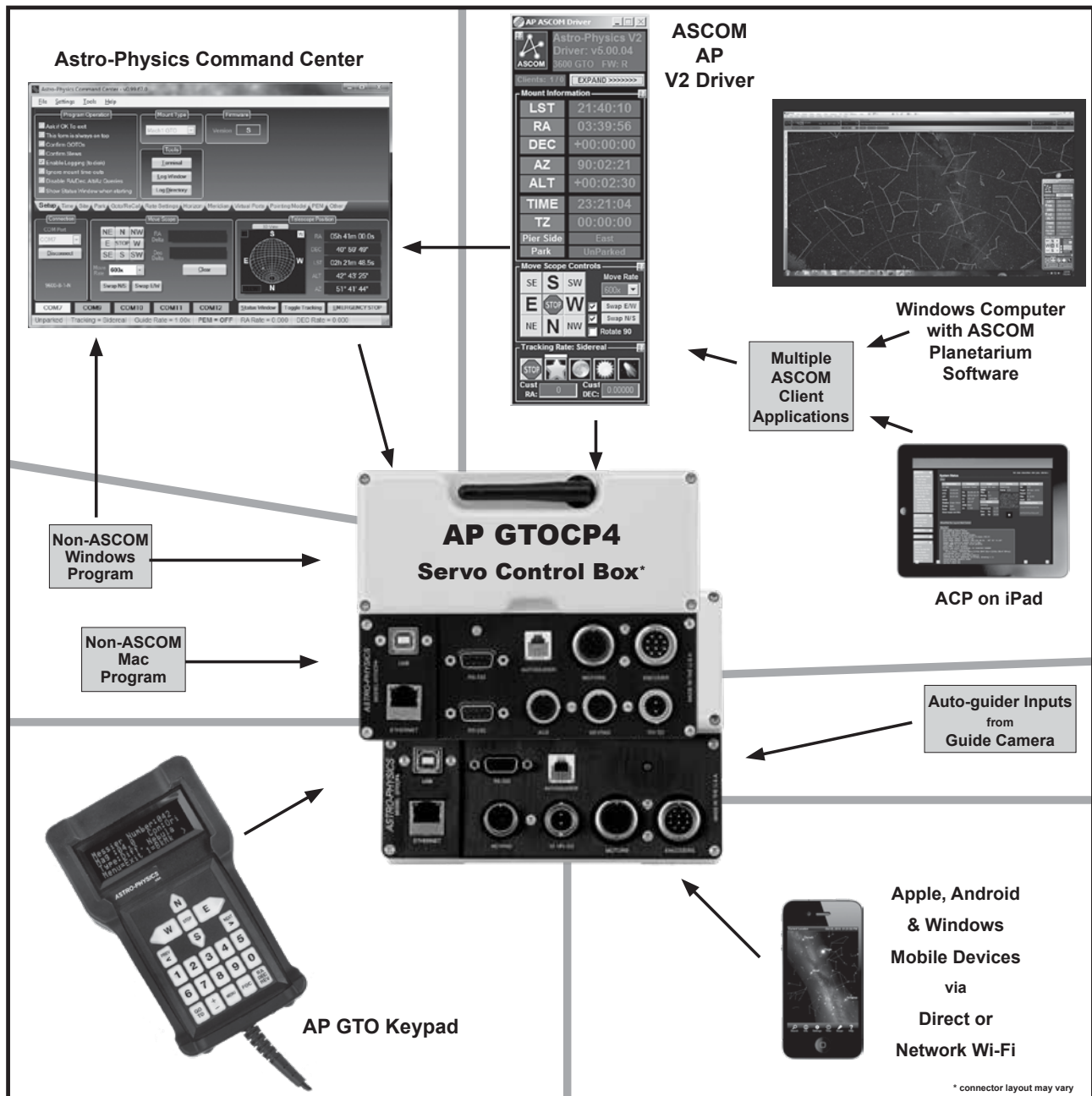


Astro-Physics

GTO Servo Drive System

Model GTOCP4

Operating Instructions



January 2024

Astro-Physics GTO Servo Drive System

Model GTOCP4

CONTENTS

ABOUT THIS MANUAL - JANUARY 2024	4
GTO CONTROL BOX- MODEL GTOCP4 -YOUR MOUNT'S BRAIN	5
ENVIRONMENTAL CONSIDERATIONS	6
GTO SERVO DRIVE SYSTEM SPECIFICATIONS	7
GTOCP4 CONTROL BOX - LAYOUT AND FEATURES	8
Receptacles	9
10-pin Receptacle for Servo Motors	9
10-pin Receptacle for Absolute Encoders	9
12-volt Locking Receptacle	9
Power Indicator Light	9
Keypad Receptacle	9
Auxiliary Receptacle (Legacy)	9
Auto-guider Port Receptacle	10
USB Port	10
RS-232 Ports (1 or 2)	10
Ethernet Port	10
WiFi Module and Antenna	10
Periodic Error Reduction or Elimination	10
PEMPro	10
Encoders	10
Removing and Installing the GTOCP4 Control Box	11
COMMUNICATING WITH YOUR MOUNT	12
Choosing Your Communication Interfaces	12
Distance of Mount from Control Device	12
Remote Observatories	12
USB Port 2.0	12
RS-232 Serial Port	13
Network Ethernet Port	14
Connect Your GTOCP4 or GTOCP5 via Ethernet	15
APCC-ST and APCC-PRO COM Setting	15
ASCOM AP V2 COM Setting	15
Determine Your IP Address	15
Default IP Address Calculator	15
Summary Network Connection Diagrams	16
Do the Math Yourself	17
Use the Hostname	17
Ping	17
Set Ethernet Parameters Using AP GTO Utilities	18
Technical Information and Terminology Regarding Ethernet	18
Network WiFi Connection	19
CP4/5 Hot Spot (Access Point) Configuration	20
Network (Station) Configuration	21

Change Your WiFi Settings	22
Ethernet and WiFi Best Practice Recommendations	22
Updating your CP4/5 with New Firmware	23
ENCODER OPERATION AND PERIODIC ERROR MANAGEMENT	24
PEMPro™	24
GTOCP4 and Absolute Encoders (1100GTO and 1600GTO)	25
APCC's AE Tab	25
GTOCP4 and Precision Encoders (3600GTOPE Only)	25
Astro-Physics Command Center (APCC)	25
For 3600GTOPE Owners Only: Installation, Settings and Operating Instructions for the Limit Switch System (36LSS) and Precision Encoder System (on the 3600GTOPE), dated March 27, 2013	26
UNDERSTANDING THE GERMAN EQUATORIAL SERVO LOGIC	27
Important General Astro-Physics GTO Concepts	27
Initialization and Shut-down	27
The role of Time and Location data in the Servo System	28
Non-sidereal Tracking and Variable Tracking Rates	28
Understanding the Auto-Guider Port Inputs vs Timed Guide Moves	29
PulseGuiding and pulse-guiding - Two Completely Different Meanings	29
Understanding Encoders	29
A Brief Introduction to the Astro-Physics Command Language	30
An Important Command Change in VCPx-P02-xx and Later	30
German Equatorial Geometry, the Meridian, the Pier, and Limits	30
The 360° Right Ascension Axis	31
The Concept of "Pier Side" as it relates to the Servo	32
How GoTo Slews are Performed	33
Sync vs. ReCalibrate	33
Safety Slew Logic	33
Tracking Past the Meridian	34
Meridian Delay or Meridian Advance	34
Limits and More Limits	34
1. APCC Meridian Tracking Limits	35
2. Mechanical Limit Switches	36
3. Encoder Limits	36
4. Keypad Limits	37
5. Hard Limits	38
CONTROLLING YOUR GTOCP4 MOUNT	39
What is Meant by "Initialization"?	40
GTO Keypad Operation	40
Using Your Keypad and PC in Shared Harmony	41
Keypads Using v5.xx Firmware	42
Setting Up the Astro-Physics ASCOM V2 Driver	43
Workflow When Using the AP ASCOM V2 Driver with Third-party Software	45
The Astro-Physics Command Center - Standard & Pro Versions	46
Some APCC Thoughts	47
Setting Up the Astro-Physics Command Center	48
Workflow When Using APCC & the AP V2 Driver with Third-Party Software	50
Workflow When Using TheSkyX™ with the AP V2 Driver	52
Planetarium, Imaging and Observatory Software from Other Vendors	53
Workflow When Using TheSkyX™ with the AP V2 Driver	54

Workflow When Using TheSkyX™ with Native Drivers	55
Workflow When Using Mobile Smart Devices	56
Thoughts Regarding Workflow When Using Devices Other than PCs	57
PEMPro™ by Sirius-Imaging	58
AUTO-GUIDING TIPS AND NOTES	59
How to Test an Auto-guider Port	59
TROUBLESHOOTING, TIPS AND SUPPORT	61
Troubleshooting and Tips	61
Additional Support	64
APPENDIX A: GTOCP4 AND GTOCP5 SOFTWARE UPDATES	65
AP GTO Utilities	65
APPENDIX B: POWER SPECIFICATION TABLES	66
Power Specifications - Mach1GTO, 400GTO and 600EGTO	66
Power Specifications - 900GTO (All) and 1200GTO (shipped prior to 2011) <i>(1200GTOs - Ser. # 1200956 & earlier)</i>	66
Power Specifications - 1100GTO, 1100GTO-AE and 1100GTO-AEL	66
Power Specifications - 1200GTO (shipped 2011 and later) <i>(Ser. # 1200957 & later)</i>	66
Power Specifications - 1600GTO	66
Power Specifications - 3600GTO	67
APPENDIX C: POWER CONSIDERATIONS	68
Introduction	68
Some Power Basics for Non-Electrical Engineers	68
Batteries	69
Results of Either Inadequate or Excessive Power	71
IMPORTANT Considerations for observatory installations:	72
APPENDIX D: COMMAND LANGUAGE	73
APPENDIX E: REGULATORY INFORMATION FOR TRANSMITTER MODULE	73
FCC Notice (USA)	73
RF Exposure	73
IC Notice (Canada)	73
CE Notice (Europe)	73
APPENDIX F: COUNTRY CODES FOR WIFI	74
APPENDIX G: NETWORK PROTOCOL LICENSE	77
lwIP's License	77
APPENDIX H: GTOCP4 / MOUNT PERSONALITY CODES	78

ABOUT THIS MANUAL - JANUARY 2024

Up until the middle of 2011, the Astro-Physics GTO Servo Motor Drive System was described in a small section toward the end of each individual mount manual. As time has passed and more options have become available - both in terms of input devices and in terms of the capabilities of the servo itself - it has become apparent that the GTO Servo System should have its own manual that would apply to all Astro-Physics GTO German Equatorial Mounts, as well as the OEM mounts that employ our servo drive. To this end, we have prepared this manual.

One of the principal advantages of using a single manual for all the GTO Servo Drives is that we will be better able to keep it current with all the latest information. This is especially important in the world of electronics and software where change is the rule, and time to obsolescence often seems to be measured in weeks rather than years!

We will do our best to keep the manual updated on our website. We expect this manual to be a constant work-in-progress, so check our Technical Support section often for the latest information. At this writing we are shipping GTOCP4s with firmware version: VCP4-P02-10. We HIGHLY recommend keeping your firmware up to date!

You should note that this manual is actually one component of a three-document system.

- Astro-Physics GTO Servo Drive System - Model GTOCP4 manual (This manual)
- xxxxGTO German Equatorial Mount manual (The specific mount manual for each individual mount)
- Astro-Physics GTO Keypad manual (only shipped with optional Keypad order)

This GTOCP4 manual covers the electronics, control connectivity and introductory software information for the Astro-Physics GTO system. The GTOCP4 can be used with the following GTO mounts (cannot be used with older stepper-motor versions of these mounts):

- 400GTO
- 600EGTO
- Mach1GTO (not the Mach2GTO which requires the GTOCP5)
- 900GTO
- 1100GTO (with or without absolute encoders)
- 1200GTO
- 1600GTO (with or without absolute encoders)
- 3600GTO (with or without precision encoders)

We highly recommend the [Support](#) section of our website for the latest information and for future updated versions of this manual. There are also valuable information and help guides. The manuals on the website are dated for easy reference.

A final note and an apology to our friends in the southern hemisphere. Many of the instructions in this manual are written entirely from the point of view of those of us in the northern hemisphere. Since descriptive terms like left and right are meaningless without a defined point of reference, we tend to use east and west to avoid ambiguity. The east and west sides of a German equatorial mount are, of course, reversed in the southern hemisphere. At one point, our thought was to always use phrases like the following: "...on the east side (west side in the southern hemisphere)..." This quickly became cumbersome and made the text more difficult to read. For simplicity, we decided to leave many of the explanations in their northern hemisphere framework. Thank you for your understanding.



Please note that some photos that appear in this manual may differ from current versions.

PLEASE RECORD THE FOLLOWING INFORMATION FOR FUTURE REFERENCE

GTOCP4 Serial Number: _____

Purchase Date: _____

User Name _____ Password _____

Ethernet IP Address _____

Access Point WiFi Network Name _____

Access Point IP Address _____

GTO CONTROL BOX- MODEL GTOCP4 -YOUR MOUNT'S BRAIN

Your mount is a unique combination of precision, intelligence and strength. The heavy-duty, CNC machined parts give the mount the strength and rigidity to hold a load in a rock-steady fashion while exposed to the elements and while that entire load is in motion. The precision of every component allows accuracies that are measured in fractional arcseconds. The intelligence to control all of this is in the GTO Servo Motor Drive System.

There are three major sub-systems to the GTO Servo Drive:

1. The GTOCP4 Control Box This is the real “brain” of your mount. Please try to understand this from the outset. Your mount is **NOT** controlled by the keypad or by your computer. They merely serve as input devices and convenient interfaces for you, the user. The GTOCP4 serves the following functions among others:

- It provides the voltage to drive the motors.
- It determines the motors' rotational direction, rotational speed and the total number of rotations required to arrive at the destination coordinates that are commanded.
- It maintains the accurate tracking speed that is chosen and applies any needed corrections from a periodic error curve that is stored in its memory.
- It takes the provided input and translates it into the correct actions that fulfill our wishes.
- In mounts equipped with the Absolute Encoder System or the Precision Encoder and Limit Switch systems, the GTOCP4 seamlessly integrates the encoder and limit functions with the regular servo control functions for an unprecedented level of control.
- It bears repeating: It is the GTOCP4 Control Box that controls the mount!



2. The Servo Motors with their integral high precision motor-encoders. These high-quality Swiss DC servo motors are the work horses that actually move the mount. Their integral encoders provide the necessary feedback information for the GTOCP4 Servo Control Box to perform its varied operations. The encoders working with the microprocessor in the GTOCP4 operate to an accuracy of 0.05 arcseconds per step. These motors can be accurately controlled over a speed range of 4800:1, which allows 0.25x sidereal for manual guiding to 1200x sidereal for 5 degree per second slewing (*Mach1GTO*, 900GTO, 1100GTO, 1200GTO and 1600GTO). The top speed has been intentionally scaled back to 600x for the 3600GTO because its larger worm wheel has more teeth than the wheels on the three smaller mounts. 400GTO and 600EGTO mounts with 32:1 gear boxes also have scaled back top button and slew rates. NOTE: The integral motor-encoders are NOT the same as the Absolute or Precision shaft encoders that we offer.

3. An external input device to interface with the user. There are now numerous devices that can provide the necessary input for directing the mount to your intended target. The GTOCP4 control box has the versatility to communicate with just about every kind of electronic device imaginable.

- A)** The interface that we offer as an optional accessory for the GTO Servo System is, of course, the venerable [GTO Keypad](#). It is simple, intuitive, rugged, and is the only thing that can reliably be operated in extreme cold.
- B)** The GTOCP4 can be directed by any **computer** with a planetarium program or observatory control software. Most of the software written to date has been for Windows PCs, but there are growing numbers of Mac and Linux programs that can also be used.
- C)** **Mobile Smart Devices** with mount command functions that employ the Astro-Physics Command Protocol are now also directing mounts with GTOCP4s.

In addition to the serial communication, the GTOCP4 also offers USB, Ethernet and WiFi connectivity. The GTO Keypad has its own manual with complete operational instructions. For more information on other external input devices, see "Controlling Your GTOCP4 Mount" on page 39.

For the discussions that follow, we also divide the types of control functions that the GTOCP4 Control Box performs into three principal categories that are discussed more fully in "Controlling Your GTOCP4 Mount" on page 39.

1. Primary Control Functions. Primary control functions include all the functions that define HOW the servo will make decisions. In particular, these are the initialization functions - time, date and location - along with Park, Meridian Delay and Sync.

2. GoTo / Move Functions. GoTo / move functions include coordinates, move commands, and rate commands.

3. Hybrid and Other Functions. Hybrid and other functions include Periodic Error Management (PEM functions) and the Re-Calibrate function which has elements of both control and GoTo / Move.

To ensure the reliability of this control equipment, the Astro-Physics Servo Drive System uses industrial components. We chose a sturdy industrial handheld computer as our keypad. These components are far more rugged than conventional consumer electronics, and they will continue to function properly well below zero degrees F (-18 C). The keypad uses a vacuum fluorescent display that does not lose its speed or readability in the coldest winter conditions...all the way down to -40 degrees F (-40 C). However, if you plan to use your mount in extreme temperatures and conditions, please contact Astro-Physics first.

All of this control and sophistication is accomplished in an incredibly efficient manner. The Servo Drive System can generally be operated from nominal 12-volt systems, although the larger mounts may benefit from slightly higher voltages. In terms of energy consumed, the AP GTO mounts generally consume less wattage than a small compact fluorescent bulb when tracking, and less than a small incandescent bulb when slewing. Power considerations are explained in detail starting on page 68.

ENVIRONMENTAL CONSIDERATIONS

Astro-Physics mounts are used in a variety of climates and conditions. Some people live in areas with high humidity and others use their mounts in dry, dusty environments. Insects can be a challenge no matter where you are located. Each of these environments present challenges for all of your electronic equipment, including your mount.

We strive to make our control boxes moisture and dew resistant; however, they are not waterproof! Please be responsible to shield them from excessive dew and condensation.

Wet and Humid Climates

The GTOCP4 control box and optional Keypad are not waterproof and should be protected from rain and excessive condensation.

- If your control box has drain holes on the backside of the two lower corners, you may wish to leave these drain holes open.
- If your mount is left outdoors under a tarp for extended periods of time, we recommend that you remove the control box and keypad and bring them indoors. Tarps and covers can cause significant moisture build up from condensation even when you use low wattage light bulbs or other means to reduce condensation.
- If you are mounting a GTOCP4 on the RA axis of the 900 or 1200 mount, you may want to consider using our Pier/Tripod Control Box Adapter (CBAPT) if you feel that the angle of the control box is too horizontal to allow adequate dew runoff.
- If your mount is caught in the rain or you forget to turn off the automatic sprinkler during your observing session, remove the control box, open the cover and pour out any water that may have accumulated. Leave it open until the components dry out and DO NOT POWER THE UNIT UP until fully dry.
- You may wish to consider a set of covers for your connectors.

Dry and Dusty Climates

- If your control box has drain holes on the backside of the two lower corners, you may wish to cover these holes. If you do not have a plastic plug, a small piece of tape will do the trick and will not be visible.
- You may wish to consider a set of covers for your connectors.

Covers for Connectors

We offer a set of covers for all of the connectors on your control box (part # CONCOVS). Although these covers will help to reduce the moisture, dust or insects that can enter your control box, they are not 100% protection.

GTO SERVO DRIVE SYSTEM SPECIFICATIONS

Electronic components	Rated for industrial and rugged automotive applications.
Motors: <i>Mach1GTO</i> , 900GTO and 1100GTO	Zero-cogging Swiss DC servo motors, enclosed in machined aluminum housing.
Motors: 1200GTO, 1600GTO and 3600GTO	High-torque, zero-cogging Swiss DC servo motors, enclosed in machined aluminum housing.
Motor encoder	2000 tic quadrature yielding an effective resolution of 0.050 arcseconds per tic for the <i>Mach1GTO</i> , 900GTO, 1100GTO, 1200GTO and 1600GTO. The 3600GTO has an even tighter resolution of 0.044 arcseconds. The 400GTO and 600EGTO have resolutions of 0.033 or 0.053 arcseconds depending on the gearbox.
Motor reduction gear train	57.6:1 gear reduction through a custom built set of large diameter, fine-toothed, precision, spur gears for vastly superior performance (Except: 400GTO and 600EGTO which had 3.2:1 spur gear reduction and either a 19.8:1 or 32:1 gear head on the motor).
Servo Motor Control Box	GTOCP4 Control Box, removable.
Hand-held computer	Optional GTO Keypad to control all mount functions. Includes extensive databases and tour features in a simple, intuitive interface. Software updates via internet.
Power consumption	0.3 to 0.8 amps at the mount's recommended voltage while tracking; 1.0 to 3.0 amps at the mount's recommended voltage - both motors slewing at the highest available slew speed. For greater detail see the individual power specs for each mount in the Power Considerations section starting on page 68.
Power requirements	12V to 18V DC at a minimum of 5 to 10 amps continuous recommended, depending on the mount model, load and environmental factors. For specific details see the individual power specs for each mount in the Power Considerations section starting on page 68.
GTOCP4 Dimensions	6.375" x 4.9" x 1.8" (16.1 x 12.5 x 4.6 cm).
GTOCP4 weight	1.8 lb. (0.8 kg).
Standards	Meets FCC and CE standards. Lead-free RoHS compliance.
Maximum slew speed: <i>Mach1GTO</i> , 900GTO, 1100GTO, 1200GTO and 1600GTO	5 degrees / second at 1200x sidereal.
Maximum slew speed: 3600GTO	2.5 degrees / second at 600x sidereal.

GTOCP4 CONTROL BOX - LAYOUT AND FEATURES

The GTO control box contains all of the circuitry to drive the two servo motors and the logic required to navigate the sky. It will be operational and track at the sidereal rate when connected to both motor / gearboxes of the mount and a power source. In order to control the movement of the mount, you will need to connect at least one of these:

- GTO Keypad.
- Computer with a planetarium program or observatory control software. The "The Astro-Physics Command Center (APCC)" is highly recommended. Astro-Physics also has a fully supported ASCOM V2 Driver available. A more detailed listing of software is in the "Controlling Your GTOCP4 Mount" on page 39. In addition, see the [Website's ASCOM page](#) and the [APCC page](#) for details on both APCC and the ASCOM driver.
- Mobile Smart Device with mount command functions that employ the Astro-Physics Command Protocol. NOTE: As of this writing, a few older programs on mobile devices may not have a means of initializing the mount. For more information, see "Initialization and Shut-down". Luminos and Sky Safari both now have full Astro-Physics support

Please remember that this box contains advanced electronics and must be treated with the same care given to other fine equipment. You can see that the unit is machined of aluminum and is built to be rugged; however, it is not indestructible.



Control Box Layouts: As of January 2024, there are now two different layouts of the CP4 Control Box ports, as shown above. Aside from port location, they are functionally equivalent for currently shipping mounts:

Receptacles

10-pin Receptacle for Servo Motors

A Y-cable or servo extension cable with 10-pin male connectors plugs into this receptacle. Attach the connector to the GTO Control Panel. Attach the short leg of the Y-cable to the RA motor housing and the long leg of the cable to the Dec. motor housing. Be sure to screw on the knurled ring to lock it in place. Refer to the appropriate section on cable management in your mount manual for further information about positioning the cables.

10-pin Receptacle for Absolute Encoders

The GTOCP4 incorporates the functionality of both the GTOAE and GTOELS into its design, thus eliminating the need for these secondary boxes when using the 1100GTO and 1600GTO mounts with Absolute Encoders or the 3600GTO with Precision Encoders. The encoder cables with 10-pin female connectors from these mounts will be connected directly into this 10-pin receptacle.

12-volt Locking Receptacle

Place the DC power cable's 2-pin locking plug into the 2-pin receptacle marked 12V or 12-18V on the GTO Control Panel and lock in place by a twist of the plug's locking collar onto the receptacle. The other end of the power cable terminates with Anderson Power Pole connectors which provide convenience when connecting to a number of different power connectors. Cigarette plug and ring terminal adapters are provided with the mount's power cable set. Several other connector types can be found through the internet. **The GTOCP4 receptacle is top pin (pin #1) positive (the orientation notch is to the right).** See photo on previous page.

We highly recommend either our 13.8 volt 15-amp power supply (PS138V15A) for most situations or our 25 Amp Variable Volt Power Supply (PSVPW25A) for the larger mounts, heavier loads and / or colder climates. DO NOT use "wall wart" or laptop power supplies.

Please read the Appendix B: Power Considerations section starting on page 68 for more information. In short, using a cheap or inadequate power supply with your mount is like buying cut-rate gas for a Ferrari.

There is no on-off switch on the GTOCP4, although on-off switches are found on most power supplies. We recommend that you connect all of your cables to the GTOCP4 Servo Control Box before applying power, whether from a power supply or from a battery. To turn the unit off, simply disconnect the power cable or flip the switch on the power supply.

Power Indicator Light

This red LED will remain illuminated when your system is powered up and operating properly. The red-colored LED indicates proper functioning of the servo system. If the servo detects a problem, the LED will turn from red to amber. An amber LED can indicate several problems: It normally means that the servo has gone into "safe mode" or "motor stall" mode and is no longer trying to drive the motors. The motors will be stopped and de-energized for safety. Position data is not lost during this condition. If the voltage falls below about 11 volts, the power LED will also turn to amber. The keypad will also not function properly below about 11 volts.

In P02-09 and later, the amber LED can also signify an encoder problem. In this case, it is merely informative and does not also signify that the servo has gone into safe mode and de-energized the motors. Encoder faults are very rare.

If you experience an amber LED, first check your power source to be sure it is delivering adequate voltage and current to drive the system. Look for loose or corroded power connections. If your power supply is good, the amber LED means that your motors are overloaded, probably due to an unbalanced load on your mount. It could also mean that your scope or counterweights have hit an obstruction and stopped the motion of the axis. Refer to the troubleshooting section of the manual for the solution.

Keypad Receptacle

Attach the 5-pin male connector plug on the end of the GTO Keypad's coiled cable to this receptacle and lock it in place (push in the knurled ring then turn). The keypad receptacle is actually a serial port with an added 12 volt power source.

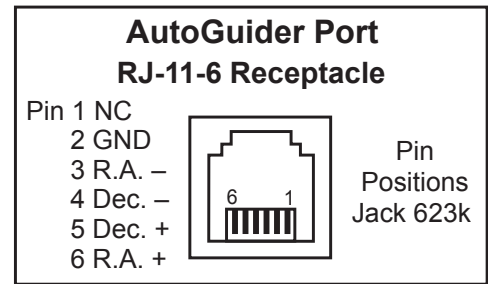
Auxiliary Receptacle (Legacy)

The auxiliary receptacle is used for connection to the limit switches of the 3600GTO mount. It is not used with currently shipping mounts and is not available on some Control Box layouts.

Auto-guider Port Receptacle

This receptacle interfaces with the RJ-11-6 modular plug of an auto-guider cable, purchased separately or as part of a CCD Imaging Camera or Auto-guider. The port uses the industry standard ST4 pinout as shown at right. Generally speaking ST-4 is considered a legacy an outdated approach to guiding. Wherever possible ascom and pulse guiding should be used.

The auto-guider will be functional and ready to go as soon as you plug it in. Please refer to the appropriate manual from the manufacturer for operation of the auto-guider. As we explain more fully in "Auto-guiding Tips and Notes" on page 59, you mustn't confuse your guiding software's X and Y axes with RA and Dec. They are NOT necessarily the same.



Removing and Installing the GTOCP4 Control Box

An important part of the design philosophy at Astro-Physics is to use a modular approach to the system components. In the rare event of a failure, many components can be easily removed for repair, replacement or temporary swap-out. This modular philosophy is exemplified by the GTOCP4 control box and its predecessors.

The GTO control box is integrated with the mount differently for the different mounts that we offer. When using the 400GTO, 600EGTO, *Mach1GTO*, 1100GTO and some of the OEM mounts that use the AP Servo Drive System, the GTOCP4 is not directly attached to the mount, but instead it is mounted onto a bracket that is then affixed to the tripod or pier. Attachment and removal are straightforward.

On the 900GTO and 1200GTO, the GTOCP4 may be held in a dovetail bracket on the top of the RA axis, or alternatively, on a bracket attached to the pier. The 1600GTO and 3600GTO have a dovetail bracket built onto the west polar fork (east polar fork if you're "down under"). The *Mach1GTO*, 400GTO and 600EGTO use the bracket attachment system.

The GTOCP4 is secured into the dovetail (or bracket) by two #8-32 thumbscrews (or two #8-32 set-screws). To remove the GTOCP4 simply loosen these thumb-screws (or set screws) and then tilt and lift the box free from the dovetail connection. Reverse the procedure to install.



Mach1GTO with CP4
Attached to Pier

Easy removal – especially handy for mounts that are subject to extra environmental stresses. The GTOCP4 can be removed and taken inside to a safer environment when not in use. *Note: The photos show thumbscrews securing the control box, but the mount may also use set screws instead.*

Outdoor Storage – If you have a mount that is left outside for extended periods covered by a tarp or scope cover, then it is highly recommended to remove the GTOCP4 and Keypad and take them inside to a safer environment. Tarps and covers cause significant moisture build up from condensation unless steps are taken to mediate the problem. Often low wattage light bulbs or fans are used to reduce condensation.



1100GTO and 1100GTO-AE/L
with CP4 Attached to Mount Base



1600GTO and 3600GTO Style
with CP4 Attached to Polar Fork
1600GTO shown



900GTO and 1200GTO Style
with CP4 Attached to Pier
900GTO shown



400GTO and 600EGTO Style
with CP4 Attached to Pier
600EGTO shown



900GTO and 1200GTO Style
with CP4 Attached to RA Axis
1200GTO shown

COMMUNICATING WITH YOUR MOUNT

The GTOCP4 and GTOCP5 (abbreviated CP4/5) introduce communication alternatives in addition to the venerable RS-232 serial ports (serial ports have full functionality for keypad downloads beginning with version VCP4-P01-14). These are USB, Ethernet and WiFi. Each will be discussed individually below, but a bit of introductory text is in order. First off, you must understand that ALL control, information and operational data passing to and from the mount is in the form of simple ASCII characters in text commands and responses. Whether you are controlling the mount from the keypad, from a computer, or from a smart phone or tablet, an order to slew the mount will consist of the exact same commands, made up of these same ASCII characters, sent in the exact same order, and basically at the same speed.

Do not be duped into thinking that traditional serial communication is somehow inferior to USB, Ethernet or WiFi. Your goal is to select the alternative(s) that best meet your needs with respect to your control device, and the distance between the control device and the mount. Crash-proof dependability of the communication medium is FAR MORE IMPORTANT than high speed!

Regardless of the communication method, when you are controlling the position of the mount with a computer program such as the Astro-Physics Command Center (APCC), DC3 Dreams' *ACP*[™], or Simulation Curriculum Corp.'s *Starry Night*[™], there is constant communication between the computer and the microprocessor in the CP4/5. The computer software requests constant updates to the position and status of the mount, and the CP4/5's microprocessor chip responds with continual RA and Dec coordinate data via the cable or wireless connections to your computer. When you use the software to give instructions to slew to a new object, the commands (RA and Dec coordinates) are sent to the mount. Please read the sections that follow entitled "Understanding the German Equatorial Servo Logic" on page 27 and "Controlling Your GTOCP4 Mount" on page 39 for additional information.

