Meade Telescope Serial Command Protocol
Revision L
9 October 2002

Introduction
This paper documents the Meade Telescope Serial Control Protocol utilized to remotely command and control Meade Telescopes. This command language contains a core of common commands supported by all telescope. Due to different implementation and technological advances the command has extension that are not supported by all model. The differences are noted in the descriptive text for the commands. Finally, there are a series of new commands proposed for the LX200GPS. These commands are indicated in the Appendix A at the end of this document.

As an extension to the Telescope Protocol beginning with the LX200GPS, a possible response to any command is ASCII NAK (0x15). Should the telescope control chain be busy and unable to accept an process the command, a NAK will be sent within 10 msec of the receipt of the '#' terminating the command. In this event, the controller should wait a reasonable interval and retry the command.

Telescope Command Groupings:

Command Group	Command Designator Symbol	AutoStar	LX200<16"	LX 16"	LX200GPS
		----------------- Supported ------------			
Alignment Query	<ACK>	x	x	x	x
Alignment*	A	x	x	x	x
Active Backlash	$B	-	-	-	x
Reticule Control*	B	x	p	p	x
Sync Control	C	p	p	p	x
Distance Bars	D	x	x	x	x
Fan*	f	-	-	p	x
Focus Control Commands	F	p	p	p	x
GPS Commands	g	-	-	-	x
Get Information	G	x	x	x	x
Home Position Commands*	h	x	-	x	x
Hour	H	x	x	x	x
Initialize Telescope	I	-	-	-	x
Library	L	p	p	p	x
Movement	M	x	p	x	x
High Precision	P	x	x	x	x
Smart Drive Control*	$Q	x	x	x	x
Quit Command	Q	x	x	x	x
Field De-rotator	r	-	-	p	x
Rate Control	R	p	p	p	x
Set Information	S	x	x	x	x
Tracking Frequency	T	p	p	p	x
User Format Control	U	p	x	x	x
Way point (Site)	W	x	x	x	x
Help Commands	?	-	x	x	-

Notes:
Commands accepted by the telescopes are shown in the table above indicated by an x entry. This means that the telescope will accept these commands and respond with a syntactically valid response where required. A "p" indicated only a subset of this command class is supported. Due to the differing implementations of the telescopes, some of the commands may provide static responses or may do nothing in response to the command. See the detailed description of the commands below to determine the exact behavior.

ACK - Alignment Query
ACK   <0x06> Query of alignment mounting mode.
        Returns:
           A   If scope in AltAz Mode
           L   If scope in Land Mode
           P   If scope in Polar Mode

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A - Alignment Commands
:Aa#   Start Telescope Automatic Alignment Sequence [LX200GPS only]
         Returns:
              1: When complete (can take several minutes).
              0: If scope not AzEl Mounted or align fails

:AL#   Sets telescope to Land alignment mode
         Returns: nothing

:AP#   Sets telescope to Polar alignment mode
         Returns: nothing

:AA#   Sets telescope the AltAz alignment mode
         Returns: nothing

$B – Active Backlash Compensation
:$BAdd#
         Set Altitude/Dec Antibacklash
         Returns Nothing

:$BZdd#
         Set Azimuth/RA Antibacklash
         Returns Nothing

B - Reticule/Accessory Control
:B+#   Increase reticule Brightness
         Return: Nothing

:B-#   Decrease Reticule Brightness
         Return: Nothing

:B<n># Set Reticle flash rate to <n> (an ASCII expressed number)
                  <n> Values of 0..3 for LX200 series
                  <n> Values of 0..9 for Autostar and LX200GPS
         Return: Nothing

:BDn#   Set Reticule Duty flash duty cycle to <n> (an ASCII expressed digit) [LX200 GPS Only]
                  <n> Values: 0 = On, 1..15 flash rate
         Return: Nothing

C - Sync Control
:CL#   Synchonize the telescope with the current Selenographic coordinates.

:CM#   Synchronizes the telescope's position with the currently selected database object's coordinates.
         Returns:
              LX200's - a "#" terminated string with the name of the object that was synced.
              Autostars & LX200GPS - At static string: " M31 EX GAL MAG 3.5 SZ178.0'#"

D - Distnace Bars
:D#   Requests a string of bars indicating the distance to the current library object.
         Returns:
              LX200's – a string of bar characters indicating the distance.
              Autostars and LX200GPS – a string containing one bar until a slew is complete, then a null string is returned.

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f - Fan Command
:f+#   LX 16"– Turn on the tube exhaust fan
           LX200GPS – Turn on power to accessor panel
           Autostar & LX200 < 16" – Not Supported
           Returns: nothing

:f-#   LX 16"– Turn off tube exhaust fan
           LX200GPS - Turn off power to accessory panel
           Autostar & LX200 < 16" – Not Supported
           Returns: Nothing

:fT#   LX200GPS – Return Optical Tube Assembly Temperature
           Returns <sdd.ddd># - a '#' terminated signed ASCII real number indicating the Celsius ambient temperature.
           All others – Not supported

F – Focuser Control
:F+#   Start Focuser moving inward (toward objective)
           Returns: None

:F-#   Start Focuser moving outward (away from objective)
           Returns: None

:FQ#   Halt Focuser Motion
           Returns: Notrhing

:FF#   Set Focus speed to fastest setting
           Returns: Nothing

:FS#   Set Focus speed to slowest setting
           Returns: Nothing

:F<n>#   Autostar & LX200GPS – set focuser speed to <n> where <n> is an ASCII digit 1..4
           Returns: Nothing
           LX200 – Not Supported

g – GPS/Magnetometer commands
:g+#   LX200GPS Only - Turn on GPS
           Returns: Nothing

:g-#   LX200GPS Only - Turn off GPS

:gps#   LX200GPS Only – Turns on NMEA GPS data stream.
           Returns: The next string from the GPS in standard NEMA format followed by a '#' key

:gT#   Powers up the GPS and updates the system time from the GPS stream. The process my take several minutes to complete.
           During GPS update, normal handbox operations are interrupted. [LX200gps only]
           Returns: '0' In the event that the user interrupts the process, or the GPS times out.
           Returns: '1' After successful updates

G – Get Telescope Information
:G0#   Get Alignment Menu Entry 0
           Returns: A '#' Terminated ASCII string. [LX200 legacy command]

:G1#   Get Alignment Menu Entry 0
           Returns: A '#' Terminated ASCII string. [LX200 legacy command]

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:G2#   Get Alignment Menu Entry 0
        Returns: A '#' Terminated ASCII string. [LX200 legacy command]

:GA#   Get Telescope Altitude
        Returns: sDD*MM# or sDD*MM'SS#
            The current scope altitude. The returned format depending on the current precision setting.

