in the Status tab are normally gray, meaning that no fault has been detected. Most fault conditions have 2 levels of detection, where the 1st level is a warning only, and the 2nd level indicates that some action was taken by the P*S controller to protect itself and the connected equipment. For the last 4 faults in the list the fault is based on a binary signal (on or off) rather than an analog signal, so there is no limit level for the user to set. The "Internal" fault is a special case that is a composite of several internal checks. It can produce a 1st or 2nd level fault, but the limits (thresholds) for both levels are fixed by the controller's firmware.

First level faults are indicated by a yellow background on the corresponding button. Second level faults are indicated by a red background. These background colors apply to both the Status tab and the Fault Actions tab, but the Fault Actions tab shows only faults that are active at the moment, while the Status tab buttons stay "on" (yellow or red) after even a brief fault detection, until the "Clear" button is clicked.

When any of the "Latched Faults" are active (at either 1st or 2nd level) in the Status tab, the FAULT button in the lower right corner (visible regardless of which tab is selected) flashes in red. An audible alert also sounds if any latched fault is active (unless disabled in the Settings>Power Hub Setup menu). The audible alert repeats once per minute for 1st level faults and once every 10 seconds for 2nd level faults.

Second level faults always result in some action being taken by the P*S controller. If the fault is related to a specific power output, that port is turned off, and a pop-up message is displayed to tell you what happened. If you can fix the situation that caused the fault (for example, by disconnecting a malfunctioning device), you can clear the fault using the "Clear" button, and turn the port back on (if desired). If a 2nd level fault is not limited to a specific output (meaning the Input Voltage, Total Current, and Internal faults), it is considered a "Fatal Fault", which results in ALL ports being turned off. The switchable USB ports and focus motor will also be disabled when a fatal fault occurs. A fatal fault also requires that the P*S application be restarted, to make sure that everything is properly initialized. Likewise, the P*S controller should be reset (powered down, then back on) after a fatal fault to ensure proper initialization. Obviously, the user should attempt to correct the fault before applying power to PH again, and the pop-up message attempts to provide as much information as possible to help you correct the fault. For example, if the input voltage drops below 10V it will result in a fatal fault, and the pop-up message will tell you that it is because of the input voltage. If power is being supplied by a battery, you should re-charge the battery, or switch to another power source.

When re-starting P*S after a fatal fault you will (usually) get a warning message reminding you that the previous session ended with a fatal fault. The purpose of this message is that when the PH controller re-starts after a fatal fault it skips the usual processing of "Power ON at startup", so everything will be off and must be turned back on manually. This is done in case a defective device is still connected.

When you remove power from P*S it may detect that the voltage is too low and report a fatal fault before the voltage gets so low that the processor cannot run. This could result in the appearance of a "fatal fault in previous session" condition every time you start it up. To avoid this, fatal faults are not recorded while the P*S app is disconnected from the P*S controller. But that only works if you remember to always click the Disconnect button before removing power.

5.2.2.5 Fault Actions Tab

The same 14 fault conditions shown in the Status Tab are again listed on the Fault Actions tab. In this case the faults are NOT latched, so you may see buttons changing between gray (normal) and yellow or red (fault indication). More importantly, the specific voltage or current level that triggers a 1st level fault can be adjusted, and check boxes next to each fault allow you to select what action the system should take when the fault is detected. For each fault condition the description is in the left-most column, then there is a button that shows the status (gray = no fault, yellow = 1st level fault, red = 2nd level fault), the limits for both 1st and 2nd level fault detection, and checkboxes for the possible actions to be taken on 1st level faults.

