

PerfectStar B

Focus Controller
by Wa-chur-ed Observatory

USER MANUAL

Thank you for purchasing a PerfectStar B (PSB) Focus Controller. PSB provides absolute position control for a telescope focuser using a bipolar stepper motor. This means that you can know the precise position and change it in precise increments. When used with third-party software, it also allows automated focusing that is accurate and repeatable. The controller can be used with Focus Motors from Wa-chur-ed Observatory, or with compatible third party bipolar stepper motors. The controller can also be used either in manual (stand-alone) mode or connected to a computer via a USB port.

This document describes the system setup, software installation, and general use of the PSB Focus Control system.

WARNING

PLEASE BE VERY CAREFUL WHEN USING A BATTERY TO POWER PSB. 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 PSB system. Please refer to section 6 of this manual for additional precautions and more detailed information on safe use.

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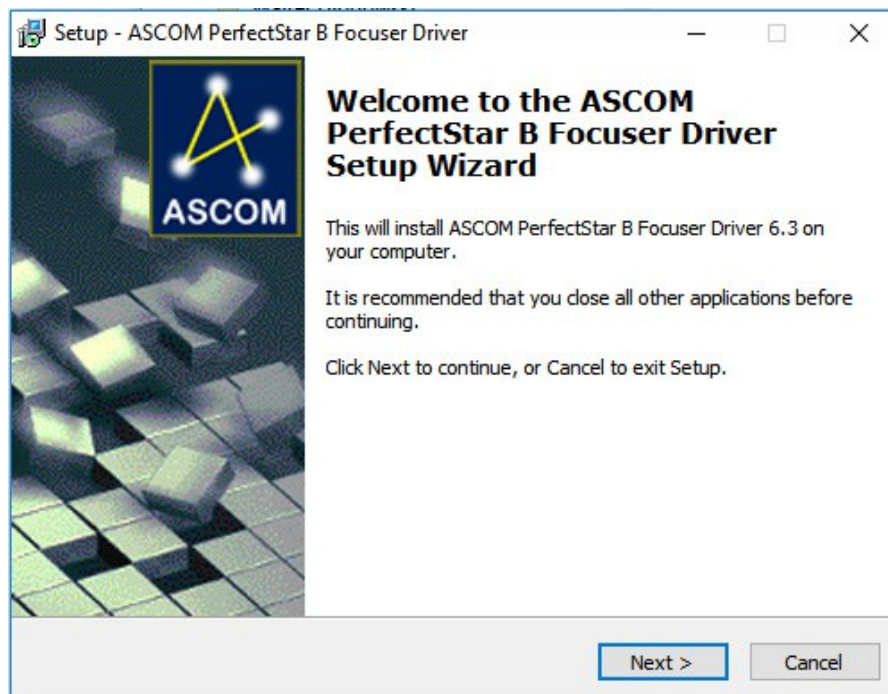
1 SOFTWARE INSTALLATION

1.1 Preparation

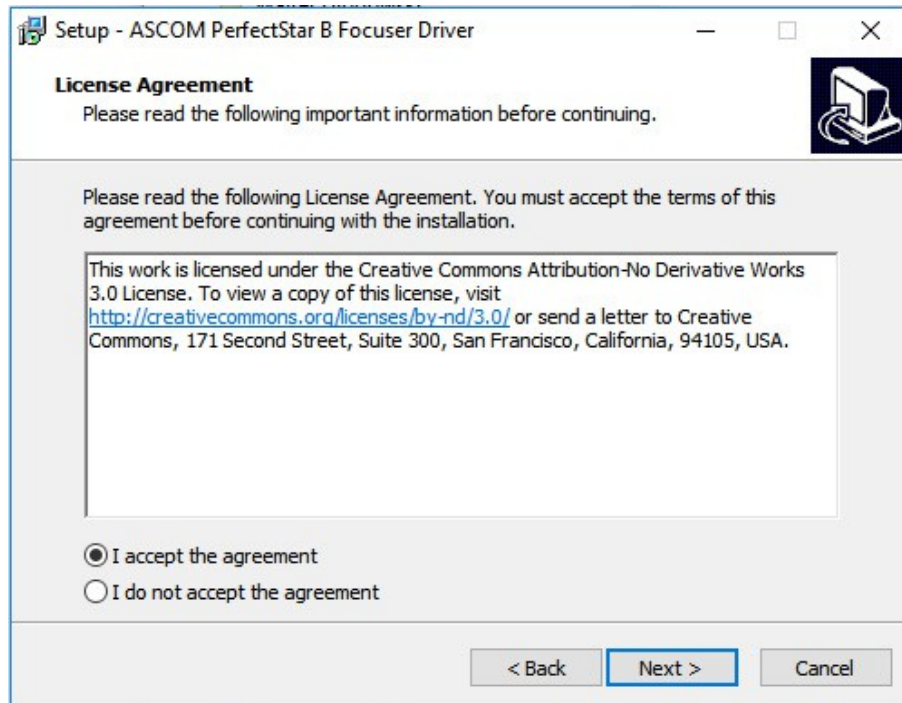
To use the PSB Focus Controller with a computer you must have ASCOM platform 6 installed before installing the PSB ASCOM driver. If you do not have version 6 (or higher) of the ASCOM platform installed already, you can download it from <http://ascom-standards.org>. Note that the ASCOM platform requires Microsoft's .NET framework, which is included and enabled with some versions of Windows, but not all. Refer to the Platform Installation Notes at the above web site.