As a final introductory note, remember that the CP4/5 is the "brains" of the system. The mount won't quit if your control device is disconnected for a while, or if you change connections mid-session. For example, at a large star party, there may be a ton of competing WiFi networks flooding the air waves. If 10 minutes into a 20 minute exposure, you realize that the WiFi is flaky, you can disconnect and then reconnect with USB, serial or an Ethernet cable. You can plug in and then unplug the GTO Keypad at will without issue. The CP4/5 will simply continue on regardless.

Choosing Your Communication Interfaces

Distance of Mount from Control Device

One of the primary factors in choosing your connection method(s) will be the distance separating the control device from the mount. And don't forget, the best control device when at the mount itself is probably the AP GTO Keypad!

- Computer closer to mount: People who have their mounts close to the controlling computer, and do not have network capabilities at hand, may find direct USB connection to be their most convenient choice. For mobile setups like observing in your backyard or going to star parties, WiFi is a flexible solution.
- Computer further from mount. Somewhat longer distances may be better served with a cabled network connection to a router, peer-to-peer Ethernet, an installed serial card or a USB-to-serial adapter and a longer serial cable. For control of a mount that is within 100 yards or so of the controlling computer, we have found the Icron Technologies Ranger 2304 USB extender to be an excellent solution.

Remote Observatories

Remote observatories will generally require a computer or an IP addressable server in the remote observatory itself, along with a high-speed internet connection for communication with your home computer. The Ethernet and WiFi discussed below will prove helpful. However, such complete long-range solutions are beyond the scope of Astro-Physics to supply or support.

If you are outfitting your observatory with a new computer, you might want to consider a small industrial computer or media-player computer like the Global Shuttle DS series (i.e. the DS57U or newer), the Cincoze line, the NUC or the Moxa V series among others. These computers are used to run the huge video billboards that are now everywhere, and they are environmentally robust, even at low temperatures. They also come with multiple true serial ports, and many operate on 12 volts - perfect for the solar-powered observatory! As with any computer electronics, change is the only real constant.

USB Port 2.0



The USB port uses an on-board FTDI RS-232 serial UART to seamlessly connect as if it were a true serial port. This device is powered both from the USB itself and also from the power of the CP4/5, providing an extra layer of redundancy over external USB-Serial devices. Because the

internal FTDI chipset in the CP4/5 remains powered, it will almost never crash. In addition, the chip is uniquely serialized, so that every time you connect to the CP4/5 it will be found on the same COM port, preventing COM port hunts. The port itself is sturdy and will provide excellent connector retention after many, many connections.

To use the USB connection, make sure you install the FTDI driver on your computer **FIRST**. The driver can be found at <http://www.ftdichip.com/Drivers/VCP.htm>. Once the driver is installed, simply plug your computer into the CP4/5 using a USB cable. The computer will take a moment to make sure it has the proper driver and designate a COM port. When this is done, all that is left is connecting software.

Drivers are available for Windows, Mac and Linux from FTDI. Newer Linux versions come with the driver already installed. We have direct links to the individual drivers in the Software Updates section of our website. The graphic below is the main driver graphic from the FTDI website as of April 2021. It has changed several times in the past few years, so don't be alarmed if the latest FTDI web page looks a bit different.

Operating System	Release Date	X86 (32-Bit)	X64 (64-Bit)	PFC	ARM	MIPSII	MIPSIV	SH4	Comments
Windows*	2017-08-30	2.12.28	2.12.28	-	-	-	-	-	WHQL Certified. Includes VCP and D2XX. Available as a setup executable . Please read the Release Notes and Installation Guides .
Linux	-	-	-	-	-	-	-	-	All FTDI devices now supported in Ubuntu 11.10, kernel 3.0.0-19. Refer to TN-101 if you need a custom VCP VID/PID in Linux. VCP drivers are integrated into the kernel .
Mac OS X 10.3 to 10.8	2012-08-10	2.2.18	2.2.18	2.2.18	-	-	-	-	Refer to TN-105 if you need a custom VCP VID/PID in MAC OS.
Mac OS X 10.9 and above	2019-12-24	-	2.4.8	-	-	-	-	-	This driver is signed by Apple.

If you need to determine which COM port is being used, open the Windows Device Manager and look for the COM ports. The device manager will display the COM ports by number alongside the device name, "USB Serial Port". The port number shown will be the port number used in the AP V2 Driver, APCC, or any other telescope control software. Note that you may need to restart any external programs (like APCC) that are running for them to find the new COM port.

As with all USB devices, this one works best when common sense is applied.

- Use a high quality USB cable and use the shortest cable that will work for your system. Remember, USB 2.0 is limited to about 15-16 ft. (5 meters). Do not try to use a USB 3.0 cable, because the 3.0 Type B connector is sized to only fit 3.0 Type B ports.
- Connect directly to a primary USB port on your computer if possible (generally these are located on the rear of a desktop computer).
- Avoid using hubs or extenders, if possible. If you must use a hub, use a high-quality hub that is powered. If you must extend your USB range we highly recommend the [Icron Ranger 2304 USB Extender \(USBIEXT4P-2304\)](#). The Icron Ranger 2304 provides four USB ports, one of which can be used for the mount, leaving 3 available USB 2.0 ports. The Icron Ranger 2304 supports isochronous data transfer and will therefore work with most USB 2.0 CCD cameras.

VERY IMPORTANT!! You MUST install the FTDI Driver onto your computer **BEFORE** you connect the CP4/5's USB port to your computer for the first time! The latest driver can be found at: <http://www.ftdichip.com/Drivers/VCP.htm>. Note also that the FTDI USB-to-serial devices are all uniquely serialized. Each one will be assigned its own COM port that will be remembered through power-cycles.

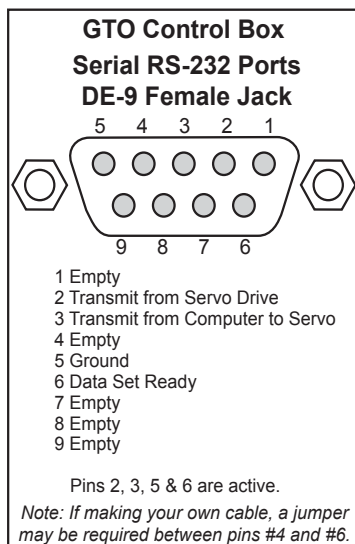
RS-232 Serial Port

RS-232 are the traditional serial ports that have been used to connect our mounts to an external computer for years. Although serial ports have been largely replaced by USB ports, they still have advantages and are recommended for their ruggedness and reliability. One of the advantages of a serial connection is that serial cables can be very long: cables up to 100 ft are generally not a problem. Industrial and commercial equipment control is still totally dominated by serial for its robust dependability and simple operation.

We offer a 15 foot straight-through (non-crossing) cable with a 9-pin (DE-9) male connector to interface with the CP4/5 panel, or you can purchase a longer cable (from 1' to 100' length). Be sure that it is a straight-through type. Our DE-9 receptacles provide locking posts to secure the cable firmly onto the control box. If your serial cable does not have a 9-pin connector, you can use a gender changer or adapter to convert it.

Please note: Make sure your serial cable is wired straight-through! The use of "crossing", "reversing", "null", or "null modem" cables is a frequent source of communications failure and frustration.

FYI – The DE-9 plug and receptacle are often mistakenly referred to as DB-9s. The E or B represents the shell size of the plug or receptacle. The B shell is the larger size used for the 25-pin DB-25 plug and receptacle, but the smaller 9-pin version uses the E size shell and is therefore correctly called a DE-9.



We provide one or two RS-232 serial-port connections on the CP4/5 to give you additional flexibility. The availability of a second port also facilitates the backup COM port feature in the Astro-Physics Command Center (APCC)..

Serial ports, by their nature cannot be Y-connected or split with hubs. Each physical serial connection that you use on the mount must have a corresponding unique COM port available on your computer. If you use a laptop, you will probably need to purchase a USB-to-serial adapter to use one of the serial ports.

In the past, we recommended and sold adapters from Keyspan. These are still fine adapters, but we are now recommending and selling adapters from FTDI. A primary reason for this change is that the CP4/5's on-board USB serial UART is also by FTDI. This way, you need only a single driver to work with all of your USB to serial applications. Another reason for the switch is that the FTDI units have a wider operating temperature range, especially important on cold nights under the stars. Unlike many lower quality devices, both the FTDI and Keyspan adapters also maintain their COM assignments when plugged into different USB receptacles on any given computer.

For desktop computers, we strongly recommend installing a multi-port PCI serial card directly onto your computer's motherboard. This is basically the same as the native serial ports that were standard on all computers back in the "old days."

Network Ethernet Port



The CP4/5 introduces Ethernet connectivity to the Astro-Physics GTO Servo System. Ethernet is the fastest communication method between the mount and the computer, operating magnitudes faster than serial and USB, and even slightly outpacing the WiFi. It is suitable for long-distance communication out to 100 m (386 feet) and can be easily customized in length with an inexpensive crimping tool. The port allows the plug to lock in place, preventing accidental pullout. The interface is the standard **RJ45-8** receptacle for Cat 5e and higher cables, and is equipped with crossover detection so that you do not have to concern yourself with whether a cable is "straight through" or "cross-over."

Ethernet connection interfaces are available in software like the Astro-Physics Command Center Standard and Pro versions (APCC-ST and APCC-Pro) and the Astro-Physics V2 ASCOM Driver.

This discussion includes a number of terms that may not be familiar to you. We have provided a glossary and further explanation in "Technical Information and Terminology Regarding Ethernet" on page 18 for your reference.

Ethernet (LAN) can be point-to-point (aka peer-to-peer) with a computer, or networked without user configuration. However, for fixed usage, it is recommended to change the DHCP setting of the unit according to the usage, see "Ethernet and WiFi Best Practice Recommendations" on page 22. Devices connected via Ethernet or WiFi are identified by their IP address. The CP4/5's internal default IP address is in the form of 169.254.x.y. The values for X and Y will depend on your CP4/5's serial number. This will be the IP address used for point-to-point connections. Most home networks will assign an IP address of the form 192.168.x.y or 10.0.x.y. There are several methods to determine the IP address, please refer to "Determine Your IP Address" on page 15.

In the pages that follow, we will provide additional information regarding the IP address and how to find it, how to connect to APCC and the ASCOM AP V2 Driver, how to configure your CP4/5 home page on your browser and load new software.

"Summary Network Connection Diagrams" on page 16 provides a visual representation of various Network configurations and combinations using Ethernet on a simple point to point network or on a local area network with a router. It also illustrates the other network connection method - WiFi. WiFi can use the CP4/5 as a hotspot, or join a network with a router.

Connect Your GTOCP4 or GTOCP5 via Ethernet

If you are simply connecting point-to-point with your computer, it is not necessary to change any settings since this is the default setting. You are ready to connect to your CP4/5. Note that it is default because we don't know your network info.

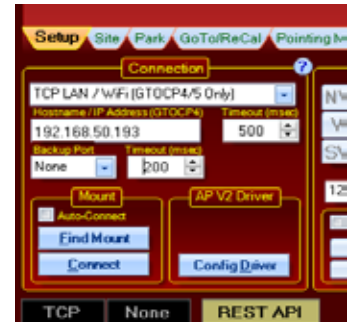
Using software with the Ethernet connection is super easy. Here is the procedure with APCC and the V2 driver. If there are multiple IP addresses available from which to choose, refer to "Determine Your IP Address" below. Other applications and programs will behave similarly.

APCC-ST and APCC-PRO COM Setting

APCC software versions 1.8.8.14 (Std) and 1.8.8.17 (Pro) or later are recommended for both the GTOCP4 and GTOCP5. The most current version is ALWAYS recommended and preferred!

- In the Connection group box, select from the top drop down list:
TCP LAN/WiFi (GTOCP4/5 Only) or
UDP LAN/WiFi (GTOCP4/5 Only)
- Click Find Mount button. This will open a list of available mount connections on your network. Find the HostName and IP address for this CP4/5 in this list. Be sure to select the LAN – not the WiFi - if that is your preference.

- NOTE: Find Mount does not find direct connect control boxes.



ASCOM AP V2 COM Setting

Select "IP/ Hostname (no APCC)" from Mount Connection Details. The IP address will display. Enter the IP address in the circled space. We suggest that you record these numbers for future reference. Refer to Connection Details in the AP V2 Driver manual for more information.

NOTE: If using APCC, only use APCC REST API Connection type.



Determine Your IP Address

You will need the IP address in order to access the CP4/5 web page in your browser. If you have already used APCC or the AP V2 Driver, as described below, you may have recorded those numbers on page 4 of this manual. If not, you can launch them again or use one of the methods described below.

The IP address of your unit will come from one of two places:

1. If the unit is plugged into a network router, the network DHCP server will assign an IP address. This is necessary to assure that all hosts on the network are on the same "logical subnet" so they can communicate. The unit default IP address is *NOT* used in this configuration.
2. If the unit is plugged directly into a computer, the unit default IP Address is used since the computer cannot assign one.

First, power up the CP4/5, and connect the Ethernet (i.e. Cat 5e or later) cable to the CP4/5 on one end, and to your computer, router, or network switch (port) on the other end.

IMPORTANT: Allow at least 30 seconds for the connections to be fully established. Once the connection is made, communications are nearly instantaneous.

We suggest that you read all of the options first to determine which one will be most appropriate for your situation.

Default IP Address Calculator

The easiest way is with the [IP Address Calculator](#) that is on the flash drive that came with newer mounts. Owners of older mounts that shipped with CDs or early flash drives can get this utility from the [Support](#) section of our website under **GTOCP4 and GTOCP5 Control Boxes -these files are useful for both**. The Default IP Address is what the CP4/5 was shipped with, but since it can be changed from the default to something else, we offer other options below for recovering

Summary Network Connection Diagrams

The following diagrams provide an easy visual summary of the connection possibilities for your GTOCP4/5 using either Ethernet, WiFi or both in several configurations. They are not a substitute for the text, but should provide help for those who are not well versed in networking specifics. They are listed in order of preference for stability and reliability.

Network Available

Most Stable and Reliable

#1 BEST Option!



WiFi from Smart Device to Router
Ethernet from Computer to Router (may go through switch)
Ethernet from CP4/5 to Router (may go through switch)

#2 Best if PC has no Ethernet port.



WiFi from Smart Device to Router
WiFi from Computer lacking E-net port to Router
Ethernet from CP4/5 to Router (may go through switch)

#3 Best if cable connection from CP4/5 to router isn't available



WiFi from Device to Router
Ethernet from Computer to Router (may go through switch)
WiFi from CP4/5 to Router

#4 Use when cabled E-net connections aren't available.

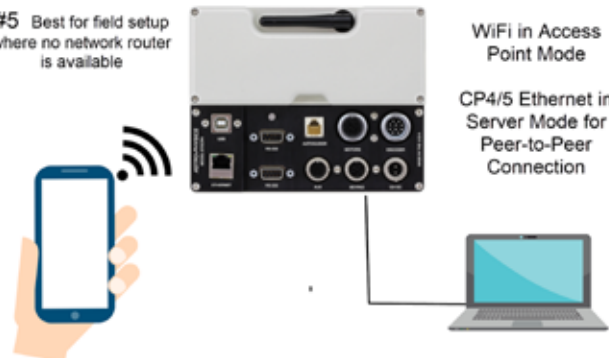


WiFi from Device to Router
WiFi from Computer to Router
WiFi from CP4/5 to Router

No Network Available

Least Stable and Reliable

#5 Best for field setup where no network router is available

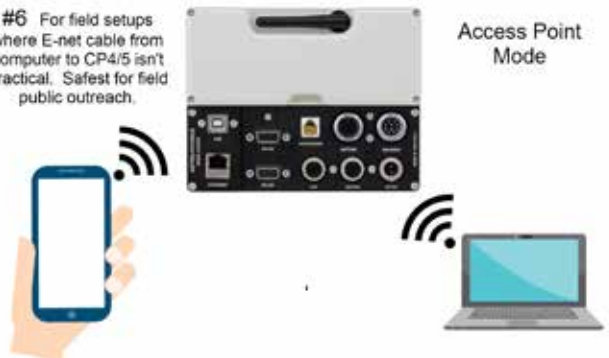


CP4/5 is the Server / WiFi Hotspot
NO Router. CP4/5 acts as Router, but NO Internet
WiFi from Device to CP4/5
Ethernet from Computer to CP4/5

WiFi in Access Point Mode

CP4/5 Ethernet in Server Mode for Peer-to-Peer Connection

#6 For field setups where E-net cable from computer to CP4/5 isn't practical. Safest for field public outreach.



CP4/5 is the WiFi Hotspot for both Device & Computer
NO Router. CP4/5 acts as Router, but NO Internet
WiFi from Device to CP4/5
WiFi from Computer to CP4/5

Access Point Mode

ASCOM Ethernet WiFi Poll Utility and FindMounts.jar



A handy ASCOM Ethernet WiFi Poll utility as well as the FindMounts.jar Java applet have also been provided on the flash drive that shipped with newer mounts (not on the older CD) and on our [Support](#) page (See more info above). These will assist finding the correct IP address for ASCOM users. They will even open up the CP4/5 web Interface in your system's default browser. **Use your software download user name and password when asked.** These were provided in the welcome letter that you received with your mount. If you can't remember your user name and password, contact Astro-Physics and be sure to jot them down. The Java applet will also work from non-Windows computers. You must

have Java installed on your computer to use this applet: <https://java.com/en/download/manual.jsp>.



Do the Math Yourself

The CP4/5's internal default IP address is in the form of 169.254.X.Y. The values for X and Y will depend on your CP4/5's serial number. Remember, x and Y can be values from 0 to 255. If you prefer to calculate, here is the underlying formula:

- Locate your CP4/5's serial number on the side of the control box. Drop any preceding zeros of your serial number. In our example, 0869 becomes 869.
- Note how many times you can subtract 256 from your serial number.
In our example: $869 - 256 = 613 - 256 = 357 - 256 = 101$
So 256 is subtracted from 869 a total 3 times, with a remainder of 101.
- The X portion of your IP address is the number of times you were able to subtract 256; in this case, 3. If your serial number is 255 or lower, then the number entered is zero.
- The Y portion is the remainder; so in this case, 101. If there is no remainder, then the number entered is zero. You might notice this is long division, keeping the remainder.
- Therefore, for serial number CP4-0869, your IP address is 169.254.3.101.

$$\begin{array}{r} 3 \\ 256 \overline{)869} \\ \underline{-768} \\ 101 \end{array}$$

Use the Hostname

All CP4/5's have been programmed with a unique **Hostname**. When running firmware P02-08 or earlier, the use of the hostname as the URL will only work on Windows machines with NetBIOS enabled. By default NetBIOS is enabled on all Windows machines through Windows 11 as of 2024, but is essentially deprecated and is only default for fixed-IP nodes like the CP4/5. *Note that you can simply substitute CP4 for CP5 and vice versa in the examples below.*

Starting with P02-09, however, hostnames may be used on machines running other operating systems like MacOS, iOS, and Linux. In this case, hostnames are in the "local domain", meaning that the URL should have a ".local" suffix. Android devices cannot use Hostname and must have the IP address.

Example: GTOCP5-123.local

Some browsers may require a prefix: <http://GTOCP5-123.local>

For a CP5, the factory default Hostname is GTOCP5-X, where X is the serial number of the GTOCP5 without leading zeros. For a CP4, it is GTOCP4-X with X again being the serial number. The hostname is user-configurable. **NOTE:** Earlier CP4/5 boxes (shipped before early spring, 2021) will use an underscore instead of the hyphen: I.e. GTOCP5_X. To use the hostname as a URL and not perform a browser search, use the form http://GTOCP5_X and press enter.

URL's may be bookmarked. If the hostname is used as the URL, it will be bookmarked rather than the IP Address. This is wonderful since a network DHCP server can assign a different IP address and the bookmark will still work.

Ping

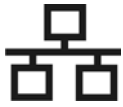
Finally, "pinging" from a command line window is another way to determine the IP Address.

>> ping gtcp5-123.local or ping gtcp4-234.local on Mac and Linux (Note: the hyphen may be an underscore.)

Or

>> ping gtcp5-123 or ping gtcp4-234 on Windows. (Note: the hyphen may be an underscore.)

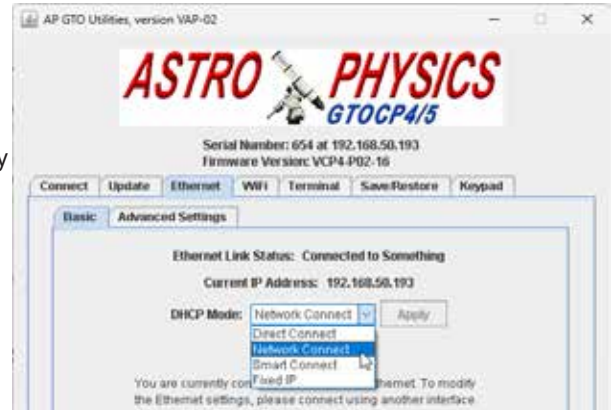
Set Ethernet Parameters Using AP GTO Utilities



Astro-Physics now provides an easy to use utility to handle most of your CP4 control box setup tasks, including settings for Ethernet and WiFi. You can see more about the AP GTO Utilities from our software update page <https://www.astro-physics.com/software-updates/>. You can also download and read the detailed user manual for the app.

The AP GTO Utilities provides easy configuration tabs for both your Ethernet and WiFi connections. It also provides an easy way to update your Control Box firmware.

The Ethernet tab has additional options for all your Ethernet connection settings. There you can do things like change the DHCP settings, the default IP address, the hostname and hostname resolution settings, and more. Only make changes to these settings if you are confident in your networking abilities, or you are attempting to troubleshoot a connection issue.



Technical Information and Terminology Regarding Ethernet

It is important to keep in mind that unlike the serial connection, which is used by a program on the computer, Ethernet is between the computer itself and the CP4/5. The computer will send packets to the CP4/5 during the initial DHCP handshake and send packets regularly to make sure the CP4/5 is still there.

All of this is handled by the computer's Ethernet card before you ever run a mount control program like APCC, the AP V2 Driver, or any of the other myriad programs that can send commands to the CP4/5 on an Ethernet connection. Information is being sent the very moment you plug the Ethernet cable into the CP4/5, and is still being sent until the very moment you unplug the cable or turn the power off.

Compared to the Serial and USB connections, Ethernet and WiFi are ALWAYS in communication. You can unplug a serial cable from the CP4/5 and the computer will never notice; unplugging Ethernet from the computer is instantly noticed.

Ethernet connection will work with any device that supports Ethernet. This means Mac, Linux, Windows, and even another CP4/5 could be connected over Ethernet. As stated earlier, Ethernet connection is between the computer and the CP4/5, NOT between the software and the CP4/5. APCC and the V2 driver can access the Ethernet connection, but they are not the only software that can. The most basic way to connect over Ethernet is to open the CP4/5 home page. In this case, the browser program is interacting with the Ethernet connection, sending data to and from the CP4/5.

Over Ethernet, the CP4/5 can not only communicate using the AP Command Protocol, but it contains embedded web pages that provide housekeeping and maintenance capabilities. For example, they can be used to update the embedded firmware, or to modify networking settings. Computers can send large files over Ethernet very quickly, like the CP4/5 firmware updates and license files. Other software like APCC, the AP V2 Driver, and others behave just like the browser. The programs tell the computer to send a packet, and the computer replies with what comes back. With this all in mind, here are some important terms you need to know to make the most out of your CP4/5 Ethernet connection.

Term	Definition
Client	A client is a computer connected to a network that requests information from other systems. Clients initiate connections to servers and await requests. Most computers behave as a client, and will try to request information from the CP4/5.
DHCP	DHCP (Dynamic Host Configuration Protocol) is the protocol used when the CP4/5 is connected to a live Ethernet cable. It establishes who talks first, and settles what IP address clients and servers will use while connected to the network. Before any further communication can occur, these important topics need to be settled.
Hostname	A human-friendly name that is assigned to a "Host" as an alternative to a (non-human friendly) IP address. Hostnames can be "resolved" into IP addresses by underlying protocols, automatically for the convenience of a human.
IP Address	This is the address by which your computer and CP4/5 talk to each other. Both the CP4/5 and computer will have an IP (internet Protocol) address, and any packets sent by one will be sent to the IP Address of the other. It is important to note that devices connected with multiple Ethernet and WiFi will have an equal number of IP addresses to differentiate the different "logical hosts".

Term	Definition
Network / LAN / Subnet	<ul style="list-style-type: none"> A network is a connected set of clients, sometimes with routers and servers. A network can be anything from a computer wired directly to a CP4/5, to a CP4/5 connected to a router that can access other routers and computers, and possibly the entirety of the internet. A LAN (Local Area Network) is the name given to a network not connected to the internet, or a network connected to but behaving independently from the internet. A subnet, as you have probably already guessed, is a subset of a larger network.
Network-Router / Network-Switch	<ul style="list-style-type: none"> A Switch is a device that can connect multiple nodes on a network. You may use a network switch so that a computer with one Ethernet port can connect to both a router and a CP4/5 at the same time. The network switch will only send information to an address if it pertains to that address. This is NOT the same as an Ethernet splitter. An Ethernet splitter should NEVER be used. A router is a switch with brains. It will pass on packets to the requested destination, preventing congestion in large networks. Routers can also allow communication with a Local Area Network (LAN). When connected to a router, the CP4/5 needs to be in Client mode so it can initiate conversation with the router. Computers can use a router to access the internet and CP4/5 at the same time, making it an ideal method for connection. A typical residential router generally also contains: <ul style="list-style-type: none"> a switch connecting every host to every other host. It allows all hosts to be full duplex. a DHCP server, a Gateway either to the Internet, or to another logical "sub-net", and even a host of its own for network maintenance and configuration. It may contain its own embedded web pages. Routers also often combine Ethernet with WiFi so that both wired and wireless network communication can occur. Note: with Ethernet, the term switch is used for a node that acts as a hub. A router is also normally a switch, but a switch isn't necessarily a router.
Node (aka Host)	A network node is any single electrical connection between cables. Nodes process information, deciding what to forward, reject, or send back. Clients, servers, routers and switches are all types of nodes. Being electrical in nature, a node is addressed by its MAC address, NOT its IP address which is logical in nature.
Packet	This is the data packet sent over an Ethernet connection. While communication protocol like serial will send encoded bytes one at a time, a packet contains an entire message and will be sent all at the same time.
Peer-to-Peer Point-to-Point	This is a connection comprised of two nodes. An example would be a CP4/5 with an Ethernet cable running straight to a computer. It is the simplest network possible. See #5 on "Summary Network Connection Diagrams" on page 16.
Server	A server hosts clients by sending them the information they request. For example, when you connect a client computer directly to a CP4/5, the CP4/5 needs to be set to Server mode in order to communicate properly. Two clients and two servers will simply ignore one another, like hosts and customers at an uptown restaurant.
TCP	TCP (Transmission Control Protocol) is a layer around a packet, telling the recipient what order the packets go in. Then, the recipient sends an acknowledgement that the packet has been received. It serves as a layer of security when packets are routed through large networks, and over the internet. If a packet is lost in transit or fails to maintain integrity, the packet will be resent.
UDP	UDP (User Datagram Protocol) is a simpler form of TCP, where there is no confirmation that a packet has been received, and dropped packets are not resent. This is a much faster connection protocol with its own advantages from TCP. For a CP4/5 that is connected directly to a computer, there is no real advantage between TCP and UDP.

Network WiFi Connection



WiFi is essentially a protocol for using radio waves instead of physical cables to communicate in a network. The CP4/5 is equipped with a powerful adjustable WiFi antenna that protrudes from the aluminum housing to provide signal strengths that can be modulated to a certain degree. This makes the CP4/5 WiFi signal not only tempered enough to communicate flawlessly with the control room or a handheld device, but also strong enough to even communicate with devices well outside your observatory. The antenna can be adjusted, if needed, to provide more or less signal. Mobile devices in very close proximity to the unit in "Access Point" mode may require the antenna to be folded in. Whereas, a unit in Station Mode, configured to join your network with the router in the house, may require the antenna to be unfolded, and without metallic structure between it and your router.

While the speed is on par with Ethernet, WiFi dominates in its ability to be mobile. With Ethernet, cables have to be run from port to port, creating tripping hazards and they can be accidentally pulled and cut. A wireless device can be moved all around without fear, and requires no physical interaction to set up. WiFi can be used to connect mobile devices to the CP4/5, so you can control the mount with just a smartphone. Each method of connecting has its advantages, and WiFi has plenty to offer.

Since WiFi communicates on the same protocols as Ethernet, a lot of what is covered in the Ethernet section applies here as well. If you are not very familiar with networking and the associated terminology, we suggest you read through "Technical Information and Terminology Regarding Ethernet" on page 18 as a primer for this one. We also suggest studying the "Summary Network Connection Diagrams" on page 16. Here are some additional terms that will be used in this discussion.

NOTE: Windows 10 machines can present difficulty when connected wirelessly to a network, and connected directly (pier-to-pier) to a unit with the Ethernet jack. This configuration presents the computer with two networks and the computer may not query the unit embedded DHCP server properly. The result may be inability to communicate. The recommended solution is to:

1. Connect directly to a unit when operating in the field where there is no network.
2. When a network is available, connect the unit and the computer to the network. An Ethernet connection will be more reliable than WiFi. Using the computer WiFi does not necessitate using the CP4/5's WiFi in a network. The computer can be connected via WiFi, and the unit connected by cable to the network router, or vice-versa. And they will be on the same network and can communicate. See the section: "Summary Network Connection Diagrams" on page 16.

Term	Definition
Access Point	Access Point - Access Point is exactly what it sounds like: a point of access to a device. Devices behaving as an Access Point will broadcast their Access Point name and WiFi IP address. Other WiFi devices can pick up this signal and establish a connection. When a point-to-point server device is connected over wireless, it is called an Access Point. See #5 and #6 in "Summary Network Connection Diagrams" on page 16.
Station Mode	Station Mode - When a network client is connected on wireless, it is called a Station. As opposed to an Access Point, a Station must be connected to a router. This could also be referred to as a 'client mode' for wireless. See #1, #2, #3 & #4 in "Summary Network Connection Diagrams" on page 16
WiFi	WiFi - A family of wireless communication protocols, typically used for short range connection to a network, designed to carry "Ethernet over Radio".

The CP4/5 can be connected to your computer using WiFi in two ways; either having the computer connect to the WiFi Access Point of the CP4/5, or by having the CP4/5 connect to the network of a WiFi router in Station Mode.

- Access Point: By having the CP4/5 acting as an Access Point, there is no need for other equipment, like a router. This is optimal for connecting to the mount in the field with your smart-device or laptop, and in some cases can be used in troubleshooting a CP4/5.
- Station Mode: Routing the CP4/5 to a network with Station Mode is optimal for observatories with lots of mounts using the WiFi, so you can connect your computer to the network and have all of the mounts available. Further, having the CP4/5 connected to a network allows you to protect the CP4/5 with your network security; in this way it is harder for others to potentially access the CP4/5.