Power Star

Connection Settings Help

Power USB Focus Status **Fault Actions** Graph

Active Faults 1st and 2nd Level

Action To Perform When 1st Level Fault Occurs

	Fault Condition Level 1 Limit Set	Level 1 Limit(s)	Level 2 Limit(s)	Ignore	Popup Message	Close Port	Close All
12VDC Input under- or over-voltage	Input Voltage	10.0V - 14.5V	10.0V - 15.0V	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Total current limit exceeded	Total Current	22.7A	30.0A	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Variable voltage under- or over-voltage	Variable Voltage	10.0% 2.7V - 10.9V	+/- 12.5%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12VDC Output 1 over-current	12V Output 1	15.0A	17.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12VDC Output 2 over-current	12V Output 2	10.0A	12.0A	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12VDC Output 3 over-current	12V Output 3	6.0A	7.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
12VDC Output 4 over-current	12V Output 4	6.0A	7.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Dew Heater A over-current	Dew A	5.0A	7.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Dew Heater B over-current	Dew B	5.0A	7.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
MP output over-current	Multi Purpose	6.0A	7.0A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Motor temp sensor (see User Manual)	Motor Temp			<input checked="" type="checkbox"/>	<input type="checkbox"/>		
Motor driver error (see User Manual)	Motor Driver			<input type="checkbox"/>	<input type="checkbox"/>		
Internal voltage error (see User Manual)	Internal			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>
Environment sensor (see User Manual)	Environment			<input checked="" type="checkbox"/>	<input type="checkbox"/>		

Reset Level 1 User Limits to Defaults

Reset Limits

Power Star

Disconnect ASCOM Driver Disconnected

No Faults

5.2.2.5.1 Adjusting 1st Level Fault Limits

To adjust the level for any of the first 10 faults, click the Fault Condition button for the one you want to adjust. This will bring up a dialog box where you can enter the desired trigger

(limit) voltage or current. In most cases, the level can be set to a precision of 0.1 amps or volts (although the accuracy of the measurement checked against the limit may not be that precise). The voltage faults (12VDC input and Variable Voltage output) have both upper and lower limits, while the current limits have only an upper limit. Each limit adjustment has its own range of permitted values, which generally allow you to get fairly close to the 2nd level fault limit, but not equal.

The Variable Voltage fault limit adjustment is unique in that instead of setting absolute upper and lower limits on the voltage, you enter a percentage tolerance. This is done so that you can change the voltage setting without having to change the limits. The system calculates the absolute limits as $\pm X\%$ of the nominal voltage. For example, with the default voltage of 8.0V and default tolerance of $\pm 10\%$, 10% of 8.0V is 0.8V, so the lower limit is $8.0 - 0.8 = 7.2\text{V}$, and the upper limit is $8.0 + 0.8 = 8.8\text{V}$.

The adjustable limits can often be left at their default values, but it is sometimes handy to adjust them to suit your particular system. For example, if your power source is a battery, you can set the upper and lower voltage limits to match what is normal for the type of battery you are using. There are also a lot of different opinions on what the minimum voltage for a lead-acid battery should be. You might want to set it very low to ensure that your imaging session runs as long as possible, or you might want to set the limit to a level that will maintain the long-term life of the battery (by not discharging it too deeply). In either case, remember that the fault detection is based on the voltage at the Power*Star, which will be somewhat less than it is at the battery, depending on the current flow and the length and gauge of the power cable between the battery and P*S.

For the current levels, you may want to determine the typical level for each connected device in your system, add a "margin" to it of 20 to 50%, and set that as the fault limit. This will allow normal operation without interruption, but give you a warning if something unusual happens.

5.2.2.5.2 First Level Fault Actions

To the right of the Fault Condition buttons are checkbox columns for the possible actions to take for a 1st level fault. The first column is "Ignore". Note that while any 1st level fault can be ignored by the P*S app, many of these faults have a second level of severity that is detected in the hardware or firmware that cannot be ignored. More on this later.

The second column of checkboxes enables a pop-up message for each fault. These messages will appear even if the P*S app is minimized, so it's a good idea to enable these messages if you typically keep the app minimized.