1.2 ASCOM driver installation

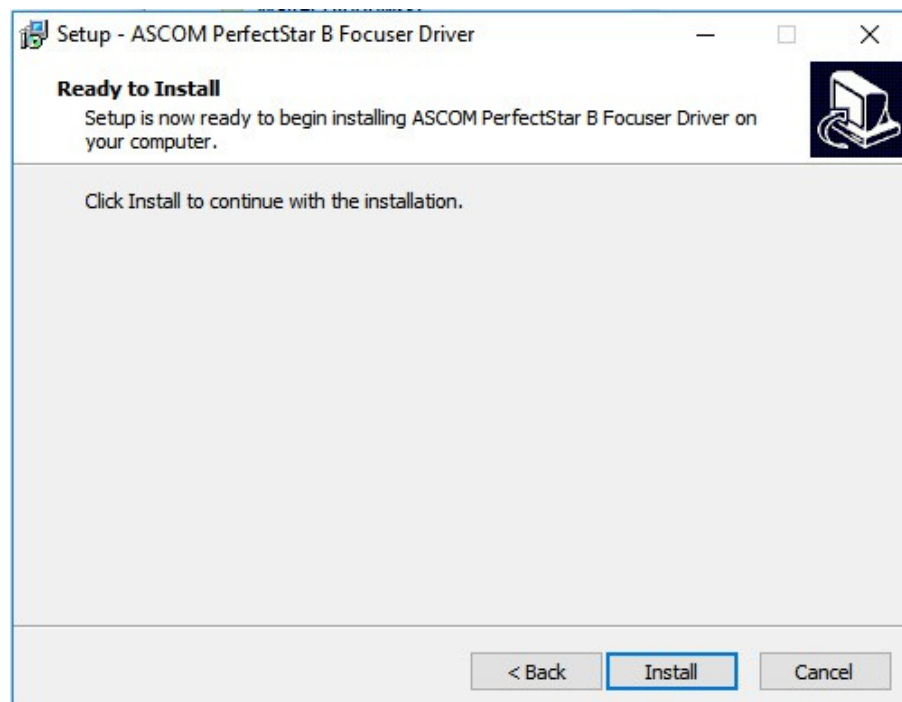
Once the ASCOM platform is ready, please install the PSB ASCOM driver by launching the "PerfectStar B Setup.exe" program and follow the on-screen instructions. At the initial window simply click 'Next' to continue.



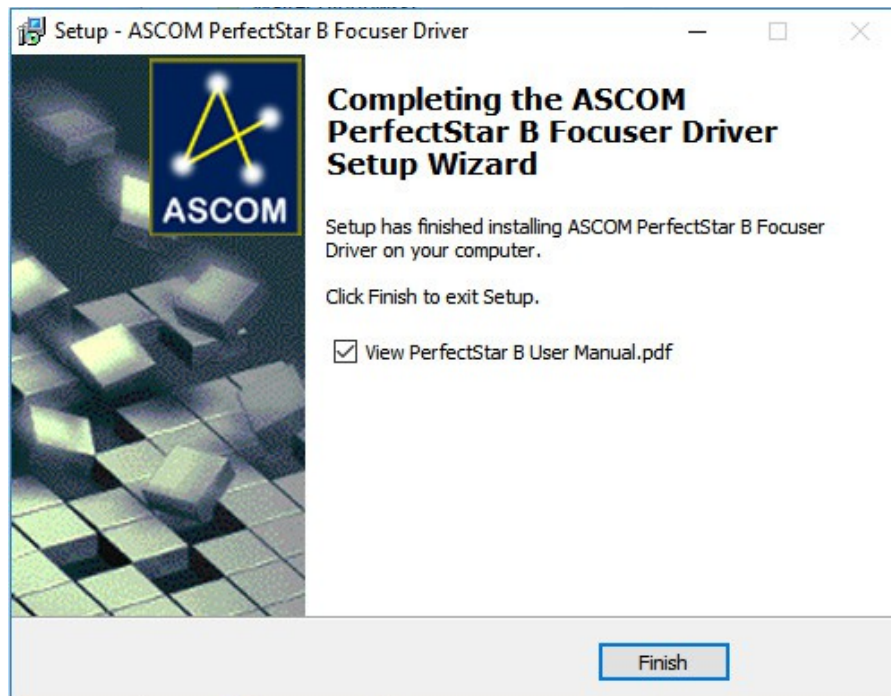
Click the button next to 'I accept the agreement' then the 'Next' button to continue.



In the next window, just click the 'Install' button to begin installation. The installer will automatically remove any previous version of the driver and will ask you to confirm that the old driver will be removed if you had this or another version of the driver previously installed.



When the installation is complete you will see the window below. By default, the installer selects to display this document. You are already looking at it, so feel free to de-select it and click the 'Finish' button.



The driver is ASCOM compliant, so any application supporting an ASCOM focus controller can be used. Please refer to section 5 for more information on using the driver.

2 Hardware Set Up



2.1 Power Connection

To use PSB with either a host computer or with the handset, connect a 12V DC power source to the 5.5 x 2.1mm power jack of the controller. Either a 12V battery or the (optional) AC adapter can be used. Please use the supplied power cord or AC adapter to ensure proper polarity. There is a self-resetting fuse inside to protect from short circuits. The actual power consumption of the system will depend on the specific motor used, but should not exceed 12 watts (1 amp at 12 volts).

2.2 Handset Connection

To use the handset, connect one end of the handset cable to the RJ-11 jack on the controller (see above figure) and the other end to the handset. It does not matter which end of the cable goes to each device.

2.3 Computer Connection (via USB)

To connect the controller to a computer (after installing the driver), connect a USB cable from the controller to a USB port on the computer. Communications will be at the USB 1.1 “full speed”. Do not use a cable of more than 5 meters in length. The controller is NOT powered from USB and must always have 12V DC supplied to operate. A hub may be used as long as the total length from computer to PSB does not exceed 5 meters.



2.4 Motor Connection

Connection from the controller to your focus motor is simple: Just plug one end of the cable (with 8-pin modular connector at each end) to the controller and the other end to the motor unit. Make sure it “clicks” into place to ensure a reliable connection. The motor cable has the same connector at both ends and it doesn't matter which end goes to the controller and which to the motor. The cable is a standard ethernet patch cable. If desired, you can substitute a shielded ethernet cable to reduce the chance of electrical noise.

2.5 Option Connector

This connector will be used for future optional features. It is the same type of connector as is used for the handset, but do not connect the handset here.