CP4/5 Hot Spot (Access Point) Configuration

Your CP4/5 has the capability of acting as a WiFi access point (aka Hot Spot). You can change the settings through the AP GTO Utilities found at <https://www.astro-physics.com/software-updates/>. Hot Spot enabled is the default factory setting for new control boxes. The access point setting will allow you to connect your devices that have WiFi directly to your CP4/5 even without the presence of a wireless router and established wireless network. As Hot Spot, the CP4/5 must then take on some of the tasks and features normally handled by the wireless router. This is why the Hot Spot mode is less efficient than station mode. However, since a WiFi router may not be available at a star party or at some locations, this capability can be quite valuable. See #5 and #6 in "Summary Network Connection Diagrams" on page 16.

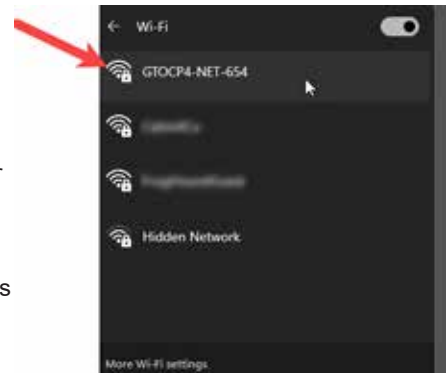


We have already assigned an IP address for Access Point mode. That

address is: 172.31.0.1 This address is hard-coded and cannot be changed by the user. Multiple CP4/5s in the same location will not conflict with each other even though they share the same IP address. This is because each unit provides a unique Access Point, which is basically a unique network. Each client computer is joined to the respective Access Points, unique in their network names – or “SSID”.

If you configure your WiFi connection from a wireless device, start by joining the CP4/5's wireless Access Point network.

1. To connect to the CP4/5 through its Access Point, simply turn on the CP4/5 and wait about 30 seconds.
2. In your wireless device (laptop, smartphone, tablet, etc.), open the device's wireless settings page.
3. Find the network ID for the CP4/5 in your device's available networks list. For a CP4, it will be named: GTOCP4-Net-X where the X at the end represents the numeric portion of the GTOCP4/5's serial number without leading zeros. Older units will have underscores instead of hyphens: ie. GTOCP4_Net_X. GTOCP5's are named similarly substituting 4 for the 5. An example of how this may look is on the right.



4. Connect your device to the network. You will be prompted for a password. The default password that we have provided during our initial programming will be: Xadmin12345 where again, the X represents the numeric portion of the serial number without leading zeros. For the GTOCP4 with the serial number CP4-2468, the password would be: 2468admin12345. For a CP5 with serial number CP5-4321, it would be: 4321admin12345
5. When the WiFi connection is established, you can do things like control the CP4/5 using telescope control apps. For apps that use a port number, like Sky Safari, use port number 23.

It is important that you consider security when using your CP4/5 as an access point. We have provided a default password that is reasonable for getting started. However, you may want to change it to something more secure **since anyone with access to this manual and knowledge of your serial number can determine the factory default password.** Any changes you make to your password will NOT take effect until the CP4/5 is power-cycled.

Passwords - Important Note: Most devices will ask you for the new password when you try to connect after you have made a password change. This is unfortunately not always the case with Windows. Once a Windows computer has made a connection with your original password, it may simply fail to connect instead of asking you for the new password.

To remedy this in Windows 7, click on the little WiFi symbol at the far right of the task bar. This will open a small box with the listing of all the currently available WiFi Networks. Find the CP4/5's WiFi name and right-click on it. Select Properties. In the next window that opens, go to the Security Tab. Here, you can enter your new password where it says Network Security Key. To make it easier, check the box to show the characters - just remember to uncheck it when you are finished. Once the password is entered, click OK. Now you should be able to connect using Windows.

In Win 10, you will access the Network & Internet section of the new Settings App. This can be done by either opening the app or by clicking the same WiFi icon mentioned above for Win 7, and then clicking the settings link at the bottom of the list. First, try connecting to the CP4/5 from the settings page. It will hopefully present you with a request for additional information (this means the password). If it does not, then click Manage WiFi Settings at the bottom, select the CP4/5 from the list and tell Windows to forget it. Now power-cycle the CP4/5, allowing at least a minute or so between power-off and power-on. (Windows needs to lose, and then re-find the new network.) Go back to the main WiFi page and you should see the CP4/5 again. Now this time, it should allow you to enter your password and connect.

Keep in mind that the WiFi module in the CP4/5 can do some router functions, but it is NOT a router-class wireless device. Although it contains a DHCP server, it does not contain a “gateway” to the internet or to other “sub-nets”, and does not contain the network switching function to bridge cabled and WiFi devices.

Network (Station) Configuration



You can also configure your CP4/5 in Network Mode using the AP GTO Utilities. When configured in Network, the CP4/5 can join an existing network like the home networks many of us have. Your existing network has a router that supervises the flow of data within the network. From the CP4/5's point of view, this is by far the most efficient and desirable wireless mode. It is what would be typical for most people who have networks for their various devices like computers, smart phones and tablets. The CP4/5 would then simply “join the network” in the same manner as your smart phone does. See #1, #2, #3, and #4 in “Summary Network Connection Diagrams” on page

16.

Like your other smart devices, once you have configured your CP4/5 for your home network, it will remember the network and the password and will connect automatically every time it is powered up, as long as the network is available. The CP4/5, however, will not remember multiple networks. If you take your system to another location with a different network, It will need to be re-configured to join that network.

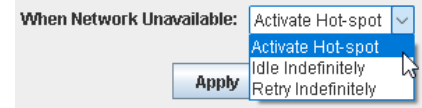
It is assumed that you have a secure home network that you will be joining. Bear in mind that anyone with access to the same network also will have access to your CP4/5.



Change Your WiFi Settings

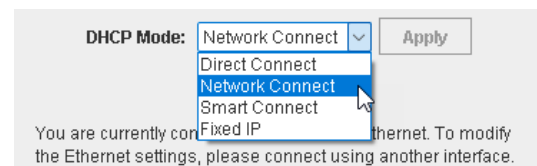
As mentioned earlier, your CP4/5 default WiFi setting was programed at Astro-Physics to be a Hot Spot. In order to configure your WiFi connection to Network Mode via a wireless device, follow the procedure below. You may also make these changes from an Ethernet connection as described in section "Set Ethernet Parameters Using AP GTO Utilities" on page 18.

1. Follow the procedure outlined in the "Access Point Configuration" section using AP GTO Utilities.
2. Find the WiFi section and change the setting to use the CP4/5 in Network Mode. Select a network and enter the network password. It will immediately find your WiFi network and connect. The home page will display the network connection, as well as the IP address and port number for the network connection. Typing the CP4/5 network IP address into a browser window will also open up the home page to verify the connection. Use the displayed IP address and port number for connecting to software that requires it.
3. Most mobile devices will continue searching for a "remembered network" indefinitely, and join the first one it finds. The CP4/5 allows you to specify what the unit does if it powers up and cannot find the wireless network it was previously joined to. Under Advanced Settings you can choose between "Activate Hot-spot", "Idle Indefinitely", and "Retry Indefinitely". Retrying will allow graceful recovery from a network that is temporarily down. Creating a Hot Spot allows the Hot Spot to be created automatically without user reconfiguration, if your equipment is relocated to a place without a network (i.e. in the field).



Ethernet and WiFi Best Practice Recommendations

- If you do not plan to use WiFi, turn WiFi OFF from the WiFi settings tab in AP GTO Utilities. There is no way to break into a wireless connection that is turned off, making your CP4/5 more secure. Furthermore, field use in proximity to large radio telescopes may require that radio communications be disabled entirely. Forgetting to turn off the unit's WiFi could be costly to you and to those paying for time on the radio telescope.
- If you plan to connect the unit Ethernet to your network permanently, set the DHCP mode to CLIENT. This will avoid minor DHCP protocol non-compliances that are required to support both network and Pier-to-Pier configurations simultaneously. This in turn will result in more robust start up handshake.
- If you ONLY use the Ethernet Peer-to-peer, set the DHCP mode to Direct Connect. This will avoid the 30 second wait time during connection.



Updating your CP4/5 with New Firmware

The CP4/5 will require software updates as time goes by. It is important to keep the CP4/5 up to date, because firmware updates usually contain bug fixes and new features that you don't want to miss. Be aware that software updates cannot be done over WiFi, but require a cabled connection - Ethernet, USB or Serial.

New firmware releases will be available through our AP GTO Utilities app, available on the [Software Updates](#) section of our website. Firmware releases are also announced on our forum at this link: <https://ap-gto.groups.io/g/main>. We encourage you to become a member of our forum in order to keep up to date as well as to share your experiences and ask questions. Note that there are two Astro-Physics forums. PLEASE use the ap-**gto** forum for all things mount related. (The ap-**ug** forum is for all things telescope and general Astronomy.) You are encouraged to join both!

Instructions for updating to the latest firmware version are covered in the AP GTO Utilities User Manual. We also have a short tutorial video on updating your firmware via AP GTO Utilities at <https://youtu.be/1M6AmboMJAA> or you can scan the QR code below using your mobile device to go directly to the video



ENCODER OPERATION AND PERIODIC ERROR MANAGEMENT

One of the truly awesome advances in Astro-Physics mount technology was the addition of encoders. GTO mounts have always had small, high-precision encoders on the individual axis motors. These encoders are how the servo measures the distances in slews and governs the speed of slewing, centering, tracking and guiding rates.

The awesome advance came when we added large-diameter, extremely precise encoders to the RA axis of the 3600GTO. The original purpose of the Precision Encoder System was to eliminate periodic error, and these encoders were only installed on the RA. This PE elimination was achieved in a stellar way. The 3600GTOPE essentially needed NO further periodic error correction. Users no longer had any need to run PEMPro to load a curve. In fact, when the encoder corrections are turned on, the CP4/5 turns off the recorded PEM. The Precision Encoder System was an optional upgrade for the 3600GTO, and needed to be installed at the factory.

With the success of the Precision Encoder System on the 3600, we then advanced to Absolute encoders which were introduced in the 1600GTO and then in the 1100GTO. Absolute encoders take the usefulness of the precision encoders a step further by always knowing their exact positions. The Astro-Physics Absolute Encoder System has opened up ultra-precise axis pointing, superior, backlash-free auto-guiding, software-based homing and both fixed and variable limits in addition to near perfect periodic error elimination. The Absolute Encoder System was engineered to be either user installed or installed as an option at our factory.

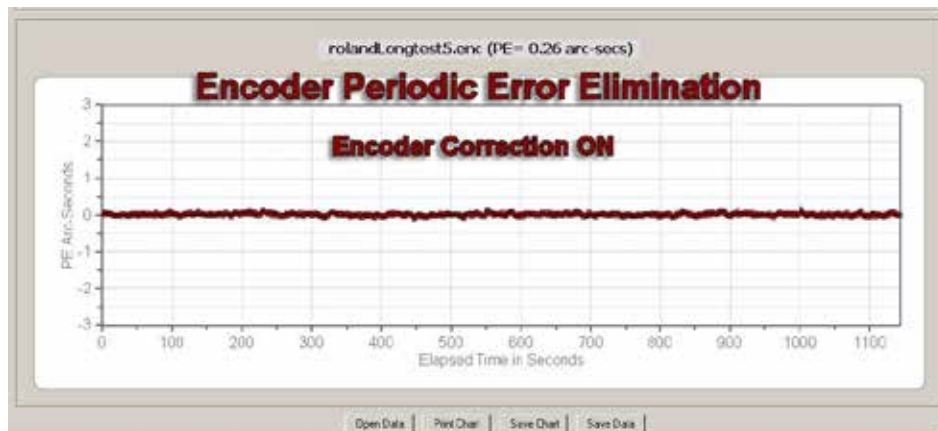
Originally, both systems were developed around a secondary control box that was purchased along with the system to work with the GTOCP3 Servo Control Box. The Precision Encoder System used the GTOELS box. The Absolute Encoder System used the GTOAE box. The GTOCP4/5 control boxes combine the functions of the two separate boxes into a much more efficient, and much faster package.

PEMPro™

We include PEMPro™ software with both encoder and non-encoder mounts. It has other utilities that encoder owners will find useful. You may wish to use PEMPro™ immediately with your new mount to take advantage of the Pole Align Wizard for accurate polar alignment.

For a new NON-encoder mount there is no need to run a new curve. Use the factory generated curve for at least 300-500 hours / 6-12 months before generating a new curve. This provides time for the gears to "run in" and stabilize.

Note: We test mounts with Absolute Encoders and load the curves in their respective control boxes. There is, however, NO NEED for PEM on an encoder mount unless the encoders are disabled for some reason. There is generally no reason to waste time running PE curves. There is also almost never a reason to turn encoders off.



DO THIS FIRST!! When using PEMPro™ to redo your PE curve, it is suggested that you save the existing curve from the control box to your computer before overwriting it with a new curve, just in case an error is made and the old curve is needed to be re-entered.

PEMPro™ remains a pillar of astronomy software. Its role in periodic error management may be diminished for encoder mounts, but for non-encoder mounts it is considered essential for imaging.



GTOCP4 and Absolute Encoders (1100GTO and 1600GTO)

1100GTO and 1600GTO mounts that are equipped with Absolute Encoders do not require a separate control box for operation. The full functionality of the previous GTOAE box has been incorporated into the CP4. This dramatically increases the processing speed of operations, as well as eliminating connection cables.

New Mount with GTOCP4

Simply connect the Absolute Encoder cable from the mount to the top right connector on the CP4 marked "Encoder". It is that easy!

Upgrade from Previous GTOCP3

Transitioning from the CP3 to the CP4 is very easy. All the mount operations are done through the one box. Start by mounting the CP4 in place of the CP3 (which it replaces). Remove the GTOAE box from the mount, along with its cables, and then connect the Absolute Encoder cable from the mount to the top right connector on the CP4 marked "Encoder". It is that easy!

APCC's AE Tab

The AE tab in APCC replaces the AE Utility for most users (the Utility will remain available for those who do not use APCC). The AE Tab only appears on CP4s that are configured for Absolute Encoders, but it appears on all CP5s. The AE tab provides all the functions found in the APAE Utility and adds new features as well. See the APCC Help documentation for additional information.

GTOCP4 and Precision Encoders (3600GTOPE Only)

Note: This section pertains to 3600GTOPE mounts only

3600GTO mounts that are equipped with Precision Encoders on the RA axis do not require a separate control box for operation. The full functionality of the previous GTOELS box has been incorporated into the CP4. This dramatically increases the processing speed of operations, as well as eliminating some connection cables.

It will, however, require a new Encoder cable (CAB36PEF), as the connector on the CP4 has changed from the one that was on the GTOELS box. Similarly, if the mount is equipped with Limit Switches, then a new Limit Switch cable (CAB36LS4) will be needed.

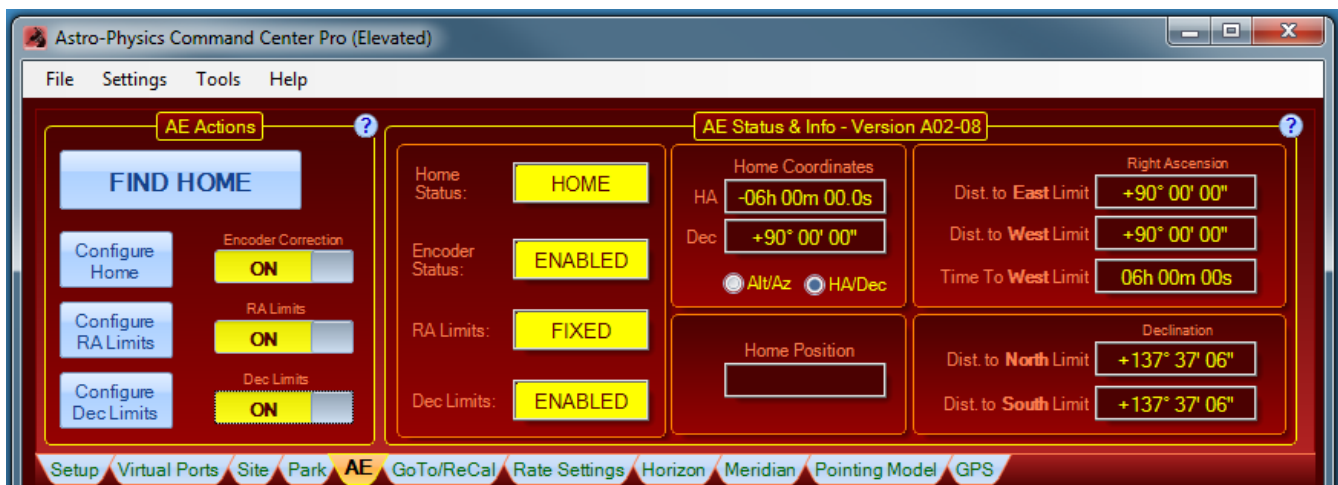
Upgrade from Previous GTOCP3

Transitioning from the CP3 to the CP4 is very easy. All the mount operations are done through the one box. Remove the GTOELS control box from the mount along with its cables. Connect the new Encoder Cable (CAB36PEF) from the rear panel of the mount to the top right connector on the CP4 marked as "Encoder". It is that easy.

If you also have the Limit Switches, attach your new Limit Switches Cable (CAB36LS4) from the rear panel to the middle connector on the CP4 bottom row marked "Aux".

Astro-Physics Command Center (APCC)

If you have a 3600GTOPE mount with the Precision Encoders, the ELS tab in APCC will be active and display. This is the preferred way to manage the settings of your Precision Encoders and Limit Switches, if you have them. Please refer to the

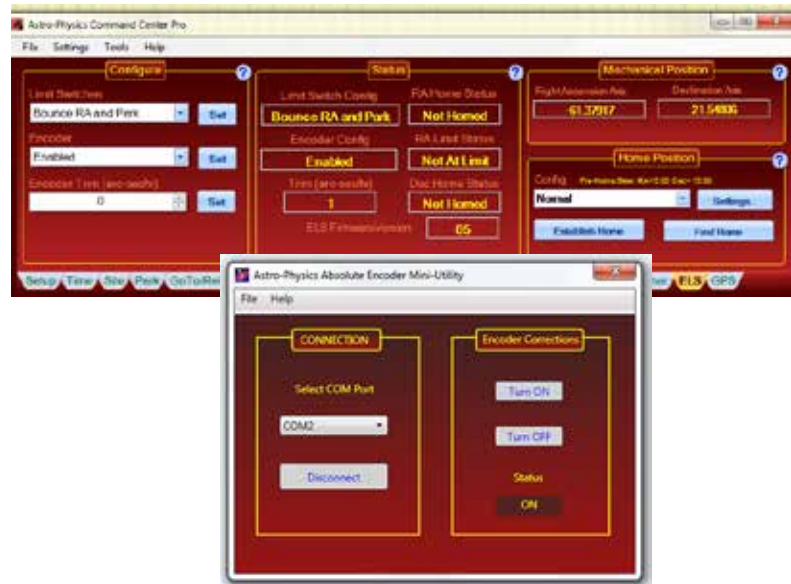


documentation in APCC for more information.

For 3600GTOPE Owners Only: Installation, Settings and Operating Instructions for the Limit Switch System (36LSS) and Precision Encoder System (on the 3600GTOPE), dated March 27, 2013

This document has not yet been updated for the GTOCP4 and the present cable arrangement. Please note the following: the vast majority of the information is still relevant and current. Simply adapt the procedures by substituting the GTOCP4 for all functions. We do not have any plans to update this document in the near future.

If you do not have this document, please contact Astro-Physics.



UNDERSTANDING THE GERMAN EQUATORIAL SERVO LOGIC

To avoid some of the more common operator errors that people make, we will attempt to describe and explain some important aspects of the servo logic that govern the movement of the mount as you perform the various operations involved in a night of astronomy. The discussion that follows will address several areas of the GTOCP4's control logic and hopefully tie those areas together.

We have divided the following discussion into two major sections. The first will deal with subjects of a more general nature that pertain to German Equatorial mount basics. Apart from the Encoder and AP command language discussions, these topics will apply to most any German Equatorial mount.

The second section will deal with the more complex problem of the German Equatorial geometry as related to the meridian and the pier, and to safety. Getting this right is the key to safe operation of your mount. It also presents some of the more difficult conceptual challenges: A list of contents for this section is presented below

- Important Concepts of a more General Nature
 - Initialization and Shut-down
 - The role of time and location data in the servo system
 - Non-sidereal tracking and variable tracking rates
 - Understanding the auto-guider port inputs vs. timed moves
 - Understanding Encoders
 - A brief discussion of the Astro-Physics Command Language
- German Equatorial Geometry, the Meridian, the Pier, and Safety Limits
 - The 360° right ascension axis
 - The concept of "pier side" as it relates to the servo
 - How GoTo slews are performed
 - Sync vs. Re-Calibrate
 - Safety Slew Logic
 - The special cases of *Tracking Past the Meridian* and *Meridian Delay* or *Meridian Advance*
 - Limits and More Limits

[This major section is still under construction. As parts of this section are completed or more fully developed, the PDF file on the website will be updated. Please check the website for the latest version of this document.]

Important General Astro-Physics GTO Concepts

Initialization and Shut-down

Initialization functions are probably the most important subset of the group of primary control functions. It is vitally important that your mount be properly initialized when it is first powered on. There is nothing magical or mysterious about proper initialization, but it is simply the process that allows the mount to recalculate its position and commence operations. Initialization should only be performed once per power cycle when the mount is first powered ON. Full initialization should not be repeated while a mount is powered on because it accesses information from the last power-down to determine its current position. That information is no longer valid in the middle of a session.

For a proper full initialization, the mount must know its current location on the earth - it's latitude and longitude. The last location entered will be remembered through a power-cycle, so this only needs to be sent if your location has changed. The same holds true for the GMT offset. Finally, current local time and date are also required. Time and date, however, need to be supplied afresh each and every time the mount is powered on. Time and date should be supplied by the control device that is being used for primary mount control. Once the current local time and date have been sent to the mount, the initialization command uses the entered data along with the saved data from the last shutdown and calculates the current pointing position. It also un parks the mount and starts normal operations in motion.

For permanent setups, the mount will accurately calculate its current pointing position when initialized. You DO NOT need to "home" the mount or perform some kind of a star-sync to get started. Portable mounts and mounts that have been moved via loosened clutches will require an additional step to reestablish initial pointing. For this, we have a set of pre-defined park positions that are easily recreated. A star-sync on a single star can also be used to reestablish pointing on portable setups, but starting from a defined park position is still recommended before the star sync to establish orientation.

Because of the design of the Astro-Physics Servo System logic, no special shut down procedures are required. Although many people choose to park the mount at the end of a session, this is entirely unnecessary from the mount's point of view. If you wish, you can simply "pull the plug" and leave the mount where you left off. When you power back on, a proper full initialization will restore the pointing without any further ado. Park positions can be handy, but they are not a requirement. With the Astro-Physics system, think of "park" as a state where the drive motors are de-energized - not a "place" where the mount goes. The park positions are simply convenient coordinate positions to use before entering that "parked" state.

The keypad, the AP V2 ASCOM driver, APCC and PulseGuide all fully handle all the initialization and shut-down tasks discussed above. They do so in a manner that is simple, automatic, and virtually fool-proof. Other software can also perform these tasks, but Astro-Physics cannot guarantee that they do so correctly all of the time.

The role of Time and Location data in the Servo System

There seems to be an obsession among astronomers with accurate time and location data. Many of our customers use *Dimension4* or some other similar time server to keep their computer clock accurate to the millisecond. GPS units are employed to precisely nail down time and location data down to the second. However, for most of your mount's operation, accurate time and location are really somewhat irrelevant. You don't want to be way off, but you probably don't need to be dead-on either. Here are some thoughts on time and location as it applies to the Astro-Physics servo system.

- The obsession with time and location accuracy probably comes from people who started with Alt/Az mounts. When a mount is set up as an Alt/Az mount, it must convert its native Alt/Az system to RA/Dec for celestial viewing. To make this conversion, the more accurate the time and location data, the more accurate the conversion. Time and location are critical to the Alt/Az astronomical mount, but not to the German Equatorial.
- Time and location come into play during initialization as discussed above. They are necessary for calculating the current RA value at start-up. Precise time at power-off followed by precise time at the following initialization will lead to a more accurate calculation of the RA. However, think about it: How important is to-the-second accuracy of your first GoTo of the evening? If your first target is off by 30 seconds of RA, or even a minute, won't it still be within the field of view? After centering and doing a ReCal, the time relevance is over.
- Time and location are used to determine the meridian (aka z-value, LST, overhead hour, etc.). They are also used to then determine the horizons. Again, the more accurate time and location are, the more accurate the meridian and horizon values will be. As above, the question to ask is how important is it if the calculated meridian or horizon is off by a little bit. You would probably never know it during a normal observing or imaging run.
- Time and location accuracy is VERY important for satellite tracking, and for astrometry. If you are using APCC's Horizons program, or you are doing research on NEOs, by all means, use a time server and GPS!!
- Once you are calibrated on a star, apart from determining the flip-point, precise time and location play almost NO ROLE WHATSOEVER in normal GoTo slews or pointing accuracy.

Many client software programs like planetarium programs and observatory control programs will demand that the mount time matches the computer clock. This is necessary for coordination among the programs. However, if you are away from an internet connection or GPS unit, and your computer clock is off from the atomic time in Boulder, CO by a little bit, you really shouldn't worry about it.

Non-sidereal Tracking and Variable Tracking Rates

A sidereal tracking rate is a rotation rate of the right ascension axis that is precisely calculated to counter the exact rate of the earth's rotation. This sounds simple enough, and the tracking rate of the Astro-Physics Servo System is remarkably accurate. However, as usual, there is a catch.

We really don't care so much about mathematical equivalence. What we want is for the star or object to stay precisely centered in our field of view. This rarely happens, even with a perfect sidereal tracking rate. The reason is that although both the earth and the mount are moving in perfect sync, **the sky does NOT APPEAR to also move at that rate**. The reasons for this are many in number. The apparent motion of the sky is affected by:

1. The accuracy of the polar alignment
2. Atmospheric refraction
3. OTA flexure, mirror shift, focuser shift, and other mechanical issues with a complete optical train.

In addition, many targets are not stationary in the sky over the timeframes typical for observation and imaging. Planets, comets and asteroids are typical examples. Satellites are an extreme example of a non-sidereal moving target.

To address these issues, the AP GTO Servo System includes a wide range of custom tracking rates in increments as small as 0.001% of sidereal or 0.00001x, equivalent to 0.54 arc-seconds per hour! The range is essentially from -1000x to +1000x sidereal. Software like APCC can set these rates as needed in each axis to keep almost any object perfectly centered.

Understanding the Auto-Guider Port Inputs vs Timed Guide Moves

The CP4/5 includes a standard ST4 style RJ11-6 auto-guider port. This was the way auto-guiding was done for many years. The auto-guider relays close the circuit for the respective move to start the correction, and then open the circuit to stop the correction. Internally, the CP4/5 **commands** motion when the circuit closes and then **commands** a "quit" when the circuit opens up again. In a practical sense it is an on / off switch, but technically it is a pair of internal software instructions. Accurate auto-guiding is dependent on perfect timing of the closing and opening of the guider relays, which in turn, is dependent on external software in an external device. The weakness in this system comes from possible timing issues that may cause over or under correction. It is, however, simple, and usually pretty reliable. It is the method used for stand-alone auto-guiders used with DSLRs or similar imagers that do not require a computer.

If a computer is controlling the mount, it is recommended to select the option to have the software send timed move commands. Timed move commands are exactly what they sound like: commands to move for a specified length of time. They do not require a precisely timed move or quit command to ensure an accurate correction move. The precise timing is a part of the command itself. For example, a 1 arc-second move would be a command to move for exactly 67 milliseconds at 1x. Timing is NOT affected by outside demands on computer resources because the computer isn't doing the timing - the CP4/5 is. For additional information on auto-guiding, see "Auto-guiding Tips and Notes" on page 59 ..

PulseGuiding and pulse-guiding - Two Completely Different Meanings

Now that we have discussed both variable tracking rates and auto-guiding, we need to clear up an unfortunate bit of terminology. In the days before ASCOM controlled auto-guiding via timed moves (for AP mounts), Ray Gralak of Sirius Imaging™ wrote a wonderful program called PulseGuide™. PulseGuide™ had many great features, but it got its name from its method of creating custom tracking rates by pulsing move and quit commands to create the effect of a custom rate. It allowed users to accurately track the moon, asteroids, comets and other non-sidereal objects before we at AP developed our smoother, servo-controlled, custom tracking rates.

When ASCOM and other software developers writing drivers for ASCOM compliant programs and mounts developed their auto-guiding packages, they used the name "pulse guide" for guiding by commands as opposed to guiding via autoguider relays. This has led to quite a bit of confusion for Astro-Physics customers. (Other mounts could not use Ray's PulseGuide™, so it was not an issue for anyone else.) It isn't really a problem as long as YOU know the difference and don't confuse the two. It also appears that most ASCOM compliant software and drivers have now switched to the more correct *auto-guiding*.

Understanding Encoders

There are encoders, and then there are encoders. Things can get confusing because there are actually 3 different types of encoders used on Astro-Physics mounts, and the third type is further divided into two sub-categories based on the mechanical mounting method. This section will briefly describe the differences, and it will attempt to clarify both the advantages and the limitations of each.

- 1. Motor Shaft Encoders.** These are the original encoders that have been a part of the Astro-Physics GTO Servo System since day-one. These encoders attach directly to, and rotate with the motor shaft, and when combined with the system's gear reduction they provide a theoretical resolution of 0.05 arcseconds. Their strengths are their simplicity, reliability and comparatively low cost. Their one major weakness is that, being attached directly to the motor shaft, they have an entire gear-reduction train between them and the sky. This means that the theoretical 0.05 arcsecond resolution can not be achieved in the sky.
- 2. Precision Encoder System: 3600GTOPE ONLY!** The Precision Encoder System was Astro-Physic's first foray into direct, axis-mounted encoders. The encoder employed was an incredibly precise incremental encoder attached directly to the gear wheel of the 3600GTO RA axis. The purpose of this encoder was to eliminate periodic error (PE) by putting the mount's sidereal (or lunar, solar, or custom) tracking into a precise feedback loop that instantly corrected any subtle deviations caused by the normal periodic error found in any gear drive system. The 3600GTOPE was developed during the reign of the venerable GTOCP3 control box. At its original inception, this system required a secondary control box - the GTOELS to control both the encoder loop and to also add the capability of limit switches and home switches on both axes. 3600GTOPE owners can now retire BOTH of those older control boxes and replace them with a single GTOCP4. Although this system was incredibly effective at eliminating PE, it could not be used for positional accuracy since the encoders were not indexed with exact positions.

- 3. Absolute Encoders.** Absolute Encoders represent the pinnacle of axis control. They have incredible precision like the incremental encoders used in the 3600GTOPE, but add absolute, positional indexing so that the encoder-brains always know their exact location on the encoder ring. This allows for the precise coordinate matching that our mounts can now offer. Ultra precise coordinate matching doesn't just benefit GoTo pointing. It effectively eliminates backlash in guiding. With these encoders, a commanded 1/4 arcsecond guide move (17 milliseconds at 1X sidereal) will correct itself to move the axis exactly 1/4 arc-second, regardless of the direction of the move. Additionally, the increased positional accuracy of the two axes makes for much more accurate modeling with external software like APCC.