Finally, you can choose to automatically turn off the part of the P*S hardware that is causing the fault. When the fault pertains to a specific port or hardware function, the checkbox appears in the "Close Port" column, and the action is limited to that part of the hardware. If the fault is of a more global nature, the checkbox appears in the "Close All" column. If such a fault occurs and the corresponding checkbox is set, all power ports, dew heaters, motors,

and (switchable) USB ports will be turned off.

Note that two of the faults are for the temperature/humidity sensors (both the external environment sensor and the temperature sensor built into the focus motor). Both of these sensors take some time to produce a measurement after power to the Power*Star is turned on, so it is normal for these faults to be active initially. Because of this, and because neither of these faults is very important, they are set to "ignore" by default. If you are using a focus motor that does not have a built-in temperature sensor this fault will always be active, so you should leave the Ignore box for Motor Temperature Sensor fault checked. Once they start operating, both the motor temperature sensor and the external temperature/humidity sensor will normally work reliably, but it is possible to see communication failures result in temporary failures. This is not a significant problem unless it persists for many minutes.

Note that the power/status indicator LED in the P*S box will flash while any of the faults is active and not set to Ignore. The purpose of this flashing LED is to alert you to faults when you are at the telescope rather than looking at your computer screen.

5.2.2.5.3 Protection Feature Details

As mentioned above, many of the faults listed in the Status and Fault Actions tabs have 2 levels of severity. The P*S app deals only with the first level, which can be considered a warning (although some are more serious than others). Although these faults are checked quite often (about once per second), that can be a dangerously long delay for the most severe faults, such as a major short circuit in a device connected to one of the power ports. Therefore, protection is also provided in the hardware and/or firmware to detect and quickly deal with more serious faults. This detection and action cannot be masked. Below is a summary of these protections.

Reverse polarity protection: Although it is not really a detected fault (since the onboard processor never gets powered up), hardware in the Power*Star detects whether the incoming 12VDC power is connected backwards and prevents this voltage from being applied to any internal circuits or connected devices.

Under-/Over-Voltage protection: If the 12VDC input voltage is greater than 15V or less than 10V all the power ports, dew heater channels, motors, and (switchable) USB ports will be turned off. The USB hub and onboard processor remain on and can continue to operate normally well beyond these limits. If the incoming voltage drops below about 6V the processor and USB hub will also shut down and the P*S app will no longer be able to communicate with either. Incoming voltage in excess of 15V is primarily dealt with by using components that can withstand very high voltages in the P*S hardware design. However, it will NOT withstand extremely high voltages. As an extreme example, applying 120VAC to the 12VDC input is very likely to cause damage to the Power*Star, and such damage could ultimately lead to excessive voltage leaking to connected devices. So please don't do this!

Transient protection: Brief voltage spikes, including those caused by electrostatic discharge (ESD) coming into the P*S will be absorbed as much as possible. This is especially important

on the 12V power input, so a large TVS diode (bidirectional) is placed across the +12V input and ground. It will begin conducting at about 20V and above 29V it provides a very low impedance path. However, such devices are meant to absorb only very brief pulses – on the order of microseconds. If more than 20V is applied continuously across the inputs the protection device will be destroyed. There is no indication that the TVS diode itself is destroyed, but other circuitry within P*S is likely to fail soon thereafter. The power outputs are more protected so that the downstream equipment is not damaged, but this cannot be guaranteed with excessive input voltage, whether AC or DC. Other ports are less susceptible to ESD. Nevertheless, caution should be used when handling any electronic equipment in an environment prone to static build up and discharge.

Over-Current protection: Excessive current drawn from the 12VDC input can cause several different problems, and so it is checked more frequently than other parameters. The firmware measures the current about 50 times per second (every 20 milliseconds), and initiates a global shutdown if the current exceeds 30 amps (far beyond normal needs). An over-current condition will typically cause a drop in the measured voltage as well (due to resistance in the power cable, etc.), which could cause the under-voltage fault described above.

