PMC-Eight™ Programmer's Reference

DOC-ESPMC8-002 Release 2

2019_February 01

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NOTE: This document is provided to our PMC-Eight™ customers for their personal use in developing applications for the PMC-Eight™ Control System in accordance with the requirements of Explore Scientific and the PMC-Eight™ OpenGOTO™ Community Steering Committee.

If you have any comments or questions about this document, please contact:

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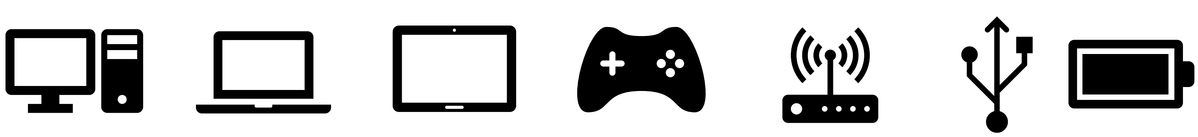
This is the third in the following series of documents for the PMC-Eight™ System:

Document Number	Title
DOC-ESPMC8-001A	PMC-Eight™ Owner's Reference Manual (Customer Use)
DOC-ESPMC8-001B	iEXOS 100 PMC-Eight™ Owner's Reference Manual (Customer Use)
DOC-ESPMC8-002	PMC-Eight™ Programmer's Reference (Customer Use)
DOC-ESPMC8-003	PMC-Eight™ JOC Command Language Reference (Internal Use)
DOC-ESPMC8-004	PMC-Eight™ Datasheet and Design Basis Document (Internal Use)
DOC-ESPMC8-005	PMC-Eight™ Firmware and Software Design Reference (Internal Use)
DOC-ESPMC8-006	PMC-Eight™ Firmware and Software Flowcharts (Internal Use Only)
DOC-ESPMC8-007	PMC-Eight™ Hardware Reference Schematics and Datasheets (Internal Use)



Document Notes

Revision History

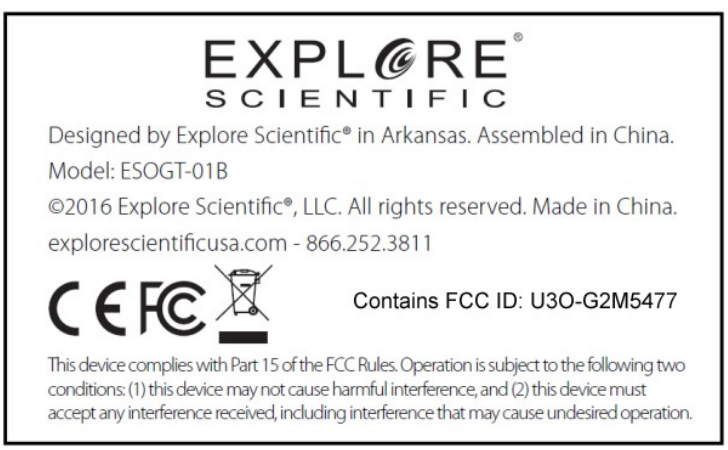
0.0	GRH	DRAFT	Initial Draft.
0.1	GRH	DRAFT	Added Sections VI and VII.
0.2	GRH	DRAFT	Revised Section V to add "ESR!" Communications Reset command.
0.3	GRH	DRAFT	Revised Section III to correct and expand on Meridian Flip discussion.
1.0	GRH	RELEASE 0	Miscellaneous cleanup of text and sections for release.
1.1	GRH	RELEASE 1	Revised Section II to add board layout information and LED and test point information. Miscellaneous revisions and formatting changes.
1.2	GRH	RELEASE 2	Revised Sections II–VIII to add information about the iEXOS 100 mount and other updates. Added Appendix section for miscellaneous information, including Application Notes. Miscellaneous cleanup of text.

This document uses the following convention for units of measure. Instead of stating: 30 counts/second or 20 arc-sec/count, or 20 arc-sec per count, the units are stated as: 30 counts sec^{-1} or 20"arc $count^{-1}$. The superscript $^{-1}$ indicates that the unit is in the denominator. You will see °, ', and " for degrees, minutes, and seconds for angular values.

Motor count values are stated in decimal (115200) and hexadecimal (0x9C40) notation. The terms counts and microsteps are synonymous depending on the usage. All the values returned by the controller are hexadecimal strings such as "1F92CA". Actual commands are shown in `Courier New` font with quotes around the command string, i.e., "ESGp0!". Do not include the quotes when typing the commands at a terminal connected to the controller. Program names used to communicate with the PMC-Eight™ are designated in ***Bold Italic***, i.e., ***Parallax Serial Terminal***.

The PMC-Eight™ Control System is warranted by Explore Scientific, LLC. If you have any questions or issues when using this reference with your PMC-Eight™ system, you should contact Explore Scientific Customer Support at +1 (866) 252-3811

CAUTION: BOARD FAILURE INDUCED THROUGH PROBING THE CIRCUITRY IS NOT COVERED UNDER THE PMC-Eight™ LIMITED WARRANTY.



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Glossary

Axis—The rotational axis that the motor is driving, either RA or DEC.
Right Ascension (RA)—The rotational axis that parallels the Earth's rotational axis.
Declination (DEC)—The rotational axis that allows the scope to move north or south.
German Equatorial Mount (GEM)—A type of mount that positions the telescope to move on one axis to counteract the rotation of the Earth.
Hexadecimal—The base 16 number system using characters "0" through "9" and "A" through "F".
Decimal—The normal base 10 number system used in everyday life using characters "0" through "9".
Rate—The rotational speed at which the motors are driving the mount.
Position—The number of microsteps the motor has moved since startup.
Direction—The direction of the motor rotation (clockwise, or counterclockwise) when looking at the shaft end.
Tracking Rate—The precision rotational speed of the RA axis motor at a very slow rate. Used to counteract the rotation of the Earth.
Tracking—The act of counteracting the rotation of the Earth to keep an object in the center of the telescope field-of-view (FOV).
North Celestial Pole (NCP)—The point in the Celestial Sphere where the Earth's rotational axis points in the Northern Hemisphere. Likewise, with the South Celestial Pole (SCP) in the Southern Hemisphere.
Firmware—The computer instructions installed in the permanent memory of the processor that communicate directly with the hardware I/O on the system. The firmware is compiled on an external computer and uploaded via the serial RS232(DB9)/USB communications port.
RS232—A communications hardware standard for serial communications.

Acronyms

DEC	Declination
EpW	East Pointing West
FOV	Field-of-View
GEM	German Equatorial Mount
HA	Hour Angle
HMI	Human-Machine Interface
I/O	Input/Output
JOC	Jinghua Optical Corporation
LDO	Low Drop Out
LMST	Local Mean Sidereal Time
NCP/SCP	North Celestial Pole/South Celestial Pole
OTA	Optical Tube Assembly
PMC	Precision Motion Controller
PMGR	Programmer
RA	Right Ascension
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
WpE	West Pointing East

I Introduction

The Explore Scientific PMC-Eight™ Controller Programmer's Reference contains the information needed to understand the controller operation and to communicate and use the base controller command language. This document contains the system description and other data that can be used to create programs to control the PMC-Eight™. More information about the PMC-Eight™ controller can be found on the Explore Scientific website at ExploreScientificUSA.com. Additional information is included in the Application Notes available on the PMC-Eight™ webpage and in Section VIII: Appendices of this document.

One of the key elements of the PMC-Eight™ System is the Explore Scientific PMC-Eight™ Command Language. This language is designed to be both flexible and powerful enough to instruct the controller to perform any task the controller can perform. This language is different from most mount controller languages in that it does not contain astronomy or telescope mount specific commands. This language contains more generic motion control commands that enable the user to quickly learn and use the system. The PMC-Eight™ System also has a built-in JOC Command Interpreter used by the OpenGOTO™ Explore Stars App available at the Microsoft App Store, Google Play Store, and Apple App Store.

The PMC-Eight™ architecture was driven by the design philosophy of abstracting the astronomical functions from the hardware/firmware layer and encapsulating them within the software driver/application layer. This provides several benefits to the overall performance, reliability, and operation of the control system. The system architecture is very similar to other industrial motion control systems that are used for single and multiple motor control functions used in robotics, power plants, and manufacturing facilities.

The model 2A circuit board design includes several features♦ that contribute to the reliability and thermal performance of the control system, including:

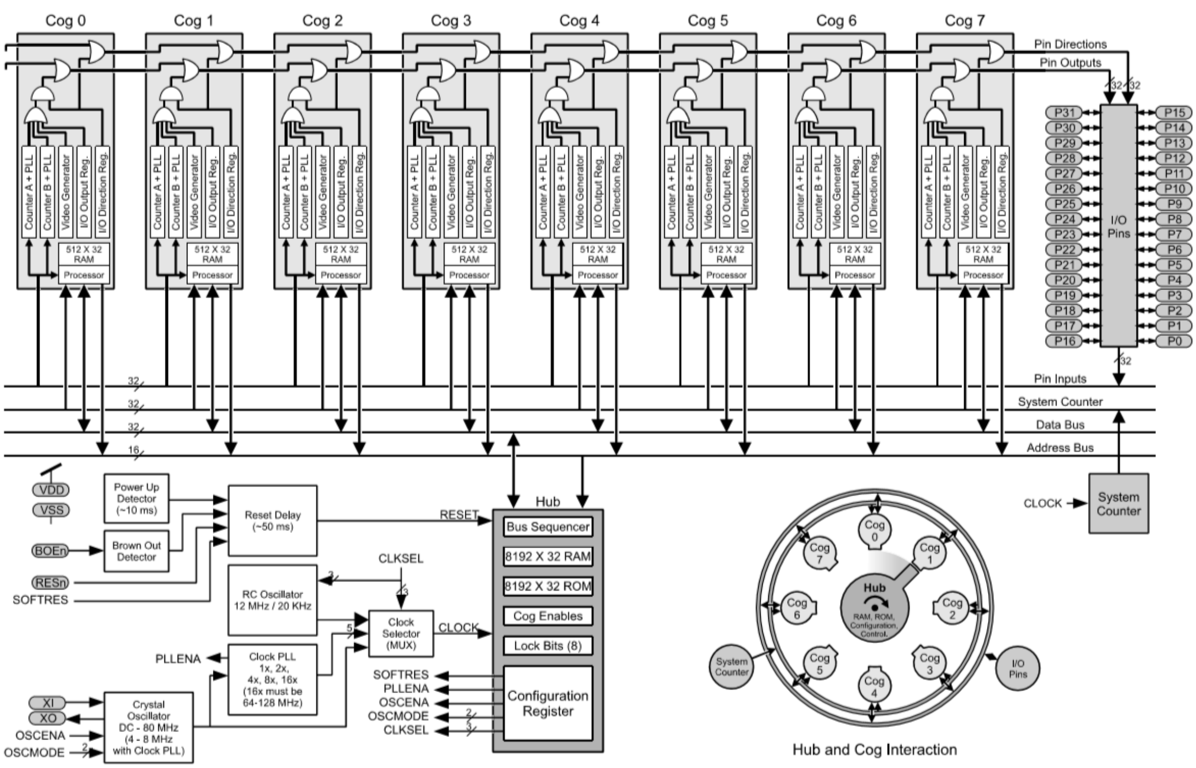
- Simple three-layer circuit assembly design with an internal ground-plane used as the system electrical common and as a thermal heat sync. This design helps evenly distribute the heat from the components throughout the board and out through the DB9 connectors and the all-aluminum enclosure. The on-board LDO voltage regulators also provide a source of heat when operating in very cold temperatures < 5°F (< -15°C).
- Electronic components are widely distributed on a single side of the circuit assembly to minimize the chance of defects arising during manufacturing that could occur when placing components on both top and bottom layers of the circuit board. This also contributes to the even distribution of heat throughout the circuit board assembly.
- Wide circuit traces are used to maximize the conductivity between component pins and minimize the voltage drop between components. This considerably reduces the amount of heat generated when power from the on-board voltage regulators is delivered to the high-current motor driver and motors. This greatly contributes to the long expected lifetime of the Model 2A.
- A conformal coating is applied to both sides of the completed circuit board assembly to create a moisture barrier that protects the components from degradation due to moisture when operating in high-humidity environments coupled with large temperature changes.

♦Most of these features are not included in the PMC-Eight™ Model 1A used in the iEXOS 100 mount.

II System Description

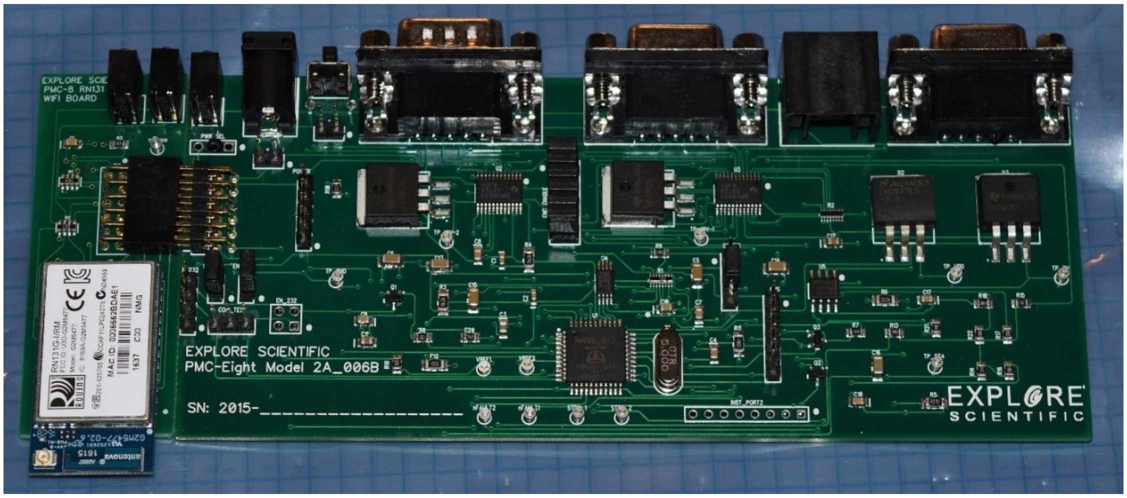
The PMC-Eight™ is a high-precision stepper motor controller that very accurately controls the pointing and tracking of a telescope mount. The design basis for this "industrial strength" Precision Motion Controller (PMC) includes features to increase the reliability and flexibility of the system. The PMC-Eight™ model 2A includes several electrical and thermal design features and characteristics that provide plenty of margin to ensure a long product lifetime in terms of individual assembly performance in the field, and in the life-cycle of the design. The model 1A includes a basic level of thermal design features that help to distribute and dissipate the heat generated in the system. Additional design elements incorporated in the model 1A and 2A firmware take full advantage of the deterministic processing inherent in the processor architecture to prevent complete system lockups. The system is designed to fail gracefully. While individual functions of the system may fail due to external factors, the whole system should not experience the lockups that other interrupt driven system may experience.

The microcontroller selected is a unique multi-processor design that uses eight processors, all working as independent units and communicating through shared global memory. Each of these processors is deterministic in its operation and DOES NOT use interrupts. This ensures that the task assigned to each processor runs independently, and any failure of any one task does not cause a cascading failure in any of the other processors; the result is a system that is designed to keep running even with a partial shutdown of the processor. For more information about the operation of the Parallax Propeller™ Microprocessor Chip, download the Propeller™ Datasheet . Note that both the model 2A and 1A use the same components and have nearly identical schematics.



Parallax Propeller™ P8X32A 8-Processor Architecture/Block Diagram

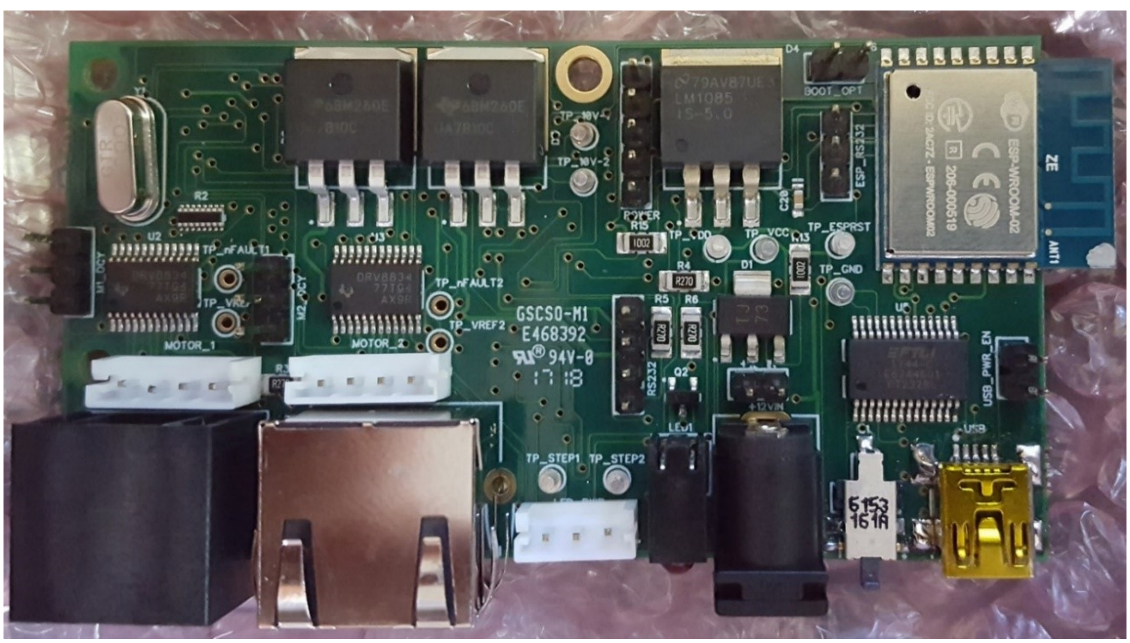
Both the PMC-Eight™ model 2A and 1A use the same components and have nearly identical schematics.