3 Manual Operation

3.1 Indicator LEDs

The controller has 3 LED indicators on the top:



The LEDs are fairly small and dim, so as not to disturb night vision adaptation. The power indicator should light up in red when power is supplied. It does not turn on until the controller has completed its initialization. Note that this LED does not necessarily mean that the source voltage is adequate to power the motor.

The "USB connect" indicator lights red when a connection is established to a computer.

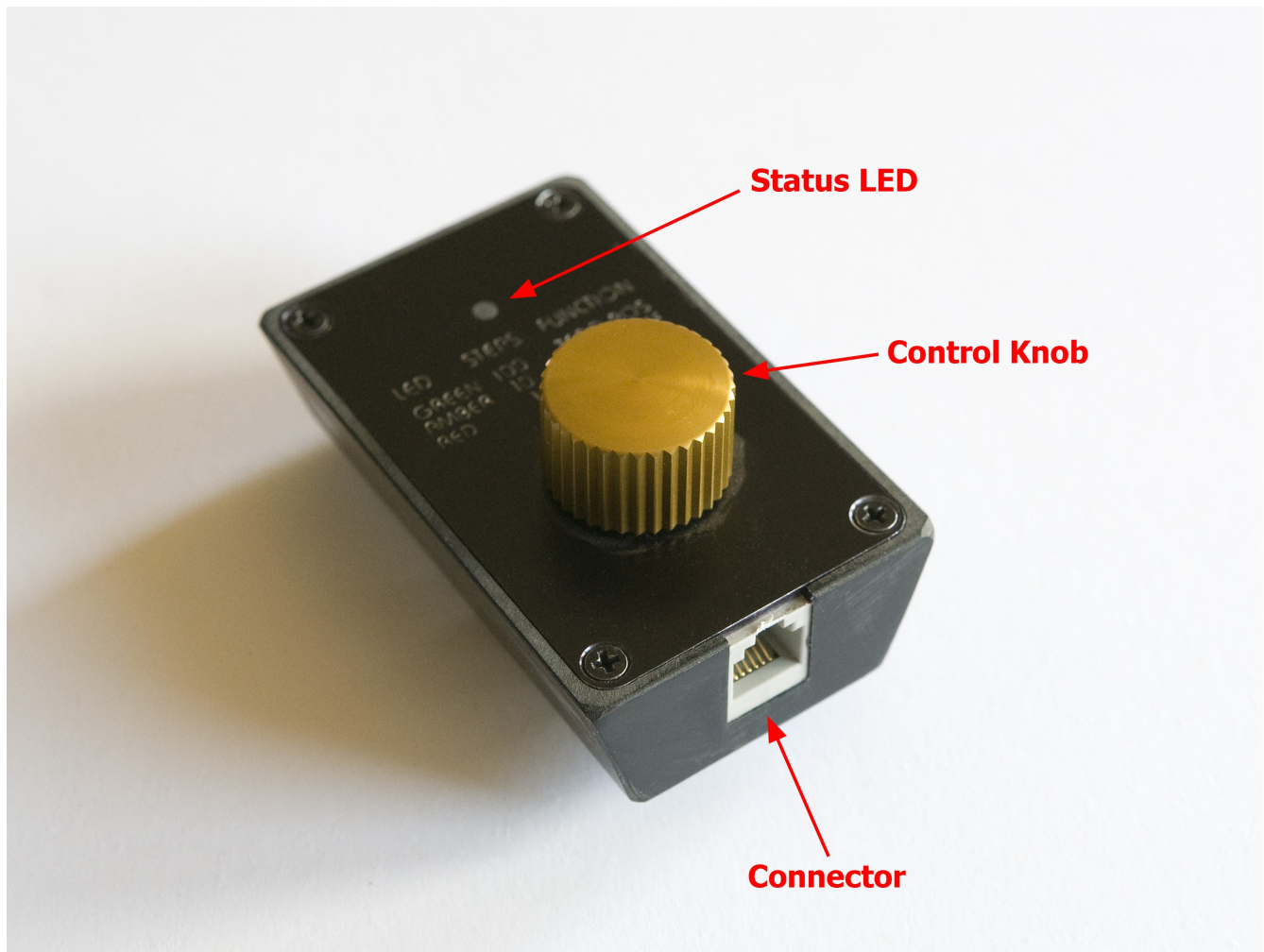
The Motor Status LED indicates whether the motor is moving, and whether temperature compensation (TC) is currently enabled. The LED is red when the motor is moving "out", or green if it is moving "in". If the LED is off it means that the motor is not moving and that TC is disabled. When TC is enabled the default color of the LED is amber instead of off, but it still changes to red or green when the motor is moving. If TC is enabled, but no temperature is available, the LED flashes amber. This might mean that the motor is not connected, but even after it is connected it can take more than 30 seconds before a valid temperature

reading is obtained, so be patient.

3.2 Using the Handset

3.2.1 Motion Control Knob

The handset is a simple box with 1 knob and a tri-color LED indicator.



Turning the knob clockwise normally produces clockwise motion of the focuser and counterclockwise produces counterclockwise motion. The relationship between knob direction and “in/out” motion depends on the mechanical design of the telescope focuser, but it can be changed in the setup of the focus controller. Refer to section 5.2.4.2 for details.

Turning the handset knob is like turning the focus knob on the telescope, except that it has “detents” (20 per full revolution) so that you can precisely control how far it moves.

3.2.2 Speed Selection / Status LED

Pressing the knob in (as you would click a mouse button) changes the “speed” of the motion control. What it actually does is to select the number of steps the motor will move for each detent of rotation. The speed is indicated by the color of the LED:

RED = 1 step (speed 1)
AMBER = 10 steps (speed 2)
GREEN = 100 steps (speed 3)

From power on the selected speed will be “100” (green) and each press of the knob switches the controller to the next lower speed. When at 1 step per detent the next press will go back to 100. The reasoning here is that you usually start at high speed to make coarse adjustments, then proceed to finer adjustments.