Internal Voltage protection: Circuitry used within the Power*Star relies on DC-DC converters to produce various voltages. The onboard processor monitors such voltages 5 times per second to ensure that there is no internal circuitry failure. Since such a failure could result in a variety of other failures, including the inability of the P*S app to communicate with the P*S hardware, everything is shut down as described above. An under-voltage on the 5V bus (which powers the onboard processor) triggers a shutdown, but is not recorded as a fatal fault since this can happen normally when the P*S is turned off, especially if the power source is an AC-DC power supply rather than a battery. To avoid fault messages at shutdown (and for other reasons as well), please click the Disconnect button before turning off power to P*S.

Per-Port Current protection: Each of the power outputs senses the current through the corresponding port. A gradually increasing current will likely be detected first by the software, but a sudden and extreme increase in current (such as if the output is shorted) will be detected almost immediately, and will result in that output being turned off. To the software, this appears as just an extremely high current level, but by that time the output will have already been turned off. The firmware may attempt to disable the individual output port, but for the 12V power outputs there is a good possibility that the fault also produces a global over-current fault, which is higher priority.

Please note that while the per-port current protection mechanisms will trigger in the event of a short circuit on a power output, such events are still dangerous for several reasons and care should be taken to avoid them. The level of danger is proportional to the voltage and the amount of current available through a given port, including the amount of current available from the power source. The 5V power in the downstream USB ports is much less dangerous than the 12V outputs. Outputs 1 & 2 are controlled by high power switches with very low resistance, so they can provide huge amounts of current for a short time – much more so than the other 12V outputs or the variable voltage output. It is strongly recommended that you turn off P*S power outputs before changing external connections. This minimizes the risk of accidental short circuits, and provides a cleaner on/off switch (the software-controlled on/off switch is relatively slow compared to the mechanical connection of cable to device).

USB Port Current protection: Each USB port can supply current at 5V to the connected device. The amount of current is monitored in hardware, and the port is shut down if the limit is exceeded. This exception is not reported to or handled by the P*S system, but by the host computer. It is reported to the host through the USB hub chip, and the host operating system can reset the port, if desired. The non-switched ports (1, 4, and 5) have their current limit set at 0.9 amps, while the switched ports (2, 3, and 6) will allow up to 2 amps. Note that the USB port shutdown does not involve the use of the signals that P*S can use to turn off a switchable port. Therefore, such faults are handled entirely independent of P*S.

5.2.2.6 Graph Tab



The graph tab displays the same kind of information as the Monitor and Status sections of the Power tab, but graphs it over time so that you can see the changes and trends.

The upper graph shows the input voltage on a fixed, linear scale of 10 to 15 volts (since voltage outside of this range necessarily results in a complete shutdown). The total current is graphed with a selectable scale of 10, 20, or 30 amps. Select the lowest scale that covers your worst-case usage so that you get the best possible resolution to read the level.

The total current is measured 50 times per second, and the value displayed and graphed in the P*S app is the average of 50 samples. Part of the reason for this frequent measurement is to ensure a quick response to over-current conditions, but another reason is that the dew heaters turn on and off (potentially making large changes in the total current) over a period of 1 second, so measuring it frequently and averaging over the same period provides an accurate indication of the effective average current. Some other devices may also be switching loads on and off at different rates, such as the PWM output. The averaging of total

current is optimized for the dew heaters, since they are often a large portion of the total system power, but it is somewhat less effective in averaging the changes in current to other devices. This means that graphing of total current may show “aliasing” - variations in current that do not appear to be related to anything. In most cases such variation will be very small and can be ignored.