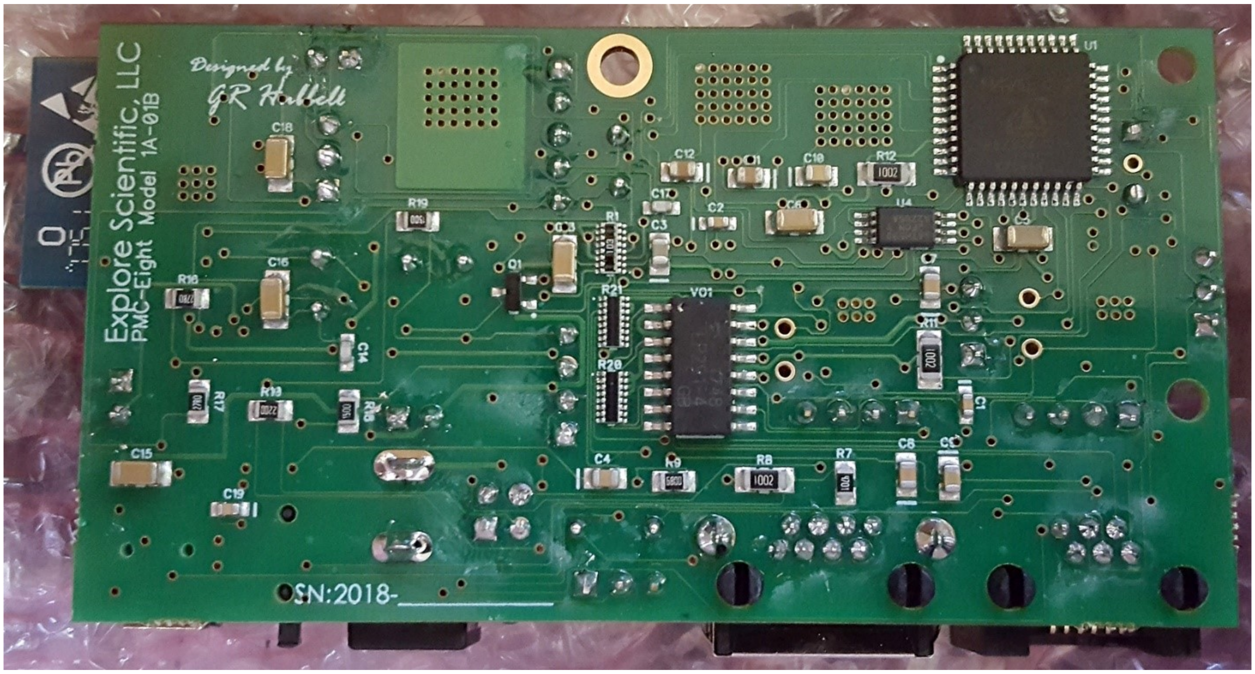
PMC-Eight™ Controller Model 2A-06B

Component	Part Number	Description
1(ea) Microcontroller	Parallax P8X32A-Q44	Propeller 8-CPU Microcontroller
1(ea) 8x64k Memory	Microchip AT24C512C	EEPROM Firmware & Storage
2(ea) Motor Driver	Texas Instruments DRV8835	Stepper Motor Driver Chip
1(ea) 2A-06B WiFi Module	Microchip RN-131G	WiFi Module
1(ea) 1A-01C WiFi Module	Espressif ESP8266	ESP-WROOM-02 WiFi Module
1(ea) 1A-01C USB	FTDI FT232RL	USB Serial Interface Chip

PMC-Eight™ Major Component List



PMC-Eight™ Controller Model 1A TOP



PMC-Eight™ Controller Model 1A BOTTOM

The PMC-Eight™ system consists of several components and is designed to interface with the Host Computer in several different ways. The primary interface to the PMC-Eight™ Model 2A-06B is through a dedicated RS-232 interface (DB-9 connector) that serves both as the programmer's (PGMR) interface for loading updated firmware into the system and as the interface for sending data request commands and receiving data. The primary interface to the PMC-Eight™ Model 1A-01C is through a dedicated mini-USB type B connector that serves both as the programmer's (PGMR) interface for loading updated firmware into the system and as the interface for sending data request commands and receiving data. A wireless network interface (Wi-Fi) is available also for sending data request commands and receiving data. This wireless interface is the primary HMI interface for the OpenGOTO™ Explore Stars application available for the Microsoft Windows OS, Google Android OS, and Apple iOS. For details, see Section VII, Miscellaneous Programming Application Notes. The controller communicates at 115,200 BAUD with No Parity, 8 Bits, 1 Stop Bit over the network, through the RS232 connection and the USB connection.

PMC-Eight™ System Boot Up

When the PMC-Eight™ system boots up, if you are connected to it via the wired PGMR/Serial port, you will see the following displayed on the ***Parallax Serial Terminal***:

```
-------------------------------------------------------------
-------------------------------------------------------------
       PPPPPPP   MM         MM  CCCCCCCC        88888
       PP    PP  MMM       MMM  CC             88   88
       PPPPPPP   MM M     M MM  CC       XXXXX   888
       PP        MM  M  M   MM  CC             88   88
       PP        MM   MM    MM  CCCCCCCC        88888
-------------------------------------------------------------
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PMC-Eight Support 1-866-252-3811
http://www.explorescientificusa.com
-------------------------------------------------------------
Portions of FIRMWARE covered by MIT LICENSE terms
-------------------------------------------------------------
Explore Scientific PMC-Eight Controller - Startup
Initializing PMC-Eight Model 1A-01C-FW10B1a 10 AUGUST 2018...
CONFORM TEST VERSION - COMMUNICATIONS TIMEOUT DISABLED
-------------------------------------------------------------
EEPROM Memory Test - Basic
MEM_TEST1:F0F0F0F0
MEM_TEST2:0F0F0F0F
MEM_TEST3:F0F0F0F0
MEM_TEST4:0F0F0F0F
MEM_TEST5:F0F0F0F0
-----------------------------------------------------------
Command Processor Started
JOC Controller Command Set:       Enabled
PMC-Eight Diagnostic Command Set: Enabled
PMC-Eight ES Command Set:         Enabled
System Initialized!
-------------------------------------------------------------
BAUD Rate Value: P0 115200
Assigned SSID: PMC-Eight-280D
Communications Channel - Enabled: P1 Serial
WiFi Protocol - Disabled: P2 UDP/IP
Assigned WiFi Channel Number: 7
ST4 port Sidereal Rate Fraction: P3 40
Unused Value: P4 0
Unused Value: P5 0
Unused Value: P6 0
Unused Value: P7 0
Unused Value: P8 0
Unused Value: P9 0
-------------------------------------------------------------
```

PMC-Eight™ Boot-Up Splash Screen

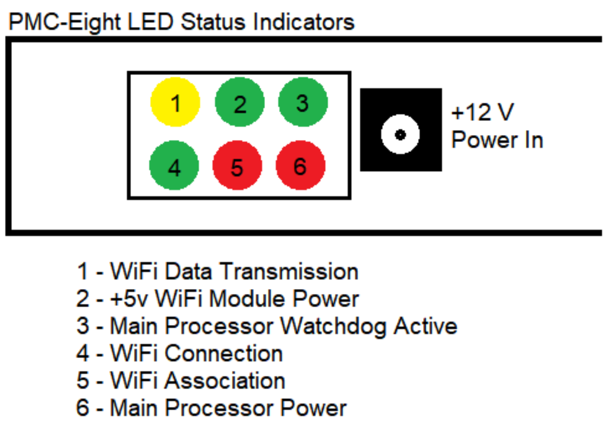
After the copyright information is displayed on the PMC-Eight™ boot splash screen, the current firmware version installed in the controller is displayed. You can also use the "ESGv!" command to obtain the current firmware version. The bottom portion of the PMC-Eight™ boot splash screen shows you the current configuration of parameters P0–P9. The ones to make note of include P1-Communications Channel, P2-WiFi Protocol, and the value of the Assigned WiFi Channel Number.

Updating/Restoring/Loading Firmware

The firmware on the PMC-Eight™ model 1A and 2A can be updated via the PGMR/Serial port. The document ***Explore Scientific PMC-Eight™ Application Note PMC8-AN001: How-To Update the PMC-Eight™ Control System Firmware*** (located in the Appendices) explains this process. The firmware files are in a Knowledge Base Article on the Explore Scientific USA website, just search for "firmware" in the Knowledge Base search tool.

Board Status Indicator LEDs

The model 2A-06B and model 1A-01C PMC-Eight™ processor boards have two LEDs; the RED LED (6) is ON when power is applied to the board. The GREEN LED (3) is ON indicating the processor status after the processor firmware boots up and active communications are going on with the processor, and the watchdog process is active monitoring the communications.



PMC-Eight™ Model 2A-06B Status LEDs

The model 2A-06B PMC-Eight™ RN-131 daughter board has four LEDs; The YELLOW LED (1) is FLASHING when there is data transmission between the PMC-Eight™ and the host computer application—either the ExploreStars application or the ASCOM Driver. The RED LED (5) is the WiFi association status and flashes until a connection to the model 2A-06B SSID (PMC-Eight-xx) of the PMC-Eight™ is made by the host computer. The GREEN LED (2) is ON when power is applied to the daughter board from the main board. The GREEN LED (4) FLASHES FAST when a connection is ACTIVE. LED (4) FLASHES SLOW when the module is waiting on a connection. The model 1A-01C PMC-Eight™ uses the Espressif ESP-WROOM-02 (ESP8266) WiFi module for wireless communications. There are no communications status lights provided on that version of the PMC-Eight™.

Switching PMC-Eight™ Communications Channels

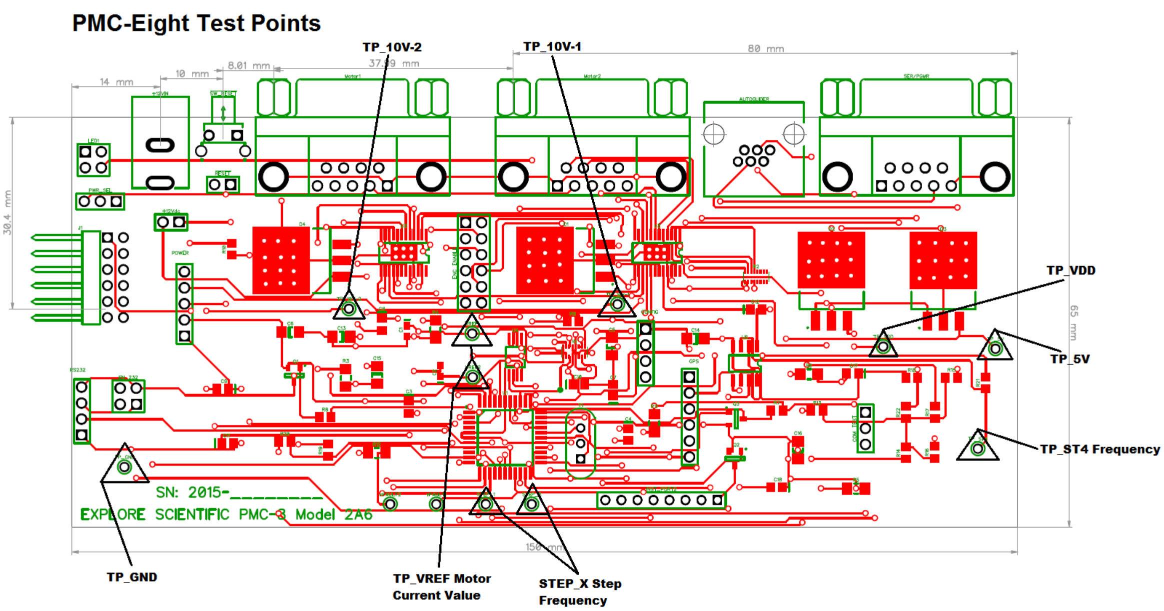
You can use the document ***Explore Scientific PMC-Eight™ Application Note PMC8-AN002: Connecting to the PMC-Eight™ with a Terminal Program to Configure the RN-131 WiFi Interface and Switching Between the WiFi Interface and the Serial Interface***, and the document ***Explore Scientific PMC-Eight™ Application Note PMC8-AN003: Switching Between the WiFi Interface and the Serial Interface on the iEXOS 100™ Mount Controller*** (available in the Appendix at the end of this document) to switch the communications channel from WiFi (UDP/TCP) to Serial and back again.

Model 2A Circuit Test Points

WARNING: Prior to opening the PMC-Eight™ enclosure, ensure that you are familiar with all applicable electrical safety procedures as they apply to working on low-voltage DC circuits. Circuit failure may occur if proper procedures are not followed when probing the circuitry. See this extensive discussion on Electrical Safety.

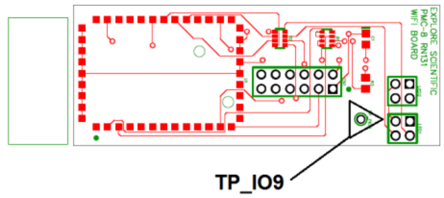
CAUTION: BOARD FAILURE INDUCED THROUGH PROBING THE CIRCUITRY IS NOT COVERED UNDER THE PMC-Eight™ LIMITED WARRANTY.

There are several test points on the model 2A-06B circuit board assembly (indicated below with a black triangle) labeled TP_XXXX, such as: TP_GND, TP_VDD, TP_10V-1, TP_10V-2, and TP_5V. There are also test points to measure the reference voltages for the current limits and the ST4 port frequency and stepper motor pulses. Headers on the assembly provide access to the RS-232 signals, the power supply voltages (3.3 Vdc, 5.0 Vdc, 10.0 Vdc, and GND), and the WiFi serial communications signals (COM_TEST header).



PMC-Eight™ Controller Version 2A-06B Test Points

The PMC-Eight™ model 2A-06B WiFi module (Microchip RN-131G) daughter board has a test point (TP_IO9) used in resetting the module to the Microchip factory defaults. ***Explore Scientific PMC-Eight™ Application Note PMC8-AN002: Connecting to the PMC-Eight™ with a Terminal Program to Configure the RN-131 WiFi Interface and Switching Between the WiFi Interface and the Serial Interface*** (*available in the Appendix at the end of this document*) describes in detail how to connect to the Microchip RN-131 Module and restore the PMC-Eight™ default configuration.



PMC-Eight™ Controller WiFi Daughter Board

CAUTION: Changing the WIFI module configuration from the default factory configuration is at your own risk.

You can also use Application Note AN002 to configure the Microchip RN-131 Module to communicate on your Local Area Network (LAN). The ***Microchip RN-131 WiFly Command Reference Manual*** is located at http://ww1.microchip.com/downloads/en/DeviceDoc/50002230B.pdf.

WiFi Channel Selection

In some instances, the WiFi environment is very busy with several SSIDs, and if the PMC-Eight™ WiFi module is configured to use the same channel as others, this can disrupt the communications, regardless of the signal strength, and may make the PMC-Eight™ WiFi drop out. The default channel configured in the RN-131 wireless module is channel 6, which is a popular channel for many WiFi devices. The solution is to change the WiFi channel. You can do this with the ST4 port (RJ12) dongle included with your PMC-Eight™ system. You can learn more about how WiFi and channels work in the specification document for IEEE 802.11. An overview is available here: https://en.wikipedia.org/wiki/IEEE_802.11

Here is the procedure to increment the channel number:

NOTE: You can monitor the channel number selected by the channel change procedure by downloading, installing, and running the program ***WiFiInfoView*** available at:

http://www.nirsoft.net/utils/wifi_information_view.html

1. **Power up** the PMC-Eight™ and it will boot up (the lights will settle out).
2. **Insert** the dongle into the Autoguider port (ST4 RJ12).
3. **Watch** the LEDs cycle, as the system reboots.
4. **Remove** the dongle.
5. **Wait** until the LEDs settle down, then **Reconnect** your tablet to the mount's SSID.
6. **Try** to connect the ExploreStars or ASCOM Client application to the PMC-Eight™
7. **IF** you still cannot connect and see the "Please Wait" message, **THEN** press the reset button.
8. **Repeat** steps 2 – 7 as needed.

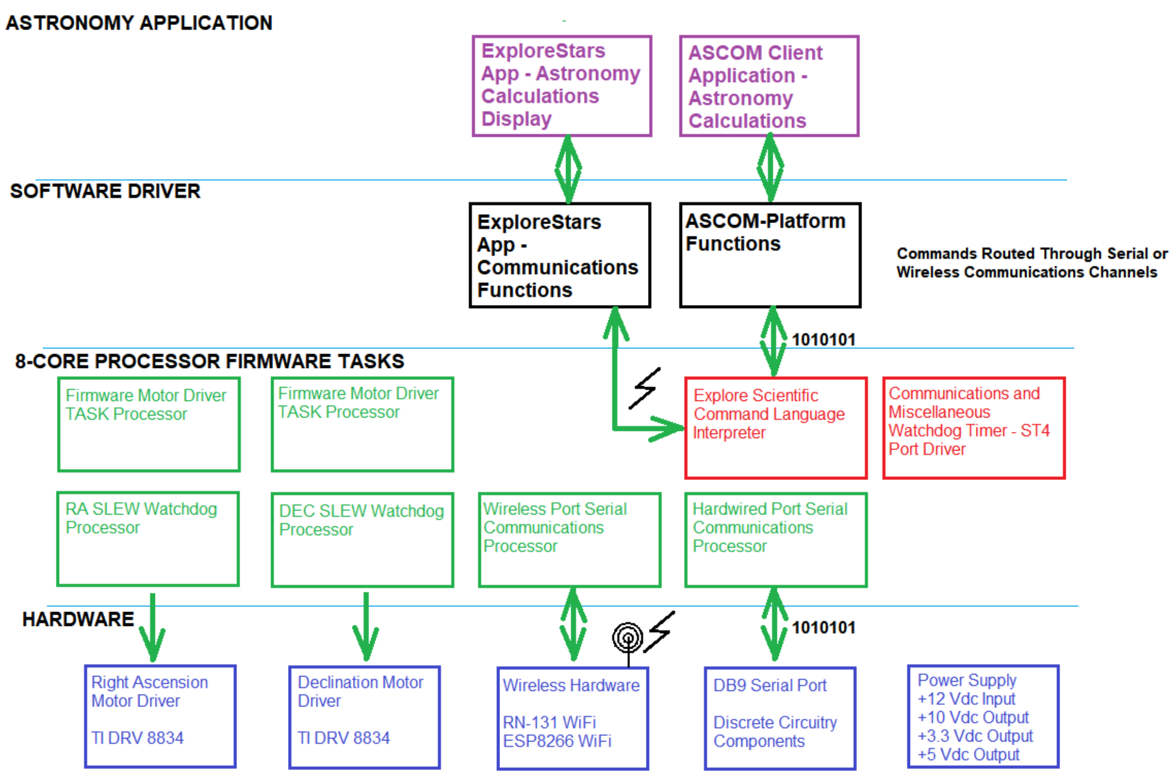
It is recommended to power down the system and then power it back up between steps 3 and 4, but this shouldn't be necessary. If the new channel still gives problems, the procedure can be repeated (step 8) until successful. The number (channel) will increment by one each time the dongle is used to change the channel and will recycle back to 1 after reaching channel 11. There are 11 channels available in total, channels 1–11.