There is also a 4th speed of 1,000 steps per detent, which is meant to provide quick positioning to an approximate position rather than for critical focus adjustment. To invoke this “fast mode”, select speed 3 (LED green), then turn the knob quickly in the desired direction. Each detent you pass will be counted, even while the motor is moving, and when the count exceeds 3, the number of steps per detent is temporarily increased to 1,000. The count is still used to determine how far the motor will move, so it is easy to make the focuser move quite far. Be careful not to let the motor keep moving when the focuser has reached the physical limits of its travel (in or out). In the fast 4th speed you can stop the motor by simply turning the knob 1 detent in the opposite direction. In any speed setting you can always stop the motor by simply pressing the knob in.

If you selected “optimize for torque” (see section 5.2.1.3) the controller will switch to “optimize for speed” while in this “fast mode”. Because the torque may be reduced, you may want to move the telescope to a horizontal position before using this mode to ensure position accuracy.

The knob on the handset is a “virtual” focus knob. The motor will sometimes not move as fast as your hand, but will end up at a position proportional to the amount of rotation you have applied. Since the actual speed is limited by the motor, you will not get there any sooner by selecting a faster 'speed', but it will reduce the amount of turning you need to do. If you accidentally start a large movement and want to cancel it there are two ways to do it: Turning the knob in the opposite direction will “subtract” from the accumulated step count, which may result in movement in the other direction. Or, press the button at any time to cancel all pending movements. Using this stop command will also change the speed selection as described above. Speed 4 can also be canceled by turning the knob just 1 detent in the opposite direction, or by depressing the knob.

In most cases the motor will respond quickly enough at speeds 1 and 2 that it appears instantaneous – as if you were turning the knob on the focuser itself. At speed 3 the amount of time that it takes to move 100 (or 1,000) steps is noticeable, so you will sense some lag in focus response.

A legend for the LED color, speeds, and extended functions is engraved on the top plate of the handset for your reference.

3.2.3 Extended Press Functions

As described above, pressing the knob in (like clicking a mouse button) is used to change the speed selection. Pressing and holding the knob invokes secondary functions – the “extended press functions”. Which function is invoked depends on the current color/speed selection, so you use short clicks (less than 2 seconds) to change the color of the LED, then press and hold (more than 2 seconds) to use the function associated with that color:

RED = Enter “Lock” mode

AMBER = Toggle temperature compensation on/off

GREEN = Zero the current position

In each case, after holding the knob down for 2 seconds the LED will flash rapidly in red until you release the button. This indicates that the extended press has been recognized. Releasing the button starts the extended function, each of which is described in more detail below. When the extended press function is complete the controller returns to the same mode it had been in, except for the “lock” function, which is a special mode.

3.2.3.1 Enter/Exit Lock Mode

The “lock” mode prevents all movement of the motor, whether initiated from the handset, a connected computer, or temperature compensation. On entering lock mode the current position is saved in non-volatile memory. This value will be restored the next time the controller is turned on, so lock mode can also be used to prepare to shut down the system: Physically lock the focuser, enable lock mode, and turn the power off. The next time you turn it on the controller will know the correct position, assuming the focuser has not been manually moved since the shut down.

If temperature compensation is enabled when lock mode begins, the TC reference point is saved in addition to the current position to invoke the Permanent Focus feature. See section 5.3 for details. Note that the Permanent Focus feature can only be enabled or disabled by entering lock mode. If TC is enabled when you enter lock mode, Permanent Focus is enabled. If TC is disabled on entering lock mode, Permanent Focus is disabled. Simply disabling TC does not cancel Permanent Focus, and TC will be automatically re-enabled the next time the controller is turned on. Likewise, moving the focuser (which re-defines the current TC reference point) does not re-define the Permanent Focus reference point. To do that, you must ensure that TC is enabled, then enter lock mode. Lock mode can be entered either by using the handset, as described here, or by clicking the “disconnect” button for the focus controller in your ASCOM application.

To enter lock mode, select the RED speed, then press and hold the button for 2 seconds. After releasing the button the LED will slowly flash, indicating that the controller is locked. To exit from lock mode simply press and hold the button for 2 seconds again.

Initially, the handset LED flashes in red, indicating that the “normal” braking current (as set in the ASCOM setup dialog – high if you select “optimize for braking” or medium if you select “optimize for low power”) is used. By clicking the knob you can change the braking power to one of three different levels: Red is “normal”, amber is “low power”, and green is “no braking”. In the green setting the motor driver is completely disabled, resulting in very low power consumption. However, with no braking the only thing holding the motor position is friction. You can increase the friction by using the focuser’s physical lock, but there is still likely to be a small amount of error in the position each time you do this, and such errors accumulate. To use the “green” mode most effectively, enter lock mode (leaving it at normal braking for the moment), then physically lock the focuser, then switch to green/no braking mode. To start up again, reverse these steps: Switch to normal braking, physically unlock the focuser, then exit lock mode.

Although the ASCOM driver does not have a “lock” function (because it is not defined in the ASCOM standard), the driver does let the controller know when it is disconnecting and the controller can enter Lock mode at that time in the same way it does for handset operation. The braking power is determined by the selection in ASCOM setup for “Lock Mode Braking”, but can be changed using the handset. See section 5.2.4.3 for more information.

3.2.3.3 Toggle Temperature Compensation On/Off

TC enable is toggled by selecting AMBER speed on the handset, then doing an extended press. When the button is released the TC mode will change from off to on or on to off.

The status of TC Enable is indicated by the Motor Status LED (see section 3.1) and is available to applications connected through ASCOM. However, applications might not read this status and therefore wouldn't recognize when the status has been changed via the handset. That is because many applications treat TC as a feature that is strictly under their control, while PSB provides this feature to the user without a computer.

More details on the operation of TC can be found in section 5.2.3.