We further divide our Absolute Encoder mounts into two categories. The two categories really have nothing to do with the actual encoders. They instead are based on how the encoder rings are interfaced with the mechanical components of the axis.

- A) Non-clutch-aware Encoders as found on the 1100GTO and 1600GTO.** Owners of 1100GTO and 1600GTO mounts with Absolute Encoders have been duly warned countless times, that moving the mount with the clutches will invalidate the pointing, home and limits until they are re-established using APCC software. These encoders were tied to the worm-gear-wheel, and were dissociated from the axis whenever the clutches were employed to move.
- B) Clutch-aware Encoders as found on the Mach2GTO.** The Mach2GTO heralded a redesign of the entire worm-wheel + clutch + encoder + axis system so that the encoder ring moved with the axis itself, and the clutch merely disengaged the worm-wheel gear. This allowed the Mach2GTO to be calibrated at the factory for its entire life. The Mach2GTO, therefore, knows exactly where it is pointed from the moment it is initialized, even if you have used the clutches to move the mount half-way around the circle of motion.

The Absolute Encoder Systems are pretty amazing, but there are still things to bear in mind:

- NO encoder system by itself can guarantee perfect pointing or tracking all over the sky.
- They can't fix poor polar alignment
- They can't compensate for refraction without additional software input.
- They won't fix instrument flexure, mirror shift or other mechanical issues in the optical train.
- They become most useful when used in conjunction with modeling software to deal with the issues listed above.

A Brief Introduction to the Astro-Physics Command Language

The key to all operations of the Astro-Physics GTO Servo System is the command language. This language is a collection of simple ASCII (text) commands that provide all of the necessary information for the mount to slew to the target you have selected at the slew rate you have chosen. Information in these commands tells the servo where it is located on the Earth's globe, and allows it to calculate the exact RA and Dec positions of the meridian and horizon at any given point in time.

There is really nothing magical about the command language. It is remarkably simple and straight-forward. The magic all takes place inside the micro-controller of the CP4/5 which takes those commands and works its magic with them. It is worth noting that the command language had its origins in the original Meade LX200 command set, in an attempt to promote industry-wide standardization. Since its original development, it has grown way beyond this original set, and the hoped-for standardization never happened.

We have published a major subset of these commands in the Support Section of our Website. The published command set has everything a user could need to write software to control the mount. It also has some helpful hints and guides for making best use of the set. Included are suggested start-up routines, shut-down procedures and general operating suggestions.

An Important Command Change in VCPx-P02-xx and Later

Starting with GTOCPx firmware VCPx-P02-01, changes were made "under the hood" for setting standard button and slew rates. Software like APCC or the AP V2 Driver already accommodate these changes in their current versions. However, there is one important exception that remains at the time of this writing: the AP GTO Keypad. Version 5 of the keypad has been updated and displays these rates correctly. Version 4.19.5 of the keypad is also updated to support this. However, version 4.19.3 or earlier of the keypad will see a discrepancy in the displayed versus the actual rate of movement for the top 2 button rates. This is due to the insertion of a 200x button rate into the CP4/5 firmware. Slew rates, tracking rates and guide rates are not affected. More information can be found in the Support Section of our Website.

German Equatorial Geometry, the Meridian, the Pier, and Limits

There are two major families of astronomical mounts for instruments under 2 meters in aperture, although some other designs do exist. The two design families that we see in virtually all amateur, and most small to moderately sized

professional systems are the Altitude–Azimuth (Alt–Az) and the Equatorial. The Equatorial family is further divided into the Equatorial Fork and the German Equatorial mount. All Astro-Physics mounts are of the German Equatorial type, although our servo systems and GTOCP4s are found on some Equatorial Forks as well.

The common feature of all equatorial mounts is that they have one axis that is parallel to the earth's axis of rotation. This is the Right Ascension or RA axis. Both types of equatorial mounts must have their right ascension axis precisely "polar aligned" - the name for making the axis perfectly parallel to the earth's axis of rotation. They then have a second axis that is precisely perpendicular to the RA axis called the Declination axis. Theoretically, this two-axis system allows equatorial mounts to point anywhere in the sky.

Equatorial forks can carry scopes with huge diameters, but are limited in the physical length of the instrument they can hold by the depth of the fork. Most Equatorial Forks carry scopes of one of the more compact compound reflecting varieties. German Equatorials, on the other hand, can carry scopes of far greater length. They can carry all kinds of optical designs, but are especially appropriate for refractors and long focal length Newtonians. They are also perfectly happy to carry short, stubby compound reflectors making them the more versatile of the two designs. The following discussion will be directed toward the German Equatorial mount.

Geometrically speaking, a German Equatorial mount starts at ground level with a vertical pier. The height of the pier is based on two factors. Most important of these is the length of the instrument. The longer the instrument, the taller the pier must be. The taller the pier, the larger its diameter should be to maintain rigidity. The other factor is how the system will be used. Imaging systems should be as short as practical for rock-steady operation. Visual systems need to accommodate the observers at the eyepiece. No one wants to lay on the ground to look through an eyepiece!

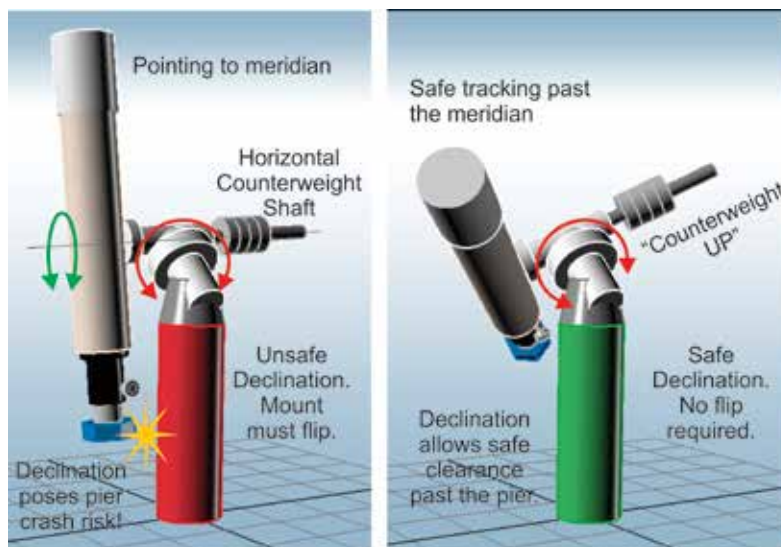
The RA axis is mounted on top of the pier by means of a polar fork assembly. This assembly has provision for precisely adjusting the axis' polar alignment. In a sense, the polar fork assembly acts as an Alt–Az mount for precisely aligning the RA axis. As mentioned before, the Dec axis sits at a precise right angle to the RA axis. The telescope is on one end of the Dec axis, and it is counterbalanced by a shaft with counterweights at the other end.

So at this point you may have two questions:

1. Why is this important to the operation of a CP4/5 control box?
2. Why is there more discussion above about the pier than there is about the mount?

The answer is really quite simple: The biggest challenge in developing a control system is to keep the telescope from crashing into the pier. The rest of this section's discussion will deal with the complexity of preventing these potential crashes while simultaneously NOT inhibiting the functionality of the mount where it is safe. This sophisticated control system is a hallmark of the Astro-Physics GTO Servo System. It has been since the days of the first GTOCP1 control box, but the GTOCP4 and 5 take it to another level.

When an RA axis has the telescope pointing up at the meridian (the best place to acquire images at any declination), it can be in a dangerous position. When pointing anywhere along the meridian, the counterweight shaft will be horizontal, pointing straight out to the east or west. If the declination is such that the focuser end of the scope is approaching the pier, a pier crash can result. However, at safe declinations, there is no worry about the pier, and you can safely track into a counterweight-up position, or you can start your image on the other side in a counterweight-up position and finish in a more normal orientation.



The 360° Right Ascension Axis

When Astro-Physics decided to start building German Equatorial mounts many years ago, one of the decisions made was whether to put hard stops in place to prevent going past the meridian without flipping the pier side, or to allow movement past the meridian. Astro-Physics is located in the northern midwest of the US. Our summers are spent enjoying the beauties of the summer Milky Way. A majority of the summer prizes are far enough to our south that pier clearance is no longer an issue. So for us, it made a lot of sense to allow the mount to simply keep tracking past the meridian.

With that in mind, we did not include any sort of mechanical stops. The Right Ascension of an Astro-Physics mount can

therefore rotate through the full 360°. This was awesome *back in the day* when there was no remote operation. A user would have been present at the mount to ensure the safety of the course the mount would track across the night sky. Life for the amateur astronomer was simpler then.

These days, remote imaging or at least unattended imaging sessions are the norm. It is therefore imperative that the control systems provide the safety in operation that was formerly handled by an on-site astronomer. Astro-Physics mounts with the CP4/5 control boxes use a number of strategies to provide both the capability to go 90° past the meridian (aka $\pm 180^\circ$ on either side = 360°), and to keep valuable instruments riding atop the mount safe and crash-free.

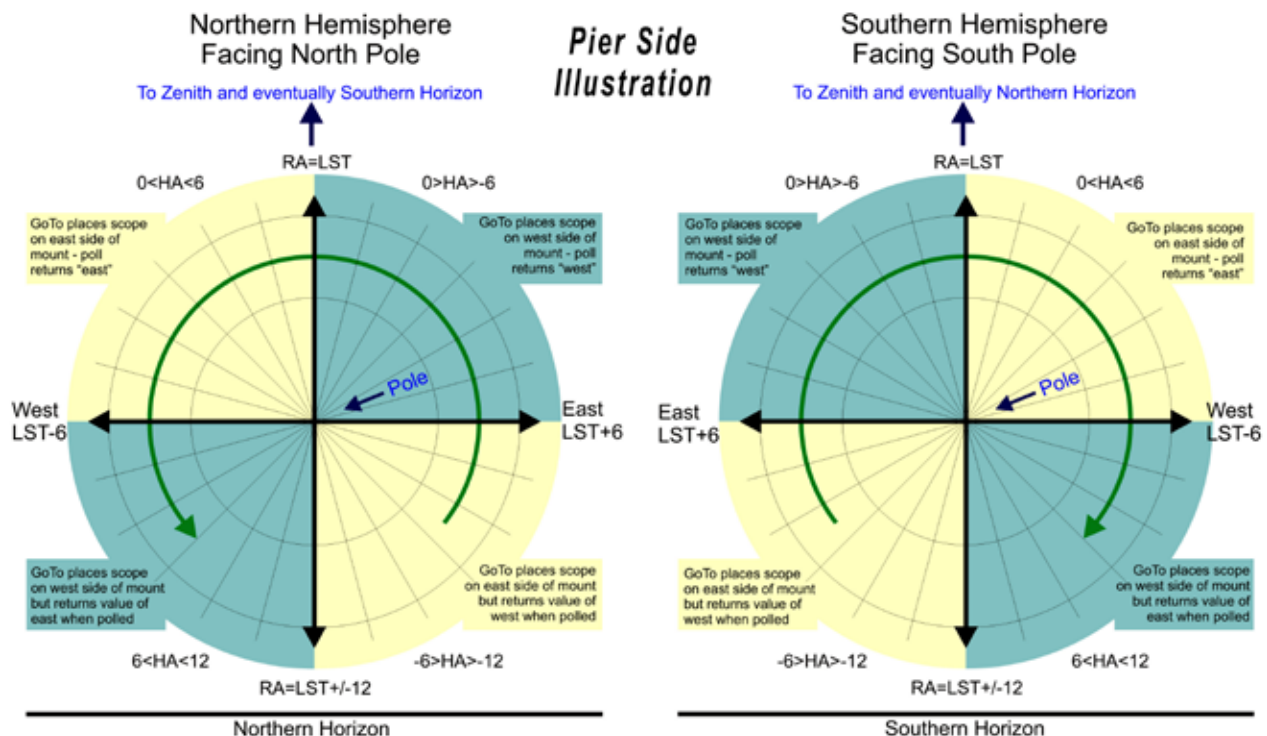
The Concept of “Pier Side” as it relates to the Servo

Pier side is something that would seem intuitively obvious at first glance, but it ends up getting confusing to many people. The conventions and rules used for pier side are NOT the invention of Astro-Physics, but are standard through the industry and are mandated by ASCOM as well. Pier side gets confusing because the correctly reported pier side can differ from what your eyes are telling you if you look at the mount. The Astro-Physics reference Park 1 position is the classic example of this. We have fielded countless support calls from frantic customers who were convinced that their mounts were lost because the scope was most assuredly on the west side of the pier in Park 1, and yet the servo (and the control software) were all reporting a pier side of East!

The reason for the confusion is that pier side has nothing to do with right ascension or hour angle. It is entirely a function of Declination. The problem is that for any physical position of the mount's RA axis there can be two declination values. This is apparent near the pole. Think of a Dec coordinate of 80 degrees. Without moving the RA axis, you can slew the Dec from 80 to 85; cross the pole at 90; and then keep on going through 85 and back to 80. The two pointing positions are 20 degrees apart, yet both have the same declination, and both share the same physical position of the RA axis. To distinguish the two positions, we do two things: 1. We report one position as having a pier side of East, and the other as having a pier side of West. 2. The RA value (and therefore also the hour angle) are different by exactly 12 hours.

In terms of the pier side, the reported side is what one would consider the "normal" side for a mount where the declination was on that particular side of the pole. Most observing is done with the scope pointing above the pole, so that is considered the normal side. For example:

1. Start with the mount in the classic German Equatorial pose (the Astro-Physics reference Park 3 - scope pointing at the pole and counterweight shaft pointing down).
2. Rotate the declination toward the east (clockwise from above in the northern hemisphere, counterclockwise down



under).

3. You will immediately see that the "normal" orientation for the RA will be to rotate it to the west placing the scope on the "West" side of the pier.

4. Likewise, if you rotate the Dec. to the west of the pole, you will want to take the scope to the east side.
5. Things only get backward when you are pointing below the pole as you do in the AP reference Park 1 position.
6. To see this, take a mount in the "normal position, and take the RA axis across the meridian without moving the Dec. You will see that the scope is pointing below the pole.

The illustration on the previous page will hopefully help to clarify this. If it is still fuzzy, the easiest way to really grasp the concept is to work with a mount and scope and actually run through the steps above.

How GoTo Slews are Performed

GoTo slews are among the most basic of modern mount functions. A good GoTo system like the Astro-Physics GTO system allows the user to simply pick their target and in effect say: "Go here!" The mount then whirs up to slew speed and moments later, the desired target is in the field of view.

The main thing to understand in this brief discussion is that a GoTo slew requires three components: two coordinates and a slew command. The coordinates are normally right ascension and declination, or else they can be altitude and azimuth coordinates. They cannot be mixtures of coordinate reference systems as in right ascension and altitude. They also must be in hexagesimal format: HH:MM:SS.ss or sDD*MM:SS.s. Catalog names such as Messier #27 or NGC 5139 have no meaning to the control box.

When the control box receives a set of coordinates and a GoTo slew command, it must perform a set of calculation gymnastics. It must evaluate the current position, the current RA of the meridian, and the target destination coordinates to answer the question: To flip, or not to flip? It must evaluate this in light of any meridian delay that the user may have set, and must determine whether a safety slew is required (see below). After its stint as a calculation gymnast, it changes careers and becomes a conductor as it orchestrates the rotation of the motors in perfect tune with the motor encoders and in harmony with the Precision or Absolute encoders if they are present in the system.

Sync vs. ReCalibrate

In days past, the distinction between Sync and ReCalibrate was one of the most critically important sections of both this manual and the Keypad manual. The reason is that the **FULL** sync established both the pointing **AND** the orientation with respect to the pier. Getting that wrong could spell disaster!

Today, the importance of that distinction has been greatly reduced by better design of the external software used to interface the user with the mount. The keypad, APCC, the AP V2 ASCOM Driver and most other software in use today follows this simple set of rules:

- Don't worry about the name. Just follow the rest of these rules.
- **ONLY** use a full Sync command when restoring the mount's position from a pre-defined AP park position. This is generally only required if the mount has been moved via the clutches.
- **EVERY** other calibration or *sync* is performed using the ReCal command. We don't care what you want to call it!

If you are interested in the full story of Sync vs. ReCal, we suggest you go to the Advanced Features section of the [Keypad v. 4.19.3 manual](#).

Safety Slew Logic

Safety Slew Logic is designed into the GTOCP4 Control Box firmware and functions with all of our GoTo mounts. Its purpose is to protect your scope from a possible crash into the pier when slewing out of some counterweight up positions.

Our mounts have the unique ability to track past the meridian while imaging, such that the counterweight will move higher than the scope (counterweight up). Normally when a GoTo slew is made, both the RA and the Dec. axes begin moving simultaneously. However, there are some counterweight up areas from which a slew with the Dec. axis moving simultaneously with the RA axis would cause the scope to hit the pier before the RA axis can take it safely into a counterweight down position.

The Safety Slew Logic knows when the mount is in a counterweight up position and will initiate an RA only slew to bring the mount back into the counterweight down safe zone where it will pause momentarily. The mount will then automatically make a second slew using both axes simultaneously to continue to your object.

Conversely, when using Meridian Delay to begin with a counterweight up imaging session, the reverse happens. A dual-axis slew will take place until the meridian is reached where the RA will stop and the Dec. axis will continue to its position. When the Dec. has reached its position and stops, the RA will make its second slew to the final position.

It is even possible that a three part slew may take place if you are slewing from a counterweight up position and into another counterweight up position.

Having this firmware logic in the GTOCP4 control box means that it will work regardless of whether you are using computer software or the keypad to control your mount.

Tracking Past the Meridian

As discussed earlier, German Equatorial mounts have the characteristic that they require a "flip" at the meridian in order to follow an object in its nightly journey across the sky. A visual observer will not be overly inconvenienced by the mechanics and delay of the flip; however, this becomes much more complicated for an imager! Enter Astro-Physics mounts!

Depending upon your chosen object's position, this all becomes unnecessary with an Astro-Physics mount. Tracking through the meridian is a unique function of AP mounts. Most objects that are located 20° to 30° or more south of the zenith (northern hemisphere) can be imaged without interruption from horizon to horizon. The mount will happily track with the counterweights high in the air.

Unlike with other manufacturer's mounts, imagers using Astro-Physics mounts will not need to:

- Stop an imaging session; often with the loss of a 20 to 30 minute sub exposure that has reached 19 or 29 minutes
- Flip the mount and reposition cables
- Rotate the camera so that you can use the same guide star
- Re-center the object to your desired composition
- Re-acquire the guide star and then re-calibrate it
- Begin the new imaging session
- Whew!!!

Remember, it is the GoTo slew that will flip the mount...not tracking!

Please note that with this wonderful feature comes the responsibility of preventing your scope and camera from striking the pier when imaging an overhead object or one that is closer to the pole. Fortunately, we have the APCC software that safeguards against this mishap! A custom contoured Meridian Limits outline can be created with APCC that keeps everything safe and sound.

Meridian Delay or Meridian Advance

The **Logical-Meridian Adjustments (Delay and/or Advance)** are one of the most powerful and useful features of Astro-Physics mounts, especially when used in conjunction with the Astro-Physics Command Center (APCC). Logical meridian adjustments can also be used in the AP GTO Keypad and the AP V2 ASCOM driver. They open up the possibility of imaging on both sides of the meridian WITHOUT wasting time on a pier flip at declinations where the scope will not strike the pier.

The AP V2 ASCOM Driver, and the mount's keypad each have the ability to set a meridian delay which controls the flip point of the mount. Starting with APCC and the Rev. "S" firmware in 2012, the method for employing this feature has been changed in the GTO Servo Control Box. The delay is no longer accomplished by "fooling" the clock in the servo. It is now an independent function with associated commands that does not change the mount's time.

The ability to work past the meridian into the west, or to start ahead of the meridian in the east has always been a hallmark of Astro-Physics mounts. Both the early keypad and the now obsolete PulseGuide program provided the ability to work beyond the meridian. However, with both of these control methods, the user would want to be present at the mount for safety. APCC created meridian limits that allow the user to safely exceed the meridian without hovering over the mount to protect the scope and imaging equipment from a potential crash. Remotely controlled observatories can now also safely image through the meridian (where declination permits it).

Limits and More Limits

There are basically five types of limits in Astro-Physics GTO mounts (listed in chronological order of when developed).

1. **APCC Meridian Tracking Limits** - limits you set up in APCC that map out variable limits based on declination

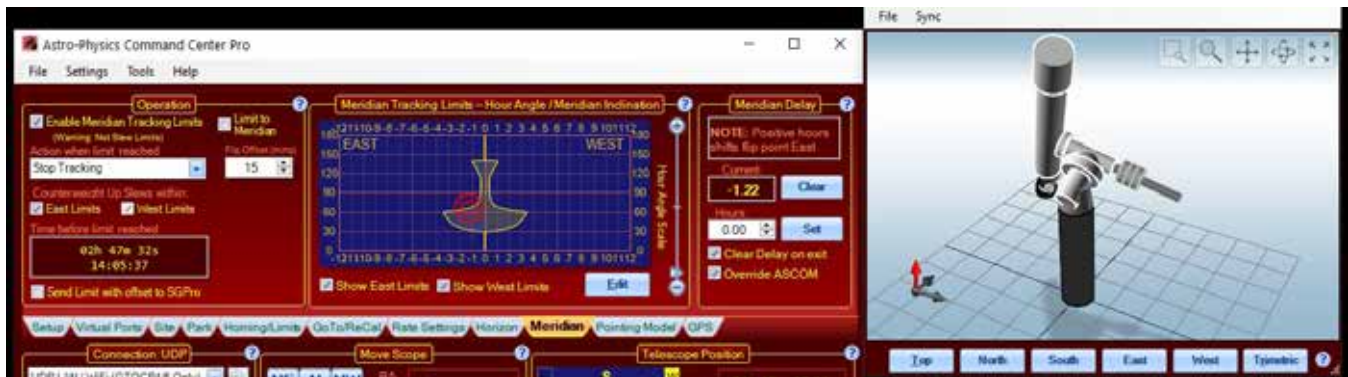
2. **Mechanical limit switches** - hardware switches - available on the 3600GTO.
3. **Encoder Limits** - limits governed by software in conjunction with absolute encoders
 - A) **Hard Encoder Limits** - remembered through a power-cycle
 - B) **Soft Encoder Limits** - dynamic limits that temporarily supersede Hard Encoder Limits - NOT remembered through a power-cycle.
4. **Keypad Limits** - software limits inside the CP4/5 - settable with the keypad
5. **Hard Limits** - aka hard stops. Physical barriers that stop the mount mechanically - only on the Mach2GTO

Earlier GTO mounts did not have any limits. Back when the first GTO systems were introduced, users were generally at the mount while it was in operation. The ability to go past the meridian was considered a top feature of AP GTO mounts. Since then, however, the situation has changed. People are imaging remotely, whether it's just in the back yard from inside the house, or half-way around the globe. The imaging systems on the backs of telescopes can cost thousands, or even tens of thousands of dollars, and unattended equipment safety became much more important and much more difficult.

Limits are conceptually simple. Limits stop motion in the mount. That's it. How they do that, and how you can recover from an in-limit state can get a bit more complex!

1. APCC Meridian Tracking Limits

These limits, when properly configured, allow you to track safely past the meridian up to the limits you set based on your unique instrument package. In addition, they allow you to begin an image ahead of the meridian by safely slewing you into a counterweight-up position to start an imaging series that can then simply continue through the meridian. However, like any powerful feature, you **MUST** understand how the meridian limits work. It is vital that you understand what they



CANNOT do as well as understanding what they can do!

APCC adds some powerful new capabilities. Three of these new features apply to West Meridian Limit points. The West limits come into play when a scope's counterweight is in the up position (scope under the mount) and the scope is pointing West of the meridian. This normally occurs when the scope is allowed to track past the meridian. The fourth feature below applies to east meridian limits and provides a unique and powerful tool for safely starting images in the east from the east side (counterweight up) using the meridian advance.

- Instead of just a single meridian limit for all declinations, you can configure arbitrary limits at different declinations. This is useful because at each declination there can be a different hour angle at which the telescope may risk contacting the pier. In declination regions where the telescope can theoretically go the full 6 hours past in the west, the meridian limits can establish horizon tracking limits for the practical distance past the meridian where you can reasonably continue to work. Likewise, in the east, they can set the practical horizon ahead of the meridian where you can reasonably start an image.
- When a meridian tracking limit is reached, you can specify the action that will happen: Tracking can be automatically stopped; the scope can be "flipped"; or the scope can be parked.
- Meridian tracking limits can also be used to create a safe zone around your pier if it interferes with even reaching the zenith, similar in a way to the safe zone in the Astro-Physics GTO keypad. The keypad's safe zone, however, is a GoTo slew limit, rather than a tracking limit. Remember that an APCC Meridian Limits safe zone that does not allow the scope to reach the Meridian must be stopped or parked. It cannot be flipped.
- When east limits are properly configured and employed, slews to targets within the east limits will automatically be made using meridian advance and APCC's safety slew logic to place the system in a counterweight-up position with the scope on the east for uninterrupted imaging through the meridian. The safety slew logic ensures that all mount movement with the counterweight up is with the RA only. Using the East Limits, the scope can image through the

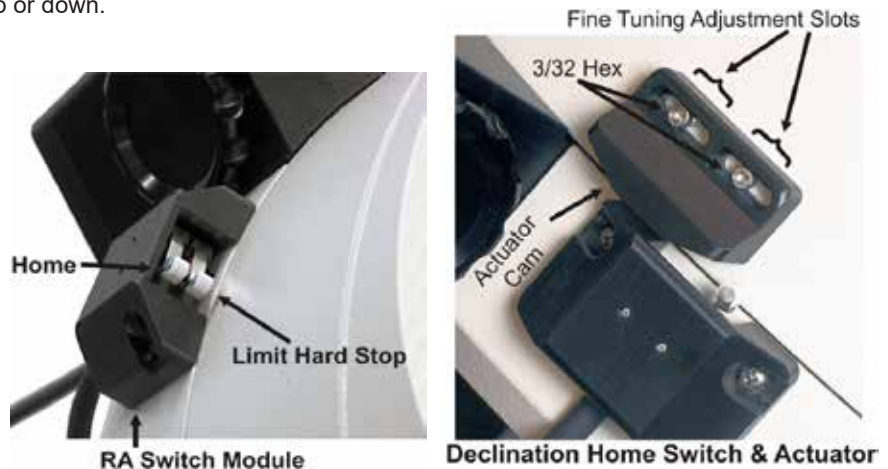
meridian and on for another 6 hours before the telescope reaches the horizon.

A Pier Flip button has been added to the APCC software that will allow an automatic flip to the other side of the mount when the button is clicked. Provided that you are within the safe limits, you can flip and view the same object from either side of the pier...either counterweight up or down.

2. Mechanical Limit Switches

As the first non-portable observatory mount in the Astro-Physics lineup, the 3600GTO was offered with optional electro-mechanical limit switches. The switches could be wired into simple kill systems by the user, or the preferred method was the GTOELS-based Limit Switch System (LSS). The full functionality of the ELS Limit Switch System is preserved in the GTOCP4.

The switches on the LSS are wired normally open. An actuator passing over the switch closes the circuit causing the limit action to take place. For the switches as a part of the ELS Limit Switch System, the mount is not simply killed, but is instead stopped dead in its tracks by software. Motion is allowed in the direction toward the home position that will take the mount out of its limit state. Motion in the other direction - deeper into the limit - is not allowed by the system. As a further feature of the LSS, the mount can be set to *bounce* back toward Home and out of the limit. The bounce is actually a small movement, but it is enough to take the mount out of the limit state.



3. Encoder Limits

The next advancement in the evolution of Astro-Physics German Equatorial mounts was the development of the Absolute Encoder System (AE). Its original incarnation used a separate box like the ELS (above), but for obvious reasons, it was called the GTOAE box. All of the functionality and then some from the AE box is now in the GTOCP4/5. The absolute positional accuracy of the AE system allowed the establishment of home and limits that were based on encoder positional readings, and that eliminated the need for mechanical switches. Because the encoder limits were software controlled, they offered a huge advantage in flexibility. Home could be established in any position, and limits could be customized with heretofore unimagined ways. The limits were further divided into two software controlled levels of operation: Hard Encoder Limits and Soft Encoder Limits. The soft encoder limits were designed to take advantage of the already established APCC Meridian Tracking Limits: see page 35.

IMPORTANT NOTES:

- Encoder-based limits are dependent on firmly establishing the relationship between the encoders, the two mount axes, and the celestial sphere (RA and Dec in the night sky).
- They are also dependent on first establishing a *Home* position as a frame of reference.
- Your mount must be properly calibrated with the night sky first: before establishing home. Then, once Home is set, limits can be established.
- Once these limits have been properly set up, they will continue to provide protection even if the mount's calibration is spoiled by an erroneous Sync or Recal.
- ***Moving the mount with the clutches breaks the relationships and invalidates previously set Home and Limits!***
- Any time the clutches are used, calibration, Home and Limits will need to be re-established.
- The system has Declination Limits as well as the RA Limits that get all the discussion and general hoopla. Dec. limits are generally set as a function of latitude and create a zone around the anti-pole where a normally functioning mount will never go. Basically, if your declination wanders into this region, something is wrong, and a limit state needs to be entered so that the problem can be safely resolved.

Encoder Home and Limits are controllable through APCC. See below for more details on hard and soft limits.

a) Hard Encoder Limits

Hard encoder limits are the limits you would set if there were no customization available. You set your hard limits using the worst declination coordinate where the camera, eyepiece or OTA will strike the pier. This is usually at a declination just slightly toward the pole from the zenith. This worst-case declination will be dependent on your latitude and your instrumentation: long vs. short scope; small camera, or eyepiece, vs. large camera with monster filter wheel; all will affect

the hard limit position.

For many remote setups, the ideal hard limit will be equal to the length of your longest exposure plus a small cushion. This is because many remote observatory control packages do not provide for past-the-meridian capabilities beyond finishing an already started image. It doesn't matter if your compact imaging system can go an hour and a half past the meridian at any declination if your longest exposure is 20 minutes. Your observatory control software may not allow it and may always cause a flip at the start of a new frame once you are past the meridian. You will never track more than about 25 minutes past the meridian, so you might as well set your hard limit accordingly. As of this writing, Sequence Generator Pro is the only observatory control software that works with APCC's custom meridian settings to allow continued imaging past the meridian, or starting images ahead of the meridian.

Hard limits are *hard* in that they have a level of permanence. Hard limits are remembered through a power-cycle, and do not need to be re-established for each session. The only time you normally need to reset your hard limits is if you have moved the mount with the clutches. In that case, you will always start by:

1. Re-establishing mount calibration,



2. Setting Home, and then
3. Setting the hard limits.

b) Soft Encoder Limits

Soft encoder limits are limits that are set temporarily by software like APCC to take advantage of your mount's innate ability to go past the meridian if the current declination coordinate positions the scope where it is safe to do so. The hard limit is set for the worst possible case. The soft limits are set for the current situation.