III PMC-Eight™ Controller and Command Language Theory of Operation

Controller Theory of Operation

The PMC-Eight™ Precision Motion Controller is designed to enable the quick and reliable movement of the telescope OTA to point to any object of interest on the celestial sphere. The controller is made up of three main electronic subsystems: a) Computer Processor and Memory System, b) Motor Driver System, and c) Communications Interface.

The Computer Processor and Memory System processes and interprets the incoming commands and provides data output to the communications channels. Eight processors are integrated into the microcontroller chip (Parallax Propeller Microprocessor P8X32A), each with its own dedicated memory space and common memory space for sharing information between the processors. There is also a system RESET/REBOOT momentary push-button switch next to the 12 Vdc Power input. Two processors are dedicated to communicating with each motor, reading the real-time motor parameters, and generating the required DIRECTION and RATE motion values real-time to command the motors . One processor is dedicated to communicating via the RS232 Serial Port via the port driver. One processor is dedicated to taking the commands and translating them into executable instructions. One processor is dedicated to monitoring the motor status and reading the Autoguider port. Two processors for the motors are used only when monitoring the status of the real-time SLEW process. The processors run independently so that if any one processor fails, it will not affect the operation of the others.

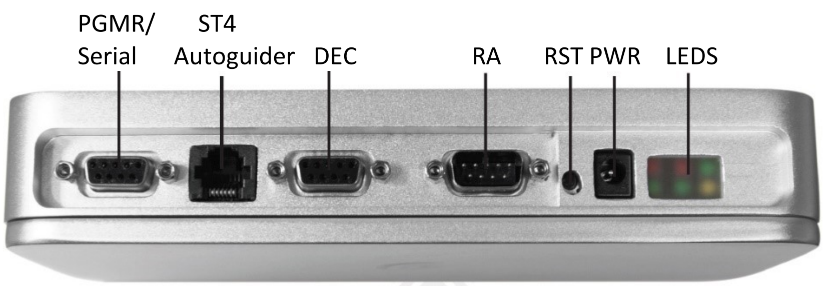


PMC-Eight™ System Architecture

The Texas Instrument DRV8834 Motor Driver integrated circuit chip (one for each motor channel) is designed to generate the required low-level stepper motor control/drive signals at the proper voltage and current levels needed to drive the mount as required. A performance margin is built into the system to enable the mount to operate over a wide temperature range. These motor driver chips are low power and very efficient in delivering the power to the stepper motors reliably.

PMC-Eight™ Communications

There are three communication interfaces on the system. The first is the base serial interface using the RS232 hardware specification and the Parallax recommended interface circuitry to provide basic communications to transfer firmware and data to the permanent memory of the Computer Processor and to configure the wireless network Wi-Fi processing module.



Model 2A PMC-Eight™ connections.

The model 2A-06B serial command processor/interpreter can be accessed via the RS232 port and via the second interface, the RN-131 wireless network interface. The model 1A-01C serial command processor/interpreter can be accessed via the mini-USB Type B port and via the second interface, the ESP-WROOM-02 (ESP8266) wireless network interface. The third communications channel is via the RJ 6P6C connector configured as an SBIG ST4 Autoguider Port. This port is also used to change the WiFi Channel, when needed, using the supplied ST4 port dongle.

PMC-Eight™ Fixed Tracking Rates

There are several fixed tracking rates available for the PMC-Eight™ ASCOM driver and one fixed rate is available for selection in the ExploreStars™ application. The Sidereal, Solar, Lunar, and Average King rates are available for selection. The following tables show the tracking rate values and their corresponding settings in the customer rate section of the ExploreStars application. These rates are pre-defined in the ASCOM driver.

NOTE: The different mount rates specified in microstep sec^{-1} are specified to the nearest 0.04 (± 0.02)"arc sec^{-1}. This value is based on the internal precision of the firmware integer calculation and setting of the precision tracking rate value. (See

Application	Object Rate	Solar-Second Rate Value "arc sec^{-1}	Sidereal-Second Rate Value "arc sec^{-1}
ExploreStars	Sidereal	15.041	15.000
ASCOM Driver	Sidereal	15.041	15.000
ASCOM Driver	Solar	15.000	14.959
ASCOM Driver	Lunar	14.491	14.451
ASCOM Driver	Average King	15.037	14.996

Fixed Tracking Rate Values

Fixed Tracking Rate	G11 0.28125 arc-sec microstep^{-1}	EXOS 2 & iEXOS 100 0.31250 arc-sec microstep^{-1}
Sidereal	53.32	48.00
Solar	53.20	47.88
Lunar	51.40	46.24
Average King	♦53.32	48.00
Custom Rate	See Calculation	See calculation

Explore Stars Mount Rate Setting Values

♦ The value of 53.32 arc-sec microstep^{-1} in the table for the G11 is very close to the actual calculated Average King rate of 53.3191 arc-sec microstep^{-1}.

The user can also set a custom rate value based on the following equation:

Rate Value ("arc microstep^{-1}) = Sidereal-Second Rate Value ("arc sec^{-1}) / X ("arc microstep^{-1})
Where X = specific mount's motor scaling value in arc-sec microstep^{-1}

For example, if you want to visually observe a comet with the ExploreStars application that is moving across the sky in RA a little faster than Sidereal, namely at 16.35 "arc sidereal-sec^{-1} with your G11 mount, then the calculation would be:

Rate Value = (16.35 / 0.28125)"arc microstep^{-1}
= 58.133"arc microstep^{-1}
= 58.12"arc microstep^{-1} (rounded to nearest ±0.02"arc microstep^{-1})

When this value is entered the ExploreStars application would immediately start tracking at that rate. There would still be a need to move the mount in Declination due to the objects motion in the Declination axis that is not corrected when in the "square-T" Tracking Mode.

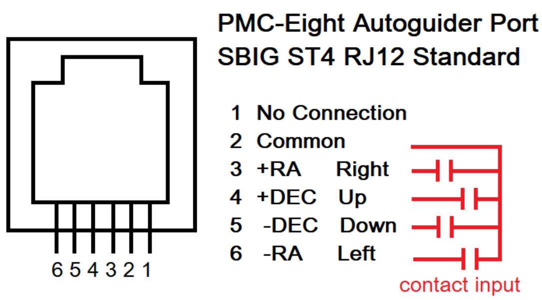
Autoguider (ST4) Port

Both the model 2A and model 1A ST4 port have dedicated interface circuitry to provide contact input commands into the controller to slowly move the mount in the four cardinal directions to correct for any tracking errors due to drift in Right Ascension (RA) or Declination (DEC) drift caused by less than perfect polar alignment.

The ST4 port on the PMC-Eight™ model 2A-06B uses an analog multiplexer design (VCO) to convert the four contact inputs sent from the Autoguider camera to the controller into numeric values that can be processed by the firmware into direction values (N, S, E, W). The analog design requires a factory default calibration that is included in the firmware. The port meets all the SBIG ST4 standard requirements for processing a "contact closure" input. Contacts are between each direction pin (N, S, E, W) and the common pin.

Most guide cameras provide an ST4 compliant "contact closure," or equivalent, via a MOSFET transistor circuit using a high-quality component. Some cameras, however, do not have a MOSFET transistor that provides the correct "contact closure" input resistance (shorted input) but instead provides a higher resistance input that does not work with the PMC-Eight™ ST4 factory default calibration. In this case, customers must contact Explore Scientific to have their ST4 input calibrated to their specific camera. See Appendix VIII.4 ***"Explore Scientific PMC-Eight™ version 2A-006A/B Autoguider (ST-4) Port Calibration Procedure (Rev 1.3) Firmware Version 9r4 08162015 AND LATER (2015 August 22)"*** for details on this procedure.

The ST4 port on the PMC-Eight™ model 1A-01C uses a digital transistor optocoupler circuit design that provides a reliable and optically isolated input to the controller from the guide camera system. This updated digital transistor optocoupler circuit design has also been incorporated into the latest Model 2A-07A board design. **The significance of this design is that it does not require calibration.**



Autoguiding (ST4) Port Pinout

Inputs to the Autoguider port are interpreted by the firmware to adjust the rate according to the Sidereal Rate Fraction, i.e., Percent Sidereal Rate, configured in the PMC-Eight™ ASCOM driver. The factory default value is set to 40% or 0.4 x 15.00"arc sec^{-1}, or 6.00"arc sec^{-1}. This value is stored in the system EEPROM as Parameter 3 (P3) so that when using the ST4 port and RJ12 (6P6C) cable to connect directly to an Autoguider camera, that camera knows what value to use. The Autoguiding software, PHD2™ corrects any tracking error by sending pulses to the mount that are different time intervals typically from 20 mS to 200+ mS in length, depending on the amount needed to move the mount back to the target star that PHD2™ is locked onto.

The total movement needed to correct a position error is the product of correction rate and pulse time. For example, with a measured position error of 1.07"arc and the Sidereal Rate Fraction set to 0.40 or 6.00"arc second^{-1}, the pulse time would equal the position error 1.07"arc / 6.00"arc second^{-1}, or 0.178 seconds (178 mS).

Command Language Theory of Operation

The Explore Scientific Command Language commands are used to send data requests and instructions to control the motors and receive status data back from the hardware. Four basic types of commands are used to interrogate the controller, two general purpose commands, and two special purpose commands. The GET and SET commands are used to get and set real-time motor parameters. These are general purpose commands to get and set a variety of parameters. The two special purpose commands are the POINT and TRACK commands. Each of these commands are applied to a given motor axis defined by the AXIS value. With a telescope mount there are 2 predefined axes: AXIS 0: RA/AZ, AXIS 1: DEC/ALT. This command language can support multiple axis controllers with any number of axes.

The GET and SET commands have several primary parameters dealing with motor operation: DIRECTION, POSITION, RATE, and TARGET. The three main parameters, DIRECTION, POSITION, and RATE are statically set and are fixed until the next time they are changed with a SET command. The SET commands for DIRECTION and RATE are immediate commands and update the values in real time. The SET POSITION command is used to adjust the motor position coordinates when calibrating the position in reference to the celestial coordinate system, or when SYNCING with the celestial coordinates of a given object.

The GET commands allow you to interrogate the controller for various real-time parameters, including: DIRECTION, POSITION, RATE, and TARGET. Other parameters that are available are FIRMWARE VERSION, SYSTEM INFORMATION via an Index value, and the current TRACKING RATE value.

NOTE: The SYSTEM INFORMATION command is not implemented in firmware versions 9T10, 11, and 12, and 10A01.

The controller is designed to handle the requirement for fast slews and very slow, precise tracking rates by implementing two rate types, like a HIGH and LOW in a four-wheel drive vehicle. Standard Rate (SLEW) and Precision Track Rate (TRACK) commands are provided. The SLEW Rates are 25x faster than the TRACK Rates. The rate values can be set to any value between 0 and 40000 (decimal), 0x9C40 (hexadecimal). For the ES/Losmandy G-11, this equates to SLEW rates up to 3.125° sec^{-1} on each axis[1]. This allows the system to SLEW the telescope 180° across the sky in 60 seconds. The TRACK rate allows for setting the RA motor rate up to 450.00"arc sec^{-1} with an accuracy of ±0.006"arc sec^{-1}. The standard GET/SET RATE command sets the SLEW rates. The TRACK command and GET TRACKING RATE command are used to SET/GET a more precise tracking rate value. This is an equivalent rate selection range of 1:1000000.

The POINT command is a higher-level FIRMWARE command that automatically calculates the necessary rates to efficiently SLEW to a TARGET. The process algorithm handles the ramping up and down of the motor rate to manage the inertial load placed on the stepper motors. In addition, the motor current is carefully managed to provide enough torque while slewing to accurately position the telescope on the object desired without exceeding the motor capability. The GET/SET commands for FIRMWARE VERSION and SYSTEM INFORMATION are used to query and set various values such as communications BAUD rate, Sync Offset Positions, and Axis Scale values.

[1] This angular rate is for the ES/Losmandy G-11 mount. Other mounts will slew faster or slower, depending on the total motor counts for the drive.

The PMC-Eight™ controller can be remotely rebooted using the BOOT SYSTEM command. This reinitializes the controller but does not reboot the wireless communications system on the model 2A. You can also use the BOOT COMMUNICATIONS command to remotely restart the wireless communication system. This is also independent of the system controller and does not reset the motor drivers or the current motor counts. To reboot the entire system, you must remove power and reapply power to the controller system.

The Get Motor Position Command returns the motor position string in Hex Value. The string is in the format "FFFFFF". The value returned is in the range 0x000000 to 0xFFFFFF, where positive values range from 0x000000 to 0x7FFFFF and the negative values range from 0xFFFFFF to 0x800000. The scaling of the motor gear position limits the actual values used to slew the motors. The two motors are on the RA and the DEC axis of a German Equatorial Mount (GEM). The angular range for counts depends on the motor count scaling value and is calculated as follows:

NOTE: This example uses the ES/Losmandy G-11 mount.

The ES/Losmandy G-11 uses direct coupled stepper motors whose motor scaling value uses only the wheel tooth count, the stepper motor steps, and the driver microstep value. The ES/Losmandy G-11 uses a 360-tooth wheel and 400-step motors. The driver uses 32 microsteps step^{-1}. The total count for a 360-degree rotation of both the RA and DEC axis is equal to 360 teeth * 400 steps * 32 microsteps, which is equal to 4,608,000 counts per 360-degree rotation. The angular motion per step in "arc is equal to the total number of "arc/4,608,000 counts. 360 degrees is equal to 360 x 60 x 60"arc or 1,296,000"arc. The "arc count^{-1} is equal to 1,296,000/4,608,000 or 0.28125"arc count^{-1}.

So, in the case of the ES/Losmandy G-11, one rotation in RA, or 24 hours (sidereal time) is equal to 4,608,000 counts or in Hex, 0x465000. The RA value counts positive and negative from the Meridian+6 hours or Local Mean Sidereal Time (LMST)+6 hours. On a GEM mount, the way the telescope is pointing is an important consideration when determining the motor counts. As the GEM is tracking, when the telescope gets to the Meridian, a maneuver called a "Meridian Flip" is performed. To help explain, this here is the sequence of events.

NOTE1: This description is only valid for mounts located in the Northern Hemisphere. The ASCOM driver detects the hemisphere where the mount is located via the LATITUDE value set in the configuration dialog box and adjusts the driven RA direction accordingly. The PARK reference position is either the NCP or SCP (North/South Celestial Pole), with a corresponding motor count on RA and DEC of 0 (0x000000).
NOTE2: This description only applies to the ES/Losmandy G-11 because the description of the motor counts increasing or decreasing depends on the gear direction for this mount.

1. The mount is pointing the telescope to an object in the EAST. The mount is tracking at SIDEREAL rate toward the WEST, and the RA motor counts are POSITIVE and INCREASING. The RA motor counts are in the range 0 (0x000000) moving toward 1152000 (0x119400). The object the mount is pointing to is also NORTH of the ECLIPTIC or has a positive DEC value between +0.000 and +90.000 degrees. This is a fixed DEC motor count value between 0 (0x000000) and 1152000 (0x119400) when WpE. The DEC axis counts INCREASE going SOUTH from the NCP. Objects that are SOUTH of the ECLIPTIC have values between 1152000 (0x119400) and 2304000 (0x232800). These values are from -0.000 to -90.000 degrees. This pointing position is called "West Pointing East" or WpE. This means that the telescope is WEST

of the PIER and pointing EAST of the MERIDIAN. In the ASCOM driver, this is referred to as "PierWEST," where the Hour Angle (HA) is less than zero (HA<0) and DECREASING in value.

2. When the mount RA axis finally arrives at the LMST value of 1152000 (0x119400), then the mount should execute a Meridian Flip. The flip maneuver SLEWS the RA axis back to the EAST equal to approximately 12 hours of RA or 180 degrees. This means that the RA motor counts DECREASE from 1152000 (0x119400) moving toward 0 (0x000000) and then continue to -1152000 (0xEE6C00). At the same time, the DEC axis SLEWS to the NORTH, DECREASING the motor counts, passing through the NCP while crossing 0 (0x000000) counts and continuing down toward the object's DEC motor count value between 0 (0x000000) and -2304000 (0xDCD800) counts.

3. At the completion of the flip maneuver, the RA tracking begins to drive at the SIDEREAL rate toward the WEST again, with the RA axis counts again INCREASING in value. The RA axis counts are in the range of -1152000 (0x119400) moving toward 0 (0x000000). In this mode, the DEC axis counts INCREASE going NORTH from -90.000 to +90.000 degrees or from -2304000 (0xDCD800) to 0 (0x000000) counts when EpW. This position, post Meridian Flip, is called "EAST Pointing WEST" or EpW. This means the telescope is EAST of the PIER and pointing WEST of the MERIDIAN. In the ASCOM driver, this is referred to as "PierEAST" where the HA is more than zero (HA>0) and INCREASING in value.

In summary, the motor count ranges for the different pointing quadrants are defined as specific values for each quadrant pointed to. The Sidereal Past is defined as object RA values that are LESS than the LMST value (RA<ST) and is WEST of the MERIDIAN. The Sidereal Future is defined as object RA values that are GREATER than the LMST value (RA>ST) and is EAST of the MERIDIAN. For example, if the LMST is currently 14:32:26.0, then 14:35:00.0 would be in the Sidereal Future, and 14:30:00.0 would be in the Sidereal Past.

When the telescope is WpE (target object RA is in the Sidereal Future):

1. The counterweight is east of the pier.
2. The telescope is west of the pier.
3. RA motor counts increase, tracking West: 0 < RA < 1152000.
4. DEC motor counts increases from NCP: 0 < N < 1152000 < S < 2304000: SCP.

When WpE, LMST is at motor count value 1152000 and is the position where the counterweight bar is horizontal to the horizon.

When telescope is EpW (target object RA is in the Sidereal Past):

1. The counterweight is west of the pier.
2. The telescope is east of the pier.
3. RA motor counts increase, tracking West: -1152000 < RA < 0.
4. DEC motor counts increase from SCP: -2304000 < S < -1152000 < N < 0: NCP.

When EpW, LMST is at motor count value -1152000 and is the position where the counterweight bar is horizontal to the horizon.