:Ga#   Get Local Telescope Time In 12 Hour Format
        Returns: HH:MM:SS#
            The time in 12 format

:Gb#   Get Browse Brighter Magnitude Limit
        Returns: sMM.M#
            The magnitude of the faintest object to be returned from the telescope FIND/BROWSE command.
        Command when searching for objects in the Deep Sky database.

:GC#   Get current date.
        Returns: MM/DD/YY#
            The current local calendar date for the telescope.

:Gc#   Get Calendar Format
        Returns: 12# or 24#
            Depending on the current telescope format setting.

:GD#   Get Telescope Declination.
        Returns: sDD*MM# or sDD*MM'SS#
            Depending upon the current precision setting for the telescope.

:Gd#   Get Currently Selected Object/Target Declination
        Returns: sDD*MM# or sDD*MM'SS#
            Depending upon the current precision setting for the telescope.

:GF#   Get Find Field Diameter
        Returns: NNN#
            An ASCIi interger expressing the diameter of the field search used in the IDENTIFY/FIND commands.

:Gf#   Get Browse Faint Magnitude Limit
        Returns: sMM.M#
            The magnitude or the birghtest object to be returned from the telescope FIND/BROWSE command.

:GG#   Get UTC offset time
        Returns: sHH# or sHH.H#
            The number of decimal hours to add to local time to convert it to UTC. If the number is a whole number the
            sHH# form is returned, otherwise the longer form is return. On Autostar and LX200GPS, the daylight savings
            setting in effect is factored into returned value.

:Gg#   Get Current Site Longitude
        Returns: sDDD*MM#
            The current site Longitude. East Longitudes are expressed as negative

:Gh#   Get High Limit
        Returns: sDD*
            The minimum elevation of an object above the horizon to which the telescope will slew with reporting a
            "Below Horizon" error.

:GL#   Get Local Time in 24 hour format
        Returns: HH:MM:SS#

        The Local Time in 24-hour Format

:Gl#   Get Larger Size Limit
        Returns: NNN'#
            The size of the smallest object to be returned by a search of the telescope using the BROWSE/FIND commands.

:GM#   Get Site 1 Name
        Returns: <string>#
            A '#' terminated string with the name of the requested site.

:GN#   Get Site 2 Name
        Returns: <string>#
            A '#' terminated string with the name of the requested site.

:GO#   Get Site 3 Name
        Returns: <string>#
            A '#' terminated string with the name of the requested site.

:GP#   Get Site 4 Name
        Returns: <string>#
            A '#' terminated string with the name of the requested site.

:Go#   Get Lower Limit
        Returns: DD*#
            The highest elevation above the horizon that the telescope will be allowed to slew to without a warning message.

:Gq#   Get Minimum Quality For Find Operation
        Returns:

SU#	Super
EX#	Excellent
VG#	Very Good
GD#	Good
FR#	Fair
PR#	Poor
VP#	Very Poor

            The mimum quality of object returned by the FIND command.

:GR#   Get Telescope RA
        Returns: HH:MM.T# or HH:MM:SS#
            Depending which precision is set for the telescope

:Gr#   Get current/target object RA
        Returns: HH:MM.T# or HH:MM:SS
            Depending upon which precision is set for the telescope

:GS#   Get the Sidereal Time
        Returns: HH:MM:SS#
            The Sidereal Time as an ASCII Sexidecimal value in 24 hour format

:Gs#   Get Smaller Size Limit
        Returns: NNN'#
            The size of the largest object returned by the FIND command expressed in arcminutes.

:GT#   Get tracking rate
        Returns: TT.T#
            Current Track Frequency expressed in hertz assuming a synchonous motor design where a 60.0 Hz motor clock would produce 1 revolution of the telescope in 24 hours.

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:Gt#   Get Current Site Latitdue
        Returns: sDD*MM#
            The latitude of the current site. Positive inplies North latitude.

:GVD# Get Telescope Firmware Date
        Returns: mmm dd yyyy#

:GVN# Get Telescope Firmware Number
        Returns: dd.d#

:GVP# Get Telescope Product Name
        Returns: <string>#

:GVT# Get Telescope Firmware Time
        returns: HH:MM:SS#

:Gy#   Get deepsky object search string
        Returns: GPDCO#
            A string indicaing the class of objects that should be returned by the FIND/BROWSE command. If the character
            is upper case, the object class is return. If the character is lowercase, objects of this class are ignored. The
            character meanings are as follws:
                        G – Galaxies
                        P – Planetary Nebulas
                        D – Diffuse Nebulas
                        C – Globular Clusters
                        O – Open Clusters

:GZ#   Get telescope azimuth
        Returns: DDD*MM#T or DDD*MM'SS#
            The current telescope Azimuth depending on the selected precision.

h – Home Position Commands
:hS#   LX200GPS and LX 16" Seeks Home Position and stores the encoder values
        from the aligned telescope at the home position in the nonvolatile memory of the
        scope.
        Returns: Nothing
        Autostar,LX200 – Ignored

:hF#   LX200GPS and LX 16" Seeks the Home Position of the scope and sets/aligns
        the scope based on the encoder values stored in non-volatile memory
        Returns: Nothing
        Autostar,LX200 - Igrnored

:hN#   LX200GPS only: Sleep Telescope. Power off motors, encoders, displays and lights. Scope
        remains in minimum power mode until a keystroke is received or a wake command is sent.