- Soft limits were designed to work with APCC's custom meridian limits.
- Soft Limits are based on the mapped meridian limits from APCC's Meridian tab.
- If activated, any time you changes declination for a different target, APCC will reset the soft limit appropriately.
- This will be a tremendous feature if observatory control developers choose to support it!

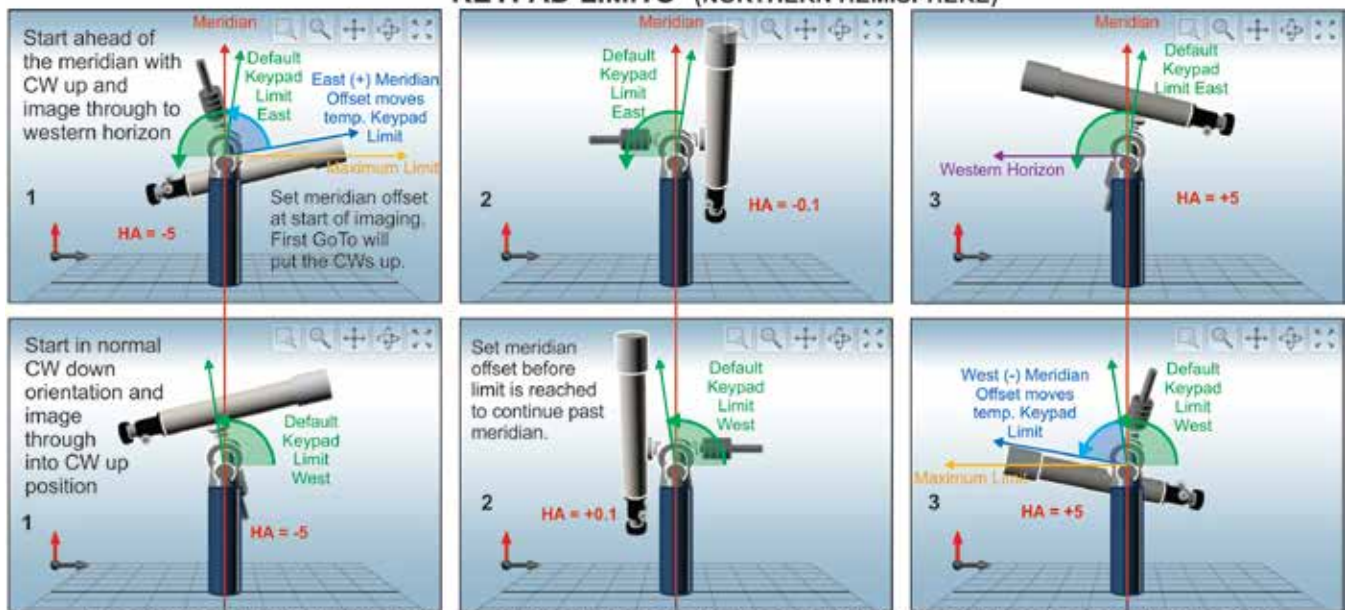
4. Keypad Limits

Keypad limits were added as a further safety measure for keypad users and for people using control devices that cannot use APCC or the AP V2 ASCOM Driver. See the section "Controlling Your GTOCP4 Mount" on page 39. They also provide added safety for mounts that do not have encoders or limit switches.

Keypad limits get their name because they can be turned off and on from the keypad. They are settable by the keypad via the meridian delay feature. However, they are not exclusive to the keypad. The keypad limits are tied to the celestial coordinates, and to any applied meridian delay or advance (meridian offset) that has been set by the user. If no meridian offsets are in use, the CP4 firmware will impose limits just beyond the meridian on either side when the limits are turned on. If you wish to go past the meridian or start a session ahead of the meridian, you must set the appropriate meridian offset. In all cases, the maximum allowable travel will be 6 hours into the counterweight up position. This is true regardless of whether the keypad limits have been turned on or off. It is also important that you are properly calibrated with the celestial sphere.

If your control software does not include the ability to set meridian delay, you can simply turn the limits on or off from the CP4/5's browser web page. This would be useful for DSLR imagers controlling the mount with Sky Safari, as an example.

KEYPAD LIMITS (NORTHERN HEMISPHERE)



IMPORTANT: WITH THE KEYPAD LIMITS SAFETY FEATURE ON, YOU MUST SET A MERIDIAN OFFSET TO GO PAST THE MERIDIAN!

We DO NOT advise using Keypad Limits in firmware versions VCP4-P02-05 and earlier. Please keep your GTOCP4 firmware current!!

5. Hard Limits

Hard Limits are currently only found in the Mach2GTO. Hard limits are the simplest of all limits. They are simply physical barriers to further movement of the axes. The barriers are as small as possible, but they do eliminate a few degrees of movement from a counterweight straight up position, or from a scope pointing directly at the antipole. This should never pose a problem to users, but it will prevent damage from cable wrapping that could occur if an axis was rotated a full 360 degrees or more.

CONTROLLING YOUR GTOCP4 MOUNT

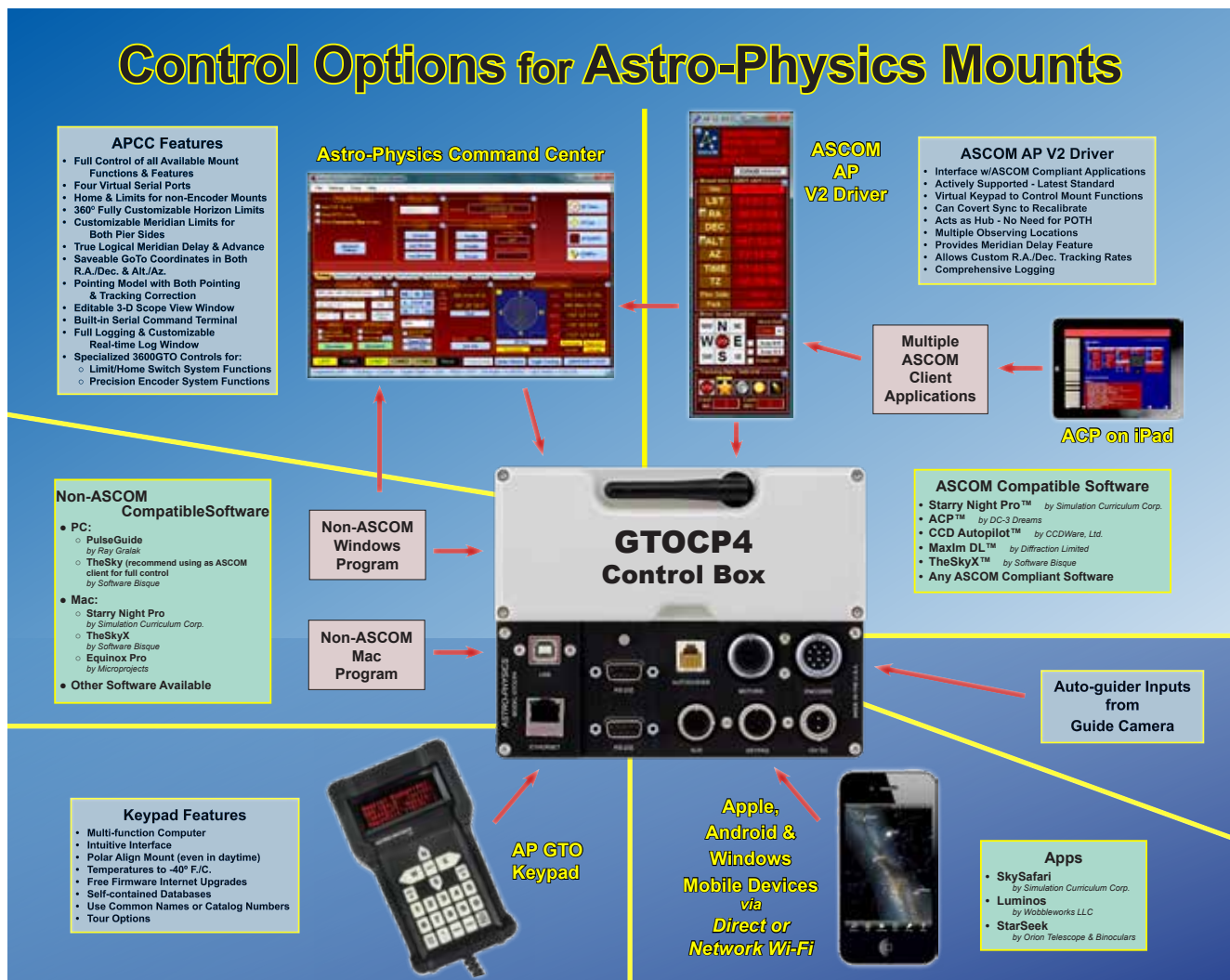
Your Astro-Physics GTO mount has a remarkable servo control system that combines with the precise mechanics of the physical components to give the mount its superb performance. Contrary to popular assumption, the brains of the mount are not found in the keypad, nor are they in an external computer that is used to send the mount off pointing here or there. **The real brains of the Astro-Physics GTO Servo Control System are in the GTOCP4 control box. Simply think of your keypad or computer as being an input device for the GTOCP4. If you understand this from the start, you will always have a better concept of how things work, and you will be less likely to make operator errors.**

As mentioned in the introduction, we divide the types of control functions that the GTOCP4 Control Box performs into three principal categories. The parameters and values for these control functions along with the commands to execute certain functions are given to the GTOCP4 control box by the input device or devices that are in use.

1. **Primary Control Functions.** Primary control functions include all the functions that define HOW the servo will make decisions. In particular, these are the initialization functions – time, date and location – along with Park, Meridian Delay and Sync. These are the most important functions to get right. Primary control functions allow the servo to know where the meridian is and to determine whether a slew requires a meridian flip.

It is of vital importance that your input device handles primary control functions correctly, and that input for primary control is limited to just one device. Initialization is discussed further below under "Initialization and Shut-down" on page 27.

2. **GoTo / Move Functions.** GoTo / Move functions include coordinates, move commands, and rate commands. All of the listed input devices provide some way to command the GTOCP4 to move the mount. Most provide pretty complete movement inputs. The exception is the guider signals from a guide camera, which, of course, cannot command a GoTo slew. Most of what you do during a typical night under the stars is to use the GoTo / Move functions.



3. **Hybrid and Other Functions.** The primary hybrid and other functions are related to periodic error management (PEM) and the Re-Calibrate function which has elements of both control and GoTo / Move. Periodic error correction can be accomplished as simply as using the GTOCP4 along with a device like the keypad to record and then play back a simple, stored PE curve. The pinnacle of Periodic Error Management for non-encoder mounts is the highly sophisticated "PEMPro™ by Sirius-Imaging" on page 58 which creates statistically sound PE curves from multiple worm cycles. Encoder equipped mounts do not need Periodic Error Management. The ReCalibrate function redefines the mount's pointing position, but it does NOT redefine the mount's orientation. All Astro-Physics software including the GTO Keypad now use Recal exclusively with the exception of initialization when the option is selected to resume from a reference park position. Then and only then, a full sync will be sent.
4. Two final categories of control commands are Networking commands and encoder control commands for encoder equipped mounts. Networking commands govern how Ethernet and WiFi communications are implemented in the CP4/5. See: "Connect Your GTOCP4 or GTOCP5 via Ethernet" on page 15, through: "Ethernet and WiFi Best Practice Recommendations" on page 22. Encoder commands set parameters for correction in both Precision Encoder Systems and in Absolute Encoder Systems. The Absolute Encoder System adds control for encoder-based Home and Limits. From the user's point of view, you will simply use external software - computer or keypad - to turn on encoder correction (All encoder mounts), and in 1100GTO and 1600GTO mounts with Absolute Encoders, you can also control home and limits.

The flow chart on the previous page provides a summary of the many different approaches to providing input to the GTOCP4 Servo Control Box. Some of these, like the Astro-Physics Command Center (APCC), the Astro-Physics V2 ASCOM Driver, and the GTO Keypad will provide ALL of the "Primary Mount Control Functions," the "GoTo and Move Functions," and last, but not least, all or most of the "Hybrid and Other Functions" to fully control the mount (APCC omits a couple rather obsolete functions like analog focuser and reticle controls). Other control items in the chart may not fully support all of the GTOCP4's more important functions and capabilities.

What is Meant by "Initialization"?

In simplest terms, "initialization" is the process of giving the mount's servo controller the information that it needs to know: 1. Where is it? 2. What is the time? And 3. How is it supposed to operate? 4. In the process, it also un parks the mount and allows you to calibrate the pointing using a defined AP park position, if needed. This is the information you entered in your software when you first installed and set it up. For keypad users, it is the information you entered when you followed the "First Session with your Keypad" instructions. These four points are detailed below.

1. Latitude and longitude coordinates tell the mount where it is. The GTOCP4 will remember where it was when last powered down, but can't know if you have moved to a new location unless it is told.
2. Time, date and time zone give the mount the necessary time information. Time information is required to calculate the mount's current pointing position if it hasn't been moved, and it is needed to calculate the meridian and the horizons. The mount's servo does not have an internal battery to maintain time between power-ups, so time is an essential part of every initialization.
3. Commands to establish the tracking, guiding, centering and slew rates along with other similar parameters like PEM tell the mount how it should operate.
4. The command to "unpark" the mount is sent. This command both ends the parked state and it also calculates the mount's current pointing position if the mount has not been moved manually by hand via loosening the clutches. The decision whether or not to calibrate on a defined AP park position will depend on the circumstances. For an established setup that has not been moved, do NOT calibrate on a park position. Resume from last parked or last position. The unpark command will have resulted in extremely accurate calculation of the current pointing position without further calibration being necessary. For new setups, or if you have moved the mount with the clutches, you will need to calibrate on (aka "resume from") an AP defined park position.

GTO Keypad Operation

Your mount can be operated with the keypad as its only controlling device. Even advanced imagers can perform all of the necessary mount control and GoTo functions with the keypad alone. With the keypad, a DSLR and a stand-alone guider (such as the SBIG SG-4), you can enjoy a full night of productive, guided imaging without the need for a computer! Please refer to the separate manual for the GTO Keypad Controller for complete instructions on Keypad operation.

The keypad can perform all three types of control functions including initialization and shut-down. See "Understanding the German Equatorial Servo Logic" on page 27 for more details on these topics.

- The keypad can be set to automatically initialize the mount upon power-up. **Auto-connect = YES** This is a very

handy method, and is preferred for any permanent setup where another device is NOT also being used to control the mount. Auto-connect = YES initializes from stored data and completes full initialization with no further actions from the user. It goes straight from power-up to the Main Menu.

- It can be set to allow manual selection of initialization parameters. **Auto-connect = NO** This is the method for portable setups that will be primarily controlled with the keypad. Initialization parameters are selected by the user in a series of steps which end at the Main Menu. Auto-connect = NO is the method required for re-establishing pointing and orientation by unparking from a defined AP park position.
- It can be set to allow a different device like a computer to perform the initialization and shut-down functions. **Auto-connect = EXT** This method is recommended for users who will be using their computer or other devices for primary control of the mount. Upon power-up, the keypad will patiently wait for the controlling device to initialize the mount. EXT also provides the option to switch to manual initialization just like Auto-connect = NO.

The keypad's full databases and intuitive structure make it a joy to use. When people become familiar with the keypad and its simple operation, they wonder why they ever needed to drag a computer into the field!



Using Your Keypad and PC in Shared Harmony

The keypad communicates with the GTOCP4/5. Your smart device communicates with the GTOCP4/5. Your computer communicates with the GTOCP4/5. NONE of these devices can talk THROUGH the GTOCP4/5 to communicate with each other. The CP4/5 cannot act as a communication hub for seamless communication between devices. Security protocols won't allow it. In addition, the keypad is not able to constantly poll the mount. It can poll the mount whenever instructed to do so, and can poll using any command in the Astro-Physics Command set, but it can't just poll at will. Consequently, there are some rules that need to be observed for keypads using v4.xx or v5.xx firmware.

- **The Keypad and the PC do not talk to each other.** When doing a GoTo, the Keypad and the PC do not know to which object the other has slewed. Therefore, you should always sync (ReCal) using the device that did the slew. There are some additional protections in v5.xx to prevent errant ReCals. APCC also has protections.

When either the Keypad or the PC issue a GoTo, the object's coordinates are sent to the CP4/5 control box which knows the current coordinates where the mount is pointing. Your CP4/5 then calculates how much each motor needs to turn to get to the new GoTo coordinates. These are strictly mathematical calculations, and they are inside the CP4/5. They are NOT in the keypad, computer or smart device..

Both the Keypad and the PC can read the current coordinates from the CPx, but the opposing device can not know to which object the mount was sent (it would simply be syncing on the last GoTo coordinates that IT sent to the mount). You should **ONLY** sync using the device that issued the latest GoTo.

However, once you send the mount to an object you can then center the object with the opposing device by doing N-S-E-W button moves. The pointing coordinates in the GTOCPx will change by the amount of the button adjustments you make, but then syncing WITH THE DEVICE THAT ISSUED THE GOTO SLEW will restore the coordinates to those requested by the GoTo slew command.

- **Set the Keypad to AutoConnect: EXT.** If you are using a computer along with the Keypad, you'll want to set the Keypad to AutoConnect: EXT. When powering up the mount using this mode the Keypad will wait patiently for the computer to initialize the mount. Once the computer has initialized the time and location information the Keypad will advance to the main menu screen. This is the preferred procedure when using both control devices, as it assumes the computer's priority status.

If a computer is not available, you can easily push the Menu button on the Keypad and then it will walk you through the Keypad initialization process - basically the Auto-connect = NO sequence.

- **Park the mount using the device that provided the initialization.** Another rule to follow is to park the mount using the device that did the initialization. The primary reason for this is that there may be a difference in time between the computer clock and the Keypad clock. This will affect GoTo and meridian flip accuracy. In a worst case, a scope/

counterweights orientation error can occur and send the scope slewing into the pier upon the first GoTo slew.

- **Review the Keypad manual.** The Keypad manual provides a wealth of detailed information. Even if you do not own a Keypad, you will find very useful information in the manual which is available in PDF format on the Technical Support page of our web site.

Keypads Using v5.xx Firmware

Keypad version 5.xx firmware is a major new release that incorporates many improvements and new features.

- v5.xx has expanded precision to take advantage of the extra precision in the CP4/5 with VCPx-P02-xx control box firmware.
- Database precision for named stars has been updated and increased as well for more accurate calibration and to facilitate better modeling
- The Named Stars list has been enlarged.
- Start-up has been streamlined and made more error-proof for systems using Auto-connect = NO.
- Communication with the CP4/5 has been expanded to provide better information to the user.
- Modeling will soon be available for CP4 users along with v5.xx. The model will be stored in the CP4 making it available, after creation with the keypad, for any software or control devices. Macs, Linux machines, smart devices - all will be able to take advantage of the CP4's internal modeling. It is the keypad's v5.xx software that allows the model to be created in the CP4, but the CP4 stores the model and remembers the state (on/off/ortho-only etc.). In addition to the keypad, users who wish to have modeling will need to purchase a special license to enable the feature in the CP4. The license is installed just like a CP4 firmware update. See: <https://www.astro-physics.com/software-updates/>
- Room to grow - Future Features
 - Home and Limits for more than Mach2GTO mounts - both Encoder and non-encoder
 - Additional object databases
- Keypads with the v5.xx firmware require a CP4/5 with VCPx-P02-05 or later firmware. As always, we strongly advise you to stay current on your CP4/5 firmware version.
- Please note that the oldest keypads (before S# 1491GTO) do not have adequate memory for v5.xx firmware unless a later repair involved replacing the main board of the keypad.
- Keypad v5.xx firmware can NOT be used with GTOCP1, 2 or 3 control boxes. In the GTOCP4, it requires VCP4-P02-05 or later firmware.

The above advances in Keypad / computer communication are the reason for our STRONG recommendation to update your Keypad to the version 5.xx firmware as soon as it's available, and to keep your GTOCP4 updated as well. However, if you have additional mounts that have GTOCP3 or earlier control boxes, then it will not be possible to share the v5.xx Keypad with them. Those earlier control boxes do not have the more advanced functionality of the CP4 and CP5 that is required.

Setting Up the Astro-Physics ASCOM V2 Driver

NOTE: If you choose to use APCC software with the ASCOM V2 driver, you can skip this step: setup is accomplished within APCC instead of ASCOM V2.

One of the first things that must be done is to set up the Astro-Physics V2 ASCOM Driver. This is extremely important, as the settings that you enter will be used to initialize the mount once you power up and connect to the mount with your third-party software.

Please note that the ASCOM Platform rules require that the AP V2 Driver only becomes active and visible when a third-party ASCOM compliant software connects to it. When disconnected, the AP V2 Driver will automatically close.

The image at the right shows the Setup Telescope for the AP V2 Driver. It is here that you enter your settings.



Entering basic settings to get started

1. Mount Configuration *Image immediate right.*

- A) Select Mount type.
- B) Select GTOCP4 control box model.



2. COM Port Details *Image far right.*

- A) If you are only using ASCOM (no APCC), you can choose to connect directly to the mount via Ethernet (IP) or USB/Serial. If Ethernet, choose IP/Hostname and enter the IP address of your mount (you will need to have your mount already connected via ethernet). If you aren't sure of the IP address, click Find Mount to locate it.
- B) If USB/Serial, choose COM Port (no APCC) and select the COM port your mount is connected to. If you aren't sure, click the Find Mount button, which will find all available.
- C) Leave the other settings in this window at default settings and check the ASCOM Serial Object box.



3. Default Park / Unpark Positions

- A) Unpark From - What you choose is dependant on whether you are permanent or portable.
 - i) Portable and setting up each night - you will want to unpark from a reference position so that the mount is automatically oriented when initialized. This will allow you to slew to your first object with reasonable accuracy and requiring a simple centering of the object and a ReCalibrate (Sync).
 - ii) Permanent setups (observatory or week-long star parties) - You will want to unpark from "Last Parked". At the end of the previous evening you will have parked to a reference position. That being the case, unparking from "Last Parked" will resume from a highly precise position and initialize with precise time agreement to your computer.
**TREAT YOUR FIRST-TIME SETUP IN A PERMANENT OBSERVATORY AS A PORTABLE SETUP! Then change to the setting outlined in 3. a) ii) above.
- B) Park To - Will be chosen based upon convenience and personal preference. For example, covering your scope at a star party is usually best done at Park 3; however, removing your scope is probably easier from a Park 2 position.



4. Site Setup

- A) Click the New button and enter a site name.
- B) Enter the Latitude and Longitude in degrees, minutes and seconds by clicking in the appropriate box each time (don't forget the N/S and E/W boxes). Then enter the Elevation, if known (optional).





1. Initialization Setup - Check all the boxes in the top right window.
 - A) Sync Mount Time at initialization - recommended to be checked.
 - B) Set Latitude / Longitude - default is to leave it Checked.
 - C) Enable Mount Tracking on Unpark - under normal circumstances this is usually Checked.
 - D) Set Slew Rate - this may be set as you like. In colder weather it is generally set to a slower speed. Also, remember that you will need to use 24 volts to achieve the fastest speed.
 - E) Set PulseGuide / Guide Rate - **This should always be set at 1.00x.**
 - F) Set PEM - for non-encoder mounts, this is usually set to Enable PEM (it has no effect for encoder mounts)
 - G) Connect Time Out and Window Priority - use default settings.
2. Other Options - recommended settings
 - A) Enable Debug Logs - Checked.
 - B) Keep Mount Time Synced to PC Time - Checked.
 - C) Convert Syncs to ReCals - Checked.
 - D) Minimize Control Window on Connect - Unchecked.
 - E) Show in Task bar when Minimized - Checked.
 - F) Reverse Dec moves on pier flip - Unchecked
 - G) Check for New Version when Starting - Checked.
 - H) Auto-enable Tracking when ASCOM Clients Send Certain Commands - Checked.
 - I) Calibrate Move Directions on First Slew - Checked if NOT using APCC.
 - J) ASCOM RA MoveAxis = 0 Stops Tracking - Unchecked.
 - K) Set Driver Window on Top - Unchecked.
 - L) Remember Last Window Position - Checked.

Workflow When Using the AP ASCOM V2 Driver with Third-party Software (examples: **Starry Night™**, **NINA**, **Voyager**, **MaxIm DL™**, **Sequence Generator Pro™**, etc.) (*TheSkyX™* is specifically discussed on page 52)

1. Be sure that you first install the current ASCOM Platform and AP V2 ASCOM Driver. Having all software and drivers current is important in order to avoid connectivity issues.

- A) ASCOM Platform 6.6SP1 or newer - install first
<http://ascom-standards.org/index.htm>

Click on the download button and install the full download. Once the download is complete, you are done; there are no settings to make.

- B) Astro-Physics V2 ASCOM Driver - install second
<http://www.gralax.com/apdriver>



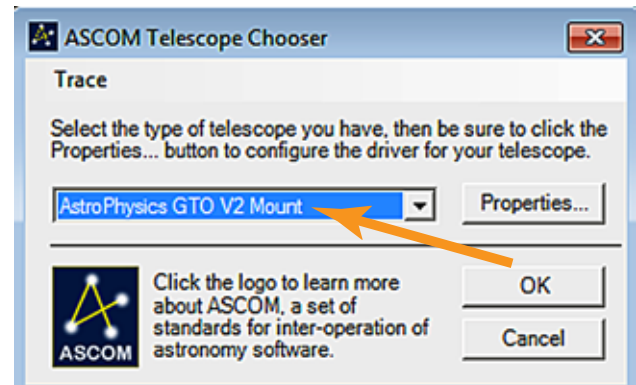
Please check frequently to ensure that you are using the current version of this driver. Important updates and bug-fixes are made periodically to ensure that your mount functions safely.

Pro Tip: Clicking on the “?” in the upper right corner of each window in all the screens found in both the AP V2 Driver and APCC will immediately jump you to that specific section of the built-in Help system!

2. Open the Setup Telescope in the AP V2 Driver folder and enter the required settings. Reference the previous section entitled "Setting Up the Astro-Physics V2 ASCOM Driver".
3. Install your third-party software.
4. Locate the Telescope Chooser or Settings in the third-party control software - all ASCOM compliant software will have a chooser or settings drop-down menu.
5. Select the AP V2 Driver. The driver will be called AstroPhysics GTO V2 Mount. See image at right.

Once you select it, you may be asked to click Properties... If you click Properties..., you will be shown the AP V2 Driver's Setup Telescope window that you filled out earlier. You can review it if you wish. Then click OK once or twice and you are done.

The Astro-Physics V2 ASCOM Driver is a hub through which all third-party ASCOM compliant software can be connected. Planetarium, camera control, and focusing software, etc. can be connected to it and operated simultaneously.



6. Polar align and power up the mount.
7. Start your control software and have it connect to the mount. It will start the AP V2 Driver which will initialize the mount. You are now ready to go to your first object.
8. After finishing your night's observing (or day's solar observing) park the mount to your chosen Park position.
9. Disconnect and close the active software programs (the AP V2 Driver will close automatically).
10. Power down the mount.

The Astro-Physics Command Center - Standard & Pro Versions

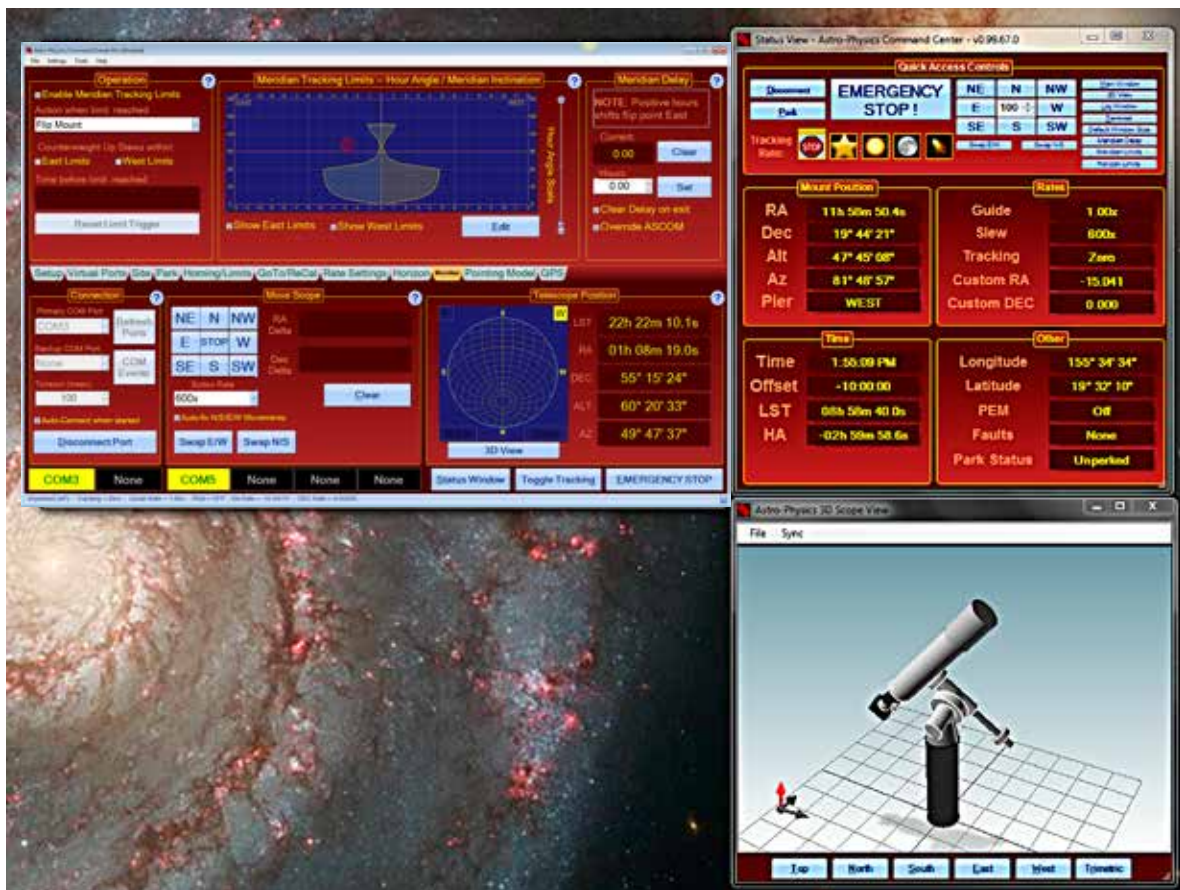
The Astro-Physics Command Center (APCC) adds many features and extended functionality to the control system of the mount and it will act as a serial hub for the use of additional applications. It takes remote operation to the next level with safety and convenience that you won't want to be without. There are two versions: APCC Standard and APCC Pro.

APCC takes its place as the final arbiter between all of your software and the mount. It is the program to which the mount directly connects. All other programs connect to AP V2 ASCOM driver, which then connect to APCC, which then connects to the mount. APCC was designed from the beginning to integrate perfectly with the AP V2 ASCOM Driver.

APCC is the master when it comes to mount initialization and shut-down controls. See "Initialization and Shut-down" on page 36. It should be the first piece of mount-related software that is opened, and the last one that is shut down.