IV PMC-Eight™ ASCII Command Language

The 16 base PMC-Eight™ ASCII Commands allow you to control the mount in various ways to set the tracking rates, slew the mount to a position, and various other functions. Each of the command strings ends with the "!" (bang/shriek/exclamation) symbol except when entering and exiting the Diagnostic Mode. The Diagnostic Mode is used to enable the Simple Base ASCII Command Interpreter within the firmware. These commands are used internally by Explore Scientific employees in troubleshooting low-level motor performance functions. The default Command mode enables both the JOC and ES Command Interpreters when the PMC-Eight™ Controller boots. The Simple Base ASCII Commands are defined further below.

The JOC Command Language is a BINARY based command system that uses a pre-defined header plus command and argument values.

NOTE: The JOC command language is only used in the ExploreStars application internal communications driver. The PMC-Eight™ ASCOM driver uses the Explore Scientific Command Language documented here.

Enter ASCII Diagnostic Mode:
```
Command:                "%%%"
Response:               "Diagnostic Mode ENABLED%"
```

NOTE: In the current version of the firmware (09T10 or later), entering the ASCII Diagnostic Mode will continuously display the analog value (Hex) for the ST4 Interface. This is used to acquire the data for calibrating the ST4 interface with a user's camera. The other low-level motor commands can be entered while the display is continuously showing the ST4 values.

Exit ASCII Diagnostic Mode:
```
Command:                "###"
Response:               "Diagnostic Mode DISABLED#"
```

To manually issue commands to the PMC-Eight™ controller, you must follow the instruction in Appendix VIII.2 (Model 2A-06B) and VIII.3 (Model 1A-01C) of this document. You will use the ***Parallax Serial Terminal*** program to communicate with the controller.

Simple Base PMC-Eight™ Commands

The Simple Base PMC-Eight™ Commands (base commands) deal with the root motor control features and allow you to start and stop each motor and set the speed, microstep, and direction values.

NOTE: You must enter Diagnostic Mode to enable the base commands. The firmware is set to continuously display the Autoguider port values. The command interpreter will still process the base commands when entered.

"B" Command: B <enter>

BOOT Command – Performs a reboot of the controller

"F" Command: FX <enter> where X is the motor channel number 0 (RA), 1 (DEC).

FAULT Command—GETS the status of the DRV8834 motor driver chip fault indicator. The chip provides a fault indication for a detection of overcurrent, overtemperature, short circuit, and undervoltage lockout conditions. See the Texas Instruments DRV8834 Datasheet for detailed information.

"R" Command: RXYYYYY <enter> where X is the RA motor (channel 0) direction and YYYYY is the decimal motor speed (microsteps/second) internally limited to 40000 microsteps/second.

RA MOTOR Command – SETS the RA motor precision tracking speed in (microsteps/second)/25. To stop the motor, issue R00 <enter> command.

"D" Command: DYYYYY <enter> where Y is the DEC motor decimal motor speed (microsteps/second).

DEC MOTOR Command—SETS the DEC motor slew speed in (microsteps/second). To stop the motor, issue D0 <enter> command.

"M" Command: MX <enter> where X is the microstep multiple index value.

MICROSTEP Command—SETS the micro-stepping multiplier value according to the equation: Multiplier Value = 2^X, i.e., for an X value of 3, 2^3 equals a scaling of 8 microsteps/step.

"X" Command: XX <enter> where X is the direction value for the RA axis.

RA DIR Command—SETS the RA axis direction value, 0 (clockwise), 1 (counterclockwise).

"Y" Command: YX <enter> where X is the direction value for the DEC axis.

DEC DIR Command—SETS the DEC axis direction value, 0 (clockwise), 1 (counterclockwise).

"P" Command: PX <enter>, PXYYYYYY <enter> where X is the parameter number and YYYYYY is the value to set.

PARAMETER Command—GETS and SETS the stored parameter values where X is 0-9, and YYYYYY is a decimal value. These parameters are pre-defined. The PX <enter> command GETS the current value for parameter X, the PXYYYYYY <enter>
command SETS the current value for Parameter X with value YYYYYY.

The current predefined parameters (Firmware 9T10, 9T11, 9T12, 10A01, 10B01) are:

P0♦—BAUD Rate: 9600-115,200 DEFAULT = 115,200
P1—Communications Channel: 0 (Serial), 1 (Wireless) DEFAULT = 1
P2—Network Protocol: 0 (TCP/IP), 1 (UDP/IP) DEFAULT = 1
P3—Autoguider (ST4) port Sidereal Rate Fraction %: 0-100 DEFAULT = 40

♦This value should not be changed; values less than 115,200 affect the control response when using the ExploreStars application and render the application inoperable without modification.

V PMC-Eight™ ASCII Command Language Syntax

The Explore Scientific Controller Command Language is an ASCII based command language system that can be parsed by a computer program to determine the desired control action and is human readable, making it easy to interpret and form messages when coding once the syntax is mastered. This language specification is implemented in the controller FIRMWARE version ES06B9T2 and later.

NOTE1: ASCII Commands are CASE SENSITIVE. Data values are specified as Hex String Values, e.g., "FFD47A". These values are converted to Long Integers (32-bit) within the FIRMWARE. Generally, when a REQUEST command is sent, the RESPONSE includes the corresponding request syntax so that future asynchronous capabilities can be accommodated in the FIRMWARE.

NOTE2: The header "ES" is required, items in brackets {} are required, items in parenthesis () are optional depending on the command, and the "!" or shriek is required as an End-Of-Line (EOL) marker. ONLY 1 (one) of each command identifier is to be specified in each {} grouping.

```
Request    Syntax:"ES{GSTPBR}{prtdvix}(A)(D) (XXXX)(YYYYYY)(ZZZZZZ)!"
Response   Syntax:"ES{GSTPBR}{prtdvix}(A)(D) (XXXX)(YYYYYY)(ZZZZZZ)!"
```

Header String: "ES" Explore Scientific Language Command

Base Commands:
"G" Get command
"S" Set Command
"T" Track Command
"P" Point Command
"B" Boot Command
"R" Reset Communications Command

NOTE3: Command Parameter Codes only apply to the Get "G" and Set "S" Base Commands.

Command Parameter Code:
"p" Position value
"r" Slew Rate value
"t" Target value
"d" Direction value
"v" Version value
"i" System Information value

Axis Values:
"0" Right Ascension / Azimuth Axis
"1" Declination / Altitude Axis

Direction Values:
"0" Clockwise
"1" Counter-Clockwise

NOTE4: Axis Direction value is determined by looking at the motor from the shaft end.

NOTE5: The following System Information Values are not fully implemented in firmware versions 09t10 and previous. Only values "0x00" and 0x01" are implemented but they are not queryable in these firmware versions.

System Information Values♦: "0x00" WIRELESS Enabled {True=1, False=0}
"0x01" BAUD Rate {2400,9600…115200}
"0x02" AXIS 0 SCALE Counts (RA/AZ Axis) {0xFFFFFF}
"0x03" AXIS 1 SCALE Counts (DEC/ALT Axis) {0xFFFFFF}
"0x04" AXIS 0 OFFSET Counts (RA/AZ Axis) {0XFFFFFF}
"0x05" AXIS 0 OFFSET Counts (DEC/ALT Axis) {0XFFFFFF}
"06" TBD … "0F" TBD
♦Not implemented as of Firmware 09T10, 10A01

NOTE6: The AXIS SCALE Counts value is related to the physical configuration of the mount's gear ratio, stepper motor configuration, and controller motor driver configuration. The ES/Losmandy G-11 mount's AXIS SCALE Count values are calculated using the following parameters: Worm/Wheel Ratio 1:360, Stepper Motor Steps/Revolution 400, Motor Attachment Gear Ratio 1:1, and Motor Driver Micro-stepping ratio: 1:32. These parameters apply to both the RA and DEC axes on the ES/Losmandy G-11 mount. The calculation for the RA and DEC AXIS SCALE Counts is: 360 x 1 x 400 x 32 = 4,608,000 (0x465000)[2]. The mount's movement in "arc/count can be calculated by dividing 1,296,000 by the AXIS SCALE Counts. In this case, the mount's resolution is (1,296,000/4,608,000)"arc count^{-1} or 0.28125"arc count^{-1}. Because the PMC-Eight™ Controller uses the Sidereal Second as the standard for internal hardware time-keeping, the Sidereal Tracking Rate of 15.000"arc sec^{-1} would be equivalent to a COUNT RATE value of (15.000"arc sec^{-1}) / (0.28125"arc count^{-1}) = 53.333 counts sec^{-1}. The mean **Lunar Tracking Rate** of 14.451"arc sec^{-1} equates to a **COUNT RATE of 51.40 counts sec^{-1}**. The mean **Solar Tracking Rate** of 15.041"arc sec^{-1} equates to a **COUNT RATE of 53.48 counts sec^{-1}**.

Mount	UNITS	ES/Losmandy G-11	EXOS 2 & iEXOS 100
Total Counts	**microsteps**	4608000	4147200
Motor Counts	**steps/revolution**	400	200
Motor Model	**number**	17HM19-1684S	11HS20-0674S
Motor Frame	**type**	NEMA 17	NEMA 11
Primary Gear Teeth	**count**	360	144
Secondary Gear Ratio	**NA**	1	4.5
Motor Current	**mA**	◊ 900	600
Sidereal Tracking Rate	**microsteps/second**	53.333	48.000
Motor Scale	**"arc/micro-step**	0.28125	0.31250
Maximum Step Frequency	**Hz**	40000	40000
Maximum Slew Rate	**°/second**	3.125	3.472

Mount Stepper Motor Drive Parameters

◊ Firmware version 9T12 increases motor current to 1300 mA

[2] See Table on page 16 for the fixed tracking rate count calculation and parameter values for each of the Explore Scientific mounts.

The following table lists the command language and the command request/response syntax. A description of all the commands is listed here for your reference and usage. Pay close attention to the command notes for any special requirements or restrictions on the command's usage.

GET Command	**Name**	**Parameter**
"ESGp!"	Get Axis Current Position	Axis
"ESGr!"	Get Axis Current Rate	Axis
"ESGt!"	Get Axis Current Target	Axis
"ESGd!"	Get Axis Current Direction	Axis
"ESGv!"	Get System Firmware Version	None
"ESGi!"	Get System Information	Value Index
SET Command	**Name**	**Parameter**
"ESSp!"	Set Axis Current Position	Axis, Position
"ESSr!"	Set Axis Current Rate	Axis, Rate
"ESSd!"	Set Axis Current Direction	Axis, Direction
"ESSi!"	Set System Information	Value Index
TRACK Command	**Name**	**Parameter**
"ESTr!"	Set Precision Tracking Rate	Axis, Rate
POINT Command	**Name**	**Parameter**
"ESPt!"	Point to Target Position	Axis, Position
SWAP Command	**Name**	**Parameter**
"ESX!"	Swap Primary Serial Interface	None
"ESY!"	Swap Network Protocol	None
RESET Command	**Name**	**Parameter**
"ESR!"	Reset WiFi Comm Controller	None
BOOT Command	**Name**	**Parameter**
"ESB!"	Reboot Motor Controller	None

List of PMC-Eight™ ASCII Commands

The firmware code modules have the following information as a ready reference to the command syntax. **NOTE:** The firmware (version 09T10+, 10A01) source code is Explore Scientific, LLC proprietary and IS NOT available for inspection.

```
'    ------------------------------------------------------------------------------
'    Explore Scientific Command Language
'    See programmers reference manual for details on command syntax
'
'    ES Internal Command Return Strings
'    ------------------------------------------------------------------------------
'    Internally, HEX Return Strings are used for the ES commands to separate out the
'    different ones. HEX values from 0x00 to 0x3F are used for the Explore Scientific
'    commands. Items in {} are required, items in () are optional depending on the
'    command. A=axis, D=direction, XXXX=rate, YYYYYY=position, ZZZZZZZZ=parameter value
'
'    ES{G,S,T,P,Y,X,R,B}{p,r,t,d,v,i,x}(A)(D)(XXXX)(YYYYYY)(ZZZZZZZZ)!
'
'    G_! 0x00     FUTURE                              ESG_!
'    Gp! 0x01     get current axis position value     ESGpA!
'    Gr! 0x02     get current axis rate value         ESGrA!
'    Gt! 0x03     get current axis target value       ESGtA!
'    Gd! 0x04     get current axis direction value    ESGdA!
'    Gv! 0x05     get current firmware version        ESGv!
'    Gi! 0x06     get current system information      ESGiZ!
'    Sp! 0x11     set axis position value             ESSpAYYYYYY!
'    Sr! 0x12     set axis slew rate value            ESSrAXXXX!     (Allows full range of rates)
'    Sd! 0x14     set axis direction value            ESSdAD!
'    Si! 0x16     set system information              ESSiAZZZZZZZZ! (A is the parameter index)
'    Tr! 0x22     set tracking rate value             ESTrXXXX!(Track rate only applies to RA)
'    Pt! 0x31     point (slew) to target using ramps  ESPtAYYYYYY!
'    Y!  0xFC     Switch IP Protocol (UDP/TCP)        ESY!
'    X!  0xFD     Switch Communications Mode (WIFI/SER) ESX!
'    R!  0xFE     Reset Communications Controller     ESR!
'    B!  0xFF     Boot PMC-Eight Controller           ESB!
'    ------------------------------------------------------------------------------
```

Command Language Syntax

"G" GET Commands:

"ESGp" GET AXIS CURRENT POSITION VALUE

```
REQUEST:  "ESGpA!"
RESPONSE: "ESGpAYYYYYY!"
```

Example: Get Current RA Axis Position Value

```
REQUEST:  "ESGp0!"
RESPONSE: "ESGp0FF37DA!"
```

NOTE: Data values are specified as Hex String Values.

"ESGr" GET AXIS CURRENT RATE VALUE

```
REQUEST:  "ESGrA!"
RESPONSE: "ESGrAXXXX!"
```

Example: Get Current RA Axis Rate Value

```
REQUEST:  "ESGr0!"
RESPONSE: "ESGr037DA!"
```

NOTE: Data values are specified as Hex String Values.

"ESGt" GET AXIS CURRENT TARGET VALUE

```
REQUEST:  "ESGtA!"
RESPONSE: "ESGtAYYYYYY!"
```

Example: Get Current RA Axis Target Value

```
REQUEST:  "ESGt0!"
RESPONSE: "ESGt062E4D7!"
```

NOTE: Data values are specified as Hex String Values.

"ESGd" GET AXIS CURRENT DIRECTION VALUE

```
REQUEST:  "ESGdA!"
RESPONSE: "ESGdAD!"
```

Example: Get Current RA Axis Direction Value

```
REQUEST:  "ESGd0!"
RESPONSE: "ESGd01!"
```

NOTE: Data values are specified as Hex String Values.

"ESGv" GET CURRENT FIRMWARE VERSION VALUE

```
REQUEST:  "ESGv!"
RESPONSE: "ESGvZZZZZZZZ!"
```

Example: Get Current FIRMWARE Version Value

`REQUEST:  "ESGv!"`
`RESPONSE: "ESGvES6B09U0!"` (version ES6B09U0)

NOTE1: Data values are specified as character string values.
NOTE2: The returned string is a combination of the hardware version "6B" and the firmware version "09U0". This is currently hard coded in the firmware for each firmware release.

"ESGi" GET CURRENT SYSTEM INFORMATION VALUE

NOTE: Not implemented in this version.

```
REQUEST:  "ESGiX!"
RESPONSE: "ESGiXZZZZZZZZ!"
```

Example: Get Current System Information 1 (BAUD Rate) Value

`REQUEST:  "ESGi1!"`
`RESPONSE: "ESGi10001C200!"` (decimal 115,200 BAUD)

Example: Get Current System Information 03 (DEC Maximum) Value

`REQUEST:  "ESGi3!"`
`RESPONSE: "ESGi300465000!"` (decimal 4,608,000 DEC MAX)

NOTE: Data values are specified as Hex String Values.

"ESGx" GET CURRENT PRECISION TRACKING RATE VALUE

```
REQUEST:  "ESGx!"
RESPONSE: "ESGxXXXX!"
```

Example: Get Current Precision Tracking Rate Value

```
REQUEST:  "ESGx!"
RESPONSE: "ESGx0535!"
```

NOTE1: Data values are specified as Hex String Values.
NOTE2: The Get Tracking Rate value only applies to Axis 0, or the RA Axis.
The Precision Tracking value is calculated by multiplying the nominal calculated Rate Counts (for ES/Losmandy G-11) by 25, i.e.,
Rate Counts = rate "arc sec^{-1}/0.28125 $count^{-1}$

The calculated precision tracking value for a sidereal rate of 15.000"arc sidereal-sec^{-1} is:
Precision Tracking value = (15.000 / 0.28125) * 25
= 53.333 * 25
= 1333 (decimal)
= 0x0535 (hexadecimal)

The Tracking Rate value is accurate to ±0.02 counts sec^{-1}, so the resulting count rate is equal to 53.32 counts sec^{-1}. This command accommodates precision count rates from 0.00 to 2621.44 counts sec^{-1}, which is equivalent to precision rate values of 0 to 7.5' arc sec^{-1} or about 0.1° sec^{-1}.

"S" SET Commands:

The RESPONSE to the SET Commands in general mimics the value returned when using the GET Commands. The RESPONSE syntax will be identical to the corresponding GET Command. This is implemented this way to simplify the coding of any function that is written to process the RESPONSE string.

"ESSp" SET AXIS POSITION VALUE

```
REQUEST:  "ESSpAYYYYYY!"
RESPONSE: "ESGpAYYYYYY!"
```

Example: Set RA Axis Position Value

```
REQUEST:  "ESSp0FF37DA!"
RESPONSE: "ESGp0FF37DA!"
```

NOTE1: Data values are specified as Hex String Values.
NOTE2: Setting the Axis Position Value UPDATES it to a NEW value on the fly without slewing the mount in any way. This can be used to recalibrate the axis pointing position when syncing the axis to an external reference point provided by a reference source such as a star catalog or planetarium program. The Axis Position Value is only set to 0 (zero) when the axis is in its PARK position. When used in the ASCOM Telescope driver, the Position value is converted back and forth between the Motor Count Hex Value and the Degrees/Minutes/Seconds System. The defined PARK position for a GEM mount is the NCP/SCP. This NCP/SCP position has coordinates RA LST (07:43:22.00) + 06:00:00.00, DEC +90° 00m 00.0s (NCP), or DEC -90° 00m 00.0s (SCP)

"ESSr" SET AXIS TRACKING RATE VALUE

```
REQUEST:  "ESSrAXXXX!"
RESPONSE: "ESGrAXXXX!"
```

Example: Set Current RA Axis Rate Value

```
REQUEST:  "ESSr037DA!"
RESPONSE: "ESGr037DA!"
```

NOTE1: Data values are specified as Hex String Values.
NOTE2: Setting the Axis Tracking Rate Value UPDATES it to a NEW value on the fly ***without initiating a ramp to rate process***. This can be used to adjust the Tracking Rate for Sidereal, Lunar, Solar, and any other object that you may want to track (within reason). The nominal Sidereal Rate for the RA axis is 53.333 counts sec^{-1} for the ES/Losmandy G-11. The nominal Lunar Rate for the RA axis is 51.387 counts sec^{-1}. To improve the resolution for setting the Axis Rate, the floating-point value for counts sec^{-1} needs to be multiplied by 25 and rounded to the nearest integer to develop the value used in sending

the REQUEST, e.g., Sidereal Rate = 53.333 Counts sec^{-1}, 25 x 53.333 = 1333.325 or 1333 integer. Finally convert the value 1333 Rate to Hex: 0x0535.