The measurement of the 12VDC input voltage is not averaged or otherwise filtered, so it is much more subject to aliasing. Fortunately, it should and usually does vary much less than the current does as the load varies. However, there is some “sag” (voltage drop) that occurs when the current increases (most such voltage drop occurs in the power cable between P*S and the power source). This means, for example, that when a high wattage dew heater is used at somewhere between 1% and 99% you will see a smooth graph of the average current (even though it is actually turning on and off once every second), but the voltage graph may show an uneven level. Since the P*S app samples and plots the voltage only once every 5 seconds, some aliasing will occur, meaning that the graph will typically show both the highest and lowest voltages, but the timing of these variations is not accurately represented.

Note that when NO outputs, USB ports, or motors are being used the total current draw is on the order of 100 to 200 milliamps, which is barely discernible from zero current, even in the 10 amp scale.

The bottom graph shows the temperature, humidity, and dew point over time. The humidity scale is fixed at 0 to 100% (relative humidity). The temperature scale automatically adjusts to be able to show the entire range of temperatures over the graphed time interval. Radio buttons in the lower right corner allow you to select whether the motor temperature or environment sensor temperature is graphed.

The time period scale can be changed by clicking one of the radio buttons; 2 minutes, 12 minutes, 1 hour, or 12 hours. Note that after changing the time scale the graph will not update until the next sample time. The time period displayed is always the most recent interval. It is not possible to “zoom in” to a smaller interval within older data – the graph shows only the most recent interval. However, you can examine the data with much greater flexibility by exporting it to a CSV file (see section 5.2.1.1.5), then loading that into a spreadsheet program.

You can customize the appearance of the graph by clicking on the Configure Graph button.

Configure Graph

Power Line Style

Input Volt Solid

Input Amps Solid

Environment Line Style

Motor Temp Solid

External Temp Solid

Humidity Solid

Dew Point Solid

Line Color Selection

☐ Input Volts

☐ Input Amps

☐ Motor Temp

☐ External Temp

☐ Humidity

☐ Dew Point

Line Thickness

Input Volt 2

Input Amps 4

Motor Temp 2

External Temp 2

Humidity 4

Dew Point 7

Color Selection

Blue

Black

Green

Cyan

Red

Magenta

Yellow

White

The default line style for each parameter is solid, but you can change them to other styles if you find this easier than using color to distinguish one line from another (as may be the case when using a red filter).

Line thickness is adjustable for two reasons: First, you can increase the thickness of a line to improve its visibility, or decrease it to make a less cluttered appearance. Second, lines may appear "on top of" other lines (the relationship is as suggested by the ordering here: Input Volts is the top layer in power graph, and Temp is the top layer in the environment graph). By using thin lines for the higher layers and thick lines for the lower layers, you can always see all the lines – none are totally obscured by lines drawn over them.

Finally, the color of line for each parameter can be selected from a drop-down menu.

6 Using the ASCOM Driver

This section describes how to use the features of the PH ASCOM drivers for focus control and environment data. Although it is theoretically possible to use other features of PH through ASCOM, this is rarely supported in 3rd party applications, so we have not created ASCOM drivers for such features.

Before the ASCOM control can be used, please refer to section 2.3 for instructions on installation of the driver software.

The PH drivers for ASCOM are relatively simple because they use the PH application to communicate with the hardware. This means that the PH app must be running before you can connect to PH through the ASCOM platform. The PH app can be minimized, but must continue running in the background while using the ASCOM driver. In fact, the PH app shows you the ASCOM driver connect status right next to the connect/disconnect button, and will not allow you to disconnect while the ASCOM driver is connected.