:hP#   Autostar, LX200GPS and LX 16"Slew to Park Position
        Returns: Nothing

:hW#   LX200 GPS Only: Wake up sleeping telescope.

:h?#   Autostar, LX200GPS and LX 16" Query Home Status
        Returns:
                0   Home Search Failed
                1   Home Search Found
                2   Home Search in Progress

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> LX200 Not Supported

H – Time Format Command
:H#   Toggle Between 24 and 12 hour time format
> Returns: Nothing

I – Initialize Telescope Command
:I#   LX200 GPS Only - Causes the telescope to cease current operations and restart at its power on initialization.

L – Object Library Commands
:LB#   Find previous object and set it as the current target object.
> Returns: Nothing
> LX200GPS & Autostar – Performs no function

:LCNNNN#
> Set current target object to deep sky catalog object number NNNN
> Returns : Nothing
> LX200GPS & Autostar – Implemented in later firmware revisions

:LF#   Find Object using the current Size, Type, Upper limit, lower limt and Quality contraints and set it as current target object.
> Returns: Nothing
> LX200GPS & Autostar – Performs no function

:Lf#   Identify object in current field.
> Returns: <string>#
>>   Where the string contains the number of objects in field & object in center field.
> LX200GPS & Autostar – Performs no function. Returns static string "0 - Objects found".

:LI#   Get Object Information
> Returns: <string>#
>>   Returns a string containing the current target object's name and object type.
> LX200GPS & Autostar – performs no operation. Returns static description of Andromeda Galaxy.

:LMNNNN#
> Set current target object to Messier Object NNNN, an ASCII expressed decimal number.
> Returns: Nothing.
> LX200GPS and Autostar – Implemented in later versions.

:LN#   Find next deep sky target object subject to the current constraints.
> LX200GPS & AutoStar – Performs no function

:LoD#   Select deep sky Library where D specifices
>>   0 - Objects CNGC / NGC in Autostar & LX200GPS
>>   1 - Objects IC
>>   2 – UGC
>>   3 – Caldwell   (Autostar & LX200GPS)
>>   4 – Arp   (LX200 GPS)
>>   5 – Abell   (LX200 GPS)
> Returns:
>>   1   Catalog available
>>   0   Catalog Not found
> LX200GPS & AutoStar – Performs no function always returns "1"

:LsD#   Select star catalog D, an ASCII integer where D specifies:
>>   0   STAR library (Not supported on Autostar I & II)
>>   1   SAO library
>>   2   GCVS library

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3	Hipparcos	(Autostar I & 2)
4	HR (Autostar I & 2)	
5	HD (Autostar I & 2)	

Returns:
1	Catalog Available
2	Catalog Not Found

:LSNNNN#
> Select star NNNN as the current target object from the currently selected catalog
> Returns: Nothing
> LX200GPS & AutoStar – Available in later firmwares

M – Telescope Movement Commands

:MA# Autostar, LX 16", LX200GPS – Slew to target Alt and Az
> Returns:
> > 0 - No fault
> > 1 – Fault
>
> LX200 – Not supported

:Me# Move Telescope East at current slew rate
> Returns: Nothing

:Mn# Move Telescope North at current slew rate
> Returns: Nothing

:Ms# Move Telescope South at current slew rate
> Returns: Nothing

:Mw# Move Telescope West at current slew rate
> Returns: Nothing

:MS# Slew to Target Object
> Returns:
> > | 0 | Slew is Possible |
> > |---|---|
> > | 1<string># | Object Below Horizon w/string message |
> > | 2<string># | Object Below Higher w/string message |

P - High Precision Toggle

:P# Toggles High Precsion Pointing. When High precision pointing is enabled scope will first allow the operator to center a nearby bright star before moving to the actual taget.
> Returns: <string>
> > | "HIGH PRECISION" | Current setting after this command. |
> > |---|---|
> > | "LOW PRECISION" | Current setting after this command. |

$Q – Smart Drive Control

$Q# Toggles Smart Drive PEC on and off for both axis
> Returns: Nothing
> Not supported on Autostar

:$QA+ Enable Dec/Alt PEC [LX200gps only]
> Returns: Nothing

:$QA- Enable Dec/Alt PEC [LX200gps only]
> Returns: Nothing

:$QZ+ Enable RA/AZ PEC compensation [LX200gps only]

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Returns: Nothing

:$QZ-   Disable RA/AZ PEC Compensation [LX200gpgs only]
Return: Nothing

Q – Movement Commands
:Q#   Halt all current slewing
Returns:Nothing

:Qe#   Halt eastward Slews
Returns: Nothing

:Qn#   Halt northward Slews
Returns: Nothing

:Qs#   Halt southward Slews
Returns: Nothing

:Qw#   Halt westward Slews
Returns: Nothing

r – Field Derotator Commands
:r+#   Turn on Field Derotator [LX 16" and LX200GPS]
Returns: Nothing

:r-#   Turn off Field Derotator, halt slew in progress. [Lx 16" and LX200GPS]
Returns Nothing

R – Slew Rate Commands
:RC#   Set Slew rate to Centering rate (2nd slowest)
Returns: Nothing

:RG#   Set Slew rate to Guiding Rate (slowest)
Returns: Nothing

:RM#   Set Slew rate to Find Rate (2nd Fastest)
Returns: Nothing

:RS#   Set Slew rate to max (fastest)
Returns: Nothing

:RADD.D#
Set RA/Azimuth Slew rate to DD.D degrees per second [LX200GPS Only]
Returns: Nothing

:REDD.D#
Set Dec/Elevation Slew rate to DD.D degrees per second [LX200GPS only]
Returns: Nothing

:RgSS.S#
Set guide rate to +/- SS.S to arc seconds per second. This rate is added to or subtracted from the current tracking
Rates when the CCD guider or handbox guider buttons are pressed when the guide rate is selected. Rate shall not exceed
sidereal speed (approx 15.0417"/sec)[LX200GPS only]
Returns: Nothing

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S – Telescope Set Commands

:SasDD*MM#

        Set target object altitude to sDD*MM# or sDD*MM'SS# [LX 16", Autostar, LX200GPS]

        Returns:

                0   Object within slew range

                1   Object out of slew range

:SbsMM.M#

        Set Brighter limit to the ASCII decimal magnitude string. SMM.M

        Returns:

                0   - Valid

                1   – invalid number

:SBn#   Set Baud Rate n, where n is an ASCII digit (1..9) with the following interpertation

                1   56.7K

                2   38.4K

                3   28.8K

                4   19.2K

                5   14.4K

                6   9600

                7   4800

                8   2400

                9   1200

        Returns:

                1   At the current baud rate and then changes to the new rate for further communication

:SCMM/DD/YY#

        Change Handbox Date to MM/DD/YY

        Returns: <D><string>

                D = '0' if the date is invalid. The string is the null string.