"ESSt" SET AXIS TARGET VALUE

```
REQUEST:  "ESStAYYYYYY!"
RESPONSE: "ESGtAYYYYYY!"
```

Example: Set Current RA Axis Target Value

```
REQUEST:  "ESSt062E4D7!"
RESPONSE: "ESGt062E4D7!"
```

NOTE1: Data values are specified as Hex String Values.

NOTE2: Setting the Axis Target Value UPDATES it to a NEW value on the fly and ***initiates a ramping rate process***. This can be used to reposition the Target in the middle of a POINT command. When used in the ASCOM Telescope driver, the Target value is converted back and forth between the Motor Count Hex Value and the Degrees/Minutes/Seconds System. See the Supplemental Command Discussion section for details.

"ESSd" SET AXIS DIRECTION VALUE

```
REQUEST:  "ESSdAX!"
RESPONSE: "ESGdAX!"
```

Example: Set Current RA Axis Target Value

```
REQUEST:  "ESSd01!"
RESPONSE: "ESGd01!"
```

NOTE1: Data values are specified as Hex String Values.

NOTE2: The direction values as looking at the shaft end of the motor are 0x0 for clockwise, 0x1 for counterclockwise.

NOTE3: Setting the Axis Direction Value UPDATES it to a NEW value on the fly. In general, this should only be done when the motor RATE value is zero or close to zero because it puts inertial stress on the motor and gear system of the mount and may result in lost motor counts and slipping of the motor position.

"ESSi" SET CURRENT SYSTEM INFORMATION VALUE

NOTE: Not implemented in versions 09T12, and 10A01 and previous.

```
REQUEST:  "ESSiXZZZZZZZZ!"
RESPONSE: "ESGiXZZZZZZZZ!"
```

Example: Set Current System Information #1 (BAUD Rate) Value

```
REQUEST:  "ESSi10001C200!"
RESPONSE: "ESGi10001C200!"
```
(decimal 115,200 BAUD)

Example: Set Current System Information #3 (DEC Maximum) Value

```
REQUEST:  "ESGi300465000!"
RESPONSE: "ESGi300465000!"
```
(decimal 4,608,000 DEC MAX)

NOTE: Data values are specified as Hex String Values.

"T" TRACK Command:

"ESTr" SET PRECISION TRACKING RATE VALUE

```
REQUEST:  "ESTrXXXX!"
RESPONSE: "ESGxXXXX!"
```

Example: Set Precision Tracking Rate Value

```
REQUEST:  "ESTr0535!"
RESPONSE: "ESGx0535!"
```

NOTE1: Data values are specified as Hex String Values.

NOTE2: The Set Tracking Rate value only applies to Axis 0, or the RA axis. The Precision Tracking value is calculated by multiplying the nominal calculated Rate Counts (for ES/Losmandy G-11) by 25, i.e.,

Rate Counts = rate "arc sec^{-1}/0.28125"arc $count^{-1}$

The calculated precision tracking value for a sidereal rate of 15.000" sec^{-1} sidereal is:

Precision Tracking value = (15.000 / 0.28125) * 25
= 53.333 * 25
= 1333 (decimal)
= 0x0535 (hexadecimal)

The Tracking Rate value is accurate to ±0.02 counts sec^{-1}, so the resulting count rate is equal to 53.32 counts sec^{-1}. This command accommodates precision count rates from 0.00 to 2621.44 counts sec^{-1}, which is equivalent to precision rate values of 0 to 7.5' arc sec^{-1} or about 0.1° sec^{-1}.

"P" POINT Command:

"ESPt" SET POINT TARGET VALUE

```
REQUEST:  "ESPtAYYYYYY!"
RESPONSE: "ESGtAYYYYYY!"
```

Example: Set Current RA Axis Target Value

```
REQUEST:  "ESPt006FAE4!"
RESPONSE: "ESGt006FAE4!"
```

NOTE1: Data values are specified as Hex String Values.

NOTE2: The Point Command is used to slew the mount from the current target to a new target specified by the YYYYYY value. The command returns the target value immediately. You must use the Get Motor Position Value command "ESGp0!", "ESGp1!" while the mount is slewing to get the current position of the mount. The controller automatically ramps the slew rate up to the maximum rate commensurate with the distance between the current position and the target position. The controller also calculates the start of the ramp-down to stop the mount movement when it reaches the target value. Both axes may be slewed concurrently as desired because these are independent processes.

"Y/X" Swap Command:

"ESY" Swap IP Protocol

```
REQUEST:  "ESY!"
RESPONSE: "ESXA!"
```

NOTE1: Data values are specified as Hex String Values.
NOTE2: The swap IP Protocol command toggles the Protocol between the TCP/IP protocol and the UDP/IP protocol. The response value "A" is either "0" or "1", denoting the protocol. Protocol "0" is the TCP/IP protocol, and Protocol "1" is the UDP/IP protocol.
NOTE3: This command is only applicable to the Espressif ESP-WROOM-02 (ESP8266) WiFi module.

"ESX" Swap Primary Interface

```
REQUEST:  "ESX!"
RESPONSE: "ESXA!"
```

NOTE1: Data values are specified as Hex String Values.
NOTE2: The swap command toggles the primary interface between the programmer's hard-wired serial port and the WiFi network serial interface. The response value "A" is either "0" or "1", denoting the port. Port "0" is the programmer's RS232 port, and Port "1" is the WiFi wireless port.

"R" RESET Command:

"ESR" Reset Communications Controller

```
REQUEST:  "ESR!"
RESPONSE: "ESR!"
```

NOTE1: The communications reset command restarts the wireless communications controller. The system controller is maintained while the wireless communications controller restarts.

"B" BOOT Command:

"ESB" Reboot System Controller

```
REQUEST:  "ESB!"
RESPONSE: "ESB!"
```

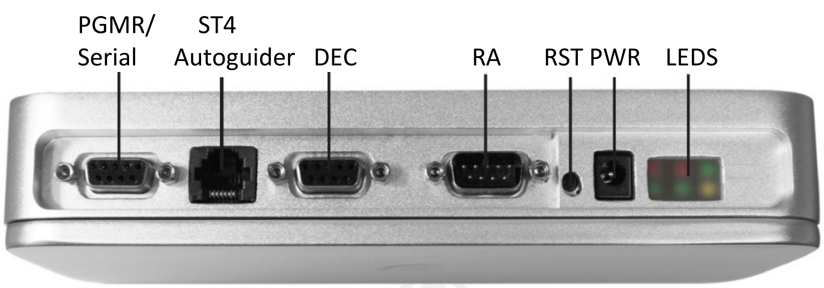
NOTE1: The system reboot command restarts the controller independent of the wireless communications controller. The wireless communications are maintained while the motor controller restarts.

VI PMC-Eight™ Hardware Interface Specifications

The PMC-Eight™ controller has several interfaces for power, motors, and communications. The system can communicate via the wireless Wi-Fi interface and through the RS232 DB-9 interface. The power connection uses a standard 5.5 x 2.1mm barrel type connector. The RA and DEC motors connect via DB-9 connections that are gender specific for each motor so that they cannot be connected wrong. The Autoguider Port uses a standard RJ12 connector of type 6P6C wired as per the SBIG ST-4 standard for contact inputs for each cardinal direction, North, South, East, and West.

The PMC-Eight™ controller limits the motor current provided to each motor to maximize torque while slewing and minimizes the current to extend the battery life. The controller requires a minimum of 12 VDC @ 2 ADC power supply for proper operation. The controller current draw is approximately 800 mA while power up and tracking. The controller current draw is approximately 1000 mA while slewing both axes.

The PMC-Eight™ controller communications BAUD rate default is 115,200 BAUD which provides near instantaneous response to incoming commands. The WiFi module used is IEEE 802.11 compliant for use in consumer equipment.



PMC-Eight™ Model 2A Enclosure

Model 2A Interface	Type	Value
5.5 x 2.1 mm Barrel Connector	Power Input	12 Vdc Input @ 2A
DB9 Connector (F)	RS232 PGMR/Serial I/O	RS232 Signal Values
RJ12 Phone Jack Connector	ST4 Contact Port Input	Autoguider input from camera
DB9 Connector (F)	DEC Motor Output	Motor Step Signals
DB9 Connector (M)	RA Motor Output	Motor Step Signals

Model 1A Interface	Type	Value
5.5 x 2.1 mm Barrel Connector	Power Input	12 Vdc Input @ 2A
Mini-USB Type B	USB PGMR/Serial I/O	USB Signal Values
RJ12 Phone Jack Connector	ST4 Contact Port Input	Autoguider Input from camera
RJ45 8P8C Connector	DEC Motor Output	Motor Step Signals
4-pin Header (internal)	RA Motor Output	Motor Step Signals

PMC-Eight™ Hardware Interface Specifications

VII PMC-Eight™ System Software Development Kit Information

The PMC-Eight™ provides a very robust and flexible platform for building custom applications to control and automate the operation of your telescope mount. Using open source OpenGOTO™ Community applications, the performance and full range of operations can be realized. Remote operation of the system is also possible by using the wireless Wi-Fi network interface.

The OpenGOTO™ ExploreStars™ application for Microsoft Windows™, Google Android™, and Apple iOS™ tablets, laptops, and PCs is the perfect "first app" for exploring the operation of the PMC-Eight™ System. The ExploreStars™ App is available at the Microsoft Windows App Store, Android Play Store, and the Apple App Store. Example source code is available written in Microsoft C# for use when developing your own software for the PMC-Eight™ System. The example code can be compiled and installed on any Windows-based system. The ExploreStars™ app internal driver uses the JOC command language in the JOC GOTO controller.

The open-source OpenGOTO™ PMC-Eight™ ASCOM driver is built using the ASCOM-Standards Platform 6.2 templates for .NET programs, and all the source code is available along with the driver for those who want to use it for their ASCOM client applications. The Explore Scientific PMC-Eight™ ASCOM driver has been tested using the ASCOM Platform Conformance tool and passes 100% of the suite. The driver has been tested successfully using the ASCOM Platform client applications MaximDL and Cartes du Ciel. The driver is a work in progress and will continue to be updated and the performance upgraded periodically. You can download the ASCOM platform and find the link to the Explore Scientific PMC-Eight™ ASCOM driver at ASCOM-Standards.org.

The PMC-Eight™ System Software Development Kit (SDK) contains all the documents, source code, instructions, procedures, and manuals you need to learn about the controller and fully understand the PMC-Eight™ System. You can use the information provided in the SDK to build your own custom application or to just better understand how the PMC-Eight works under the hood. The SDK is updated up to twice a year to keep the information current. Other updates to the driver and other documents are continuously released during the year so the SDK may not contain the most recent version of these documents and ASCOM driver. Be sure and go to our software and downloads page to get the latest version of our software.

The PMC-Eight™ System SDK is available for download at www.explorescientific.com/pmc-eight/

VIII Miscellaneous System Information

This page will be updated at various times in the future to provide miscellaneous information about the PMC-Eight™ System including information about the availability of new documents or information included in our Knowledge Base, User Manuals, and other documents since the last release of the SDK.

IX Appendices

1. Explore Scientific PMC-Eight™ Application Note PMC8-AN001: How-To Update the PMC-Eight™ Control System Firmware

2. Explore Scientific PMC-Eight™ Application Note PMC8-AN002: Connecting to the PMC-Eight™ with a Terminal Program to Configure the RN-131 WiFi Interface and Switching Between the WiFi Interface and the Serial Interface

3. Explore Scientific PMC-Eight™ Application Note PMC8-AN003: Switching Between the WiFi Interface and the Serial Interface on the iEXOS 100™ Mount Controller

4. Explore Scientific PMC-Eight™ version 2A-006A/B Autoguider (ST-4) Port Calibration Procedure (Rev 1.3) Firmware Version 9r4 08162015 AND LATER (2015 August 22)

5. ASCOM Platform Conformance Test Report—Explore Scientific PMC-Eight™ ASCOM Driver

Explore Scientific PMC-Eight™ Application Note PMC8-AN001: How-To Update the PMC-Eight™ Control System Firmware

The Explore Scientific PMC-Eight™ Control System firmware can be updated using the PGMR/SERIAL port. This port uses an industry standard nine-pin female DB-sub style connector for Data Communications Equipment (DCE). Because very few modern computer systems use the old-style DB9 connectors anymore, a USB-to-DB9 serial adapter is required to connect a PC to the PMC-Eight™ controller. These adapters can be purchased online or at your local computer electronics supply store. They can be found online by searching for "USB to DB9 adapter". It is recommended that you purchase an adapter that uses the popular FTDI chipset.

If you do not want to purchase a USB-to DB9-adapter, you can send your PMC-Eight™ Control System back to Explore Scientific for firmware updates. Please call Customer Service for a Return Merchandise Authorization (RMA) number, and then ship your controller to:

Explore Scientific, LLC.
1010 S. 48th Street
Springdale, AR 72762
ATTN: Firmware Update Requested

The procedure to update the firmware on the PMC-Eight™ Control System is a fairly simple process. Updating the firmware does not overwrite any internally stored firmware parameters set in non-volatile memory. The procedure uses the open source Propellent.exe program developed by Parallax, Inc. and copyrighted by Parallax Semiconductor 2013. It is available at https://www.parallax.com/downloads/propellent-software . If you are interested, the source code is also available on the Parallax website. We include the Propellent.exe program in our download .zip package for your convenience.

REQUIRED ITEMS

NOTE: The software items listed below can be downloaded from the PMC-Eight™ webpage on ExploreScientific.com.

1. PMC-Eight™ Control System Box and Power Supply.
2. PC System with Internet Access.
3. USB to DB9 Serial Adapter (as needed).
4. Firmware Loading Program.

5. Firmware Image File.

APPLICABLE PMC-Eight™ Hardware/Firmware Versions

1. PMC-Eight™ System Controller version 06B or later
2. PMC-Eight™ System Controller Firmware version 9T10 or later

PROCEDURE

1. Download and extract the required firmware update file, i.e., PMC8_FirmwareUpdate_9T10.zip, from the ExploreScientific.com website. Extract the files to a known location. You will have the following files (the .eeprom filename will be specific for each version):

    ESAN001_rev0.pdf (This document)
    Propellent.exe
    ES_MotionController_9t_10.eeprom

2. Connect the PMC-Eight™ Control System PGMR/SERIAL port to the male DB9 connector on the USB-to-DB9 adapter.

3. Connect the USB connector to your PC. Ensure that your PC recognizes the adapter and prompts you to load the drivers. Your PC may already have the required drivers installed, in that case, it will show that the USB adapter has been connected.

NOTE: In the next step, you do not need to connect the motor cables from your mount to the PMC-Eight™ Control System to power up the controller for firmware updates. It can be near your PC and away from your mount if necessary.

4. Power up the PMC-Eight™ Control System.

5. Start a Windows Command Prompt (cmd.exe) session. You will be greeted with a command line prompt, i.e.,

    "`C:\Users\jerry>`"

6. Set the directory using the CD command to the location that the firmware update file was extracted to, i.e.,

    "`C:\Users\jerry> cd Documents\PMC8_firmware`".

7. Verify the program "Propellent.exe" is in that directory and issue the following command at the DOS prompt for the version of the firmware you are installing. In this example, you are installing firmware version 9T10. (Note that there is a space between "/eeprom" and the filename).

   `"C:\Users\jerry\Documents\PMC8_firmware> propellent /eeprom ES_MotionController_9t_10.eeprom".`

8. The program will connect to the PMC-Eight™ Control System and update the firmware.

9. Once the program has completed, power down the PMC-Eight™ Control System and disconnect the USB-to-DB9 adapter cable.

10. Your PMC-Eight™ is ready to use on your mount.

If you have any issues performing this procedure, or if you have suggestions, comments, or questions, please contact support@explorescientific.com or call our customer support number (866) 252-3811.

EXPLORE SCIENTIFIC

Explore Scientific PMC-Eight™ Application Note PMC8-AN002: Connecting to the PMC-Eight™ with a Terminal Program to Configure the RN-131 WiFi Interface and Switching Between the WiFi Interface and the Serial Interface

PMC EIGHT™ PRECISION MOTION CONTROLLER

The Explore Scientific PMC-Eight™ Control System RN-131 WiFi module can be configured over the air using the default WiFi Interface (interface 1). The program Putty is used to configure the module once the connection to the "PMC-Eight-XX" SSID is enabled.

In addition, the terminal program Putty can be used to switch the default interface from the WiFi Interface (interface 1) to the PGMR/SERIAL port (interface 0). This port uses an industry standard nine-pin female DB-sub style connector for Data Communications Equipment (DCE). Once the "ESX!" command is sent to the controller to toggle from the WiFi Interface (interface 1) to the PGMR/SERIAL port (interface 0), a USB-to-DB9 serial adapter is required to communicate with the PMC-Eight™. These adapters can be purchased online or at your local computer electronics supply store. They can be found online by searching for "USB to DB9 adapter". It is recommended that you purchase an adapter that uses the popular FTDI chipset.

Once you are connected to the PMC-Eight™ via the PGMR/SERIAL port (interface 0), you can enter diagnostic mode to perform other functions. This is the subject of "Explore Scientific PMC-Eight™ Application Note PMC8-AN004: Entering and Using the PMC-Eight™ Diagnostic Mode."

Once you have established communications with the PMC-Eight™ using the PGMR/SERIAL port, you can again switch the default interface back to the WiFi Interface (interface 1) by issuing the "ESX!" command over the PGMR/SERIAL port (interface 0). The Parallax Serial Terminal program is used to perform this switch back to the WiFi Interface (interface 1).