3.2.3.4 Zero Current Position

It is often useful to set the current position to a particular value without actually moving the motor. The ASCOM driver allows setting any position, but with just the handset you can set the position to zero. This is commonly used to define a known reference point (such as where the focuser is racked in all the way) or to define a point near the best focus position so that the reported position is a relatively small number. However, please remember that the position is an unsigned value and the controller will never have a "negative" position. When using the handset, if the position becomes negative it is simply redefined as zero. Through the computer interface the controller will stop when it reaches zero. Thus, setting a zero position also defines a travel limit in the inward direction. When connected to a host computer you can also define a "Max position", which acts as a travel limit in the outward direction. The outward travel limit applies to both computer and handset operation, while the inward limit applies only to moves initiated by the connected computer.

Since inward movement with the handset is not limited, please be careful not to drive the focuser past its physical limit. Small and brief movements against the limit will generally not harm anything and this technique can be used to "find" the physical limit.

To zero the current position, select the GREEN speed and do an extended press. There is no explicit acknowledgment of the setting, but you can see the position change in connected ASCOM applications.

4 Firmware Updates

The firmware in the PSB controller is stored in flash memory and can be updated through the USB interface. Check the Wa-chur-ed Observatory website for announcements of available updates. When/if an update is released, a ".hex" file will be available for download. Have this file handy before initiating the update. You should also have the "HIDBootloader.exe" program and related files from the CD that came with your controller. There is no installation needed for this program, but it must be run from the directory where it and the associated files are located.

4.1 Initiating Update Mode

To initiate an update, disconnect the controller from your computer and turn the controller off. Ensure that the handset is connected. Press and hold the button on the handset as you turn on the controller. Instead of the usual start-up behavior, the controller will enter a special mode, which is indicated by the power LED being off. The handset LED will also be off, and the controller will not respond to the handset in this mode, so you should click the button to ensure that it does not respond. If it does respond (by changing the LED color), turn the power off and try again.

Once you have succeeded in getting the controller into update mode, connect it to your computer with the USB cable. The device should be recognized and a driver automatically installed. At that point the controller will start rapidly flashing the USB status LED.

To ensure that the update process does not fail, it is recommended that all other applications on the computer be closed to prevent them from possibly crashing or slowing the computer.

4.2 Flashing the Code

Run the HIDBootloader.exe program and click the "open file" icon. Navigate to the location containing the "PSB xx.hex" file (where "xx" is the version number) and select it. **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. Once the correct file is loaded, click the "Erase/Program/Verify" button to flash the controller. It usually takes just a few seconds to update the firmware, but it is very important that you not turn off either the PSB controller or your computer or disconnect them until the process is done. Once the update is done, disconnect the USB cable and power cycle the PSB controller. **DO NOT** click the "reset" icon or turn off the controller before disconnecting the USB cable. Once turned back on, the controller should then be running the new firmware version. You can confirm the version number in the driver setup dialog.

5 Using the ASCOM Driver

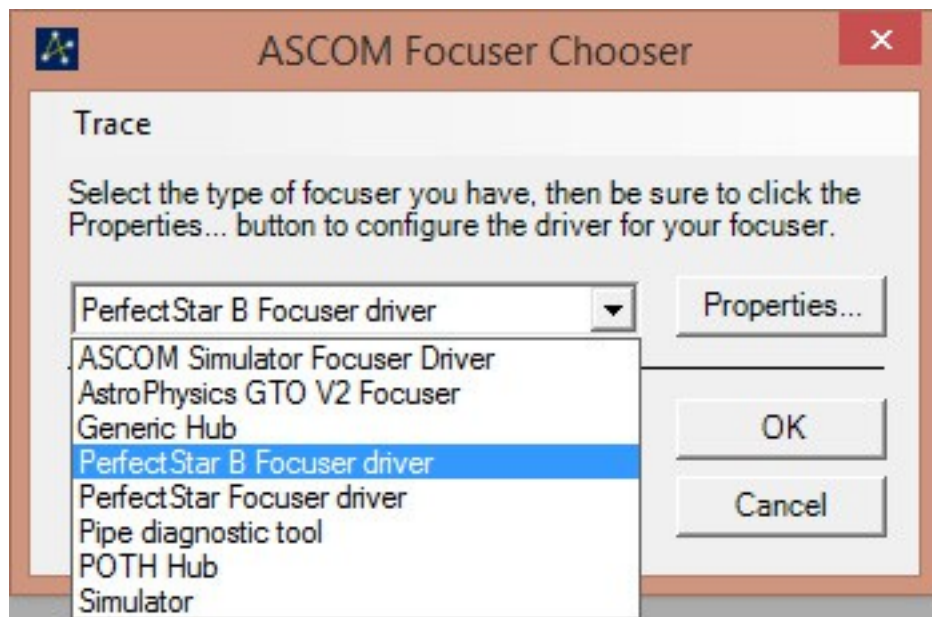
This section describes how to use the features of the PSB ASCOM driver. Before it can be used, please refer to sections 1 and 2 for instructions on installation of the software and set up of the hardware.

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 some applications one or both of these features can be handled by the application software. The PSB 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 – or even a computer. However, the user must ensure that these features are never enabled to be performed by both the controller and the application. In general, we recommend that you use PSB's 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 applications handle BC and TC, but do know that there are many mistakes that could be made in implementing these features.

At least one application we know of allows the user to enable/disable TC even though the actual function of TC is done entirely in the controller. You can identify such an application because it will have a button or checkbox to enable TC, but does not have any way to specify the TC coefficient, etc. In such cases it can work reasonably well to set up the TC parameters in the PSB setup dialog, and use the application to enable/disable TC. However, if you do that you should avoid also using the handset to enable/disable TC because the application cannot tell when you have changed the state. Well, it could, but the examples we have seen do not bother to check – they just assume that they are completely in control of the TC enable/disable.