                D = '1' for valid dates and the string is "Updating Planetary Data#   #"

        Note: For LX200GPS this is the UTC data!

:SdsDD*MM#

        Set target object declination to sDD*MM or sDD*MM:SS depending on the current precision setting

        Returns:

                1 - Dec Accepted

                0 – Dec invalid

:SEsDD*MM#

        Sets target object to the specificed selenographic latitude on the Moon.

        Returns 1- If moon is up and coordinates are accepted.

                0 – If the coordinates are invalid

:SesDDD*MM#

        Sets the target object to the specified selenogrphic longitude on the Moon

        Returns 1 – If the Moon is up and coordinates are accepted.

                0 – If the coordinates are invalid for any reason.

:SfsMM.M#

        Set faint magnitude limit to sMM.M

        Returns:

                0 – Invalid

                1 - Valid

:SFNNN#

        Set FIELD/IDENTIFY field diamter to NNNN arc minutes.

Returns:
0 – Invalid
1 - Valid

:SgDDD*MM#
Set current site's longitude to DDD*MM an ASCII position string
Returns:
0 – Invalid
1 - Valid

:SGsHH.H#
Set the number of hours added to local time to yield UTC
Returns:
0 – Invalid
1 - Valid

:ShDD#
Set the minimum object elevation limit to DD#
Returns:
0 – Invalid
1 - Valid

:SlNNN#
Set the size of the smallest object returned by FIND/BROWSE to NNNN arc minutes
Returns:
0 – Invalid
1 - Valid

:SLHH:MM:SS#
Set the local Time
Returns:
0 – Invalid
1 - Valid

:SM<string>#
Set site 1's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SN<string>#
Set site 2's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SO<string>#
Set site 3's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SP<string>#
Set site 4's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

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:SoDD*#

    Set highest elevation to which the telescope will slew

    Returns:

        0 – Invalid

        1 - Valid

:Sq#

    Step the quality of limit used in FIND/BROWSE through its cycle of VP … SU. Current setting can be queried with :Gq#

    Returns: Nothing

:SrHH:MM.T#

:SrHH:MM:SS#

    Set target object RA to HH:MM.T or HH:MM:SS depending on the current precision setting.

    Returns:

        0 – Invalid

        1 - Valid

:SsNNN#

    Set the size of the largest object the FIND/BROWSE command will return to NNNN arc minutes

    Returns:

        0 – Invalid

        1 - Valid

:SSHH:MM:SS#

    Sets the local sideral time to HH:MM:SS

    Returns:

        0 – Invalid

        1 - Valid

:StsDD*MM#

    Sets the current site latitdue to sDD*MM#

    Returns:

        0 – Invalid

        1 - Valid

:STTT.T#

    Sets the current tracking rate to TTT.T hertz, assuming a model where a 60.0 Hertz synchronous motor will cause the RA axis to make exactly one revolution in 24 hours.

    Returns:

        0 – Invalid

        1 - Valid

:SwN#

    Set maximum slew rate to N degrees per second. N is the range (2..8)

    Returns:

        0 – Invalid

        1 - Valid

:SyGPDCO#

    Sets the object selection string used by the FIND/BROWSE command.

    Returns:

        0 – Invalid

        1 - Valid

:SzDDD*MM#

    Sets the target Object Azimuth [LX 16" and LX200GPS only]

    Returns:

0 – Invalid
1 - Valid

T – Tracking Commands

:T+#   Increment Manual rate by 0.1 Hz
         Returns: Nothing

:T-#   Decrement Manual rate by 0.1 Hz
         Returns: Nothing

:TL#   Set Lunar Tracking Rage
         Returns: Nothing

:TM#   Select custom tracking rate
         Returns: Nothing

:TQ#   Select default tracking rate
         Returns: Nothing

:TDDD.DDD#
         Set Manual rate do the ASCII expressed decimal DDD.DD
         Returns: '1'

U - Precision Toggle

:U#   Toggle between low/hi precision positions
                 Low   - RA displays and messages HH:MM.T sDD*MM
                 High   - Dec/Az/El displays and messages HH:MM:SS sDD*MM:SS
         Returns Nothing

W – Site Select

:W<n>#
         Set current site to <n>, an ASCII digit in the range 0..3
         Returns: Nothing

? – Help Text Retrieval

:??#   Set help text cursor to the start of the first line.
         Returns: <string>#
                 The <string> contains first string of the general handbox help file.

:?+#   Retrieve the next line of help text
         Returns: <string>#
                 The <string> contains the next string of general handbox help file

:?-#   Retreive previos line of the handbox help text file.
         Returns: <string>#
                 The <string> contains the next string of general handbox help file

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Appendix A: LX200GPS Command Extensions

:Aa#	Automatically align scope
:$BAdd#	Set Altitude/Dec Antibacklash
:$BZdd#	Set Azimuth/RA Antibacklash
:BD<n>#	Programmable Reticule Duty Cycle
:F<n>#	Set Focuer Speed
:g+#	Turn on GPS power
:g-#	Turn off GPS power
:gps#	Stream GPS data
:gT#	Updates Time of Day from GPS
:I#	Initialize Telescope
:$QZ+#	RA PEC Enable
:$QZ-#	RA PEC Disable
:$QA+#	Dec PEC Enable
:$QA-#	Dec PEC Disable
:RADD.D#	Programmable Slew Rates
:REDD.D#	Programmable Slew Rates
:RgSS.S#	Programmable Guiding Rates
:SBn#	Set Baud Rate

NexStar Communication Protocol

This document describes the serial commands supported by the Celestron NexStar hand control. This information applies to the NexStar GPS, NexStar GPS-SA, NexStar iSeries, NexStar SE Series, NexStar GT, CPC, SLT, Advanced-GT, and CGE mounts.