Features of APCC Standard are too many to list, but include the following:

- Direct Ethernet and / or Wi-Fi connection to the mount from your PC. No Ethernet to serial emulators required!
- REST API to connect multiple applications.
- Customizable Meridian Tracking Limits to avoid pier crashes and optimize counterweight up observing.
- Customizable Horizon Tracking Limits stop tracking or park the mount when horizon is reached.
- Full support for the CP4 and compatible mounts, and GTOCP5/ Mach2GTO.
- Errant Sync / ReCal prevention.
- Editable and customizable 3-D viewer showing the orientation of the scope and mount for remote users – includes warning for deviations over 5 degrees between mechanical and celestial coordinates.
- GoTo – ReCal tab for custom RA/Dec, HA/Dec, and Alt/Az target coordinates with saveable targets for precise return to that perfectly framed object.
- Horizons Program for accurately pointing to and tracking comets, asteroids and satellites.
- Complete mount control including terminal interface.

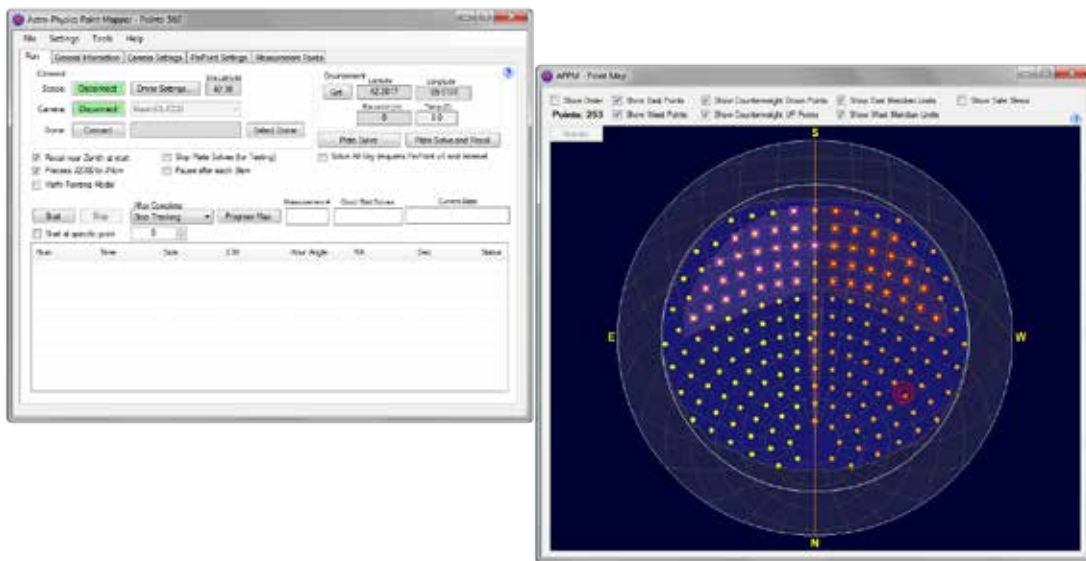


- Advanced logging features for troubleshooting.
- Much more !!!

The APCC Pro version includes the following additional features:

- Highly-sophisticated pointing model and variable tracking for both axes; includes the Astro-Physics Point Mapper (APPM) for automated collection of pointing data.
- Camera options: NINA, Maxim, Sequence Generator Pro, ASCOM camera and SkyX Image Linking camera Add-on (part of APPM).
- Plate solving choices: ASTAP, PinPoint, Sequence Generator Pro, NINA, and SkyX Plate Solving. Note: these third party programs must be purchased separately.(they are not part of APPM).
- Supports THUM temperature reading sensors as well as ASCOM-capable environmental monitors.
- Safety monitor support.

We suggest that you keep an eye on the [APCC page](#) of the Astro-Physics website and the [ap-gto users group](#) for updates and details.



Some APCC Thoughts

- Always launch APCC first before any other software. APCC should always be the first software started and the last to be closed at the end of the evening. Starting it first will ensure that the mount is properly initialized. Many customers include APCC in the auto-start of their Windows startup routine.
- It connects directly to the mount on its physical interface: RS-232, USB, Ethernet or Wi-Fi.
- It then creates the REST API interface for the AP V2 ASCOM Driver. Note: Other program connections, such as *Starry Night*™, *NINA*, *Voyager*, *TheSkyX*™, *MaxImDL*™, etc. only connect to the AP V2 Driver. You should not attempt to use proprietary or direct connections using APCC's REST API.
- Since AP V2 ASCOM is a hub, multiple programs can connect to the mount at the same time, even programs that don't normally want to share a connection to the same mount with other programs.

Setting Up the Astro-Physics Command Center

APCC can be as simple or as complex as you wish to make it. This Quick Start guide will only touch upon the Setup of this software. The Help menu will provide more detailed information. Don't forget to click of the "?" in the corners to access context-sensitive help information for that window!

Entering Basic Settings

1. Program Operation window

- A) Ask if OK to Exit - Checked (uncheck for remote).
- B) Keep APCC on Top - Unchecked.
- C) Show Emergency Stop Window - Checked.
- D) Clear all errors when starting and connecting to the mount - Checked.

2. Advanced Settings (click Advanced Settings button).

- A) Auto Initialize (secs) - Check & set to "0".
- B) Auto Shutdown (secs) - Unchecked.
- C) Enable Logging (to disk) - Checked.
- D) Purge old logs on startup - Checked and set to 30
- E) Show Status Window when Starting - Unchecked.
- F) Prevent Errant RECALLs - Checked.
- G) Keep mount time synced to PC Time - Checked.
- H) Keep Mount Time Synced to PC Time (enabling will override driver's setting) - Checked.
- I) Enable Tracking Rate Tweak Window - Unchecked.

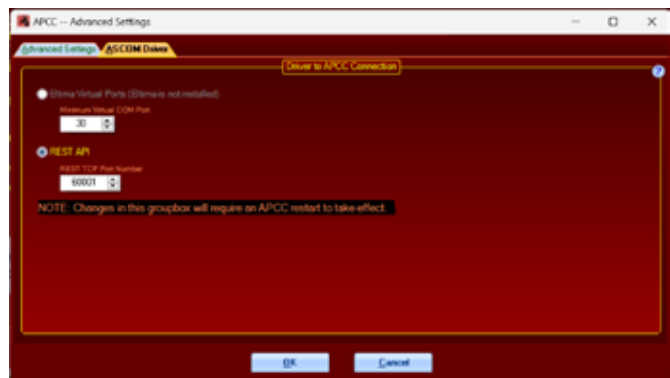
3. ASCOM Driver Tab

- A) REST API - Selected.
- B) REST TCP Port Number: 60001

Remember: APCC will connect to the mount using USB/Serial/Ethernet/WiFi, and the AP V2 Driver will connect to APCC via the REST API. Third-party software then connects to the AP V2 Driver, which is a hub. In third-party software the AP V2 Driver is titled 'AstroPhysics GTO V2 Mount.'

4. Edit Initialize Mount Settings window (choose from Setting in the Menu Bar)

- A) Initialization Site and Unpark will fill in automatically from the other tabs.
- B) Optional Initialization
 - i) Set Tracking Rate - Sidereal.
 - ii) Set Guide Rate - 1.00x (always).
 - iii) Set Slew Rate - your favorite speed. It is recommended to use slower speeds in cold weather.



5. Site Tab - Site Information

Be sure that it agrees with AP V2 Driver. Updating one does not update the other.

- A) Click Manage Sites button.
- B) Create a Named Site.
- C) Enter Latitude and Longitude.
- D) Click Time Offset button (at right).
- E) Enter Elevation, Temp (approximate) and default Pressure.



- 6. **Connection** (reference the Help file by clicking the "?" in the top right corner) Additional information can be found by going to the [Software Updates](#) page of our website and selecting APCC Current Version. There you'll find the up-to-date copy of APCC Installation and Getting Started Quick Guide - PDF Documentation.

The most robust and recommended methods of connection are Ethernet or Serial. These will also allow greater computer-to-mount connectivity distance (up to 100' or more). USB is an excellent choice if that connection distance is less than 15'.

The GTOCP4 uses an industrialized and self-powered USB connector and its robustness will only be limited by the USB of your computer (the weak link). Avoid using USB hubs which can reduce reliability. If you must use a hub, then buy a high-quality, powered hub.

In addition to the primary connection, you can also specify a backup connection port in the event your primary connection fails.

- A) Auto-Connect - this is a personal choice (generally this is checked for remote applications and unchecked when you are using the mount next to you).



Workflow When Using APCC & the AP V2 Driver with Third-Party Software

(Examples: *Starry Night™*, *MaxIm DL™*, *NINA*, *Voyager*, *Sequence Generator Pro™*, etc.)
(*TheSkyX™* is discussed on page 52)

1. Be sure that you first install the current ASCOM Platform and AP V2 ASCOM Driver. Having all software and drivers current is important in order to avoid connectivity issues.

- A) ASCOM Platform 6.6SP1 or newer - install first
<http://ascom-standards.org/index.htm>

Click on the download button and install the full download. Once the download is complete you are done. There are no settings to make.

- B) Astro-Physics V2 ASCOM Driver - install second
<http://www.gralak.com/apdriver>

Detailed information regarding setting up the AP V2 ASCOM Driver are found on page 43. Please check frequently to ensure that you are using the current version of this driver. Important updates and bug-fixes are made periodically to ensure that your mount functions safely.

- C) Astro-Physics Command Center (APCC) - install third

Please refer to the [APCC Installation and Getting Started Quick Guide](#) (PDF) located in the same section of our website as the APCC downloads files. We suggest that you download this PDF and the full manual for future reference.

Pro Tip: Clicking on the "?" in the upper right corner of each window in all the screens found in both the AP V2 Driver and APCC will immediately jump you to that specific section of the Help Menu!

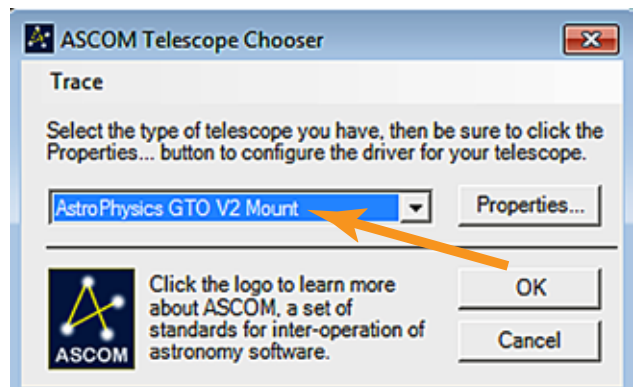
2. Open the AP V2 Driver's Setup Telescope and enter the required settings.

Important: When using the AP V2 Driver with APCC, you will need to change some settings in the driver's Setup Telescope. The box APCC Virtual Port will need to be checked and a high number COM port (for example COM21) will need to be chosen so that it does not conflict with real COM ports. This will be a Virtual COM port. You will need to create a Virtual port in APCC that corresponds with the chosen number. Detailed information is found in the APCC Help Menu.

3. Install your third-party software.
4. Locate the Telescope Chooser or Settings in the third-party control software - all ASCOM compliant software will have a chooser or settings drop down menu.
5. Select the AP V2 Driver. The driver will be called AstroPhysics GTO V2 Mount. See image at right.

Once you select it, you may be asked to click Properties... If you click Properties... you will be shown the AP V2 Driver's Setup Telescope window that you filled out earlier. You can review it if you wish. Then click OK once or twice and you are done.

The Astro-Physics V2 ASCOM Driver is a hub through which all third-party ASCOM compliant software can be connected. Planetarium, camera control and focusing software, etc. can be connected to it and, operated simultaneously.



6. Polar align and power up the mount.
7. Start APCC and have it connect to the mount. APCC will be the software that initializes the mount with the settings that you have set in APCC. It will also start the AP V2 Driver if you have it set to auto-connect.
8. Start your third-party software and connect it to the mount. You are ready to enjoy the evening.
9. After finishing your night's observing (or day's solar observing) park the mount to your chosen park position.

10. Once the mount is parked disconnect and close the active third-party software.

11. Close APCC. The AP V2 Driver will automatically close.

12. Power down the mount.

**Important note: If you use APCC, you initialize the mount only through APCC.
APCC will override any settings in the AP V2 ASCOM Driver.**

Workflow When Using TheSkyX™ with the AP V2 Driver

1. Be sure that you first install the current ASCOM Platform and AP V2 ASCOM Driver. Having all software and drivers current is important in order to avoid connectivity issues.

- A) ASCOM Platform 6.6SP1 or newer - install first
<https://ascom-standards.org/index.htm>

Click on the download button and install the full download. Once the download is complete you are done. There are no settings to make.

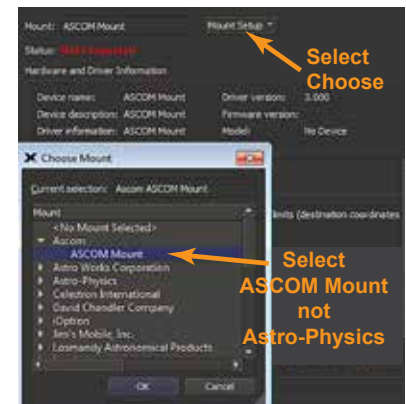
- B) Astro-Physics V2 ASCOM Driver - install second
<https://www.gralak.com/apdriver/>

Detailed information regarding setting up the AP V2 ASCOM Driver are found on page 43. Please check the link above frequently to ensure that you are using the current version of this driver. Important updates and bug-fixes are made periodically to ensure that your mount functions safely.

Pro Tip: Clicking on the "?" in the upper right corner of each window in all the screens found in both the AP V2 Driver and APCC will immediately jump you to that specific section of the Help Menu!

2. Open Setup Telescope in the AP V2 Driver and enter the required settings. Reference the section entitled "Setting Up the Astro-Physics V2 ASCOM Driver" on page 43
3. Install TheSkyX™ and any other third-party software.
4. Go to Telescope in the menu bar and locate the Telescope Chooser in the drop-down menu. Then select ASCOM Mount. *See image at right.*

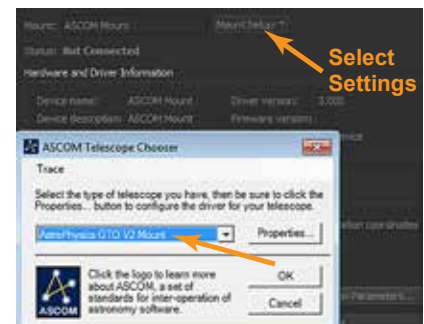
Important Note: Do NOT select Astro-Physics from that list. These are TheSkyX™ native drivers and NOT Astro-Physics drivers. They will NOT connect through ASCOM and the AP V2 Driver, nor through APCC; consequently, you will not be able to take full advantage of the functionality, precision and safety that is available through our software.



5. Go back to the drop-down menu and select Settings. It will open the ASCOM Telescope Chooser and you will select AstroPhysics GTO V2 Mount. *See image below right.*
6. Once you select it you may be asked to click Properties. If you click Properties, you will be shown the AP V2 Driver's Setup Telescope window that you filled out earlier. You can review it if you wish. Then click OK once or twice and you are done.

The Astro-Physics V2 ASCOM Driver is a hub through which all third-party ASCOM compliant software can be connected. Planetarium, camera control and focusing software, etc. can be connected to it and operated simultaneously.

7. Polar align your mount using any of the methods outlined in the manual that came with your mount. .
8. Power up the mount, and then start TheSkyX™. When TheSkyX™ connects to the mount, it will start the AP V2 Driver which initializes the mount.
9. After finishing your night's observing (or day's solar observing), park the mount to your chosen park position.
10. Disconnect and close the active software programs (the AP V2 Driver will close automatically). Power down the mount.



Planetarium, Imaging and Observatory Software from Other Vendors

There are a number of planetarium and camera control programs that can be used to control the Astro-Physics GTO Servo System. Many of these use the ASCOM interface and will take advantage of the V2 ASCOM driver mentioned previously. Any software that can use the AP V2 ASCOM driver will have extensive mount control capabilities because of the driver's "virtual keypad" features. Other programs employ native drivers that the software designers wrote based on our publicly available command set. The list that follows is certainly not exhaustive, but does offer some resources.

Resources for PC users:

- [Starry Night Pro/Pro Plus™](#) from Simulation Curriculum Corp. (Windows with ASCOM support). Currently v7.0.
- [The Sky X™](#) from Software Bisque (Windows with ASCOM support and native driver). Currently v10.5.0.
- [The Earth Centered Universe™](#) from Nova Astronomics (Windows with ASCOM support). Currently v6.1.
- [SkyMap Pro™](#) by Chris Marriott (Windows with ASCOM support). Currently v12.0.
- [Sky Tools 3™](#) by Skyhound (Windows with ASCOM support).
- [Voyager™](#) from Carina Software (Windows). This product does not use the ASCOM interface. Currently v4.5.
- [MaxImDL™](#) from Diffraction Limited (Windows with ASCOM support). Currently v6.16.
- [ACP™ Observatory Control Software](#) by DC-3 Dreams (Windows with ASCOM support).
- [Sequence Generator Pro](#) by Main Sequence Software (Windows with ASCOM support). Currently v2.6.
- [CCDWare Product Suite](#) (Windows). The suite includes CCDNavigator™, PEMPro™, CCDInspector™, FocusMax4™, CCDAutoPilot™ and CCDStack™ software. They all use the ASCOM interface. These products can also be purchased individually.
- Any other ASCOM compliant software. *Be sure to update to the most current AP V2 ASCOM driver (supported by Astro-Physics).*

Resources for Mac users:

- [Starry Night Pro/Pro Plus™](#) from Simulation Curriculum Corp. (Mac version with native driver). Currently v7.0.
- [The Sky X™](#) from Software Bisque (Mac version with native driver). Currently v10.5.0.
- [Voyager™](#) from Carina Software (Mac version with native driver). Currently v4.5.
- [SkySafari 6™ for OS X](#) by Simulation Curriculum Corp.

In addition to the Mac software mentioned above, check out this resource of additional Mac software: *The Mac in Astronomy* by David E. Illig. Website: <http://www.primordial-light.com/macastronomer.html>

Mobile Smart Devices:

- [SkySafari 6™ for iOS](#) and Android by Simulation Curriculum Corp – This software is offered through the App Stores in three versions. They do not use the ASCOM interface. Mount initialization is performed.
- [Luminos™](#) for iOS by Wobbleworks LLC – This software is offered through their internet website. They do not use the ASCOM interface. Mount initialization is performed.

Write your own computer program:

The Astro-Physics GTO protocol for the GTOCP3 Control Box through version Q is freely available to those who would like to write their own computer program for controlling the mount. Note that this does not include the command language for either the Precision Encoders or the Absolute Encoders. Please note that with our substantial investment in both the Astro-Physics V2 ASCOM driver and in APCC, we cannot also provide free technical support to anyone who wants to try their hand at mount control software. We strongly encourage all customers to use the available software options, if possible.

Workflow When Using TheSkyX™ with the AP V2 Driver

1. Be sure that you first install the current ASCOM Platform and AP V2 ASCOM driver. Having all software and drivers current is important in order to avoid connectivity issues.

- A) ASCOM Platform 6.5SP1 or more recent - install first

<http://ascom-standards.org/index.htm> .

Click on the download button and follow the instructions to install the full download. Once the download and installation are complete you are finished. There are no additional settings or configurations to worry about.

- B) Astro-Physics V2 ASCOM driver - install second

<http://www.gralak.com/apdriver>

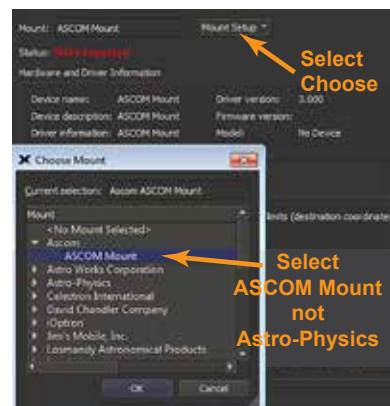


Detailed information regarding setting up the AP V2 ASCOM driver are found at "Setting Up the Astro-Physics V2 ASCOM Driver". Please check frequently to ensure that you are using the current version of this driver. Important updates and bug-fixes are made periodically to ensure that your mount functions safely.

Important Note: Clicking on the "?" in the upper right corner of each window in all the screens found in both the AP V2 driver and APCC will immediately jump you to that specific section of the Help Menu!

2. Open the "Setup Telescope" in the AP V2 driver and enter the required settings. Reference the section that follows entitled "Setting Up the Astro-Physics V2 ASCOM Driver".
3. Install TheSkyX™ and any other third party software.
4. Go to "Telescope" in the menu bar and locate the Telescope Chooser in the drop-down menu. Then select ASCOM Mount. See image at right.

Important Note: Do NOT select Astro-Physics from that list. These are TheSkyX™ native drivers and NOT Astro-Physics drivers. They will NOT connect through ASCOM and the AP V2 driver, nor through APCC; consequently, you will not be able to take full advantage of the functionality, precision and safety that is available through our software.



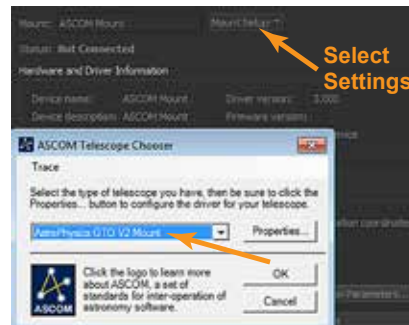
5. Go back to the drop-down menu and select "Settings". It will open the ASCOM Telescope Chooser and you will select "AstroPhysics GTO V2 Mount". See image below right.
6. Once you select it you may be asked to click "Properties...". If you click "Properties..." you will be shown the AP V2 driver's "Setup Telescope" window that you filled out earlier. You can review it if you wish. Then click "OK" once or twice and you are done.

The Astro-Physics V2 ASCOM driver is a hub through which all third party ASCOM compliant software can be connected. Planetarium, camera control and focusing software, etc. can be connected to it and operated simultaneously.

7. Place the system into a defined AP Park position. See the section in the Mount Manual illustrating Park Positions.

- A) If you are setting up the mount afresh (as when you need to disassemble the mount each night), you will tell the mount to unpark from a specific numbered position (for example Park 4).

- B) If you simply park the mount each night (in an observatory or at a multi-night star party), then you will always unpark from "Last Parked". This assumes that you have not moved the position of the telescope since your last session.



8. Power up the mount and then start TheSkyX™. When TheSkyX™ connects to the mount it will start the AP V2 driver which initializes the mount.
9. After finishing your night's observing (or day's solar observing) it is best to park the mount to your chosen Park position using the AP V2 driver, rather than using TheSkyX™.
10. Disconnect and close the active software programs (the AP V2 driver will close automatically). Power down the mount.

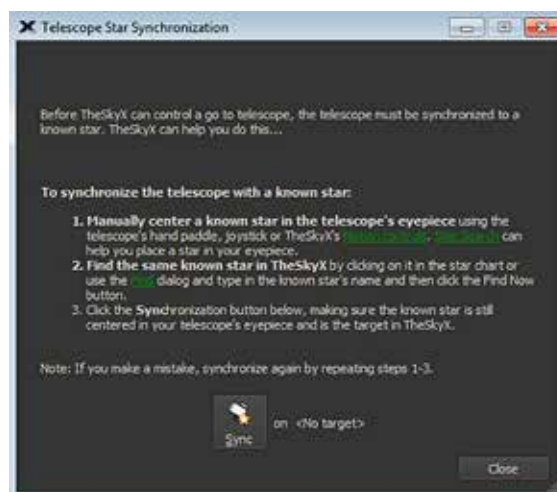
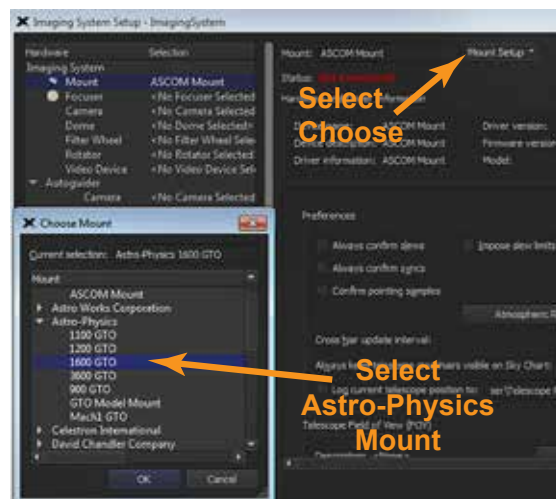
Workflow When Using TheSkyX™ with Native Drivers

Note: This should also apply when using TheSkyX™ with native drivers on a Mac. Note: We did not confirm this on a Mac. However, when using a PC we highly recommend using the ASCOM driver connection to obtain full functionality, precision and safety.

1. Install TheSkyX™ and any other third party control software.
2. Go to “Telescope” in the menu bar and locate the Telescope Chooser in the drop-down menu. Then select Astro-Physics and the appropriate mount type. *See image at right.*
3. Connect the computer to the mount using any of the four connection options (USB, Serial, Ethernet or WiFi). If using USB or serial connection, open your computer’s Device Manager and see which COM port is being used or available.
4. Go back to “Telescope” in the menu bar and locate the Telescope Settings in the drop-down menu. Be sure that the correct COM port has been chosen.
5. Power up the mount and start TheSkyX™.
6. Open the Telescope tab and click on the Start Up drop-down menu. Select and click Connect Telescope.
7. Locate a bright star that you recognize about 40 to 60 degrees up from the east or west horizon. Manually center the star, either by loosening the mount’s clutches and pushing the scope by hand, or using move buttons or with the Keypad direction buttons.
8. Find the star in TheSkyX™’s planetarium field and click on it or right-click the field and select Find. In the Start Up menu click Star Synchronization. Click the Sync button. You are now ready to enjoy your night. *See image below.*
9. After finishing your night’s observing (or day’s solar observing) it is best to park the mount by selecting Park in the above mentioned Shut Down menu.. **Note:** Establish a park position by going to a position of convenience for parking and set it with Set Park Position in the Telescope Tab’s Shut Down drop-down menu (this can be done prior to finishing your evening).
10. Disconnect and close the active software programs.
11. Power down the mount.

Important Note: If you encounter a problem using TheSkyX™ native drivers, you will need to contact Software Bisque for support.

This will be especially true when operating with a Mac. We may be able to help with some minor problems, but Software Bisque will be the best source for addressing issues with their software.



Workflow When Using Mobile Smart Devices

- [SkySafari™ for iOS](#) and Android by Simulation Curriculum Corp – This software is offered through the App Stores in three versions. They do not use the ASCOM interface. Mount initialization is performed when connection is made.
- [Luminos™](#) for iOS by Wobbleworks LLC – This software is offered through their internet website. They do not use the ASCOM interface. Mount initialization is performed when connection is made and the mount is unparked.

Mobile smart devices will all connect over WiFi. The GTOCP4 ships out from the factory in Access Point mode which means that it will act as a hotspot for your smart device. If you wish to have both the GTOCP4 and Smart device go through a local area network, please see the information in "Station Configuration". For this quick guide, we present the simple direct connection where you select the GTOCP4's network as the host for your device.

The screen shot to the right shows an iOS device running Sky Safari 5 Plus™, but it generically illustrates what must be done for any device.

1. Open the device's Settings page and then open the WiFi settings.
2. Find and then select the GTOCP4 network. You will need the password: xxxadmin12345 where the xxx is the numeric portion of the GTOCP4's serial number.
3. Position the scope. See the section in the Mount Manual illustrating Park Positions.
 - A) Put the mount in a Park 4 position when using SkySafari™ (the only position recognized by SkySafari™ at this time).
 - B) Put the mount in any of the Astro-Physics Park positions if using Luminos™ (or restart from Current Position if previously parked and unmoved).
4. Open SkySafari™ or Luminos™ and enter settings for the Astro-Physics mounts.
 - A) Start SkySafari™ 5/6 - See image at right.
 - i) Click Settings at bottom of the screen.
 - ii) Scroll down to Telescope Setup and click.
 - iii) Scope Type: Astro-Physics.
 - iv) Mount Type: Equatorial GoTo (German).
 - v) Enter IP Address: 172.31.0.1
 - vi) Enter Port Number: 23
 - vii) Turn on Set Time & Location and then click Done.
 - B) Start Luminos™ - See image bottom right.
 - i) Click Observe at bottom of screen.
 - ii) Click Remote and then Configure.
 - iii) Protocol - select Astro-Physics and then click mount to go back.
 - iv) Connection - select WiFi serial device and then click mount to go back.
 - v) IP Address - click Edit at top and enter 172.31.0.1 as the IP address and 23 as the port; then click Done.
5. To Connect to the mount (initialization will take place).

A) SkySafari™

- i) Side scroll at bottom to Scope and click.
- ii) Click Connect (mount must be in Park 4).



B) Luminos™

- i) Click Observe at bottom of screen.
- ii) Click Remote Control and then the Connection slider.
- iii) Scroll down and click Un-Park.
- iv) Choose and click the correct Park Position. Click Done.

6. After an evening enjoying the stellar marvels:

A) SkySafari™

- i) Click Disconnect.
- ii) Choose either Park 4 Position to park mount, or Disconnect to leave unparked or Cancel.

B) Luminos™

- i) Click Observe at the bottom of the screen.
- ii) Click Remote Control.
- iii) Scroll down to see Park and click it.
- iv) Choose Park Position 1-4 or Current.
- v) Scroll up and click the Connection slider to disconnect. Click Done.

7. Power down the mount.

Thoughts Regarding Workflow When Using Devices Other than PCs

Most Astronomy control software with which we are concerned is PC based and written to be ASCOM compliant. However, this is not universally true. There are some Mac based products that have developed their own drivers and there are also a few iPhone and Android products. See: "Planetarium, Imaging and Observatory Software from Other Vendors" on page 53

Although these products will allow mount control, they are limited in their scope. They are not able to take advantage of the many high precision, safety and expanded functionality features that are available in the AP V2 ASCOM driver and especially in APCC.

We do not have enough expertise with these Mac based products to feel confident to advise you and, thus, will refer you to the specific vender of the product. If you experience problems, you will need to seek solutions through the appropriate vender.

We can supply limited connection information for the Mobile Smart Devices previously described in order to get you started.

PEMPro™ by Sirius-Imaging

(Included with the 1100GTO, 1600GTO and 3600GTO mounts)

For a visual observer or an imager who takes short exposures, the native performance of your GTO mount will be without additional periodic error correction. However, those of you who take long exposure images may wish to further refine your mount's performance. This may be especially important if your images are unguided.

PEMPro™ (Periodic Error Management Professional) is a Windows software application that makes it easy to characterize and reduce periodic error. *PEMPro™* gives you powerful tools to program your mount's periodic error correction software to achieve the best possible performance for your mount. *PEMPro™* dramatically improves guided and unguided imaging resulting in better images and fewer lost exposures.