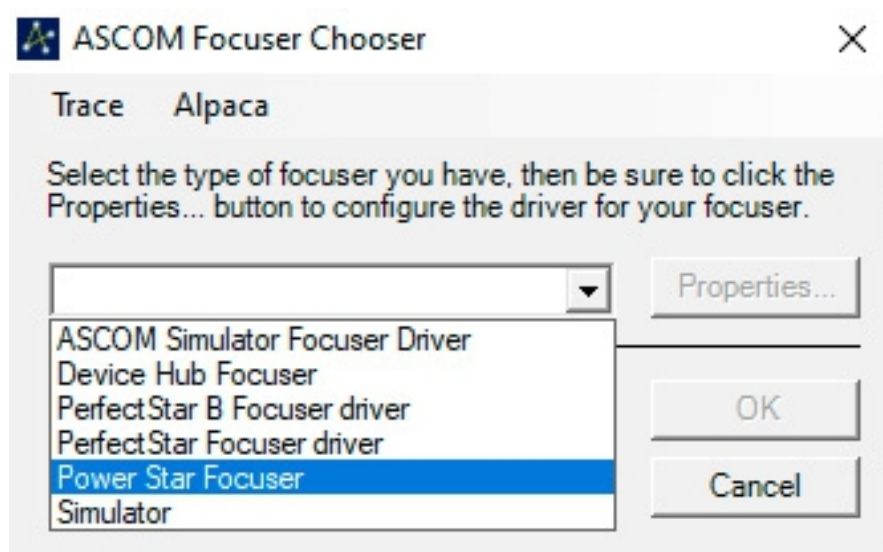
A note on controller compatibility with ASCOM applications: ASCOM does not enforce a well-defined method of implementing certain features. In particular, this leads to some variations in the implementation of backlash compensation (BC) and temperature compensation (TC) in the focus controller. In some applications one or both of these features can be handled by the application software. The PH Focus Controller implements both of these features in the controller itself, which provides certain advantages, such as the ability to use these features without needing an ASCOM application. However, the user must ensure that these features are never set up to be performed by both the controller and the application. In general, we recommend that you use the PH internal BC and TC because we put considerable effort into making them work correctly, and understand exactly how they work. We don't know much about how various 3rd party applications handle BC and TC, but do know that there are many mistakes that could be made in implementing these features.

Another area where ASCOM-compliant applications vary is in the reporting of temperatures when the sensor becomes unavailable. ASCOM provides a mechanism that the driver can use to report that no temperature information is available, but some applications treat this as an indication that there will NEVER be temperature information, so they stop requesting it. To get around this issue, when an application requests temperature information from PH when none is available, it returns a value of -500 degrees C (-868 degrees F). This is an impossible temperature (far below absolute zero), but not such a large negative number that any application would have trouble with it. If you see this temperature reported, please understand that it just means that accurate information is not available at the moment.

Temperature information is not available if the sensor is not connected to the controller. Furthermore, when the controller is powered on, or when the sensor is connected while power is on, it can take up to 10 seconds before an accurate temperature measurement is available. In rare cases it can also happen that the controller has difficulty reading the temperature from the sensor due to electrical noise. If you think you may be seeing this problem, please consider using a shorter cable.

6.1 ASCOM Chooser

Each application has its own way of accessing the controls for ASCOM devices such as the P*S focus controller, so you will have to refer to the documentation for your application. At some point, you will be presented with the ASCOM Chooser, a dialog box that allows you to select which specific device within a category you want to use (for P*S, the supported categories are “focusers” and “observing conditions”). The application will also have a Properties or Setup button. After selecting Wa-chur-ed Observatory Power*Star Focuser (or Observing Conditions) from the drop down menu, click on the properties button to set it up.



6.2 ASCOM Setup

The ASCOM focus control setup is identical to (and uses the same interface as) the setup described in section 5.2.1.2. The only caveat in using the ASCOM setup is that you should not disable TC in the P*S app if it is being used by the ASCOM client application. This is because there is no way to tell the client application that you have done so. More generally, we recommend unchecking the ASCOM TC Available checkbox before connecting the ASCOM client application and using only the P*S app to configure and enable/disable TC.