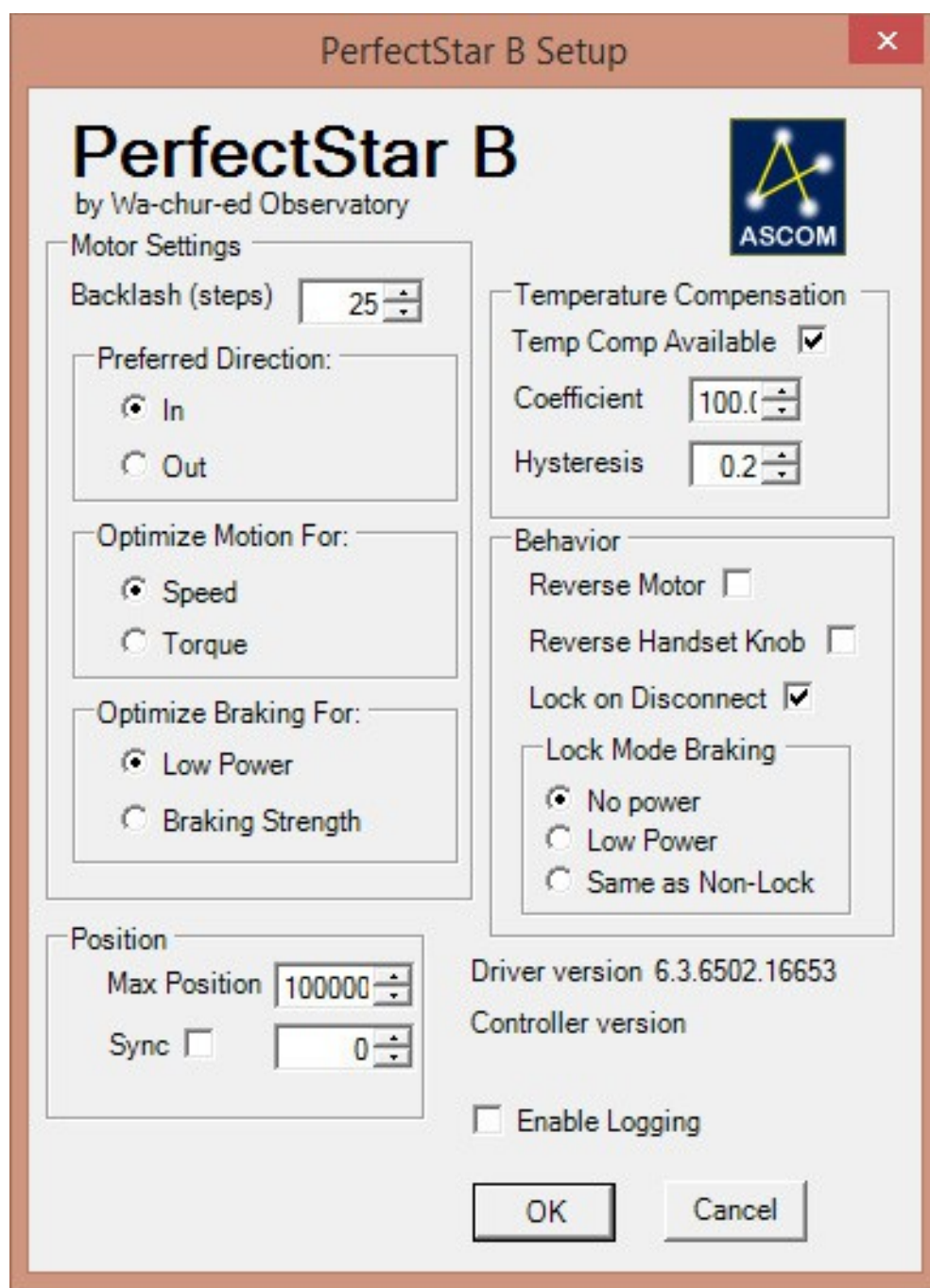
5.1 ASCOM Chooser

Each application has its own way of accessing the controls for ASCOM devices such as the PSB 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 (in this case, focus controllers) you want to use. It will also have a “properties” or “set up” button. After selecting “PerfectStar B Focuser” from the drop down menu, click on the properties button to set it up.



5.2 Set Up

The setup screen contains a number of parameters that you can change. Most of these values are saved on the computer so that you don't have to re-enter them each time you use the driver. Many of the values are also sent to the controller and saved in internal non-volatile memory there. In some cases the values saved by the driver take precedence and over-write the values in the controller, but it is important that the controller also remember the values so that they apply to manual controls as well.



The image shows a Windows-style dialog box titled "PerfectStar B Setup". The title bar is orange with a red close button (X) on the right. The main area has a light gray background. At the top left, the text "PerfectStar B" is in a large, bold, black font, followed by "by Wa-chur-ed Observatory" in a smaller font. To the right of this text is the ASCOM logo, which consists of a blue square with a yellow triangle and the word "ASCOM" in white. Below the title, the settings are organized into several groups. The "Motor Settings" group includes a "Backlash (steps)" spinner set to 25, a "Preferred Direction:" section with radio buttons for "In" (selected) and "Out", an "Optimize Motion For:" section with radio buttons for "Speed" (selected) and "Torque", and an "Optimize Braking For:" section with radio buttons for "Low Power" (selected) and "Braking Strength". The "Temperature Compensation" group has a "Temp Comp Available" checkbox checked, a "Coefficient" spinner set to 100.0, and a "Hysteresis" spinner set to 0.2. The "Behavior" group includes a "Reverse Motor" checkbox, a "Reverse Handset Knob" checkbox, a "Lock on Disconnect" checkbox checked, and a "Lock Mode Braking" section with radio buttons for "No power" (selected), "Low Power", and "Same as Non-Lock". At the bottom left, the "Position" group has a "Max Position" spinner set to 100000 and a "Sync" checkbox with a spinner set to 0. On the right side, the "Driver version 6.3.6502.16653" and "Controller version" are displayed. At the bottom right, there is an "Enable Logging" checkbox and two buttons: "OK" and "Cancel".