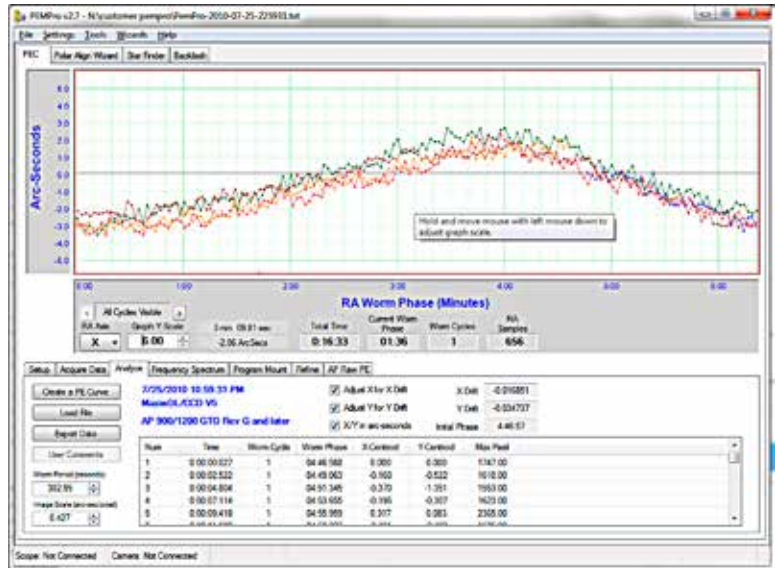
PEMPro™ will analyze the performance of any mount that is equipped with a CCD camera and compatible camera control software. Compatible CCD camera control software includes: ASCOM, *MaxImDL/CCD™*, *TheSkyX Camera™*, *CCDSOFT v5™*, *AstroArt™*, Meade DSI Series™, *SGPro™* and Video.

PEMPro™ also provides a way to use a low-cost webcam or video camera to perform all of its functions. *PEMPro™* has a Video interface application that can work with any DirectShow or WDM compliant device including most capture cards and webcams (like the Philips Toucam Pro™ and Meade LPI™).

The uncorrected periodic error of your mount is at or better than spec when it leaves our facility. We will have reduced this already small native error significantly by loading the error curve from our extensive testing procedures into the servo system. The resulting error that remains should be negligible, and will probably be satisfactory for all but the most demanding applications. You can, however, reduce the error even further to maximize performance without auto-guiding by recording a much longer run with *PEMPro™* that will average more complete cycles of the worm.

The serious imager may wish to redo the *PEMPro™* run once a year (more or less depending on usage) to compensate for gear run-in. If you ever remove your motor/gearbox or manually turn the worm gear, you will also invalidate any previously recorded corrections and will need to do a new *PEMPro™* run. (Manually moving the telescope by loosening the clutches does NOT turn the worm gear, so that is not a problem!) Complete documentation is provided in the help menu of the installed program. Also, please read the Important Information HTML file on the thumb drive included with your mount (CD with older mounts) before loading *PEMPro™* onto your computer.

PEMPro™ uses the ASCOM interface to control the mount. In addition to the functions available through the ASCOM interface, *PEMPro™* also includes a very handy and effective Polar Alignment Wizard, a Backlash Analysis Routine and a StarFinder Routine.



AUTO-GUIDING TIPS AND NOTES

Auto-guiding is an art. It can be the most complicated, yet most important, part of acquiring images. If it is not mastered, then images can suffer. Anything that you can do to make your auto-guider's job easier is a good thing. Here are some suggestions and things to keep in mind.

Important Misconception on Auto-guiding: The directions represented by the X+, X-, Y+ and Y- in your guiding software do not necessarily correspond to any given cardinal or equatorial directions. To the guiding software, "X" and "Y" simply refer to the rows and columns of pixels on the guide chip – nothing more. They do NOT mean RA and Dec!

The act of calibration tells the guiding software how to relate a guide star's drift along the columns and rows to move directions in the mount, but it does not make it so that X is necessarily always right ascension and Y always declination. To further complicate this, each time you alter the camera's orientation, you effectively change the relationship between X / Y and RA / Dec.

Your very first step in diagnosing any type of guiding problem should be to determine the actual current relationship between the X and Y of the guiding software and the RA and Dec. of your mount. This is easily done in your guiding software by making a manual move in one axis during an exposure and comparing this to a guide move from the keypad (use the keypad – not your computer software!) where you know the axis and direction for certain.

We have seen customers waste countless hours (not to mention dollars) in trying to fix a guiding problem on an axis that was performing perfectly. Meanwhile, their true problem remained, all because of this axis mix-up.

Another Important Note on Auto-guiding: The auto-guider port remains a popular way to use an auto-guider system, but you might want to consider making your guiding moves through the serial, USB or Ethernet connections via the AP V2 ASCOM driver instead. Guiding moves require millisecond timing to be accurate. When you guide through the auto-guider port, you are depending on the system to operate the guiding relays with this very accurate timing. Guiding through the AP V2 driver on the other hand sends a timed move command. There are no relays to open and close at an exact moment in time. The command itself contains the precise time interval in milliseconds for the move.

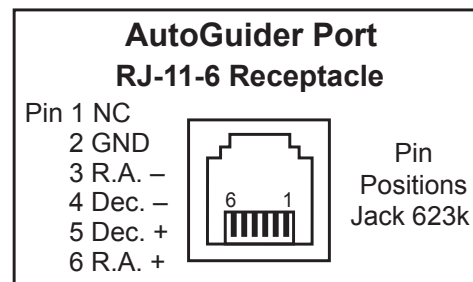
- Ensure that your auto-guider calibration is a good one:
 - Perform the calibration near the meridian and celestial equator. As you move towards the pole, RA becomes increasingly compressed and less accurate. This is a significant problem near the pole.
 - Calibrate for sufficient time so that the star travels at least $\frac{1}{4}$ to $\frac{1}{2}$ across the guide chip for a good arcseconds / pixel calculation. Your software's calibration numbers should agree with the following numbers. Guider calibration formula: Sidereal rate (arc sec / sec) x guide rate ÷ guide system image scale
example: $15.04107 \times 1.0 \div \text{guide system image scale (arc sec / pixel)} = (\text{pixels / second})$
- Use a 3-5 second sub-exposure for guiding. This will reduce the scintillation effect of the air. If you have good polar alignment, even longer sub-exposures can be used as long as a saturated star is not chosen.
- Choose a star in the brightness mid-range...not too dim and not saturated.
- Calibration and guiding should always be done at 1x guide rate.
- Turn all backlash to zero (Keypad and computer software) and turn off "stiction".
- The servo controller of all AP mounts is designed to work with PE correction on, even when getting auto-guide signals from your imaging software. The PE corrections do not fight the incoming auto-guide corrections, rather they help the auto-guiding. With a good PE curve you can do longer exposures of the auto-guider and guide on very faint stars.
- If you have one of our absolute encoder mounts, then PE correction is no longer needed. The encoder eliminates all periodic error, so no need for doing PE compensation. Auto-guiding works superbly well with the encoder mounts.

How to Test an Auto-guider Port

Here is the test for the auto-guider port. To perform the test, you will need a foot or so of 6 conductor flat phone cable with a standard RJ11-6 plug on the end. Remove the insulating material from 3 – 4 inches of the bare end of the cable to expose the six colored wires. Remove the insulation from about $\frac{1}{4}$ " to $\frac{3}{8}$ " of the ends of each of these wires, although you could skip the wire corresponding to pin #1 if you wish. The #1 wire will typically be either the white or the blue, depending on how the plug was attached. In addition to the cable I just described, I find a short test lead with alligator clips on each end to be very handy.

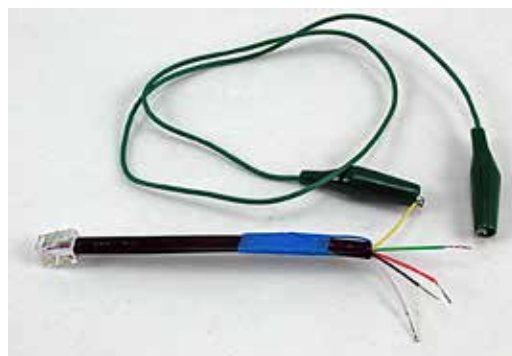
Note the pinout on the following page.

You may find it helpful to list the wire numbers and color codes before you start. Most likely, you will have: blue, yellow, green, red, black & white or else the exact reverse of this. If you hold the test cable so that you are looking at the bottom of the plug, with the plug's clip away from you, You can see the colored wires in order exactly as they go into the jack illustrated to the right.



To test:

1. Power up the mount.
2. Remove the covers from the gearboxes that cover the reduction spur gears.
3. If you have never done so before, set the keypad button rate to 1x and press the direction buttons to familiarize yourself with just how slow the gears actually are turning at 1x. Note also that in the RA, you have default rotation at sidereal. Pressing the EAST button at 1x simply stops the tracking rotation. Pressing the west turns the gears at 2x. The DEC axis is more straightforward.
4. Set the guide rate to 1x
5. If you have a test lead, attach one of the alligator clips to the #2 wire of the cable you have made. Make sure that none of the bare wires are touching.
6. Plug the cable into the auto-guider port of the AP Control Box.
7. Take the other end of the alligator clip test lead and clip it on the bare #6 wire from your test cable. (If you don't have the test lead, simply hold the #6 wire's bare end in contact with the #2 wire's bare end. This method goes for all the steps below using the relevant wire and the #2 wire.)
8. Observe the gears in the RA axis gearbox. They should be stopped as you observed in step #3.
9. Remove the test lead from wire #6 and attach the alligator clip to wire #3 on your test cable.
10. Observe the RA gears again. They should be turning at 2x sidereal in the same direction as normal sidereal tracking.
11. Remove the test lead from wire #3 and attach it to wire #4.
12. Observe the DEC gears for rotation at 1x. Be sure to note the direction of rotation.
13. Remove the test lead from wire #4 and attach it to wire #5.
14. Observe the DEC gears for rotation at 1x. The direction of rotation should be opposite of the direction observed in step #12.
15. Note any differences from the expected performance for communication with the technical staff at Astro-Physics. If the mount performs as expected, then the issue must lie elsewhere.



All any ST-4 compatible guider does is to close the circuit to cause the desired motion and then open the circuit to stop the motion. There is nothing more to it from the mount's perspective. If the mount performs as expected, then the issue must lie elsewhere.

- Auto-guider port relay commands do not involve the driver or APCC at any level. They cannot be logged.
- Auto-guider commands that go through the AP V2 ASCOM driver are timed commands. The precise timing is a part of the command itself so no external action to precisely stop a command is required.
- Auto-guider commands through APCC can actually be isolated in the log window in real-time for troubleshooting. You can watch the correction blip up on the guider graph and see the corresponding timed move command that is sent AS IT HAPPENS!

TROUBLESHOOTING, TIPS AND SUPPORT

Troubleshooting and Tips

Additional troubleshooting questions are in the individual mount manuals and in the GTO Keypad manual. Some of the issues discussed in the keypad manual also relate to mount communication issues whether you use the keypad or control the mount with a planetarium program or *PulseGuide*™. Please refer to them.

The GTOCP4/5 LED Indicator Light

A normally operating CP4/5 will have a steady red LED showing. Red was chosen for the *situation normal* condition to go along with dark-adaptation norms in astronomical observing. The other possible color is amber (a darker yellow). The following is a list of possible states and conditions where the light may NOT be its normal steady red:

- The LED will briefly flash amber at power-up and at power-down. This is normal and can be ignored. Newer CP4/5s with the Omega WiFi module in the digital board will rapidly flash the red LED at power-up until the Omega finishes its boot-up. This may take a minute or two during which WiFi will not yet be available. Older units with the original WiFi module boot up quickly and do not have the flashing LED at power-up. (The Omega is still a better module!)

Amber LED – causes and solutions

- **Encoder Fault.** The LED on your GTOCP4 may be amber if there is a problem with the Absolute or Precision Encoder system. Normal mount operation is still possible, but you will not have the advantages of the encoder system. Note that this does NOT apply to the GTOCP5 on the Mach2GTO which requires encoder function for its normal mount operation. The only user serviceable approach for this is to check the cable connections. Make sure the contacts are clean and that the plugs are properly seated.
- **Limit Fault.** The LED will turn to amber if the mount moves into a limit. This can be either an encoder limit or a servo limit. (Note: APCC Meridian limits will not cause the LED to turn amber.) If you are in a limit, motion that would move the mount further into the limit is not allowed. However, you will still be able to move in the direction that would be moving toward the *Home* position. If home hasn't been defined, the allowed motion will generally be toward the Park 3 position, or back from whence the mount came. Confirm that the mount is properly calibrated with the night sky, and make sure that Home and Limits are correctly set.
- **Low Power Fault.** The LED will turn amber if the voltage or current being supplied to the GTOCP4 goes below the acceptable minimum. Checking your power supply should always be one of the first steps in troubleshooting an amber LED. Inadequate power is the most common issue with mount performance.

Additional explanation: During slewing under load, the two motors draw up to 3 amps from a 12-volt source. This may increase when the temperature approaches freezing or below. It is recommended that your supply be rated at a minimum of 12 volts DC at 5 amps continuous. 12.3 to 25 volts with a capacity of 5 to 10 amps is recommended for best performance. Do NOT exceed 28 volts! See "Appendix C: Power Considerations" on page 68.

If you also power other equipment (CCD cameras, dew heaters, etc.) from the same source (NOT recommended!), you will need a supply capable of up to 10 amps. The more equipment you have, the more current capability you will need. We always recommend giving the mount its own supply and using additional supplies for other equipment. An air conditioner turning on in the summer can cause the power to drop, if on the same circuit.

For portable applications, we recommend heavy-duty deep-cycle batteries designed for deep discharge applications. Lithium batteries are also becoming more widely available as the technology improves and the price comes down. See "Appendix C: Power Considerations" on page 68.

- **Motor Stall.** The LED will turn to amber if a motor stall occurs. A motor stall means that the servo loop detected that the motors have not driven an axis to where the servo thinks it should be. This can happen during tracking or slewing. If a motor fails to track or slew the axis to where it belongs at the rate that is prescribed, the servo will send more power to try to overcome the discrepancy. Stall detection, therefore, is vitally important to prevent burning out the expensive servomotors on the mount. There are several reasons that a stall might occur.
 - By far, the most common reason for a motor stall is imbalance in one or both axes. The remedy for this is simple in theory: rebalance the axes. When rebalanced, you can clear the stall condition and test the effects of the rebalancing by using the direction buttons – either on the keypad or in the control software being used. Start with a short button push. Releasing the button sends a quit command which clears the stall. Since you have moved the axes to rebalance, you will almost certainly need to recalibrate the mount. The best approach may simply be to resume from a defined AP park position after power-cycling the mount. If you are using the keypad, remember to set Auto-Connect to NO before cycling the power so that you have the option to resume from a defined park position in New Setup.
 - Another possible reason for a stall is that the gears may be meshed too tightly. Gear problems do NOT just appear out of nowhere in a mount that has been working just fine. You should therefore NOT suspect this unless you have recently re-meshed or adjusted the gears. Information on servicing your gears can be found in the mount manuals and in the Support sections of the AP website.

- Make sure that you do not have any obstructions preventing movement. Did you maybe forget to stow the ladder away after installing the new dew heater controller on top of the OTA? (True story...)

The keypad reset (or locked up) when I plugged my CCD camera, PC (or other equipment) into the same battery as the GTO mount was using. The battery has a meter, which shows 12V.

The meter is reading an average and will not show dips. Battery users, PLEASE see "Appendix C: Power Considerations" on page 68 for information on battery usage.

For polar alignment, I am using declination drift technique with stars on east & south. Now, I do not see any drifts in declination on both sites (E & S), so the mount "should" be properly aligned. However, I have still small drift in RA which looks like the RA motor is a bit faster than earth rotation. This drift is something like 1.5 arcseconds during 1 minute or so & accumulates over time, so it doesn't look like periodic error.

The sidereal tracking rate is exact in the mount (it is crystal controlled and checked here for accuracy). However, the stars do not move at exactly the sidereal rate everywhere in the sky. The only place they move at that rate is straight overhead. As soon as you depart from that point in the sky, the stars will be moving more slowly, especially as you approach the horizons. Thus, it looks like the mount is moving slightly faster than the sidereal rate. Just because you have done a classic drift alignment, does not mean that the stars will now be moving at the sidereal rate everywhere in the sky.

Please see the relevant sections on polar alignment in your mount manual, and in the keypad manual if you have an AP GTO keypad.

The Astro-Physics Command Center (APCC) includes tracking and pointing correction based on calculations from atmospheric refraction all the way up to sophisticated real-world models based on plate-solve data for your specific instrument package.

Also, note that the GTOCP4 now also includes a King rate for tracking. This can be accessed through software or V5.xx of the keypad.

Initially, the mount was working fine. Then, suddenly the mount stopped tracking altogether!

First, check the LED on the GTOCP4. See the section on the previous page for more info.

If the LED was red indicating proper conditions in the GTOCP4, chances are that the motor was turning properly and driving the worm gear, but that your clutches might have been loose and therefore the scope was not following the motion of the worm gear. The fact that the high slew rate did move the scope does not change this, because Roland has seen this himself where the tracking rate did not overcome the slipping clutches but the slew rate did.

If you are unsure of the motion of the motor, just remove the motor cover plate and look inside. You will see the motor turning. Sometimes when you have the clutches loosely engaged and the counterweights are somewhat out of balance, being heavy in the east, then the clutches might slip at the slow sidereal rate.

In any case, just to set your mind at ease, simply remove the motor cover next time something like this happens and look at the motor shaft. If the motor is not turning, you will have some kind of electrical problem. If it is turning, then it is mechanical.

The motors sound louder and more labored in cold weather.

As the temperature drops, we recommend that you reduce your slewing speed to the slowest slew rate. The cold causes the lubricants to get stiff in the gearboxes. This can make the high-speed gears resonate and sound screechy. Lowering the slew speed in winter will eliminate or reduce this. You might also want to check the lubrication in the reduction spur gears. Grease kits are available from Astro-Physics. In the meantime, the noise is nothing to worry about.

The declination axis does not appear to be moving properly. How can I check it?

Please refer to your mount manual for the instruction sheet: "Characterizing the Dec. Axis Motions," which explains how to use Diffraction Limited's *MaxIm DL*™ software to characterize your mount's performance.

I am experiencing trailed stars after a slew and apparently a high, variable backlash.

Check to make sure that the spur gear that is attached to the end of the worm is not loose. A loose screw will indeed

cause the axis to delay during reversal. In a few cases, we have seen that the set screw on this spur has backed off and needs to be retightened. If you have any doubts about where this worm and spur gear is in the scheme of things, call Astro-Physics and we will talk you through the procedure to check this.

Remember this: Any backlash or looseness in Dec. will NOT cause trailed stars after a slew. That is because the Dec. axis does not move once it gets to its new position, so no trailing is possible. So, if you are getting trailed stars for a short time, don't look for something in the Dec. axis.

However, the RA axis WILL cause trailed stars after a slew if the spur gear is loose. That is because this axis must move at the sidereal rate immediately after getting to the new position. If the spur gear is loose on the worm shaft, it will turn slowly at the sidereal rate without imparting this motion to the worm itself (because it is slipping). At some point, the set screw will catch on the edge of the flat on the worm shaft and begin to drive the worm gear. So, this looks like classical backlash, when in fact it is not backlash at all, and all attempts at setting the gear mesh on the worm are futile to correct this lost motion.

A complete set of instructions has been posted on our website showing how to check for this loose gear condition. Even without those instructions, you can take the cover off the motor gearbox and acquaint yourself with the spur gears inside. Do not be afraid to move and wiggle things by hand to see how stuff works.

One more thing. Sometimes a person will be absolutely certain that it is the Dec. axis that is giving him a problem because the CCD program he is using shows some improper function in the Y-axis, and he is absolutely certain that Y = Dec. After much sending of equipment back and forth to our facility, it finally is determined that it was the other axis after all that had the problem. PLEASE, please make sure that you have identified the proper axis. In the case of any kind of motion problem like this, it would be really helpful if you removed your camera, inserted an eyepiece with crosshairs and actually looked to see what was happening. You can then identify exactly which direction, RA or Dec., is moving after a slew. Sometimes because of mix-ups in the CCD software (*MaxImDL*™, for instance), the axes are identified backwards.

When you are trouble shooting, remember, RA is the only axis that must move at the sidereal rate and is the only axis that can trail a star if it is not moving correctly at that rate. The Dec. axis does not move after a slew and will not trail a star except by a very slow long period drift due to polar misalignment, etc. It will not trail a star image EVEN if it has 10 degrees of backlash, so that analysis is definitely suspect.

I'm having a frustrating guiding problem with my mount and need to figure out my next steps.

To begin with, the directions represented by the X+, X-, Y+ and Y- in your guiding software do not necessarily correspond to any given cardinal directions. To the guiding software, "X" and "Y" simply refer to the rows and columns of pixels on the guide chip – nothing more.

The act of calibration tells the guiding software how to relate a guide star's drift along the columns and rows to move directions in the mount, but it does not make it so that X is necessarily always right ascension and Y always declination. To further complicate this, each time you alter the camera's orientation, you effectively change the relationship between X / Y and RA / Dec.

Your very first step in diagnosing any type of guiding problem should be to determine the actual current relationship between the X and Y of the guiding software and the RA and Dec. of your mount. This is easily done in your guiding software by making a manual move in one axis during an exposure and comparing this to a guide move from the keypad (use the keypad – not your computer software!) where you know the axis and direction for certain.

We have seen customers waste countless hours (not to mention dollars) in trying to fix a guiding problem on an axis that was performing perfectly. Meanwhile, their true problem remained, all because of this axis mix-up.

Your next step would be to remove the camera and place a high power eyepiece with crosshair reticle into the focuser. Then sit down and watch what happens to the guide star. With the eyepiece and reticle, you can see whether or not the mount is tracking smoothly and how the periodic error is manifesting itself. Yes, you will have periodic error, and any good CCD camera will pick it up to give you oval stars - that is a given. What you need to find out is whether this periodic error is within limits (± 3.5 arcseconds for the *Mach1GTO*, 900GTO and 1100GTO and ± 2.5 arcseconds for the 1200GTO, 1600GTO and 3600GTO) and whether it is smoothly varying. You can also do some hand guiding using the 4 buttons on the keypad. It will tell you how responsive the mount is to your guiding inputs and may even show some hidden problems when you try to keep the star on the crosshairs.

Alternately, you can use *PEMPro*™ to characterize your periodic error. It will tell you things like the peak value and the smoothness of the error.

You can also characterize your mount tracking and guiding abilities using the "Characterizing the Dec. Motions" test outlined in the Technical Support section of our AP website and included in the back of this manual. Many times a problem guiding in RA can be the result of a Dec. axis mechanical problem. Not knowing this, you will be forever chasing down the problem on the RA axis, and never reaching a solution. Characterizing your Dec. Axis will at least show you that the mount

reacts properly to the 4 guide directions. If it shows a problem area, then at least we will know how to fix it.

Once you know that the mount is tracking in a normal fashion with normal periodic error profile, you can go from there to begin setting up your guiding parameters. Once you know that the mount responds properly to the guide inputs, it should be possible to set it up to work accurately.

My GTOCPx Control Box does not appear to be working properly. Can I use the control box from my other Astro-Physics mount with the mount that is having problems?

The answer depends on which model your other Astro-Physics mount is. The GTOCP4, GTOCP3 and /or GTOCP2 control boxes from your *Mach1GTO*, 900GTO, 1100GTO, 1200GTO or 1600GTO mount can all be interchanged. The interchange works in either direction between any of these five mounts. Note, however, that GTOCP3 and GTOCP2 boxes do not include Absolute and/or Precision Encoder functions. A GTOCP4 that is configured for encoders will still control a non-encoder mount, and a GTOCP2 or 3 will still control an encoder mount, but without encoder functionality.

A GTOCP1 should not be used in an interchange without consulting Astro-Physics first. DO NOT interchange the control boxes from 400GTO, 600EGTO, or 3600GTO mounts or from a mount purchased from an OEM partner that uses our GTO system. These mounts employ different gearing in their servo drives and therefore use different personality parameters in the servo controller.

As a final note, if you “borrow” another control box for your mount, you must disable the PEM since the PE curve in the borrowed box will be for a different mount. You can always record a new PEM data set if you wish, and there is no reason to preserve the PEM data set in the borrowed box since it will no longer be valid. Any time that you use a different control box on a mount, the PEM data becomes out of phase and will need to be redone. This applies to both the borrowing mount and the lending mount. It is something to consider before trading control boxes, especially if you have achieved a particularly good PEM result with the mount that is to be the “lender.”

Additional Support

For additional information regarding the Astro-Physics GTO Servo Drive System, refer to the Technical Support Section of our website. We also encourage you to participate in the ap-gto user group. The members of this group are very knowledgeable about the operation of their mounts, CCD imaging and other related issues. The staff of Astro-Physics also participates and you will find a wealth of information in the archives. To find the group, link from User Groups in our website's sidebar.

If any problems occur, please don't hesitate to contact Astro-Physics for assistance.

We encourage you to submit your technical support questions directly to Astro-Physics by phone or e-mail: support@astro-physics.com.

We may add additional troubleshooting tips to future versions of this manual or in a separate technical document. In such an instance, we would add this information to the Technical Support section of our website as well.

ASTRO-PHYSICS, INC
11250 Forest Hills Road
Machesney Park, IL 61115
Telephone: (815)-282-1513
Fax: (815)-282-9847
support@astro-physics.com
www.astro-physics.com

APPENDIX A: GTOCP4 AND GTOCP5 SOFTWARE UPDATES

AP GTO Utilities

Firmware updates for the CP4 and CP5 are now accomplished through the AP GTO Utilities software application. This is included on your thumbdrive that came with the mount, and is also available for download from the Software Updates page on our website at <https://www.astro-physics.com/software-updates/>

The AP GTO Utilities an all-in-one application for managing your GTOCP4 or GTOCP5 Controller (with some capabilities for managing your CP3). It replaces and extends the AP USB/Serial Utilities and provides the following features and benefits:

- Review the current status and firmware version of your CP4/5.
- One-button auto-update of your CP4/5 firmware.
- Review and change Ethernet and Wi-Fi network settings.
- Use a command terminal interface to send commands and see results.
- Save/Restore your CP4/5 settings when changing controllers or replacing components.
- In the future you be able to update your keypad firmware and database using this utility.
- Runs on Windows, Mac, Linux (Java applet, you will need to have Java platform installed).
- Can be connected using Serial, USB, Ethernet, or WiFi (firmware updates can only be done through USB/Serial until Control Box is updated to firmware version P02-16 or later).



APPENDIX B: POWER SPECIFICATION TABLES

Power Specifications - Mach1GTO, 400GTO and 600EGTO	
Power consumption	0.3 to 0.5 amps at 13.8 volts tracking; 1.0 to 2.2 amps at 13.8 volts - both motors slewing at top speed of 1200x. (GTO Keypad connected; no load; room temperature)
Power requirements	12 to 18 volts DC at a minimum of 5 amps continuous recommended. (acceptable range: 11.5 volts at a minimum of 5 amps up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 7.5 or 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle!

Power Specifications - 900GTO (All) and 1200GTO (shipped prior to 2011) (1200GTOs - Ser. # 1200956 & earlier)	
Power consumption	0.3 to 0.5 amps at 13.8 volts tracking; 1.1 to 2.3 amps at 13.8 volts - both motors slewing at top speed of 1200x. (GTO Keypad connected; no load; room temperature)
Power requirements	12 to 18 volts DC at a minimum of 5 amps continuous recommended. (acceptable range: 11.5 volts at a minimum of 5 amps up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 7.5 or 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle!

Power Specifications - 1100GTO, 1100GTO-AE and 1100GTO-AEL	
Power consumption	0.3 to 0.6 amps at 13.8 volts tracking; 1.1 to 2.5 amps at 13.8 volts - both motors slewing at top speed of 1200x. (GTO Keypad connected; no load; room temperature)
Power requirements	12 to 18 volts DC at a minimum of 5 amps continuous recommended. (acceptable range: 11.5 volts at a minimum of 5 amps up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 7.5 or 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle!

Power Specifications - 1200GTO (shipped 2011 and later) (Ser. # 1200957 & later)	
Power consumption	0.3 to 0.6 amps at 13.8 volts tracking; 1.3 to 2.5 amps at 13.8 volts - both motors slewing at top speed of 1200x. (GTO Keypad connected; no load; room temperature)
Power requirements	12 to 18 volts DC at a minimum of 5 amps continuous recommended. (acceptable range: 12.0 volts at a minimum of 5 amps up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 7.5 or 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle! IMPORTANT! These power specifications are for the 1200GTO mounts that began shipping in April, 2011. Older mounts use the previous table above.

Power Specifications - 1600GTO	
Power consumption	0.3 to 0.7 amps at 13.8 volts tracking; 1.3 to 2.8 amps at 13.8 volts - both motors slewing at top speed of 1200x. (GTO Keypad connected; no load; room temperature)
Power requirements	12 to 18 volts DC at a minimum of 5 amps continuous recommended. (acceptable range: 12.0 volts at a minimum of 5 amps up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 7.5 or 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle!

<i>Power Specifications - 3600GTO</i>	
Power consumption	0.4 to 0.8 amps at 15 volts tracking; 1.5 to 3.0 amps at 15 volts - both motors slewing at top speed of 600x. (GTO Keypad connected; no load; room temperature; no optional Precision Encoder System or Limit Switch System - therefore no GTOELS box;)
Power requirements	15 volts DC at 10 amps continuous recommended. (acceptable range: 13.8 volts at a minimum of 5 amps (mounts without Precision Encoder System - 6 amps minimum for the 3600GTOPE) up to 18 volts at a maximum of 10 amps) Higher amperage supplies should be fused at 10 amps for the mount's power leads. We do not recommend exceeding a nominal 18V system (i.e. one 12V and one 6V in series.) Never exceed 28V at the GTOCP4's input receptacle!

APPENDIX C: POWER CONSIDERATIONS

Introduction

Astro-Physics German Equatorial mounts are designed to carry a wide range of loads. The *Mach1GTO*, 900GTO, 1100GTO, 1200GTOs (shipped prior to 2011) and the first run of 3600GTOs (shipped in 2008 and 2009) all employ the same powerful Swiss DC servo motors. Starting with the second run of 3600GTOs, the 2011 run of 1200GTOs and all 1600GTOs are outfitted with even more powerful, high-torque servo motors.

Above all, Astro-Physics mounts all have large worm gears that are meshed into appropriately large, precisely machined worm wheels. These mechanical components make contact over a much larger surface area than smaller worm systems of lesser precision. The large worm gear and worm wheel contribute to the mount's excellent performance, but they are also capable of generating significant drag on the motors and demanding higher current than smaller mounts. This is especially true when temperatures drop and lubrication is at a higher viscosity.

When you consider your mount's overall performance and capabilities, it is truly remarkable that it can do so much on so comparatively little power. As a simple point of comparison, even the mighty 3600GTO rarely uses as much energy as a single, small incandescent light bulb! The high efficiency of the Astro-Physics Servo System makes portability and remote operation a real possibility for these mounts. We want you to get the most out of your mount, wherever you operate it. We also want you to understand the mount's power requirements from the outset, so that you can provide the best power source possible to the system.

If you have purchased our recommended 13.8 volt 15-amp power supply (PS138V15A) or the bigger 25 Amp Variable Volt Power Supply (PSVPW25A) to power the mount – just the mount and nothing else – you will be fine and can probably skim through the following text with few concerns. If you plan to use other power sources, especially portable battery power, please read carefully and try to follow the guidelines presented below.