If you have any concerns or issues with your PMC-Eight™ after reconfiguring your system, you can send your PMC-Eight™ Control System back to Explore Scientific for resetting the RN-131 back to the factory default values. There may be a fee associated with this service. Please call Customer Service for a Return Merchandise Authorization (RMA) number, and then ship your controller to:

Explore Scientific, LLC.
1010 S. 48th Street
Springdale, AR 72762
ATTN: Reset WiFi Configuration to Factory Default

REQUIRED ITEMS

NOTE: The software items listed below can be downloaded from the links included.

1. PMC-Eight™ Control System Box and Power Supply.
2. PC System with Internet Access.
3. USB to DB9 Serial Adapter (as needed).
4. Putty https://www.chiark.greenend.org.uk/~sgtatham/putty/
5. Parallax Serial Terminal https://www.parallax.com/downloads/parallax-serial-terminal

APPLICABLE PMC-Eight™ Hardware/Firmware Versions

6. PMC-Eight™ System Controller version 06B or later
7. PMC-Eight™ System Controller Firmware version 9T10 or later

PROCEDURE

First, install both programs by following the installation instructions included in the installation. The TELNET parameters to connect to the PMC-Eight™ for Putty are:

IP ADDRESS: 192.168.47.1
PORT: 54372

The serial port parameters to connect to the PMC-Eight™ for Putty and the Parallax Serial Terminal are:

BAUD Rate: 115200
Data Bits: 8
Stop Bits: 1
Parity: NONE
Flow Control: NONE

If you want to change the PMC-Eight™ WiFi RN-131 configuration, then perform the following procedure:

NOTE: Please refer to the *Microchip WiFly Command Reference Manual* located here: http://ww1.microchip.com/downloads/en/DeviceDoc/50002230B.pdf

CAUTION*: You change these parameters at your own risk*, if you want to go back to the Explore Scientific default settings, you will need to FIRST perform a Microchip RN-131 factory reset by issuing the command "factory RESET" at the <4.xx> prompt. After a factory reset, you will need to run the Explore Scientific configuration commands (see command list at the end of this application note to return your PMC-Eight™ RN-131 configuration to factory default values.). Step 6 below provides a list of the default parameters as set by Explore Scientific. Ensure that logging is enabled on the Putty terminal program to record these default parameters so that you have a record of these default factory values.

1. Set your SSID to the PMC-Eight-xx, whichever yours is.
2. Using Putty, TELNET into address 192.168.47.1 port 54372.
3. You should be greeted with the *HELLO* prompt of the RN-131 module.
4. Enter "$$$", and you should see "CMD".
5. Hit Enter again and the version number prompt, i.e., "<4.41>", is displayed.
6. Enter "get everything" to obtain a list of all the parameters and what they are set to.

You can now enter configuration commands for the RN-131 module.

NOTE: If you change the default IP Address and Port number, then you need to use the new IP Address and Port number when connecting to the PMC-Eight™ with your terminal program.

If you want to change the interface from the default WiFi Port (interface 1) to the Serial Port (interface 0), do the following:

NOTE: This assumes that you start with the delivered configuration of the PMC-Eight™ with the WiFi interface enabled.

1. Set your SSID to the PMC-Eight-xx, whichever yours is.
2. Using Putty, TELNET into address 192.168.47.1 port 54372.
3. You should be greeted with the *HELLO* prompt of the RN-131 module.
4. Enter "###", and you should see "Diagnostic Mode Disabled#!".
5. Enter "ESX!", and you should see "ESX0!", which indicates that the interface was switched to the serial port (interface 0).

If you want to change the interface from the Serial Port (interface 0) to the WiFi Port (interface 1) then do the following:

1. Using the Parallax Serial Terminal, connect to the assigned serial port with connection parameters: 115200, N, 8, 1.
2. Once connected, you should see the startup information scroll on the screen.

3. At the top line, enter "###" you should see "Diagnostic Mode Disabled#".
4. Enter "ESX!", and you should see "ESX1!", which indicates that the interface was switched to the WiFi port (interface 1).

RN-131 WiFi Module Explore Scientific Default Configuration Setup Commands

NOTE: It is suggested that you cut and paste each block of commands into the terminal and then manually type and enter the "save" command. Ensure you receive the "AOK" response after each command is entered. Please refer to the *Microchip WiFly Command Reference Manual* located here: http://ww1.microchip.com/downloads/en/DeviceDoc/50002230B.pdf

```
set uart b 115200
set comm size 64
set dns addr 0.0.0.0
set dns backup 0.0.0.0
save

set dns name dns1
set ftp addr 0.0.0.0
set ftp time 200
save

set ip dhcp 4
set ip flag 0x47
set ip gate 192.168.47.1
set ip addr 192.168.47.1
set ip net 255.255.0.0
save

set ip host 0.0.0.0
set ip protocol 0x03
set ip remote 54372
set ip local 54372
save

set sys autosleep 0
set sys sleep 0
set sys wake 5
set sys trigger 0x01
save

set wlan auth 4
set wlan hide 1
set wlan join 7
set wlan chan 8
save
```

NOTE: In the following, set the SSID to your specific module SSID, replacing the XX with your number.

```
set wlan ssid PMC-Eight-XX
set apmode ssid PMC-Eight-XX
set opt deviceid PMC-Eight
save

set wlan passphrase PMC-Eight
set apmode passphrase PMC-Eight
save

set wlan ext_antenna 1
save

Reboot
```

If you have any issues performing this procedure, or if you have suggestions, comments or questions, please contact support@explorescientific.com or call our customer support number (866) 252-3811.

Explore Scientific PMC-Eight™ Application Note PMC8-AN003: Switching Between the WiFi Interface and the Serial Interface on the iEXOS 100™ Mount Controller

The Explore Scientific PMC-Eight™ iEXOS 100™ Mount Control System (Model 1A) uses the Espressif ESP-WROOM-02 WiFi module for wireless access. The ESP-WROOM-02 module can be configured to connect to the ExploreStars™ application (Explore Scientific default) via the UDP/IP protocol OR to the PMC-Eight™ ASCOM Driver via the TCP/IP protocol.

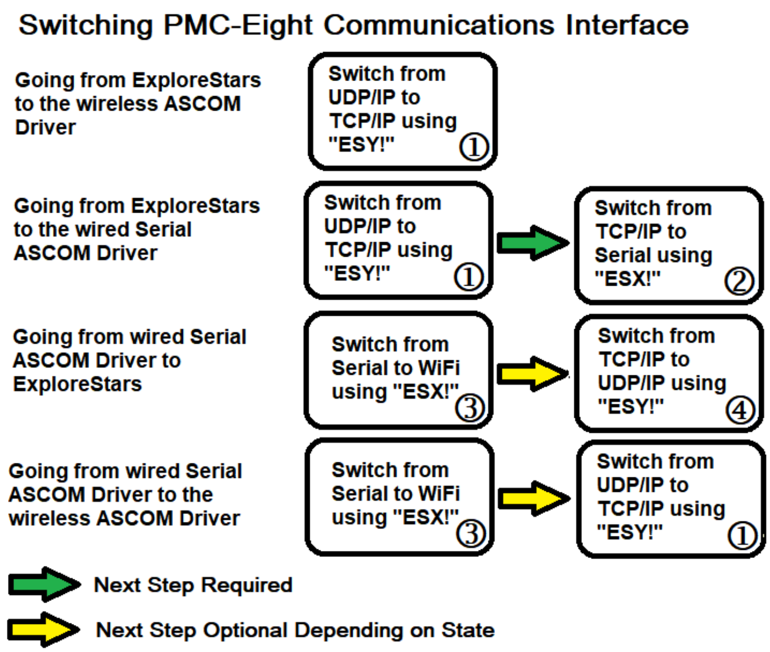
Unlike the WiFi module used in the PMC-Eight™ Model 2A (Microchip RN-131) the Espressif ESP-WROOM-02 module cannot run both the UDP/IP and TCP/IP protocols at the same time. During the boot process, the PMC-Eight™ firmware configures the WiFi module based on the selected, stored protocol selection. The firmware command "ESY!" is used to toggle the protocol to either UDP/IP or TCP/IP. The program ***Packet Sender*** can be used to send the "ESY!" command to specifically switch the WiFi protocol from UDP/IP to TCP/IP. The terminal program ***Putty*** can then be used to specifically switch the WiFi protocol back from TCP/IP to UDP/IP by sending the "ESY!" command again.

Once you have issued the "ESY!" command and switched to the TCP/IP protocol from the UDP/IP protocol, the terminal program ***Putty*** can be used to switch the default interface from the WiFi Interface (interface 1) to the PGMR/SERIAL port (interface 0) by sending the "ESX!" command. The PGMR/SERIAL port uses a mini-USB Type B (female) style connector for Data Communications Equipment (DCE). A USB type A (male) to mini-USB Type B (male) cable is required to communicate with the iEXOS 100™ PMC-Eight™ when selected to the SERIAL interface (interface 0). These cables can be purchased online or at your local computer electronics supply store.

Once you are connected to the PMC-Eight™ via the mini-USB Type B (female) PGMR/SERIAL port (interface 0), you can use the program ***Parallax Serial Terminal*** to enter diagnostic mode to perform other functions or connect the PMC-Eight™ ASCOM Driver using the serial port connection. You can again switch the default interface back to the WiFi Interface (interface 1) by issuing the "ESX!" command over the PGMR/SERIAL port (interface 0). The ***Parallax Serial Terminal*** program is used to perform this switch back to the WiFi Interface (interface 1). The WiFi protocol will be either TCP/IP or UDP/IP, depending on where you left it last when issuing the "ESY!" command.

WORKFLOW DIAGRAM

Use the Workflow Diagram to identify the procedures to perform for each specific switching configuration you require. The procedure numbers (circle number) are indicated in each box below.



REQUIRED ITEMS

NOTE: The software items listed below are FREE and can be downloaded from the links shown below.

1. PMC-Eight™ Control System Box and Power Supply.
2. Microsoft Windows® PC System with Internet Access.
3. USB type A to mini-USB type B cable.
4. Packet Sender program https://packetsender.com/
5. Putty terminal program https://www.chiark.greenend.org.uk/~sgtatham/putty/
6. Parallax Serial Terminal https://www.parallax.com/downloads/parallax-serial-terminal

APPLICABLE PMC-Eight™ Hardware/Firmware Versions

1. PMC-Eight™ System Controller version 1A-01C or later. (Only used in the iEXOS 100.)
2. PMC-Eight™ System Controller Firmware version 10B01 or later.

SERIAL communications port mini-USB Type B and USB type A connectors and cable.

SETUP PROCEDURE

First, install both programs by following the installation instructions included in the installation. The TELNET parameters to connect to the PMC-Eight™ for ***Putty*** are:

IP ADDRESS:	192.168.47.1
PORT:	54372

The serial port parameters to connect to the PMC-Eight™ for ***Putty*** and the ***Parallax Serial Terminal*** are:

BAUD Rate:	115200
Data Bits:	8
Stop Bits:	1
Parity:	NONE
Flow Control:	NONE

Procedure ①

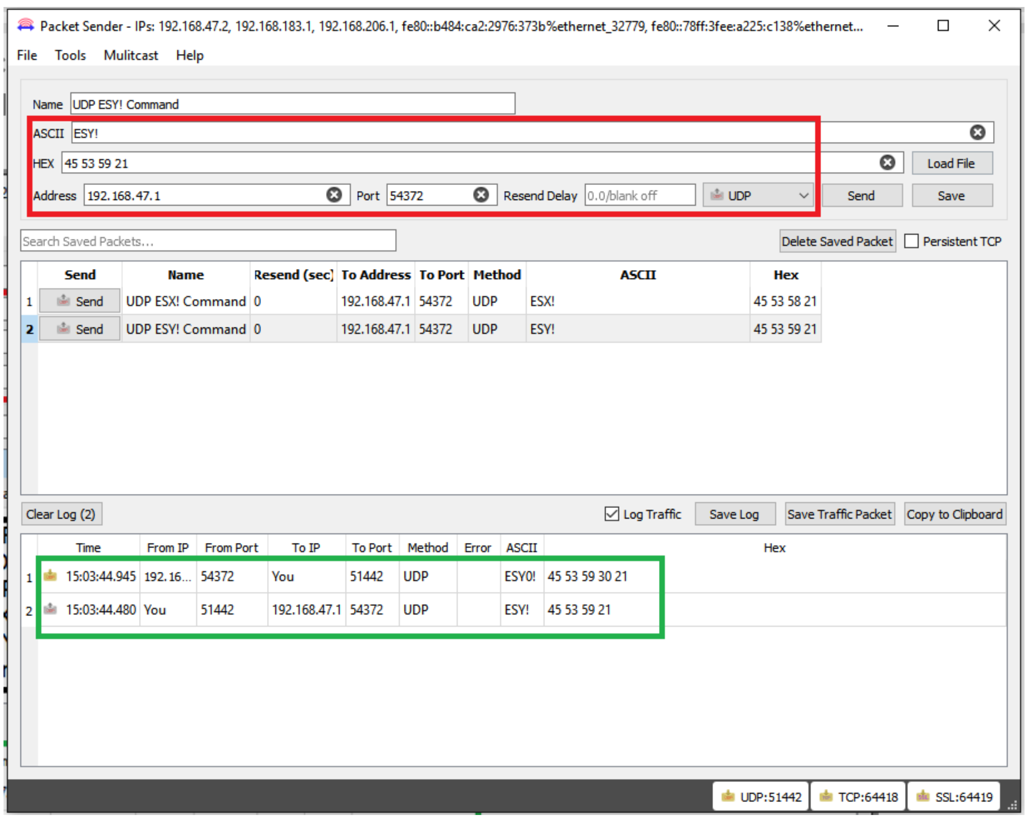
Switch from UDP/IP to TCP/IP using the "ESY!" command

NOTE: This procedure assumes that you start with the delivered configuration of the PMC-Eight™ with the WiFi interface enabled.

1. Launch the program Packet Sender.
2. Power up your iEXOS 100™ mount
3. Switch your computer over to the PMC-Eight-xxxx SSID specific to your controller.
4. Using Packet Sender, configure the following fields as shown in the figure below in the RED box:

   ASCII: ESY!
   Address: 192.168.47.1
   Port: 54372
   Protocol: UDP (pull-down)

5. While watching the RED and GREEN LEDs on the iEXOS 100 mount, press the SEND button to transmit the "ESY!" command. You should see the GREEN LED flash on.
6. Verify that the request and response are shown in Packet Sender as illustrated in the figure below in the GREEN box. You should see an "ESY0!" response.
7. You should now be able to connect via TELNET using PUTTY.



Procedure ②
Switch from TCP/IP to SERIAL using the "ESX!" command

1. Switch your computer over to the PMC-Eight-xxxx SSID specific to your controller. Using Putty, TELNET into address 192.168.47.1 port 54372.

NOTE: You will not see any prompt on the terminal screen.

2. Enter "ESX!" on the terminal window, and you should see an "ESX0!" response, which indicates that the communications interface was switched to the serial port (interface 0).
3. You should now be able to use the SERIAL mini-USB Type B (female) connection with your mini-USB Type B (male) to USB Type A (male) cable to communicate with the iEXOS 100.

Procedure ③
Switch from SERIAL to WiFi using the "ESX!" command

NOTE: You can determine the assigned com port number in the following step by using the windows settings program *Device Manager.*

1. Using the Parallax Serial Terminal, connect to the assigned com port number with connection parameters: 115200, N, 8, 1.
2. Once connected, you should see the firmware startup splash screen information scroll on the screen. (See firmware startup splash screen example at the end of this document.)
3. At the top line, enter "###". You should see "Diagnostic Mode Disabled#".
4. Enter "ESX!", and you should see "ESX1!", which indicates that the interface was switched to the WiFi port (interface 1).

Procedure ④
Switch from TCP/IP to UDP/IP using the "ESY!" command

1. Switch your computer over to the PMC-Eight-xxxx SSID specific to your controller.
2. Using Putty, TELNET into address 192.168.47.1 port 54372.

NOTE: You will not see any prompt on the terminal screen.

3. Enter "ESY!", and you should see "ESY1!", which indicates that the interface was switched to UDP/IP from TCP/IP on WiFi (interface 1).
4. You should now be able to wirelessly use the ExploreStars™ application with the iEXOS 100™.

PMC-Eight™ Firmware Startup Splash Screen

This is the startup splash screen that you will see when booting up the system while connected via the SERIAL port with the Parallax Serial Terminal.

```
-------------------------------------------------------------
-------------------------------------------------------------
       PPPPPPP   MM         MM  CCCCCCCC        88888
       PP    PP  MMM       MMM  CC             88   88
       PPPPPPP   MM M     M MM  CC       XXXXX   888
       PP        MM  M   M  MM  CC             88   88
       PP        MM   MM    MM  CCCCCCCC        88888
-------------------------------------------------------------
Copyright 2013-2018 Explore Scientific LLC., Gerald R Hubbell
1010 South 48th Street, Springdale, AR 72762
PMC-Eight Support 1-866-252-3811
http://www.explorescientificusa.com
-------------------------------------------------------------
Portions of FIRMWARE covered by MIT LICENSE terms
-------------------------------------------------------------
Explore Scientific PMC-Eight Controller - Startup
Initializing PMC-Eight Model 1A-01C-FW10B1a 10 AUGUST 2018...
CONFORM TEST VERSION - COMMUNICATIONS TIMEOUT DISABLED
-------------------------------------------------------------
EEPROM Memory Test - Basic
MEM_TEST1:F0F0F0F0
MEM_TEST2:0F0F0F0F
MEM_TEST3:F0F0F0F0
MEM_TEST4:0F0F0F0F
MEM_TEST5:F0F0F0F0
-----------------------------------------------------------
Command Processor Started
JOC Controller Command Set:        Enabled
PMC-Eight Diagnostic Command Set: Enabled
PMC-Eight ES Command Set:          Enabled
System Initialized!
-------------------------------------------------------------
BAUD Rate Value: P0 115200
Assigned SSID: PMC-Eight-280D
Communications Channel - Enabled: P1 Serial
WiFi Protocol - Disabled: P2 UDP/IP
Assigned WiFi Channel Number: 7
ST4 port Sidereal Rate Fraction: P3 40
Unused Value: P4 0
Unused Value: P5 0
Unused Value: P6 0
Unused Value: P7 0
Unused Value: P8 0
Unused Value: P9 0
-------------------------------------------------------------
```

If you have any issues performing these procedures, or if you have suggestions, comments, or questions, please contact support@explorescientific.com or call our customer support number (866)252-3811.