Communication to the hand control is 9600 bits/sec, no parity and one stop bit via the RS-232 port on the base of the hand control.

Note: the GT hand control prior to version 104.0 should be treated as version 1.2 in the tables below. Version 104.0 should be treated as version 4.03.

Get Position Commands

The following commands retrieve the position of the telescope in either RA/DEC or AZM-ALT coordinates.

The position is returned as a hexadecimal value that represents the fraction of a revolution around the axis. Two examples are given below:

- If the Get RA/DEC command returns 34AB,12CE then the DEC value is 12CE in hexadecimal. As a percentage of a revolution, this is 4814/65536 = 0.07346. To calculate degrees, simply multiply by 360, giving a value of 26.4441 degrees.
- If the precise GET AZM-ALT command returns 12AB0500,40000500 then the AZM value is 12AB0500 in hexadecimal. As a percentage of a revolution, this is 313197824/4294967296 = 0.0729 or 26.252 degrees.

The standard commands offer a precision of 1/65536 * 360 * 60 * 60 = about 19.8 arcseconds per unit while the precise commands offer a precision of 1/16777216 * 360 * 60 * 60 = about 0.08 arcseconds per unit (only the upper 24 bits are used).

Note: if the telescope has not been aligned, the RA/DEC values will not be meaningful and the AZM-ALT values will be relative to where the telescope was powered on. After alignment, RA/DEC values will reflect the actual sky, azimuth will be indexed to North equals 0 and altitude will be indexed with 0 equal to the orientation where the optical tube is perpendicular to the azimuth axis.

Command Function	PC Command	Hand Control Response	Applies to Versions
Get RA/DEC	"E"	"34AB,12CE#"	1.2+
Get precise RA/DEC	"e"	"34AB0500,12CE0500#"	1.6+
Get AZM-ALT	"Z"	"12AB,4000#"	1.2+
Get precise AZM-ALT	"z"	"12AB0500,40000500#"	2.2+

GOTO Commands

The following commands direct the telescope to GOTO a specified RA/DEC or AZM-ALT position. As with the Get Position commands, the values are in hexadecimal and represent the fraction of a rotation around the axis.

Note: GOTO RA/DEC commands will not work unless the telescope is aligned.

Command Function	PC Command	Hand Control Response	Applies to Versions
GOTO RA/DEC	"R34AB,12CE"	"#"	1.2+
GOTO precise RA/DEC	"r34AB0500,12CE0500"	"#"	1.6+
GOTO AZM-ALT	"B12AB,4000"	"#"	1.2+

GOTO precise AZM-ALT	"b12AB0500,40000500"	"#"	2.2+

Sync

To Sync to an object via serial commands, the user should center a known object in an eyepiece. Then the Sync serial command should be sent, using the celestial coordinates (RA and DEC) for that object. This causes future GOTO or Get Position commands to use coordinates relative to the Sync'd position, improving pointing accuracy to nearby objects. (we probably don't need to mention "from the planetarium package" since it also improves pointing accuracy if they GoTo objects via the hand control.) The format for the RA/DEC positions in the Sync command is identical to the GOTO RA/Dec command.

Command Function	PC Command	Hand Control Response	Applies to Versions
Sync RA/DEC	"S34AB,12CE"	"#"	4.10+
Sync precise RA/DEC	"s34AB0500,12CE0500"	"#"	4.10+

Tracking Commands

The following commands retrieve or set the tracking mode.

Depending on the mount type, following tracking modes are available:
0 = Off
1 = Alt/Az
2 = EQ North
3 = EQ South

Note: On the CGE and Advanced GT hand control versions 3.01 through 3.04 the value for EQ North is 1 and EQ South is 2. This has been corrected to match the other models in current hand control versions.

Command Function	PC Command	Hand Control Response	Applies to Versions
Get Tracking Mode	"t"	chr(mode) & "#"	2.3+
Set Tracking Mode	"T" & chr(mode)	"#"	1.6+

Slewing Commands

The following commands allow you to slew (move) the telescope at fixed or variable rates.

For **variable rates**, multiply the desired rate by 4 and then separate it into a high and low byte. For example if the desired tracking rate is 150 arcseconds/second, then:
trackRateHigh = (150 * 4) \ 256 = 2, and
trackRateLow = (150 * 4) mod 256 = 88

For **fixed rates**, simply use a value from 1-9 (or 0 to stop) to mimic the equivalent hand control rates.

Note: in most configurations, issuing the slew commands will override (or conflict with) the tracking mode of the mount. Hence it is always best to disable tracking first using the **Tracking Commands**, issue the slew command, then re-enable tracking. The main exception to this is when tracking equatorially - the **fixed rate** slews at 1 or 2 will not override tracking. This can be useful to simulate autoguiding.

Note: on GT models, the fixed rate slews at rate 9 move at 3 degrees per second instead of the maximum rate.