Some Power Basics for Non-Electrical Engineers

Please note that the discussion below is rather general and was written to apply loosely to all mounts currently under production at Astro-Physics. Please refer to "APPENDIX B: Power Specification Tables" on page 66 for your specific mount for more detailed recommendations.

It is vitally important that you understand what is meant by "adequate power." Adequate power has two major criteria that must BOTH be satisfied: adequate voltage and adequate current (amperage). Think of voltage as the pressure or push of the electrical energy. Voltage represents the potential difference or electromotive force across a circuit. More simply put, voltage is how much the electrons "desire" to move through a circuit. On the other hand, think of amperage as the volume or quantity of the electrical energy. Amperage is more accurately described as the total number of electrons that move through the circuit over a given amount of time. Water is often used as an analogy for electricity with pressure (i.e. psi - pounds per square inch) somewhat equivalent to voltage and flow rate (i.e. gpm - gallons per minute) somewhat equivalent to amperage.

Your Astro-Physics GTO servo drive system needs energy that is pushing its way through the system at a "pressure" of at least 12.0 volts. It will normally perform best if that voltage pressure is between 12.3 and 16 volts for the smaller mounts, or up to 18 volts for the larger mounts. The GTOCP4 can take electrical pressure up to 28 volts at the power input receptacle. A properly balanced and maintained mount should never need the servo to send more than 15 or 16 volts to the motors, even at 1200x slew speed.

Your servo drive system needs available current of 5 to 10 amperes (amps). Even though it normally consumes under one amp during regular tracking, and only about 1.5 to 4.5 amps when slewing at high speed under normal conditions, the mount should have at least 5 amps (at 12 volts) continuously available to it to ensure that it is adequately energized. (We recommend a bit higher minimum capacity for the 3600GTO.) A power supply that can deliver 10 amps would have the reserve capacity to deliver steady power through any peaks in demand, such as when new movement is initiated and acceleration is underway.

You must also understand that voltage and amperage are not independent of each other. If your mount demands more current (amps) than your power supply can deliver, the result will be a drop in the pressure or voltage of the current. A power supply of insufficient current or amperage capacity cannot maintain the pressure or voltage when a system demands excess current, even if only momentarily. The analogy of connecting a big fire hose to a weak, garden-hose hydrant comes to mind.

A lower voltage power supply will need more available amperage than a higher voltage supply. This is easiest to understand if you remember that the work done, or energy converted into work, measured in watts, is always equal to the volts times the amps. Imagine a water wheel that must turn a mechanical device. A small stream of water at high pressure will turn the wheel, but so will a large volume of water at low pressure. If you are inside the building watching the device

operate, you can't tell whether the wheel is being turned by a small volume at high pressure or by a large volume at low pressure.

Since watts are the real measure of potential work done, the goal should be to provide all the watts necessary to perfectly drive the mount without wasting any in the form of heat buildup. This goal is achieved by supplying the proper blend of volts and amps to match the servo system's design specifications. Too much voltage will generate heat as the excess energy is dissipated. Too much available amperage will pose a threat to the equipment should something "open the floodgates" so-to-speak and allow excessive current into the system. Too little of either volts or amps will starve the system of the required watts for proper operation.

So, what are the "DO's and DON'T's"? All this discussion of volts, amps and watts is fine, but how do we translate this into some meaningful recommendations for powering the mount? The following general list should help with this, and the individual Power Specification Tables referenced earlier (page 66) will fully address the details for each of the four Astro-Physics mounts that are currently in production.

- DO NOT use power supplies designed for portable stereos, laptop computers or other consumer electronics.
- DO NOT use the supply from a Meade or Celestron system, even though they may claim to provide adequate power.
- DO NOT power additional devices from your mount's power source – especially dew heaters which are notorious for initiating momentary voltage dropouts as they cycle on and off! Dew heaters also put a lot of switching noise on the power lines that can disrupt sensitive electronics, like servo control boxes or cameras.
- DO NOT use a DC extension cord between your DC power supply and the Mount's power cord. Run any needed extension cords on the AC side, or move your battery pack closer to the mount.
- DO NOT use batteries or battery packs with less than 30 amp-hours of power. In fact, for the larger mounts, we would recommend nothing less than a large (i.e. 50+ amp-hour) deep-cycle marine battery. See the Batteries section starting below.
- DO give your mount its own power source, if possible, and power other devices from a separate source or sources.
- DO use power inverters to go from standard household AC current to DC current that are **both filtered and regulated** to ensure clean steady power delivery.
- DO inspect your mount's power cord regularly to be sure that it is not damaged.
- DO use higher voltages – up to 16 to 18 volts – for extremely cold temperatures.
- DO keep an eye on the power LED on your GTOCP4 control box.

It bears repeating: The two power supplies that we offer (PS138V15A and PSVPW25A) are excellent choices for virtually all customers with U.S. standard 110 to 120-volt, 60-Hz, AC household current.

Batteries

If you are using battery power, be sure that you are using fully-charged, deep-cycle, type batteries with an absolute minimum 30 amp-hour (Ah) rating. Readily available batteries are generally divided into three application categories. (We will omit a discussion of more esoteric batteries like lithium ion.) These applications are: starting, deep-cycle and marine.

- Starting or "car" batteries are designed to provide a huge amount of current (many amps) for a very short time. In normal usage, they are not discharged below a few percent below full charge. To provide the high current demanded by starting, they employ many very thin spongy lead plates to maximize the surface area exposed to the electrolyte. Repeated deep discharge will dissolve these thin plates and ruin the battery. **Starting or "car" batteries are NOT recommended.** This includes motorcycle and garden tractor batteries.
- Deep-cycle batteries are designed to provide a more moderate, steady flow of current over a long time. True deep-cycle batteries employ much thicker, more robust lead plates since they do not require the ability to provide the huge burst of current required for cold-starting an engine. Repeated deep discharge will not dissolve the plates the way it does for starting batteries. True deep-cycle batteries include industrial (i.e. fork-lift) batteries and golf cart batteries - both normally rather large, high amp-hour formats - as well as smaller batteries designed for electric mobility devices ranging from electric mopeds to scooters and electric wheelchairs. **Deep-cycle batteries are the recommended application type for use with your mount.**
- Marine deep-cycle batteries are generally a hybrid design. They attempt to both provide the current to start a boat motor and the deep discharge capability for trolling motors or houseboat electrical systems. These are not as good a choice as true deep-cycle batteries, but are often much less expensive than true deep-cycle batteries. Note also that

many batteries marketed as “marine deep-cycle” are actually hybrid designs that are really more for starting than deep discharge. If the battery advertises its cranking power (i.e. CCA or cold cranking amps), then it is a hybrid at best, regardless of what the label says. **Marine deep-cycle batteries are suitable for powering your mount, but should not be discharged as deeply as true deep-cycle batteries.**

All the battery application types listed above refer to lead-acid batteries of one form or another. Since the original writing of this power guide back in 2011, newer technologies like Lithium Ion (Li-ion) and Lithium Iron Phosphate (LiFePO₄) have really taken hold. Lead-acid batteries still have a cost advantage – both in terms of the battery itself and in terms of the widely available, inexpensive chargers that they use. Also, for many of the deep-cycle applications like golf carts and forklifts, portability of the battery itself is not an issue. You simply drive the battery to the charging station.

The various lithium and lithium-metal technologies have had their applications either in the rather small (think laptop or cell phone), or in the rather large (think electric automobiles) where size and weight constraints require the maximum power to size ratios. As intermediate sized, general purpose lithium batteries become more available, we hope to have more information on these newer technologies for upcoming versions of this manual. We also don't want to forget the environmental impacts of the various battery technologies. Lead and lithium are both problematic, but lithium appears to be more recyclable and therefore more environmentally friendly.

For now, however, we will concentrate a bit more on the standard, lead-acid, deep-cycle battery. Just as there were three application types, there are also three battery construction types: flooded or “wet”, gel or Gel-cell, and AGM (for Absorbed Glass Mat).

Flooded batteries require some regular maintenance: basically keeping the electrolyte topped off - usually by the addition of distilled water to the individual cells. The largest industrial and golf cart batteries tend to be flooded. Large, heavy, flooded batteries may pose limitations in terms of portability, but the other benefits may outweigh the portability issues, depending on the mount and the situation. If you are setting up a 3600GTO on a remote mountain top, you can probably also handle these large batteries.

Gel-cells and AGM batteries are often grouped together as “valve-regulated” batteries. Both are sealed up to the limits of their regulating relief valve. This is a great advantage in terms of portability. Gel-cells can have a rather high internal resistance which makes them subject to momentary voltage drops when the demanded load changes. For this reason, we try to **avoid Gel-cell batteries** for the mounts. They are fine for items like dew heaters. **AGM** batteries are often the best choice for portable battery operation of your mount, and they are now available in a very wide range of suitable sizes.

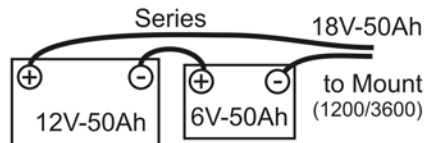
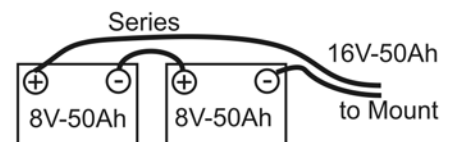
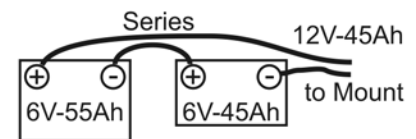
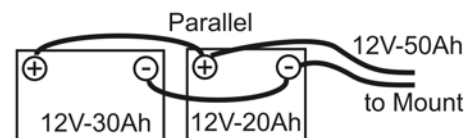
To summarize, true deep-cycle batteries with AGM (absorbed glass mat) construction are among the best to use as they deliver relatively steady power levels throughout their discharge cycle and provide the required portability. They are also designed to recover from more extreme levels of discharge and can be drained and re-charged many times without suffering a loss of capacity as happens with typical car batteries. As a final plus, they are also readily available.

Remember that batteries with smaller amp-hour ratings can be wired in parallel to achieve an equivalent single battery of the same voltage, but with the summed amp-hour rating. In other words, a 20 Ah battery and a 30 Ah battery can be wired in parallel to be the equivalent of a single 50 Ah battery. See the diagram at right.

Also, batteries with smaller voltage ratings can be wired in series to achieve the sum of their voltages. Batteries wired in series should be of similar amp-hour rating. The amp-hour rating of batteries wired in series is NOT additive and will be limited to the **weakest** battery in the set. As shown in the diagram, a 6 V, 55 Ah battery wired in series to a 6 V, 45 Ah battery will be the equivalent of a 12 V, 45 Ah battery. It will not yield 50 Ah (the average of the two) or the 55 Ah of the larger 6 V battery.

Do not be tempted to wire a bunch of batteries together in parallel in order to power multiple devices from one source. In terms of overall efficiency, this might make sense, but you will have better success if you give the mount its own power source. Also, as a general rule, do not mix battery construction types: i.e. a flooded and a gel cell. This is more important when charging than when discharging the batteries in normal deep-cycle usage.

An excellent battery choice for the larger mounts is to purchase 6 or 8-volt golf cart or fork-lift batteries that are then wired in series. If you choose the 8-volt sizes, two of these wired in series would yield 16 volts - perfect for a 1200GTO, 1600GTO or 3600GTO mount. Be aware, however, that there are limitations in available charging systems. Eight volt batteries are normally used with three batteries in series to create a 24-volt system and are charged accordingly. To use 8-volt batteries, you might need to purchase 3 batteries and use them in rotations of 2 for each astronomy session, and then connect all three in series for charging.



The proliferation of personal mobility devices, or “scooters” has also led to the wide availability of deep-cycle batteries in the 20 Ah to 60 Ah range. Many of these are perfectly suited to the smaller mounts as they can be found in a very wide array of sizes. We repeat: Give the mount its own battery. Use multiple batteries if powering multiple devices!

All of the lead-acid based batteries, whether traditional “flooded” or “wet”, gel or AGM, will basically measure about 2.14 to 2.3 volts per cell when new, fully charged and under no load. In an actual operating circuit, the output of a fully charged battery cell ranges from about 2.05 to 2.2 volts per cell, depending on the load. Even a 3600GTO at maximum slew speeds will not draw down the output voltage of a fully charged deep-cycle battery below about 2.1 volts per cell. Therefore, the “standard” 12-volt battery when new and fully charged will measure up to 2.3 volts x 6 cells = 13.8 volts with no load applied, and will conservatively measure about 12.6 volts under a normal mount load of up to a couple amps. Likewise, a “16-volt” setup as described above under normal load actually delivers roughly 2.1 volts x 8 cells = 16.8 volts.

A battery is considered fully discharged at about 1.75 volts per cell. You DO NOT EVER want to discharge a battery below this level, even if it is a deep-cycle battery. A 12-volt battery discharged to this level (1.75 volts x 6 cells = 10.5 volts) is totally insufficient to power the GTO Servo Drive System. A 16-volt system consisting of two 8-volt batteries discharged to this level still has 14 volts, but the battery will be in danger of ruin.

Note: At 50% discharge, under a normal mount load, a typical 12-volt, 50 amp-hour deep-cycle battery will still deliver between 2.0 and 2.05 volts per cell or 12.0 to 12.3 volts to the mount. We do not recommend discharging batteries below 50%. When selecting battery amp-hour ratings, keep this recommended 50 % discharge rule in mind.

Amp-hours, C/xx rates and the “Peukert number.” Here is a very brief explanation of some terms you will find when battery shopping: Amp-hours is the simplest of these terms. The amp-hour capacity of a battery is the product of amps and time in hours that will fully discharge a battery. Without stressing anyone’s math abilities, a 50 amp-hour battery should then be able to discharge at a 1 amp rate for 50 hours, 5 amps for 10 hours, or 50 amps for an hour. Simple, right?

The trouble is that unfortunately, it doesn’t quite work that way. The reason for this is that discharge capacity increases as rate of discharge decreases and vice versa. If things were linear, our 50 amp-hour battery (measured and rated by discharging at 1 amp per hour), would last 50 hours at 1 amp, 10 hours at 5 amps, and 500 hours at 0.1 amps. However, the reality is that at a 5 amp discharge rate, the afore-mentioned battery will last significantly less than 10 hours, and at 0.1 amps, the same battery will last well over 500 hours.

The compromise is to use the C/xx rating system - normally C/20 for deep-cycle batteries. This means that you discharge the battery at a rate that will deplete it in 20 hours to determine the amp-hour rating. This does a better job of relating a particular battery to its expected load. For our 50 amp-hour battery, this would mean that it could discharge at a rate of 2.5 amps for 20 hours (2.5 x 20 = 50). A 30Ah (C/20) battery could be discharged at 1.5 amps for 20 hours, and so on. The obvious reason to be aware of this is that an unscrupulous manufacturer or seller may market a battery with an amp-hour spec based on something like a C/100 rate. This will dishonestly inflate the apparent capacity of the battery. If the seller can’t tell you the C/xx rating for the advertised amp-hour specification, you should become skeptical.

For the last of our battery terms, we have the beautifully named Peukert number (and Peukert’s formula). Explaining this in great detail is beyond the scope of this manual, but be aware that the Peukert number normally falls between 1.08 and 1.5. The lower the number, the better. Peukert’s formula tells you how long a battery will really last at a given discharge load. The formula is: $T = C / I^n$ T = time in hours C = actual amp-hour capacity at one amp discharge rate (sometimes labeled C_{MAX}) I = the load’s discharge current in amps n = the Peukert number for the battery AGM batteries tend to have the lowest Peukert numbers.

Just as a deep-cycle battery will have greater capacity if discharged slowly, it will build up a greater capacity if charged slowly. Modern “smart chargers” will charge slowly and monitor the battery’s state-of-charge. When fully charged, they will switch to a maintenance or trickle charge mode and can be left connected to the battery indefinitely. Some of our mount owners run their systems entirely off of batteries - even when in their AC powered observatories. The smart charger is left connected, and the battery barely discharges at all during a full evening’s usage. AC power outages or brownouts (common in rural / dark sky areas) are never a concern since the batteries are powering the system.

Now you’re ready to shop for batteries!

Results of Either Inadequate or Excessive Power

So, what happens if inadequate power is supplied to the mount? The answer is: a number of things. Which of these happens first is hard to predict without knowing other factors. Rest assured knowing that you will not damage or break anything by supplying inadequate power. You will, however, spoil that evening’s observing or imaging plans until the power situation is rectified. Here then are the most common symptoms of a poor power supply:

- A labored sound from the motors when slewing at high speed. Be aware, however, that there are other things that can cause a motor/gearbox to make strange noises. If power is a concern, use slower slew speeds!

- The power LED on the GTOCP4 turns from red (normal) to amber (motor stall or safe mode) or goes out completely. When the power light changes color to amber, the servo shuts down and quits trying to drive the motors. A note of caution: The amber light does not necessarily signify low voltage from your power supply. A number of things can cause the servo to go into this condition including balance issues and gear mesh, but power issues should always be looked at first if the amber light occurs. The mount does NOT get lost when it goes into safe mode!
- Keypad resets. The keypad will suddenly click and go back to the startup screen. As voltage gets lower, resets of the keypad become ever more frequent.

OK! So, what happens if you connect to a power supply that delivers too high a voltage? This was much more of a problem in the older GTOCP1, 2 & 3 servo control boxes than in the GTOCP4. As mentioned before, the CP4 can handle 24 volts without damage, and can take up to 28 volts before serious problems arise. The AP GTO Keypad is limited to 28 volts maximum, after which damage will occur, so keypad users please take extra precautions. The thing to keep in mind is that the GTO Servo System as a whole was designed for 12 – 16 volts with the exception of the Mach2GTO which uses a GTOCP5 control box. Again, conditions will play a role. Here are some considerations:

- First, excess heat shortens the life of electronic components over the long term. Too much heat from extreme over-voltage will even damage the components and may "burn up the unit" right before your eyes.
- Second, energy that is being dissipated as heat by the voltage regulator is basically being wasted.
- In addition, at even higher voltages, your motors may experience chatter from the excessive gain, and there is an increased likelihood of damage to the motors, encoders and system components, not to mention the heat damage to the control box as voltages climb higher.
- The voltage that matters is the voltage that enters the control box. For example, two 12-volt batteries, connected in series, (producing roughly 25 to 26 volts) that are 50 feet away from the mount in a truck, might only deliver about 20 volts to the mount by the time the current has gone through all that (hopefully very heavy gauge) cable.
- Note that a 24 volt system attached to a charger may be receiving over 28 volts from the charger!
- Cold weather does three things: It demands more voltage from the system, especially for slews, and it allows heat to dissipate faster. The third thing is that it reduces the output voltage of batteries. At temperatures below freezing, you may be safe with up to 24 volts for the large mounts, or 18 volts for the smaller mounts, but we do not recommend this as a general practice. ***A far better practice for cold weather is to reduce your slew speed and thereby your voltage demands!***
- If using a supply with voltage over 26V (at the CP4 input), you should periodically check the GTOCP4 to be sure it is not overheating. Warm to the touch is OK. Too hot to touch continuously is TOO HOT! Keep the ambient temperature in mind. Reasonable voltage at freezing might be too much in the desert sun.
- Finally, you should be aware that voltages above about 28 volts begin to pose a shock hazard to humans, and an arcing hazard to electronics that are not designed for that voltage. Please be smart and be careful!

IMPORTANT Considerations for observatory installations:

Ideally, we would suggest that you disconnect your GTO Control Box from 110V and any other device (CCD camera, computer, etc) when you are not using your mount so that if your observatory experiences a power surge or lightening strike, your mount electronics will not be damaged. If you operate your mount remotely, you will have to leave your power cable connected just as you do for the rest of your electronic equipment. You may want to consider surge protectors or other protective measures to protect from voltage spikes. A disconnect relay to remove power from both the 12-volt and ground wire is highly recommended in this situation. Power handling, power / surge protection, and lightning protection should be primary design criteria for any remote observatory.

Remember also that electronics can be damaged by "Ground Rise Potential" that can enter the electronics through communications connections – not just power connections. A cheap "surge protector" doesn't offer much (if any) protection to a remote or robotic observatory. A Transtector on the outside of the observatory, intercepting the power before it enters the observatory would be significantly better. And there is still the issue of effective lightning protection grounding which is NOT the same as standard electrical grounding. See the [Motorola R56 Standards and Guidelines for Communications Sites manual](#) for detailed information on proper lightning protection of exposed sensitive facilities like observatories.

Failure in this area can be very costly!

APPENDIX D: COMMAND LANGUAGE

As with the Firmware Update instructions briefly discussed in "Appendix A: GTOCP4 and GTOCP5 Software Updates" on page 65, this section has been removed to a separate document. It can be found at <https://www.astro-physics.com/support/>

APPENDIX E: REGULATORY INFORMATION FOR TRANSMITTER MODULE

FCC Notice (USA)

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures: reorient or relocate the receiving antenna, increase the separation between the equipment and receiver, connect the equipment into an outlet on a circuit different from that to which the receiver is connected, or consult the dealer or an experienced radio/TV technician for help.

RF Exposure

"WARNING: To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 20 cm or more should be maintained between the antenna of this device and persons during operation. To ensure compliance, operations at closer distances than this are not recommended."

IC Notice (Canada)

The term "IC" before the certification/registration number only signifies that the Industry Canada technical specifications were met.

Le terme "IC" devant le numéro de certification /d'enregistrement signifie seulement que les spécifications techniques Industrie Canada ont été respectées.

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to

The following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Cet appareil est conforme avec Industrie Canada RSS standard exempts de licence (s). Son utilisation est soumise à Les deux conditions suivantes: (1) cet appareil ne peut pas provoquer d'interférences et (2) cet appareil doit accepter Toute interférence, y compris les interférences qui peuvent causer un mauvais fonctionnement du dispositif.

This device complies with Health Canada's Safety Code 6 / IC RSS-210. The installer of this device should ensure that RF radiation is not emitted in excess of the Health Canada's requirement. Information can be obtained at: http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php

Cet appareil est conforme avec Santé Canada Code de sécurité 6 / IC RSS-210. Le programme d'installation de cet appareil doit s'assurer que les rayonnements RF n'est pas émis au-delà de l'exigence de Santé Canada. Les informations peuvent être obtenues: http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radio_guide-lignes_direct-eng.php

CE Notice (Europe)

This device has been tested and certified for use in the European Union.

If this device is used in a product, the OEM has the responsibility to verify compliance of the final product to the EU standards. A Declaration of Conformity must be issued and kept on file as described in Annex II of the Radio and Telecommunications Terminal Equipment Directive.

APPENDIX F: COUNTRY CODES FOR WIFI

If you are operating the GTOCP4 in a country other than the United States, locate the appropriate “Country Code” in the table below, and enter it in the Country Code field (per ISO 3166-1, alpha-2) in the Advanced WiFi Settings Web page of the GTOCP4’s built-in web pages. When entered, click “Change” next to the entry box. The country code accounts for differences in regulations such as the availability of channels or Access Point transmit power.

<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>
Afghanistan	AF	Botswana	BW	Croatia	HR
Albania	AL	Bouvet Island	BV	Cuba	CU
Algeria	DZ	Brazil	BR	Cyprus	CY
American Samoa	AS	British Indian Ocean Terr.	IO	Czech Republic	CZ
Andorra	AD	Brunei		Denmark	DK
Angola	AO	Darussalam	BN	Djibouti	DJ
Anguilla	AI	Bulgaria	BG	Dominica	DM
Antarctica	AQ	Burkina Faso	BF	Dominican Republic	DO
Antigua and Barbuda	AG	Burundi	BI	Ecuador	EC
Argentina	AR	Cambodia	KH	Egypt	EG
Armenia	AM	Cameroon	CM	El Salvador	SV
Aruba	AW	Canada	CA	Equatorial Guinea	GQ
Ascension Island	AC	Cape Verde	CV	Eritrea	ER
Australia	AU	Cayman Islands	KY	Estonia	EE
Austria	AT	Central African Republic	CF	Ethiopia	ET
Azerbaijan	AZ	Chad	TD	Falkland Islands	FK
Bahamas	BS	Chile	CL	Faroe Islands	FO
Bahrain	BH	China	CN	Fiji	FJ
Bangladesh	BD	Christmas Island	CX	Finland	FI
Barbados	BB	Clipperton Island	CP	France	FR
Belarus	BY	Cocos Islands	CC	French Guiana	GF
Belgium	BE	Columbia	CO	French Polynesia	PF
Belize	BZ	Comoros	KM	French Southern Territories	TF
Benin	BJ	Congo	CG	Gabon	GA
Bermuda	BM	Congo, Democratic Republic	CD	Gambia	GM
Bhutan	BT	Cook Islands	CK	Georgia	GE
Bolivia	BO	Costa Rica	CR	Germany	DE
Bosnia and Herzegovina	BA	Cote D’Ivoire	CI	Ghana	GH
				Gibraltar	GI

<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>
Greece	GR	Korea, Dem. Peoples Rep. of	KP	Mongolia	MN
Greenland	GL	Korea, Republic of	KR	Montenegro	ME
Grenada	GD	Kuwait	KW	Montserrat	MS
Guadeloupe	GP	Kyrgyzstan	KG	Morocco	MA
Guam	GU	Lao, Peoples Dem. Rep of	LA	Mozambique	MZ
Guatemala	GT	Latvia	LV	Myanmar	MM
Guernsey	GG	Lebanon	LB	Namibia	NA
Guinea	GN	Lesotho	LS	Nauru	NR
Guinea-Bissau	GW	Liberia	LR	Nepal	NP
Guyana	GY	Libya	LY	Netherlands	NL
Haiti	HT	Liechtenstein	LI	Netherlands Antilles	AN
Heard or McDonald Islands	HM	Lithuania	LT	New Caledonia	NC
Holy See (Vatican City-State)	VA	Luxembourg	LU	New Zealand	NZ
Honduras	HN	Macao	MO	Nicaragua	NI
Hong Kong	HK	Macedonia	MK	Niger	NE
Hungary	HU	Madagascar	MG	Nigeria	NG
Iceland	IS	Malawi	MW	Niue	NU
India	IN	Malaysia	MY	Norfolk Island	NF
Indonesia	ID	Maldives	MV	North Mariana Islands	MP
Iran	IR	Mali	ML	Norway	NO
Iraq	IQ	Malta	MT	Oman	OM
Ireland	IE	Man, Isle of	IM	Pakistan	PK
Israel	IL	Marshall Islands	MH	Palau	PW
Italy	IT	Martinique	MQ	Palestinian Terr.	PS
Jamaica	JM	Mauritania	MR	Panama	PA
Japan	JP	Mauritius	MU	Papua New Guinea	PG
Jersey	JE	Mayotte	YT	Paraguay	PY
Jordan	JO	Mexico	MX	Peru	PE
Kazakhstan	KZ	Micronesia	FM	Philippines	PH
Kenya	KE	Moldova	MD	Pitcairn	PN
Kiribati	KI	Monaco	MC	Poland	PL
				Portugal	PT

<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>	<u>Country</u>	<u>Country Code</u>
Puerto Rico	PR	Svalbard and Jan Mayen	SJ	Virgin Islands, British	VG
Qatar	QA	Swaziland	SZ	Virgin Islands, US	VI
Reunion	RE	Sweden	SE	Wallis and Futuna	WF
Romania	RO	Switzerland	CH	Western Sahara	EH
Russian Fed.	RU	Syria	SY	Yemen	YE
Rwanda	RW	Taiwan	TW	Yugoslavia	YU
Saint Helena	SH	Tajikistan	TJ	Zambia	ZM
Saint Kitts and Nevis	KN	Tanzania	TZ	Zimbabwe	ZW
Saint Lucia	LC	Thailand	TH		
Saint Pierre and Miquelon	PM	Timor-Leste	TL		
Saint Vincent and the Grenadines	VC	Togo	TG		
Samoa	WS	Tokelau	TK		
San Marino	SM	Tonga	TO		
Sao Tome and Principe	ST	Trinidad and Tobago	TT		
Saudi Arabia	SA	Tristan Da Cunha	TA		
Senegal	SN	Tunisia	TN		
Serbia	RS	Turkey	TR		
Seychelles	SC	Turkmenistan	TM		
Sierra Leone	SL	Turks and Caicos Island	TC		
Singapore	SG	Tuvalu	TV		
Slovakia	SK	Uganda	UG		
Slovenia	SI	Ukraine	UA		
Solomon Islands	SB	United Arab Emirates	AE		
Somalia	SO	United Kingdom	GB		
South Africa	ZA	United States	US		
South Georgia and Sandwich Islands	GS	US Minor Outlying Islands	UM		
Spain	ES	Uruguay	UY		
Sri Lanka	LK	Uzbekistan	UZ		
Sudan	SD	Vanuatu	VU		
Suriname	SR	Venezuela	VE		
		Viet Nam	VN		

APPENDIX G: NETWORK PROTOCOL LICENSE

The GTOCP4 implements the network protocol stack using Light Weight IP (LwIP):

LwIP's License

LwIP is licenced under the BSD licence:

Copyright (c) 2001-2004 Swedish Institute of Computer Science.
All rights reserved.

Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Redistributions of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
2. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
3. The name of the author may not be used to endorse or promote products derived from this software without specific prior written permission.

THIS SOFTWARE IS PROVIDED BY THE AUTHOR "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED.

IN NO EVENT SHALL THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

APPENDIX H: GTOCP4 / MOUNT PERSONALITY CODES

Each GTOCP4 control box is assigned a personality code that allows it to work with given mounts. This personality can be changed if it becomes necessary to switch the control box to a different mount in the future. However, the control box would either have to be returned to us or we can change it remotely. It is not user changeable.

<u>Part #</u>	<u>Config #</u>	<u>Description</u>
GTOCP4-110	110	AP Germ. Eq. Mounts NO Absolute Encoders Mach1, 900, 1100, 1200, 1600
GTOCP4-120	120	AP Germ. Eq. Mounts with Absolute Encoders 1100, 1600
GTOCP4-130	130	AP400/600 Germ. Eq. 32:1 ratio, w/7.2V
GTOCP4-140	140	AP400/600 Germ. Eq. 19.8:1 ratio, w/7.2V
GTOCP4-150	150	AP3600 Germ. Eq., NO ELS, w/ 7.2 or 9V
GTOCP4-152	152	AP3600 Germ. Eq., ELS Support, w/ 7.2 or 9V
GTOCP4-310	310	Parallax/Mathis Germ. Eq., 360 tooth
GTOCP4-311	311	Mathis Eq. FORK, 360 tooth (MI-500F)
GTOCP4-320	320	Mathis Germ. Eq., 450 tooth (MI-750G)
GTOCP4-321	321	Mathis Eq. FORK, 450 tooth (MI-750F)
GTOCP4-331	331	Mathis Eq. FORK, 450 tooth (MI-750F) 18:1 Gear head 21:72 pulley reduction
GTOCP4-340	340	Mathis Germ. Eq., 450 tooth (MI-750G) 18:1 Gear head 30:72 pulley reduction
GTOCP4-341	341	Mathis Eq. FORK, 450 tooth (MI-750F) 18:1 Gear head 30:72 pulley reduction