CUSTOMER NOTE: The procedure provided here is for reference only and is for internal Explore Scientific Use Only.

CUSTOMERS SHALL NOT HAVE ACCESS TO, NOR POSSESS THE PMC-Eight™ SYSTEM FIRMWARE SOURCE CODE (.SPIN) FILES REFERRED TO IN THE FOLLOWING PROCEDURE.

ALL PMC-Eight™ SYSTEM FIRMWARE IS EXPLORE SCIENTIFIC, LLC PROPRIETARY INFORMATION AND CONFIDENTIAL.

Explore Scientific PMC-Eight™ version 2A-006A/B Autoguider (ST-4) Port Calibration Procedure (Rev 1.3) Firmware Version 9r4 08162015 AND LATER

2015 August 22

NOTE: This procedure is applicable to all firmware later than version 9r4 08162015. The steps that refer to a specific version also apply to later versions of the firmware that include AUTOGUIDER support (Hardware version 2A_006A and 2A_006B). In those steps, load, modify, and compile the latest version of the firmware available. This procedure also works with OpenGOTO™ application version 1.1.5.1 OR LATER.

1.0 Discussion

The Autoguider port on the Explore Scientific PMC-Eight™ controller uses a Voltage Controlled Oscillator (VCO) circuit to convert ST-4 port contact inputs to a unique frequency for that contact input combination. The circuit uses an SE555 timer chip to create the square wave output that is measured by the processor firmware and processed into a frequency value. This design was used to minimize the number of I/O pins used (only one is used, versus four that would be necessary) because the number available on the propeller chip is very limited in this design.

There is a test point, TP_ST4, available on the PMC-Eight™ controller board to measure the frequency using a digital multimeter with frequency measurement or an oscilloscope. IT IS IMPORTANT TO NOTE: this measured value cannot be used for calibration; the following procedure shows how to use the built in firmware test (command mode) to take the measurements and do the calibration.

The firmware constant AG_TOLERANCE is used to compensate for a small variation in the measured frequencies over time and is used also as a discriminator, so the measured value is stable and does not chatter. Normally this value will not change, but it may be necessary in certain cases. The AG_TOLERANCE is set to +/- 40 Hz.

The range of frequencies is approximately 2500 Hz to 5600 Hz. This design will be modified in that the circuit components will be changed to create frequencies from 2500 Hz to 8800 Hz to help discriminate the contact input and increase the tolerance range so that a common set of frequency values can be used on the system. This mitigates the need for the custom calibration of the controller that this procedure is designed to perform. This procedure is also used to perform the initial calibration of the production sample to apply to all the production level hardware.

2.0 Purpose

The purpose of this procedure is to measure the PMC-Eight™ Autoguider Port frequencies generated for each contact input condition. These values are used in the firmware to calculate which of the four contacts are closed and modify the RA and DEC position accordingly to maintain a lock on the desired object. This procedure describes how to adjust and save the measured values in the firmware and reprogram the system.

3.0 Equipment Used

3.1 PMC-Eight™ System version 2A-006A controller
3.2 Autoguider Switch Test Box and RJ cable
3.3 Firmware version 9r4 08162015 OR LATER
3.4 Parallax Propeller Editor/Development System (IDE) version 1.3.2
3.5 USB/Serial cable—Programmer Port Connection
3.6 Windows WinBook Tablet with the OpenGOTO™ Ver 1.1.5.1 OR LATER installed.

4.0 Procedure

4.1 VERIFY that all the equipment listed in section 3.0 is available and in working order.
4.2 START the Propeller IDE on the PC.
4.3 CONNECT the PC to the PMC-Eight™ controller Serial Port using the USB/Serial cable.
4.4 CONNECT the RJ cable to the PMC-Eight™ Autoguider Port and the Autoguider Switch Test Box.
4.5 APPLY power to the PMC-Eight™ controller.
4.6 In the IDE, NAVIGATE to the directory that contains the FIRMWARE version 9r4 08162015.
4.7 ENSURE that the following files are in the directory:
4.7.1 ES_MotionController_9r_4.spin OR LATER
4.7.2 SerialMirror_3.spin
4.7.3 Basic_I2C_Driver.spin
4.7.4 settings.spin
4.8 RIGHT CLICK the file "ES_MotionController_9r_4.spin" OR LATER, and SELECT "Top Object File".
4.9 CLICK the file "ES_MotionController_9r_4.spin" OR LATER to load it into the IDE code window.

4.10 In the IDE, CLICK the Run, Identify Hardware… menu items and VERIFY that the following message displays: Propeller chip version 1 found on COMx. RECORD the COM port identified.

4.11 In the IDE, SCROLL DOWN to code line number (line numbers are located at the lower left of the IDE window) 142 to IDENTIFY the AUTOGUIDER constants section. Lines 143–153 list the FREQUENCIES for each contact combination.

4.12 In the IDE, SCROLL DOWN to line number 308 and IDENTIFY the SP_SELECT value.

4.13 In the IDE, MODIFY the line to read: "SP_SELECT := 0", this places the firmware in the Terminal Interface mode.

4.14 In the IDE, CLICK Run, Compile Top, Load EEPROM menu items to compile the code and load it onto the PMC-Eight™ system.

4.15 In the IDE, CLICK the Run, Parallax Serial Terminal… menu item to start the terminal program. ENSURE that the baud rate is set to 115,200 and that the COM port is set to the value recorded in step 4.8.

4.16 On the Terminal program, CLICK the ENABLE button on the lower right.

4.17 PUSH the RESET button on the PMC-Eight™ and VERIFY that the following messages appear in the OUTPUT window:

```
Explore Scientific PMC-Eight Controller - Startup
Copyright 2013-2014 Explore Scientific, Gerald R Hubbell
Portions of FIRMWARE covered by MIT LICENSE terms
Initializing PMC-Eight Model 2A-06B-FW9R4 16 August 2015...
EEPROM Memory Test - Basic
MEM_TEST1:F0F0F0F0
MEM_TEST2:0F0F0F0F
MEM_TEST3:F0F0F0F0
MEM_TEST4:0F0F0F0F
MEM_TEST5:F0F0F0F0
JOC Controller Command Set: Enabled
PMC-Eight Simplified Command Set: Enabled
032032Command Processor Started
System Initialized!
```

4.18 In the Terminal program, ENTER "$$$" into the INPUT window at the top of the program. CLICK the PAUSE button at the bottom of the Terminal program.

4.19 SCROLL up the OUTPUT window and VERIFY that the following messages appear in the OUTPUT window:

```
ASCII Command Mode Started
Watch Dog Timer STOPPED
2618 1
2618 1
2618 1
2618 1
...
```

4.20 CLICK the RESUME button at the bottom of the Terminal Program to start the scrolling live view of the Autoguider Frequencies. There are two values shown, the Frequency value and the calculated, enumerated contact combination value. For each button push, the values will change accordingly.

NOTE: The following step is only a quick functional test performed prior to performing the Frequency measurements and calibration. It is important that this test is successful prior to measurement and verifies that the hardware is operating correctly.

4.21 On the Autoguider Switch Test Box, PRESS each of the Test Box buttons and VERIFY that the value changes accordingly.

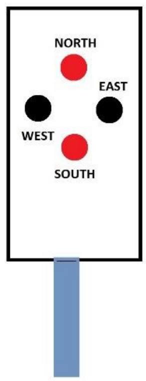


Fig. 1 Autoguider Switch Test Box

NOTE: In the following step, the Autoguider Switch Test Box when handled will cause the frequencies to vary. It is important to estimate and record a middle value in the range of values displayed. The AG_TOLERANCE value is used to compensate for this variation in values and should not be an issue.
4.22 FOR EACH of the following buttons (refer to Fig. 1) RECORD a representative sample of the displayed Frequencies. PRESS the PAUSE and RESUME button on the Terminal program AS NECESSARY to view each value and record the value. NOTE that the OPEN position is NO BUTTONS PUSHED.

4.22.1 OPEN ________________
4.22.2 NORTH ________________
4.22.3 EAST ________________
4.22.4 SOUTH ________________
4.22.5 WEST ________________
4.22.6 NORTH AND EAST ________________
4.22.7 NORTH AND WEST ________________
4.22.8 SOUTH AND EAST ________________
4.22.9 SOUTH AND WEST ________________

4.23 USING the values recorded in step 4.22, in the IDE, SCROLL to line number 142 and MODIFY each of the lines for each button combinations.

4.24 REPEAT Step 4.22 only to VERIFY that the enumerated contact combination displays a value other than 0 (zero). IF THIS IS NOT SUCCESSFUL, REPEAT steps 4.22–4.23 and RECORD new values for those button combinations that display a 0 (zero) for the enumerated button combination.

4.24 In the IDE, MODIFY the line identified in step 4.12 to: "SP_SELECT := 1"; this places the firmware in the Wireless Interface mode.

4.25 In the IDE, CLICK Run, Compile Top, Load EEPROM menu items to compile the code and load it onto the PMC-Eight™ system.

4.26 On the IDE, CLICK the File, Save, menu item to save the values in the Firmware file.

4.27 RESET the PMC-Eight™ by pressing the RESET button to restart the system.

4.28 USING the OpenGOTO™ application on the Windows tablet, CONNECT to the controller, and with the program in TRACK MODE as indicated by the "Tr" icon, perform the following step.

4.29 PUSH each button combination on the Autoguider Switch Test Box and VERIFY that the RA and DEC positions change as desired.