Command Function	PC Command	Hand Control Response	Applies to Versions
Variable rate Azm (or RA) slew in positive direction	"P" & chr(3) & chr(16) & chr(6) & chr(trackRateHigh) & chr(trackRateLow) & chr(0) & chr(0)	"#"	1.6+
Variable rate Azm (or RA) slew in negative direction	"P" & chr(3) & chr(16) & chr(7) & chr(trackRateHigh) & chr(trackRateLow) & chr(0) & chr(0)	"#"	1.6+
Variable rate Alt (or Dec) slew in positive direction	"P" & chr(3) & chr(17) & chr(6) & chr(trackRateHigh) & chr(trackRateLow) & chr(0) & chr(0)	"#"	1.6+
Variable rate Alt (or Dec) slew in negative direction	"P" & chr(3) & chr(17) & chr(7) & chr(trackRateHigh) & chr(trackRateLow) & chr(0) & chr(0)	"#"	1.6+
Fixed rate Azm (or RA) slew in positive direction	"P" & chr(2) & chr(16) & chr(36) & chr(rate) & chr(0) & chr(0) & chr(0)	"#"	1.6+
Fixed rate Azm (or RA) slew in negative direction	"P" & chr(2) & chr(16) & chr(37) & chr(rate) & chr(0) & chr(0) & chr(0)	"#"	1.6+
Fixed rate Alt (or DEC)	"P" &	"#"	1.6+

slew in positive direction	chr(2) & chr(17) & chr(36) & chr(rate) & chr(0) & chr(0) & chr(0)		
Fixed rate ALT (or DEC) slew in negative direction	"P" & chr(2) & chr(17) & chr(37) & chr(rate) & chr(0) & chr(0) & chr(0)	"#"	1.6+

Time/Location Commands (Hand Control)

The following commands set the time and location in the hand control.

The format of the location commands is: ABCDEFGH, where:
A is the number of degrees of latitude.
B is the number of minutes of latitude.
C is the number of seconds of latitude.
D is 0 for north and 1 for south.
E is the number of degrees of longitude.
F is the number of minutes of longitude.
G is the number of seconds of longitude.
H is 0 for east and 1 for west.

For example, to set the location to 118°20'17" W, 33°50'41" N, you would send (note that latitude is before longitude):
"W" & chr(33) & chr(50) & chr(41) & chr(0) & chr(118) & chr(20) & chr(17) & chr(1)

The format of the time commands is: QRSTUVWX, where:
Q is the hour (24 hour clock).
R is the minutes.
S is the seconds.
T is the month.
U is the day.
V is the year (century assumed as 20).
W is the offset from GMT for the time zone. **Note**: if zone is negative, use 256-zone.
X is 1 to enable Daylight Savings and 0 for Standard Time.

For example, to set the time to 3:26:00PM on April 6, 2005 in the Eastern time zone (-5 UTC: 256-5 = 251) you would send:
"H" & chr(15) & chr(26) & chr(0) & chr(4) & chr(6) & chr(5) & chr(251) & chr(1)

Note: All values are sent in binary format, not ASCII.

Note: The Get commands do **not** retrieve the time and location from the GPS unit (if one is present). The time and location are retrieved from the hand control. You must first enter the View Time/Site menu to update the hand control time if you want the time from the GPS or, use the GPS Commands in the next section.

Command Function	PC Command	Hand Control	Applies to Versions

		Response	
Get Location	"w"	chr(A) & chr(B) & chr(C) & chr(D) & chr(E) & chr(F) & chr(G) & chr(H) & "#"	2.3+
Set Location	"W" & chr(A) & chr(B) & chr(C) & chr(D) & chr(E) & chr(F) & chr(G) & chr(H)	"#"	2.3+
Get Time	"h"	chr(Q) & chr(R) & chr(S) & chr(T) & chr(U) & chr(V) & chr(W) & chr(X) & "#"	2.3+
Set Time	"H" & chr(Q) & chr(R) & chr(S) & chr(T) & chr(U) & chr(V) & chr(W) & chr(X)	"#"	2.3+

GPS Commands

The following table shows various commands that can be sent to a GPS unit. Note: all units of time are in UT.

Command Function	PC Command	Hand Control Response	Applies to Versions
Is GPS Linked? X > 0 if linked, 0 if not linked	"P" & chr(1) & chr(176) & chr(55) & chr(0) & chr(0) & chr(0) & chr(1)	chr(x) & "#"	1.6+
Get Latitude ((x*65536)+(y*256)+z)/(2	"P" & chr(1) & chr(176) &	chr(x) & chr(y) & chr(z) &	1.6+

^24) is a fraction of a rotation. To convert to degrees, multiply by 360.	chr(1) & chr(0) & chr(0) & chr(0) & chr(3)	"#"	
Get Longitude ((x*65536)+(y*256)+z)/(2^24) is a fraction of a rotation. To convert to degrees, multiply by 360.	"P" & chr(1) & chr(176) & chr(2) & chr(0) & chr(0) & chr(0) & chr(3)	chr(x) & chr(y) & chr(z) & "#"	1.6+
Get Date x is month (1-12) y is day (1-31)	"P" & chr(1) & chr(176) & chr(3) & chr(0) & chr(0) & chr(0) & chr(2)	chr(x) & chr(y) & "#"	1.6+
Get Year (x * 256) + y = year	"P" & chr(1) & chr(176) & chr(4) & chr(0) & chr(0) & chr(0) & chr(2)	chr(x) & chr(y) & "#"	1.6+
Get Time x is the hours y is the minutes z is the seconds	"P" & chr(1) & chr(176) & chr(51) & chr(0) & chr(0) & chr(0) & chr(3)	chr(x) & chr(y) & chr(z) & "#"	1.6+

RTC Commands

The following table shows various RTC commands on the CGE mount.