PerfectStar B Setup

PerfectStar B
by Wa-chur-ed Observatory

ASCOM

Motor Settings

Backlash (steps) 25

Preferred Direction:

☒ In
☐ Out

Optimize Motion For:

☒ Speed
☐ Torque

Optimize Braking For:

☒ Low Power
☐ Braking Strength

Temperature Compensation

Temp Comp Available ☒

Coefficient 100.0

Hysteresis 0.2

Behavior

Reverse Motor ☐

Reverse Handset Knob ☐

Lock on Disconnect ☒

Lock Mode Braking

☒ No power
☐ Low Power
☐ Same as Non-Lock

Position

Max Position 100000

Sync ☐ 0

Driver version 6.3.6502.16653

Controller version

☐ Enable Logging

OK Cancel

5.2.1 Motor Settings

This section contains parameters that affect how the motor is driven.

5.2.1.1 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 PSB 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. It is better to under-compensate than over-compensate, so enter 1 less than the count of steps before you detect motion.

Backlash compensation is accomplished in two different ways, depending on whether the movement is requested through the host computer or the handset. The ideal backlash compensation defines a “preferred direction”, which is generally “in” for a telescope focuser because that is the direction in which the motor is working against gravity (assuming the telescope is pointed more “up” than “down”). When movement is requested for 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. To ensure that enough compensation is applied, this mode uses approximately 10% more steps than specified by the user (and at least 1 step).

For manual control it is wasteful to apply this type of backlash compensation on every step, and we don't know how many steps there will be. So for manual control, backlash compensation uses a different technique: If the requested movement is in the same direction as the most recent movement, it is executed directly. If it is in the opposite direction, the backlash amount is added to the requested movement size (number of steps). In this case it is up to the user to make the final movement in the preferred direction so that gravity cannot cause the focuser to slip through the backlash amount.

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). This has no effect on manual control.

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 “halt” methods (such as pressing the knob on the handset) will not stop a backlash compensation movement and halting in the middle of a movement requested by a host computer in the non-preferred direction will still be compensated with a movement in the preferred direction. Movements requested by temperature compensation are not corrected for backlash.

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

5.2.1.2 Preferred Direction

In almost all cases the preferred direction is “in” (the default), as discussed above. But if, for some reason, you need to change it to “out”, simply click the “out” radio button.

5.2.1.3 Speed/Torque Selection

Stepper motors have multiple coils and move by activating these coils in a specific sequence. The amount of time that is required for each step depends on many factors, including the motor model and the load it is moving. There is a trade-off between torque (how much force the motor can apply to move the focuser) and the speed with which it can move. Since speed is generally not very important, it is usually best to select “Optimize Motion for Torque”, but if you want quicker focus operations you can select “Optimize for Speed”. “Speed” should not be selected if the focuser is operating near its maximum load. Also, the motor uses the faster speed in “speed 4” move operation, so be sure that it works correctly in that mode as well.

5.2.1.4 Brake Power Selection

When the motor is not moving, a small amount of current is still applied to the motor (without changing which coils are driven) to hold the position, effectively acting as a brake. The correct amount of current to use for braking is a trade-off between strength of braking and power consumption. In most cases, the “Low Power” option (default) is more than adequate, given the large reduction ratio in gears between the motor and focuser. However, with an exceptionally heavy load you may prefer to select “Braking Strength”.

5.2.2 Position

This section contains parameters that affect the number associated with the focuser position.

5.2.2.1 Max Position

The maximum position is a limit on the position applied by both the driver and the 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 driver or the hardware will allow the focuser to move to a negative position. However, you can move inward as much as you like using the handset, since this is generally how you “find” the full inward travel. If you use the handset to move “in” when the position is already zero, it executes the move and redefine the new position as zero. Because inward movement via the handset is unrestricted, please be careful not to let the motor drive hard against the physical stop point of the focuser.

5.2.2.2 Sync

Click the check box and enter a value to force the “current position” to the specified value. This sets the value of the internal variable without moving the motor at all. This is most commonly used to specify the zero point, but can also be used to specify any arbitrary point, such as “1000”. The value will be transferred to the controller when the connection is made.

5.2.3 Temperature Compensation

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

Temperature Compensation (TC) automatically adjusts the focuser position to maintain critical focus as the temperature changes. Using TC requires calibrating your system, which produces a temperature coefficient that specifies the number of steps needed per degree of temperature change. This coefficient is generally accurate over a wide temperature range and does not change as long as the hardware components (telescope, focuser, and motor) do not change. A host computer connection is required to set the temperature coefficient in the controller, where it is stored in non-volatile memory. Once the coefficient is stored, TC can be used in manual operation.

Temperature compensation is possible only if you have a temperature sensor connected to the motor. There is no danger in making TC available or turning it on in your application. As with the handset, you can enable TC at any time, but it does not become active until a valid temperature reading is available. The "available" check box simply reduces confusion by telling the application whether or not you want to attempt to use compensation.

Note that TC movements are calculated based on the "reference point" established when you click the "enable" check box. 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. This means that the reference position must be adjusted if the position is changed by either manual (handset) control or host-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). Since the usual case is either

reporting the extension of the draw tube in millimeters or in the somewhat arbitrary unit of “motor steps”, we think that the opposing philosophy is preferable: PSB reports the number of steps out from a user-defined zero point, including any adjustments made for temperature compensation.

5.2.3.1 Temperature Compensation Available

Check this box to make the TC feature available to the ASCOM-compliant application, or uncheck it if you do not want to use TC in the application and want to avoid accidentally enabling it there. You can still enable/disable it through the handset.

5.2.3.2 Temperature Compensation Coefficient

You can set the coefficient and hysteresis parameters at any time, but the “enable” check box may be grayed out in some applications until the driver gets a temperature report from the hardware. Note that the initialization of the temperature sensor can take a minute or two after turning on the PSB controller and connecting a motor and sensor. 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.

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).

5.2.3.3 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.

5.2.4 Behavior

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

5.2.4.1 Reverse Motor Check Box

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 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 ASCOM application and the physical movement of the focuser. Note that reversing the motor direction for software use also changes the relationship with the handset knob, so you might end up having the knob behave opposite to what the physical focus knob did with regard to in/out directions.