ASCOM Platform Conformance Test Report – Explore Scientific PMC-Eight™ ASCOM Driver

```
Conform Report Hash (V1): BAC544670181C9C373F29317D03DBEA7D6F48D4A593FA875C8B97DF2C366C89905F266ED70A96ADD71E012F8E4730E90A055AD3001489F6BF46D0842809FC410


ConformanceCheck ASCOM Device Conformance Checker Version 6.2.59.0, Build time: 1/9/2017 8:44:30 AM
ConformanceCheck Running on: ASCOM Platform 6.4 SP1 6.4.1.2695

ConformanceCheck Driver ProgID: ASCOM.ES_PMC8.Telescope

Error handling
Error number for "Not Implemented" is: 80040400
Error number for "Invalid Value 1" is: 80040401
Error number for "Invalid Value 2" is: 80040405
Error number for "Value Not Set 1" is: 80040402
Error number for "Value Not Set 2" is: 80040403
Error messages will be interpreted to infer state.

14:43:54.231 Driver Access Checks              OK
14:43:54.942 AccessChecks                      OK       Successfully created driver using late binding
14:43:55.145 AccessChecks                      OK       Successfully connected using late binding
14:43:55.154 AccessChecks                      INFO     The driver is a .NET object
14:43:55.163 AccessChecks                      INFO     The AssemblyQualifiedName is: ASCOM.ES_PMC8.Telescope, ASCOM.ES_PMC8.Telescope, Version=6.0.0.1,
Culture=n
14:43:55.174 AccessChecks                      INFO     The driver implements interface: ASCOM.DeviceInterface.ITelescopeV3
14:43:56.069 AccessChecks                      INFO     Device does not expose interface ITelescopeV2
14:43:56.836 AccessChecks                      INFO     Device exposes interface ITelescopeV3
14:43:58.310 AccessChecks                      OK       Successfully created driver using driver access toolkit
14:43:58.387 AccessChecks                      OK       Successfully connected using driver access toolkit

Conform is using ASCOM.DriverAccess.Telescope to get a Telescope object
14:43:59.867 ConformanceCheck                  OK       Driver instance created successfully
14:43:59.986 ConformanceCheck                  OK       Connected OK

Common Driver Methods
14:44:00.049 InterfaceVersion                  OK       3
14:44:00.083 Connected                         OK       True
14:44:00.116 Description                       OK       ES_PMC8 Telescope
14:44:00.150 DriverInfo                        OK       Explore Scientific PMC-Eight Mount Controller ASCOM Driver. Developed by GRHubbell. Contact Explore
Scientific at www.explorescientificusa.com . Version: 6.0
14:44:00.185 DriverVersion                     OK       6.0
14:44:00.227 Name                              OK       Explore Scientific PMC-Eight ASCOM Driver
14:44:00.262 CommandString                     INFO     Conform cannot test the CommandString method
14:44:00.271 CommandBlind                      INFO     Conform cannot test the CommandBlind method
14:44:00.280 CommandBool                       INFO     Conform cannot test the CommandBool method
14:44:00.289 Action                            INFO     Conform cannot test the Action method
14:44:00.299 SupportedActions                  OK       CanPark
14:44:00.311 SupportedActions                  OK       CanSetTracking
14:44:00.328 SupportedActions                  OK       CanSlew
14:44:00.337 SupportedActions                  OK       CanSlewAltAz
14:44:00.348 SupportedActions                  OK       CanSlewAsync
14:44:00.360 SupportedActions                  OK       CanSlewAltAzAsync
14:44:00.369 SupportedActions                  OK       CanSync
14:44:00.381 SupportedActions                  OK       CanSyncAltAz
14:44:00.392 SupportedActions                  OK       CanUnpark
14:44:00.404 SupportedActions                  OK       CanMoveAxis
14:44:00.414 SupportedActions                  OK       DoesRefraction
14:44:00.424 SupportedActions                  OK       Can...

Can Properties
14:44:00.503 CanFindHome                       OK       True
14:44:00.514 CanPark                           OK       True
14:44:00.525 CanPulseGuide                     OK       True
14:44:00.536 CanSetDeclinationRate             OK       True
14:44:00.547 CanSetGuideRates                  OK       True
14:44:00.559 CanSetPark                        OK       True
14:44:00.571 CanSetPierSide                    OK       True
14:44:00.582 CanSetRightAscensionRate          OK       True
14:44:00.595 CanSetTracking                    OK       True
14:44:00.607 CanSlew                           OK       True
14:44:00.618 CanSlewltAz                       OK       True
14:44:00.631 CanSlewAltAzAsync                 OK       True
14:44:00.651 CanSlewAsync                      OK       True
14:44:00.665 CanSync                           OK       True
14:44:00.678 CanSyncAltAz                      OK       True
14:44:00.691 CanUnPark                         OK       True

Pre-run Checks
14:44:00.750 Mount Safety                      INFO     Scope is parked, so it has been unparked for testing
14:44:00.817 Mount Safety                      INFO     Scope tracking has been enabled
14:44:00.860 TimeCheck                         INFO     PC Time Zone:  Eastern Standard Time, offset 5 hours.
14:44:00.873 TimeCheck                         INFO     PC UTCDate:    07-Jan-2019 19:44:00.873
14:44:00.889 TimeCheck                         INFO     Mount UTCDate: 07-Jan-2019 19:44:00.889

Properties
14:44:00.969 AlignmentMode                     OK       algGermanPolar
14:44:01.056 Altitude                          OK       38.33
14:44:01.095 ApertureArea                      OK       0.00817
14:44:01.131 ApertureDiameter                  OK       0.102
14:44:01.170 AtHome                            OK       False
14:44:01.207 AtPark                            OK       False
14:44:01.283 Azimuth                           OK       0.00
14:44:01.330 Declination                       OK        90:00:00.00
14:44:01.371 DeclinationRate Read              OK       0.00
14:44:01.425 DeclinationRate Write             OK       0.00
14:44:01.462 DoesRefraction Read               OK       True
14:44:01.502 DoesRefraction Write              OK       Can set DoesRefraction to False
14:44:01.543 EquatorialSystem                  OK       equLocalTopocentric
14:44:01.583 FocalLength                       OK       0.714
14:44:01.620 GuideRateDeclination Read         OK       0.00
14:44:01.633 GuideRateDeclination Write        OK       Can write Declination Guide Rate OK
14:44:01.671 GuideRateRightAscension Read      OK       0.00
14:44:01.690 GuideRateRightAscension Write     OK       Can set RightAscension Guide OK
14:44:01.728 IsPulseGuideing                   OK       False
14:44:01.794 RightAscension                    OK       03:41:30.65
14:44:01.832 RightAscensionRate Read           OK       15.00
14:44:01.873 RightAscensionRate Write          OK       15.00
14:44:01.909 SiteElevation Read                OK       100
14:44:01.966 SiteElevation Write               OK       Invalid Value exception generated as expected on set site elevation < -300m
14:44:01.984 SiteElevation Write               OK       Invalid Value exception generated as expected on set site elevation > 10,000m
14:44:02.019 SiteElevation Write               OK       Legal value 100m written successfully
14:44:02.055 SiteLatitude Read                 OK        38:19:58.80
14:44:02.095 SiteLatitude Write                OK       Invalid Value exception generated as expected on set site latitude < -90 degrees
14:44:02.126 SiteLatitude Write                OK       Invalid Value exception generated as expected on set site latitude > 90 degrees
14:44:02.158 SiteLatitude Write                OK       Legal value  38:19:58.80 degrees written successfully
14:44:02.200 SiteLongitude Read                OK       -77:42:38.16
14:44:02.237 SiteLongitude Write               OK       Invalid Value exception generated as expected on set site longitude < -180 degrees
14:44:02.265 SiteLongitude Write               OK       Invalid Value exception generated as expected on set site longitude > 180 degrees
14:44:02.282 SiteLongitude Write               OK       Legal value -77:42:38.16 degrees written successfully
14:44:02.400 Slewing                           OK       False
14:44:02.448 SlewSettleTime Read               OK       Optional member threw a PropertyNotImplementedException exception.
14:44:02.497 SlewSettleTime Write              OK       Optional member threw a PropertyNotImplementedException exception.
14:44:02.516 SlewSettleTime Write              OK       Optional member threw a PropertyNotImplementedException exception.
14:44:02.577 SideOfPier Read                   OK       pierWest
14:44:02.591 SiderealTime                      OK       21:41:32.41
```

```
14:44:02.604 SiderealTime                    OK       Scope and ASCOM sidereal times agree to better than 1 second, Scope: 21:41:32.41, ASCOM:
21:41:32.41
14:44:02.643 TargetDeclination Read          OK       .NET Not Set exception generated on read before write
14:44:02.695 TargetDeclination Write         OK       Invalid Value exception generated as expected on set TargetDeclination < -90 degrees
14:44:02.718 TargetDeclination Write         OK       Invalid Value exception generated as expected on set TargetDeclination < -90 degrees
14:44:02.752 TargetDeclination Write         OK       Legal value  01:00:00.00 DD:MM:SS written successfully
14:44:02.791 TargetRightAscension Read       OK       .NET Not Set exception generated on read before write
14:44:02.832 TargetRightAscension Write      OK       Invalid Value exception generated as expected on set TargetRightAscension < 0 hours
14:44:02.860 TargetRightAscension Write      OK       Invalid Value exception generated as expected on set TargetRightAscension > 24 hours
14:44:02.890 TargetRightAscension Write      OK       Legal value 17:41:32.71 HH:MM:SS written successfully
14:44:02.928 Tracking Read                   OK       True
14:44:04.022 Tracking Write                  OK       False
14:44:05.135 TrackingRates                            Found drive rate: driveSidereal
14:44:05.148 TrackingRates                            Found drive rate: driveLunar
14:44:05.162 TrackingRates                            Found drive rate: driveSolar
14:44:05.178 TrackingRates                            Found drive rate: driveKing
14:44:05.192 TrackingRates                   OK       Drive rates read OK
14:44:05.229 TrackingRate Read               OK       driveSidereal
14:44:05.279 TrackingRate Write              OK       Successfully set drive rate: driveSidereal
14:44:05.327 TrackingRate Write              OK       Successfully set drive rate: driveLunar
14:44:05.390 TrackingRate Write              OK       Successfully set drive rate: driveSolar
14:44:05.455 TrackingRate Write              OK       Successfully set drive rate: driveKing
14:44:05.510 UTCDate Read                    OK       07-Jan-2019 19:44:05.510
14:44:05.527 UTCDate Write                   OK       Optional member threw a PropertyNotImplementedException exception.

Methods
14:44:05.639 CanMoveAxis:Primary             OK       CanMoveAxis:Primary True
14:44:05.681 CanMoveAxis:Secondary           OK       CanMoveAxis:Secondary True
14:44:05.721 CanMoveAxis:Tertiary            OK       CanMoveAxis:Tertiary False
14:44:07.728 Park                            OK       Success
14:44:07.741 Park                            OK       Success if already parked
14:44:07.769 Park:AbortSlew                  OK       AbortSlew did raise an exception when Parked as required
14:44:07.839 Park:FindHome                   OK       FindHome did raise an exception when Parked as required
14:44:07.884 Park:MoveAxis Primary           OK       MoveAxis Primary did raise an exception when Parked as required
14:44:07.938 Park:MoveAxis Secondary         OK       MoveAxis Secondary did raise an exception when Parked as required
14:44:07.987 Park:PulseGuide                 OK       PulseGuide did raise an exception when Parked as required
14:44:08.044 Park:SlewToCoordinates          OK       SlewToCoordinates did raise an exception when Parked as required
14:44:08.091 Park:SlewToCoordinatesAsync     OK       SlewToCoordinatesAsync did raise an exception when Parked as required
14:44:08.137 Park:SlewToTarget               OK       SlewToTarget did raise an exception when Parked as required
14:44:08.187 Park:SlewToTargetAsync          OK       SlewToTargetAsync did raise an exception when Parked as required
14:44:08.246 Park:SyncToCoordinates          OK       SyncToCoordinates did raise an exception when Parked as required
14:44:08.291 Park:SyncToTarget               OK       SyncToTarget did raise an exception when Parked as required
14:44:08.655 UnPark                          OK       Success
14:44:08.690 UnPark                          OK       Success if already unparked
14:44:08.796 AbortSlew                       OK       AbortSlew Ok when not slewing
14:44:08.866 AxisRate:Primary                OK       Axis rate minimum: 2.5 Axis rate maximum: 2.5
14:44:08.880 AxisRate:Primary                OK       Axis rate minimum: 0.2083333 Axis rate maximum: 0.2083333
14:44:08.896 AxisRate:Primary                OK       Axis rate minimum: 0.0208333 Axis rate maximum: 0.0208333
14:44:08.911 AxisRate:Primary                OK       Axis rate minimum: 0.0025 Axis rate maximum: 0.0025
14:44:08.929 AxisRate:Primary                OK       Axis rate minimum: 0 Axis rate maximum: 0
14:44:08.945 AxisRate:Primary                OK       No overlapping axis rates found
14:44:08.961 AxisRate:Primary                OK       No duplcate axis rates found
14:44:08.981 AxisRate:Secondary              OK       Axis rate minimum: 2.5 Axis rate maximum: 2.5
14:44:09.001 AxisRate:Secondary              OK       Axis rate minimum: 0.2083333 Axis rate maximum: 0.2083333
14:44:09.017 AxisRate:Secondary              OK       Axis rate minimum: 0.0208333 Axis rate maximum: 0.0208333
14:44:09.033 AxisRate:Secondary              OK       Axis rate minimum: 0.0025 Axis rate maximum: 0.0025
14:44:09.049 AxisRate:Secondary              OK       Axis rate minimum: 0 Axis rate maximum: 0
14:44:09.064 AxisRate:Secondary              OK       No overlapping axis rates found
14:44:09.080 AxisRate:Secondary              OK       No duplcate axis rates found
14:44:09.097 AxisRate:Tertiary               OK       Empty axis rate returned
14:44:09.735 FindHome                        OK       Found home OK.
14:44:09.820 MoveAxis Primary                OK       Can successfully set a movement rate of zero
14:44:09.874 MoveAxis Primary                OK       Exception correctly generated when moveaxis set below lowest rate (-3.5)
14:44:09.949 MoveAxis Primary                OK       Exception correctly generated when moveaxis set above highest rate (3.5)
14:44:14.185 MoveAxis Primary                OK       Successfully moved axis at minimum rate: 0
14:44:18.664 MoveAxis Primary                OK       Successfully moved axis at maximum rate: 2.5
14:44:22.966 MoveAxis Primary                OK       Tracking state correctly retained for both tracking states
14:44:23.045 MoveAxis Secondary              OK       Can successfully set a movement rate of zero
14:44:23.078 MoveAxis Secondary              OK       Exception correctly generated when moveaxis set below lowest rate (-3.5)
14:44:23.157 MoveAxis Secondary              OK       Exception correctly generated when moveaxis set above highest rate (3.5)
14:44:27.394 MoveAxis Secondary              OK       Successfully moved axis at minimum rate: 0
14:44:31.982 MoveAxis Secondary              OK       Successfully moved axis at maximum rate: 2.5
14:44:36.285 MoveAxis Secondary              OK       Tracking state correctly retained for both tracking states
14:44:36.352 MoveAxis Tertiary               OK       Received an invalid value exception
14:44:38.474 PulseGuide                      OK       Synchronous pulseguide found OK
14:45:17.634 SlewToCoordinates               INFO     Slewed within 53.6 arc seconds of expected RA: 20:42:08.49, actual RA: 20:42:04.92
14:45:17.667 SlewToCoordinates               OK       Slewed OK. DEC:  01:00:00.00
14:45:17.723 SlewToCoordinates (Bad L)       OK       Correctly rejected bad RA coordinate: -01:00:00.00
14:45:17.749 SlewToCoordinates (Bad L)       OK       Correctly rejected bad Dec coordinate: -100:00:00.00
14:45:17.818 SlewToCoordinates (Bad H)       OK       Correctly rejected bad RA coordinate: 25:00:00.00
14:45:17.842 SlewToCoordinates (Bad H)       OK       Correctly rejected bad Dec coordinate: 100:00:00.00
14:45:26.653 SlewToCoordinatesAsync          INFO     Slewed within 23.3 arc seconds of expected RA: 19:42:47.97, actual RA: 19:42:49.52
14:45:26.685 SlewToCoordinatesAsync          OK       Slewed OK. DEC:  02:00:00.00
14:45:26.728 SlewToCoordinatesAsync (Bad L)  OK       Correctly rejected bad RA coordinate: -01:00:00.00
14:45:26.751 SlewToCoordinatesAsync (Bad L)  OK       Correctly rejected bad Dec coordinate: -100:00:00.00
14:45:26.815 SlewToCoordinatesAsync (Bad H)  OK       Correctly rejected bad RA coordinate: 25:00:00.00
14:45:26.835 SlewToCoordinatesAsync (Bad H)  OK       Correctly rejected bad Dec coordinate: 100:00:00.00
14:45:35.545 SlewToTarget                    INFO     Slewed within 21.3 arc seconds of expected RA: 18:42:56.98, actual RA: 18:42:58.39
14:45:35.576 SlewToTarget                    OK       Slewed OK. DEC:  03:00:00.00
14:45:35.619 SlewToTarget (Bad L)            OK       Telescope.TargetRA correctly rejected bad RA coordinate: -01:00:00.00
14:45:35.643 SlewToTarget (Bad L)            OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: -100:00:00.00
14:45:35.719 SlewToTarget (Bad H)            OK       Telescope.TargetRA correctly rejected bad RA coordinate: 25:00:00.00
14:45:35.752 SlewToTarget (Bad H)            OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: 100:00:00.00
14:45:44.547 SlewToTargetAsync               INFO     Slewed within 21.8 arc seconds of expected RA: 17:43:05.92, actual RA: 17:43:07.38
14:45:44.578 SlewToTargetAsync               OK       Slewed OK. DEC:  04:00:00.00
14:45:44.625 SlewToTargetAsync (Bad L)       OK       Telescope.TargetRA correctly rejected bad RA coordinate: -01:00:00.00
14:45:44.659 SlewToTargetAsync (Bad L)       OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: -100:00:00.00
14:45:44.732 SlewToTargetAsync (Bad H)       OK       Telescope.TargetRA correctly rejected bad RA coordinate: 25:00:00.00
14:45:44.751 SlewToTargetAsync (Bad H)       OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: 100:00:00.00
14:45:44.817 DestinationSideOfPier           OK       DestinationSideOfPier is different on either side of the meridian
14:46:57.016 SlewToAltAz                     OK       Slewed to target Azimuth OK: 150:00:00.00
14:46:57.079 SlewToAltAz                     OK       Slewed to target Altitude OK: 50:00:00.00
14:46:57.126 SlewToAltAz (Bad L)             OK       Correctly rejected bad Altitude coordinate: -100:00:00.00
14:46:57.148 SlewToAltAz (Bad L)             OK       Correctly rejected bad Azimuth coordinate: -10:00:00.00
14:46:57.211 SlewToAltAz (Bad H)             OK       Correctly rejected bad Altitude coordinate: 100:00:00.00
14:46:57.234 SlewToAltAz (Bad H)             OK       Correctly rejected bad Azimuth coordinate: 370:00:00.00
14:47:02.564 SlewToAltAzAsync                OK       Slewed to target Azimuth OK: 155:00:00.00
14:47:02.629 SlewToAltAzAsync                OK       Slewed to target Altitude OK: 55:00:00.00
14:47:02.688 SlewToAltAzAsync (Bad L)        OK       Correctly rejected bad Altitude coordinate: -100:00:00.00
14:47:02.715 SlewToAltAzAsync (Bad L)        OK       Correctly rejected bad Azimuth coordinate: -10:00:00.00
14:47:02.785 SlewToAltAzAsync (Bad H)        OK       Correctly rejected bad Altitude coordinate: 100:00:00.00
14:47:02.815 SlewToAltAzAsync (Bad H)        OK       Correctly rejected bad Azimuth coordinate: 370:00:00.00
14:48:07.372 SyncToCoordinates               INFO     Slewed to start position within 967.4 arc seconds of expected RA: 18:44:33.23, actual RA:
18:45:37.72
14:48:07.405 SyncToCoordinates               OK       Slewed to start position OK. DEC:  19:09:59.40
14:48:07.533 SyncToCoordinates               OK       Synced to sync position OK. RA:   18:40:33.23
14:48:07.565 SyncToCoordinates               OK       Synced to sync position OK. DEC:  18:09:59.40
14:48:13.049 SyncToCoordinates               INFO     Slewed back to start position within 57.5 arc seconds of expected RA: 18:44:33.23, actual RA:
18:44:37.06
14:48:13.082 SyncToCoordinates               OK       Slewed back to start position OK. DEC:  19:09:59.40
14:48:13.209 SyncToCoordinates               OK       Synced to reversed sync position OK. RA:   18:48:33.23
14:48:13.241 SyncToCoordinates               OK       Synced to reversed sync position OK. DEC:  20:09:59.40
14:48:18.678 SyncToCoordinates               INFO     Slewed back to start position within 56.8 arc seconds of expected RA: 18:44:33.23, actual RA:
18:44:37.02
14:48:18.710 SyncToCoordinates               OK       Slewed back to start position OK. DEC:  19:09:59.40
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14:48:18.753 SyncToCoordinates (Bad L)        OK       Correctly rejected bad RA coordinate: -01:00:00.00
14:48:18.775 SyncToCoordinates (Bad L)        OK       Correctly rejected bad Dec coordinate: -100:00:00.00
14:48:18.858 SyncToCoordinates (Bad H)        OK       Correctly rejected bad RA coordinate: 25:00:00.00
14:48:18.881 SyncToCoordinates (Bad H)        OK       Correctly rejected bad Dec coordinate: 100:00:00.00
14:48:24.547 SyncToTarget                     INFO     Slewed to start position within 48.5 arc seconds of expected RA: 18:45:49.50, actual RA:
18:45:52.74
14:48:24.578 SyncToTarget                     OK       Slewed to start position OK. DEC:  19:09:59.40
14:48:24.706 SyncToTarget                     OK       Synced to sync position OK. RA:   18:41:49.50
14:48:24.739 SyncToTarget                     OK       Synced to sync position OK. DEC:  18:09:59.40
14:48:30.206 SyncToTarget                     INFO     Slewed back to start position within 56.7 arc seconds of expected RA: 18:45:49.50, actual RA:
18:45:53.29
14:48:30.239 SyncToTarget                     OK       Slewed back to start position OK. DEC:  19:09:59.40
14:48:30.368 SyncToTarget                     OK       Synced to reversed sync position OK. RA:   18:49:49.50
14:48:30.400 SyncToTarget                     OK       Synced to reversed sync position OK. DEC:  20:09:59.40
14:48:35.853 SyncToTarget                     INFO     Slewed back to start position within 56.6 arc seconds of expected RA: 18:45:49.50, actual RA:
18:45:53.28
14:48:35.885 SyncToTarget                     OK       Slewed back to start position OK. DEC:  19:09:59.40
14:48:35.929 SyncToTarget (Bad L)             OK       Telescope.TargetRA correctly rejected bad RA coordinate: -01:00:00.00
14:48:35.956 SyncToTarget (Bad L)             OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: -100:00:00.00
14:48:36.031 SyncToTarget (Bad H)             OK       Telescope.TargetRA correctly rejected bad RA coordinate: 25:00:00.00
14:48:36.062 SyncToTarget (Bad H)             OK       Telescope.TargetDeclination correctly rejected bad Dec coordinate: 100:00:00.00
14:48:36.412 SyncToAltAz                      OK       Synced Altitude OK
14:48:36.435 SyncToAltAz                      OK       Synced Azimuth OK
14:48:36.478 SyncToAltAz (Bad L)              OK       Correctly rejected bad Altitude coordinate: -100:00:00.00
14:48:36.501 SyncToAltAz (Bad L)              OK       Correctly rejected bad Azimuth coordinate: -10:00:00.00
14:48:36.568 SyncToAltAz (Bad H)              OK       Correctly rejected bad Altitude coordinate: 100:00:00.00
14:48:36.592 SyncToAltAz (Bad H)              OK       Correctly rejected bad Azimuth coordinate: 370:00:00.00

SideOfPier Model Tests
14:50:01.919 SideOfPier Write                 INFO     This test will now wait for 7 minutes while the mount tracks through the Meridian
14:58:21.129 SideOfPier Write                 OK       Successfully flipped pierWest to pierEast
15:04:55.028 SideofPier                       OK       Reports the pointing state of the mount as expected
15:04:55.045 SideofPier                       INFO     Reported SideofPier at HA -9, +9: WE
15:04:55.062 SideofPier                       INFO     Reported SideofPier at HA -3, +3: WE
15:04:55.082 SideofPier                       OK       pierWest is returned when the mount is observing at an hour angle between -6.0 and 0.0
15:04:55.107 SideofPier                       OK       pierEast is returned when the mount is observing at an hour angle between 0.0 and +6.0
15:04:55.123 DestinationSideofPier            OK       Reports the pointing state of the mount as expected
15:04:55.141 DestinationSideofPier            OK       pierWest is returned when the mount will observe at an hour angle between -6.0 and 0.0
15:04:55.157 DestinationSideofPier            OK       pierEast is returned when the mount will observe at an hour angle between 0.0 and +6.0
15:04:55.174 DestinationSideofPier            INFO     Reported DesintationSideofPier at HA -9, +9: WE
15:04:55.192 DestinationSideofPier            INFO     Reported DesintationSideofPier at HA -3, +3: WE

Performance
Transactions per second: <1=Rather low, 1-2=OK, 2-10=Good, >10=Rather high
15:05:00.313 Performance: Altitude            INFO     Transaction rate: 20.6 per second
15:05:05.399 Performance: AtHome              INFO     Transaction rate: 20.6 per second
15:05:10.437 Performance: AtPark              INFO     Transaction rate: 18160.8 per second
15:05:15.522 Performance: Azimuth             INFO     Transaction rate: 20.6 per second
15:05:20.572 Performance: Declination         INFO     Transaction rate: 61.7 per second
15:05:25.614 Performance: IsPulseGuiding      INFO     Transaction rate: 17398.0 per second
15:05:30.677 Performance: RightAscension      INFO     Transaction rate: 30.9 per second
15:05:35.731 Performance: SideOfPier          INFO     Transaction rate: 61.8 per second
15:05:40.773 Performance: SiderealTime        INFO     Transaction rate: 14775.1 per second
15:05:45.821 Performance: Slewing             INFO     Transaction rate: 30.9 per second
15:05:50.862 Performance: UTCDate             INFO     Transaction rate: 16735.3 per second

Post-run Checks
15:05:50.970 Mount Safety                     OK       Tracking stopped to protect your mount.

Conformance test complete

No errors, warnings or issues found: your driver passes ASCOM validation!!

Driver Hash Value: 8A91BA639244CEF66FC46E4C203B24E77C9DB5519A66C3F40AAF1CF9E62720F7BAA25BA03CB95B8B9AAF2E8F1D40359C507F2DB3FE1B6413D979BFD8868F3623
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PRECISION MOTION CONTROLLER

EXPLORE SCIENTIFIC

Designed by Explore Scientific® in Arkansas. Assembled in China.

Model: ESOGT-01B

explorescientificusa.com - 866.252.3811

Contains FCC ID: U3O-G2M5477

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.