7 SAFETY PRECAUTIONS

THE Power*Star SYSTEM RUNS ON 12VDC AND PROVIDES THIS VOLTAGE TO THE CONNECTED DEVICES THROUGH USER-ACCESSIBLE CONNECTORS. CONTACT WITH THIS VOLTAGE, EITHER DIRECTLY OR THROUGH OTHER SYSTEMS, CAN CAUSE SERIOUS PERSONAL INJURY OR DAMAGE TO PROPERTY. USE CAUTION WHEN HANDLING THE POWER SOURCE, THE CONTROLLER, AND INTER-CONNECTING CABLES.

USE ONLY THE INPUT POWER CORD SUPPLIED BY Wa-chur-ed Observatory. ENSURE THAT POWER CABLES BETWEEN Power*Star AND EXTERNAL EQUIPMENT HAVE THE RIGHT KIND OF CONNECTOR AND ARE CONSTRUCTED WITH WIRE CAPABLE OF CARRYING THE MAXIMUM CURRENT POSSIBLE FOR THE CONNECTED EQUIPMENT.

FOR AC POWER OPERATION USE ONLY UL APPROVED AC-DC ADAPTERS (POWER SUPPLIES) WITH AN OUTPUT VOLTAGE OF 12 TO 13.6 VOLTS DC.

USE EXTREME CAUTION WHEN CONNECTING TO A BATTERY, SINCE BATTERIES CAN PROVIDE VERY LARGE AMOUNTS OF CURRENT, RESULTING IN OVER-HEATING, FIRE, OR EXPLOSION. DO NOT MAKE BATTERY CONNECTIONS WHERE FLAMMABLE GASES MAY BE PRESENT, SINCE EVEN NORMAL CURRENT FLOW CAN PRODUCE SPARKS WHILE CONNECTING OR DISCONNECTING. LEAD-ACID BATTERIES PRODUCE HIGHLY FLAMMABLE HYDROGEN GAS WHILE CHARGING OR DISCHARGING AND SHOULD ONLY BE USED WHERE ADEQUATE VENTILATION IS PROVIDED.

WHEN USING A BATTERY TO POWER EQUIPMENT, A FUSE SHOULD BE INSTALLED NEAR THE BATTERY. EVEN THOUGH Power*Star PROVIDES PROTECTION FROM EXCESS CURRENT FLOWING THROUGH THE DEVICE, IT CANNOT PROTECT AGAINST SHORT CIRCUITS BETWEEN ITSELF AND THE BATTERY. A 30 AMP FUSE SHOULD BE ADEQUATE FOR ALL APPLICATIONS, BUT YOU MAY WISH TO USE A LOWER CURRENT FUSE IF YOUR SYSTEM HAS A MAXIMUM CURRENT DRAW OF LESS THAN 15 AMPS. MOST ASTROPHOTOGRAPHY SYSTEMS WILL USE LESS THAN 15 AMPS.

WHEN SETTING THE CURRENT LEVELS FOR MOTORS, DO NOT EXCEED THE MOTOR MANUFACTURER'S RECOMMENDED MAXIMUM CURRENT. DOING SO MAY DAMAGE THE MOTOR AND PRODUCE EXCESSIVE HEAT.

THE MOTOR CONNECTORS ON THE CONTROLLER ARE FEMALE MODULAR JACKS TO MINIMIZE THE EXPOSURE OF THE 12V SUPPLY OUTSIDE THE CONTROLLER. DO NOT USE CABLES THAT EXPOSE THE CONDUCTORS. DO NOT INSERT ANYTHING INTO THE CONNECTORS OR CONNECT TO ANYTHING OTHER THAN AN APPROPRIATE MOTOR. IN PARTICULAR, THESE CONNECTORS ARE THE SAME TYPES USED FOR OTHER EQUIPMENT, SUCH AS ETHERNET CABLES, BUT ARE **NOT** AN ETHERNET INTERFACE, AND YOU SHOULD NEVER MAKE A CONNECTION BETWEEN THESE JACKS AND ANYTHING OTHER THAN AN APPROPRIATE MOTOR.