Command Function	PC Command	Hand Control Response	Applies to Versions
Get Date x is month (1-12) y is day (1-31)	"P" & chr(1) & chr(178) & chr(3) & chr(0) & chr(0) & chr(0) &	chr(x) & chr(y) & "#"	1.6+

		chr(2)		
Get Year (x * 256) + y = year	"P" & chr(1) & chr(178) & chr(4) & chr(0) & chr(0) & chr(0) & chr(2)	chr(x) & chr(y) & "#"	1.6+
Get Time x is the hours y is the minutes z is the seconds	"P" & chr(1) & chr(178) & chr(51) & chr(0) & chr(0) & chr(0) & chr(3)	chr(x) & chr(y) & chr(z) & "#"	1.6+
Set Date x is month (1-12) y is day (1-31)	"P" & chr(3) & chr(178) & chr(131) & chr(x) & chr(y) & chr(0) & chr(0)	"#"	3.01+
Set Year (x * 256) + y = year	"P" & chr(3) & chr(178) & chr(132) & chr(x) & chr(y) & chr(0) & chr(0)	"#"	3.01+
Set Time x is the hours y is the minutes z is the seconds	"P" & chr(4) & chr(178) & chr(179) & chr(x) & chr(y) & chr(z) & chr(0)	"#"	3.01+

Miscellaneous Commands

Command Function	PC Command	Hand Control Response	Applies to Versions
Get Version	"V"	chr(major) & chr(minor) & "#"	1.2+

Get Device Version Devices include: 16 = AZM/RA Motor 17 = ALT/DEC Motor 176 = GPS Unit 178 = RTC (CGE only)	"P" & chr(1) & chr(dev) & chr(254) & chr(0) & chr(0) & chr(0) & chr(2)	chr(major) & chr(minor) & "#"	1.6+
Get Model 1 = GPS Series 3 = i-Series 4 = i-Series SE 5 = CGE 6 = Advanced GT 7 = SLT 9 = CPC 10 = GT 11 = 4/5 SE 12 = 6/8 SE	"m"	chr(model) & "#"	2.2+
Echo - useful to check communication	"K" & chr(x)	chr(x) & "#"	1.2+
Is Alignment Complete? - align=1 if aligned and 0 if not	"J"	chr(align) & #	1.2+
Is GOTO in Progress? - Response is **ASCII** "0" or "1"	"L"	prog & "#"	1.2+
Cancel GOTO	"M"	"#"	1.2+

Developer Notes

Timeouts

If the hand control is sent a command that requires it to communicate with another device, then the hand control will make multiple attempts to get the message through in the event of communications problems. Examples include "Get Position" commands, "GOTO in Progress" commands, etc.

Software drivers should be prepared to wait up to 3.5s (worst case scenario) for a hand control response. If serial commands are "blindly" sent without waiting for a response, then some commands may be dropped or the software driver could see responses that are for earlier commands.

Pass-through Commands with No Response

Commands that start with 'P' are special pass-through commands that communicate with a specific telescope device. For instance, the Slew commands talk directly to the motor control. If a 'P' command is sent but no response is returned (because the device is not there or the command is unknown or there was a communication problem) then one extra data byte is returned before the '#' terminating character and any returned data is garbage. This is done to give software drivers a flag that something went wrong so appropriate action can be taken. It is particularly useful if you want to check for the existence of a device: for instance, check the time from the GPS unit, and look for an error response. Software drivers should check for the '#' termination character and if it is a different character then the next character (hopefully '#') should be consumed and any command-specific handling should be done.

APPENDIX B - RS-232 CONNECTION

The SynScan™ telescopes are designed to receive control commands sent from a computer via the RS-232 port and RS-232 cable. Once connected, the SynScan™ can be controlled by most popular planetarium software program. The SynScan™ will communicate with the personal computer at 9600 bits/sec, no parity and stop bit. All angles are communicated with 16 bit angle and communicated using ASCII hexadecimal.

Description	PC Command ASCII	Hand Control Response	Notes
Echo	Kx	X#	Useful to check communication
Goto Azm-Alt	B12AB, 4000	#	10 characters sent. B=Command, 12AB=Azm, comma, 4000=Alt. If command conflicts with slew limits, there will be no action.
Goto Ra-Dec	R34B, 12CE	#	Scope must be aligned. If command conflicts with slew limits, there will be no action.
Get Azm-Alt	Z	12AB, 4000#	10 characters returned, 12AB=Azm, comma, 4000=Alt, #
Get RA-Dec	E	34AB, 12CE#	Scope must be aligned.
Cancel Goto	M	#	
Is Goto in Progress	L	0# or 1#	0=No, 1=Yes: "0" is ASCII character zero
Is Alignment Complete	J	0# or 1#	0=No, 1=Yes
HC version	V	22	Two bytes representing V2.2
Stop/Start Tracking	Tx x= 0 (Tracking off) x= 1 (Alt-Az on) x= 2 (EQ-N) x= 3 (EQ-S)	#	Alt-Az tracking requires alignment
32-bit goto RA-Dec	r34AB0500,12CE0500	#	
32-bit get RA-Dec	e	34AB0500, 12CE0500#	The last two characters will always be zero.
32-bit goto Azm-Alt	b34AB0500,12CE0500	#	
32-bit get Azm-Alt	z	34AB0500, 12CE0500#	The last two characters will always be zero.

Physical Connection Diagram

The Back of the DB9 Pinout
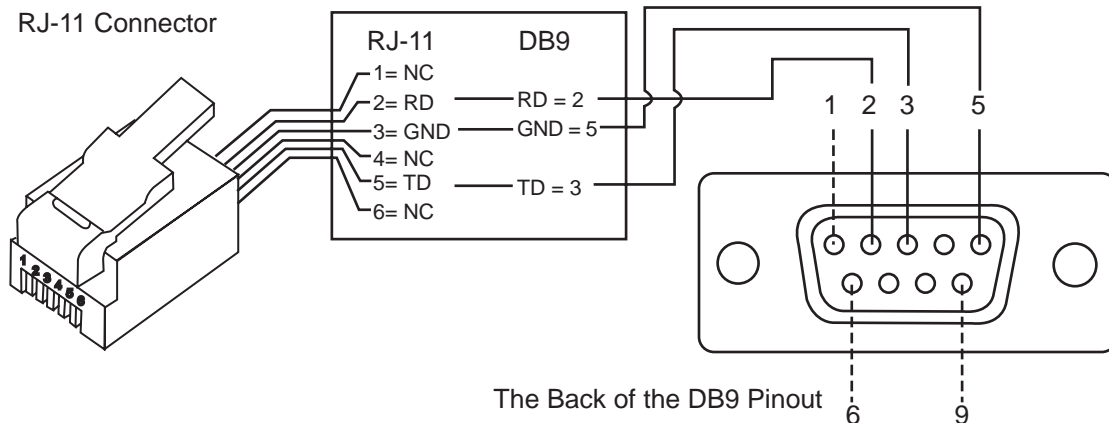
Additional RS232 Commands