5.2.4.2 Reverse Handset Knob Check Box

Section 5.2.4.1 describes the relationship between linear motion of the focuser ("in" versus "out") and the motor direction, where "in" and "out" are used by an ASCOM-compliant application. When using an application to control focus that is all that matters. But you might also have a personal preference (usually based on your previous experience with manually focusing the telescope) for which direction of the handset knob corresponds to "in". By default, clockwise motion is "in". You can change this by checking the "Reverse Handset Knob" check box.

5.2.4.3 Lock on Disconnect

When an ASCOM-compliant application disconnects from the focus controller, you may want the controller to enter the lock mode, as described in section 3.2.3.1. You can always do this manually with the handset, but to make it more convenient (and so that you don't forget to do it), check the "Lock on Disconnect" box, and select the level of braking power desired in lock mode.

5.2.4.4 Lock Mode Braking

Typically, the amount of current used to hold the motor in lock mode is the same as in normal mode, and this is the default selection, "Same as Non-Lock". However, since the telescope may be parked in a position that does not require as much power, you can also select "Low Power" (the same as "Low Power" in the Optimize Braking section), or "No Power", which

completely shuts down the motor driver chip. Note that “No Power” greatly 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.

5.2.5 Driver and Firmware Version Numbers

The setup dialog reports the version numbers from both the ASCOM driver and the controller firmware. The purpose is just that you can confirm whether you are running the proper versions. The controller firmware version is actually read from the controller over the USB connection, so it will be blank if the controller is not connected (as was the case for the image shown above).

5.3 Permanent Focus Feature

Building on the “Lock Mode” operation described above, Permanent Focus also remembers the last established reference position and temperature (the “reference point”) for temperature compensation (TC). To use the Permanent Focus feature, simply enable TC before executing the lock/disconnect. When the controller is next powered up the controller will automatically enable TC and adjust the focus position according to the new temperature. If you use filters that are not perfectly parfocal (most are not), you may also need to measure the focus offset for each filter and apply these in your image capture application. The combination of filter offsets and the Permanent Focus feature means that as long as the imaging setup stays in place you might never need to focus again!

There are some important details to consider when using Permanent Focus:

- A TC reference point is not established until the controller gets a valid temperature reading. If the ASCOM client application is showing a temperature, it's ready.
- Entering Permanent Focus mode is triggered by disconnecting the controller from your ASCOM-compliant application (or using the handset to enter lock mode) while TC is enabled, so it is generally automatic, and you have to remember to disable TC if you don't want to use this feature.
- The TC reference point remains in non-volatile memory until the next time you enter lock mode, at which point it is either updated if TC is enabled, or cleared if not.
- While in lock mode the controller will not respond to move commands from either the handset or ASCOM client. However, connecting to PSB through ASCOM automatically exits lock mode.
- When powering up the controller, Permanent Focus can be canceled by disabling TC (either with the handset or through an ASCOM client) before it gets a temperature reading. Since this always takes at least 30 seconds, you have plenty of time to disable TC. The focus position will then be exactly where it was when you last shut down.

6 SAFETY PRECAUTIONS

PerfectStar B FOCUS SYSTEMS RUN ON 12VDC AND PROVIDE THIS VOLTAGE TO THE EXTERNAL MOTOR THROUGH A USER-ACCESSIBLE CONNECTOR. 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, THE MOTOR UNIT, AND INTER-CONNECTING CABLES.

FOR AC POWER OPERATION USE ONLY THE AC ADAPTER SUPPLIED BY WA-CHUR-ED OBSERVATORY. THIS IS A UL LISTED DEVICE AND IS COVERED BY ITS MANUFACTURER (NOT WA-CHUR-ED OBSERVATORY) FOR WARRANTY AND LIABILITY.

FOR DC POWER OPERATION USE ONLY THE DC POWER CORD SUPPLIED BY WA-CHUR-ED OBSERVATORY. THE 'CIGARETTE LIGHTER' CONNECTOR CONTAINS A 5 AMP FUSE. DO NOT BYPASS THIS FUSE OR REPLACE IT WITH A FUSE OF HIGHER RATING. 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. NOTE THAT LEAD-ACID BATTERIES PRODUCE FLAMMABLE HYDROGEN GAS WHILE CHARGING OR DISCHARGING AND SHOULD ONLY BE USED WHERE ADEQUATE VENTILATION IS PROVIDED.

THE CONTROLLER ALSO INCLUDES AN INTERNAL SELF-RESETTING FUSE RATED AT APPROXIMATELY 1.5 AMPS. HOWEVER, BOTH THIS INTERNAL FUSE AND THE FUSE IN THE DC POWER CORD ARE OF THE 'SLOW BLOW' TYPE, SO SIGNIFICANTLY GREATER CURRENT MAY FLOW FOR SOME PERIOD OF TIME BEFORE ONE OR BOTH FUSES OPEN. THIS WILL HAPPEN IF THE 12V POWER IS SHORTED TO GROUND.

DO NOT CONNECT THE CONTROLLER TO ANY POWER SOURCE WITH REVERSE POLARITY. THE CENTER PIN OF THE COAXIAL POWER CONNECTOR MUST BE CONNECTED TO THE POSITIVE SIDE OF A 12VDC POWER SOURCE.

DO NOT USE ANY MOTOR OTHER THAN THOSE APPROVED BY WA-CHUR-ED OBSERVATORY.

THE MOTOR CONNECTOR ON THE CONTROLLER IS A FEMALE RJ-45 JACK TO MINIMIZE THE EXPOSURE OF THE 12V SUPPLY OUTSIDE THE CONTROLLER. DO NOT USE CABLES THAT EXPOSE THE CONTACTS. DO NOT INSERT ANYTHING INTO THE CONNECTOR OR CONNECT TO ANYTHING OTHER THAN AN APPROVED MOTOR. IN PARTICULAR, THIS CONNECTOR IS THE SAME TYPE THAT IS USED FOR ETHERNET CABLES, BUT YOU SHOULD NEVER MAKE A CONNECTION BETWEEN THE CONTROLLER AND ANY NETWORKING COMPONENTS.