Sending a track rate through RS232 to the hand control

1. Multiply the desired tracking rate (arc seconds /second) by 4. For example: if the desired track rate is 120 arc seconds/second (proximately 8 times of sidereal rate), then the TRACKRATE = 480.
2. Separate TRACKRATE into two bytes, such that (TRACKRATE =
3. TrackRateHighByte*256 + TrackRateLowByte). For example TRACKRATE = 480, then TrackRateHighByte = 1, TrackRateLowByte = 224.
   To send a tracking rate, send the following 8 bytes:

   a. Positive Azm tracking: 80, 3, 16, 6, TrackRateHighByte, TrackRateLowByte, 0, 0
   b. Negative Azm tracking: 80, 3, 16, 7, TrackRateHighByte, TrackRateLowByte, 0, 0
   c. Positive Alt tracking: 80, 3, 17, 6, TrackRateHighByte, TrackRateLowByte, 0, 0
   d. Negative Alt tracking: 80, 3, 17, 7, TrackRateHighByte, TrackRateLowByte, 0, 0

4. The number 35 is returned from the hand control.

Sending a slow-Goto command through RS232 to the hand control

1. Convert the angle position to a 24bit number. Example: if the desired position is 220?, then POSITION_24BIT = (220/360)*224 = 10,252,743
2. Separate POSITION_24BIT into three bytes such that (POSITION_24BIT = PosHighByte * 65536 + PosMedByte * 256 + PosLowByte). Example: PosHighByte = 156, PosMedByte = 113, PosLowByte = 199
3. Send the following 8 bytes:
   a. Azm Slow Goto: 80, 4, 16, 23, PosHighByte, PosMedByte, PosLowByte, 0
   b. Alt Slow Goto: 80, 4, 17, 23, PosHighByte, PosMedByte, PosLowByte, 0
4. The number 35 is returned from the hand control.

Reseting the position of Az or Alt

1. Convert the angle position to a 24bit number, same as Slow-Goto example.\
2. Send the following 8 bytes:
   a. Azm Set Position: 80, 4, 16, 4, PosHighByte, PosMedByte, PosLowByte, 0
   b. Alt Set Position: 80, 4, 17, 4, PosHighByte, PosMedByte, PosLowByte, 0
3. The number 35 is returned from the hand control.

Linking with A Computer

Another feature of SynScan™ is the ability to connect to a computer via a serial communication cable. Many commercially available planetarium softwares can be used to control SynScan™. SynScan™ Version 3.00 and later is compatible with Celestron 5i/8i and NexStar GPS command protocol.

1. Make sure that the telescope has been aligned.
2. Connect the RS-232 cable to the RJ-11 connector on the hand control and to the COM-port of your computer (Fig.p)

Fig.p — Hand Control

RJ- 11

Do not use RS-232 cable other than the one provided to connect between the hand control and your computer. It may damage your computer or the hand control. If you are making your own cable based on the information provided in Appendix B, make sure that only pin 2, 3 and 5 connect to the com connector on your computer.

RJ-11 Pin-outs

1= EXPD+
2= TD
3= GND
4= EXPD-
5= RD
6 5 4 3 2 1   6= +12V

3. In the planetarium software of your choice, choose "Celestron NexStar 5i" or "Celestron 8/9/11 GPS" in the driver setup menu and follow the instructions provided by your program to establish the connection to the telescope. The SynScan™ should be under the full control of your computer once the connection is successfully established.

4. When you are finished, follow the instructions provided by your software to close the connection to the telescope.
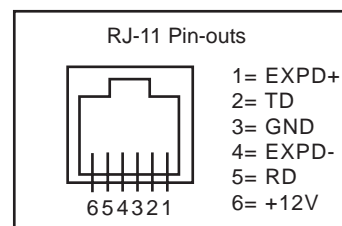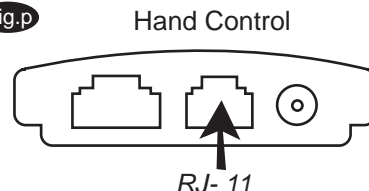
See Appendix B for more information on RS-232 connection.

Auto Guiding

Fig.q

The SynScan™ has a designated autoguider interface on the mount for use with an auto guider (see Fig.a, a-1). The pin-outs on the 6 pin modular connector is ST-4 compatible and can be used for most autoguiders on the market. Refer to Fig.q when connecting the autoguider cable to the SynScan™ and calibrating the autoguider. Relay box can be added for extra protection. Note that the four inputs are active-low, with internal pull-ups. Guiding speed can be adjusted using the Auto Guide Speed function in the Setup Menu.

1= NC
2= Ground
3= +RA (left)
4= +DEC (up)
5= -DEC (down)
6 5 4 3 2 1   6= -RA (right)
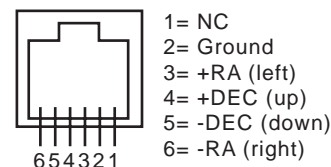
Periodic Error Correction

Periodic Errors are found in almost all worm gears due to slight eccentricities and misalignments. The PEC (Periodic Error Correction) function provides a manual correcting method to reduce the amplitude of the worm errors. By recording a full cycle of guiding actions versus motor shaft angle, SynScan™ can work to compensate for the drifting in the RA sidereal tracking caused by the periodic errors. Below describes a step-by-step procedure on how to perform the PEC:

PEC Training function is recommended for advanced users interested in long-exposure astrophotograhy only. Careful guiding is required. Regular sidereal tracking is adequate for all casual visual use of the SynScan™ and PEC Training is not required.

Required accessory: Illuminated reticle eyepiece with double crossline pattern capable of producing at least 300X magnification in combination with your telescope. The true field of view should not exceed 10 arc min. See "Choosing the appropriate eyepiece" in the HEQ5/EQ6 manual for more information on calculating the field of view.