SOFTWARE AND HARDWARE AUTOGUIDING ISSUES WITH THE LX200GPS

If you've had problems getting K3CCDTools, GuideDog or other autoguiding software to successfully control your LX200GPS through the RS-232 port, it may not be your mistake or faulty software that is causing the problem. This paper explores a number of issues related to autoguiding through the RS-232 port, and suggests solutions.

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Introduction

Many LX200GPS owners have been frustrated in their attempts to perform remote guiding of their telescopes using serial commands directed to the mount through the RS-232 port. This paper examines some of the issues potentially causing this frustration, and presents some solutions to these problems.

Information presented here has been developed by testing my 10" LX200GPS with several of the most widely-used freeware packages, with serial port monitoring programs, and with some diagnostic programs I wrote with Visual Basic. I also learned a great deal from information posted on the ASCOM-Talk, Meade LX200GPS, Meade LX200, Meade Uncensored and QCUIAG Yahoo discussion groups, as well as www.MeadeLX200GPS.com, the Meade Advanced Products Users' Group (www.mapug.com), the Meade Instruments web page, a number of other LX200GPS users, and authors of some popular autoguiding software.

This paper should be considered a work in progress. Meade continues to release new versions of firmware for the LX200GPS, and software creators continue to develop new drivers and applications - all of which may affect the information presented here.

This paper does not address guiding through the LX200GPS autoguider port. Guiding in this manner is an entirely different matter, generally using hardware specifically designed for the task (*e.g.*, purpose-built CCD autoguiders). The autoguider port of LX200 and other telescopes and mounts expects, rather than serial communications, contact closures to command guiding movements. While not exactly "plug and play," there are a number of readily available (although expensive) and relatively problem-free solutions for autoguiding through the autoguider port. Many LX200 users have reported good success with these solutions.

External Control of the LX200GPS via the RS-232 Connection

Meade computer-controlled telescopes (such as the LX200, LX90 and ETX models) can be commanded remotely by serial commands delivered to the telescope through the RS-232 port. (See Figure 1.) A connection between the LX200GPS and the serial port of a personal computer (or other device such as a PDA) can be made using Meade's #507 connection cable. The connection cable, which has a RJ-11 (telephone) connector at one end and a female DB-9 connector at the other, can be easily put together in a few minutes using the instructions posted at http://www.meadelx200gps.com/images/other/LX200_cable_diagram.gif and elsewhere.

Meade Telescope Serial Command Protocol (MTSCP) is a series of commands, sent to the telescope from a personal computer or other device, that duplicate many of the capabilities of the Autostar II handbox. Meade has published a listing of the serial command protocol at http://www.meade.com/support/CommandSet.html. These commands can be generated by software run on the personal computer or other device. Not all of the commands available on the Autostar II handbox are included in the MTSCP; however, some commands are available through the MTSCP that are not available via the handbox. Most commands simply cause the LX200GPS to

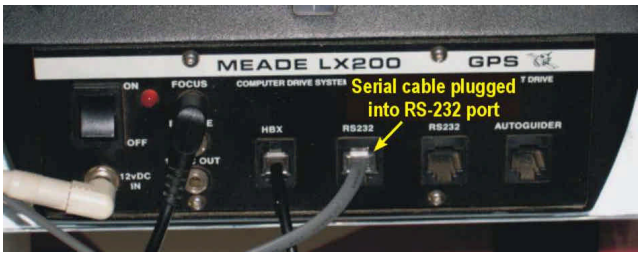

Figure 1. Use of the RS-232 port

do something, but some return information (*e.g.*, current pointing position or OTA temperature) to the external device.

Commercial software packages such as Meade's Autostar Suite, as well as shareware and freeware applications (*e.g.*, Cartes du Ciel, Iris and GuideDog) can generate commands for the LX200GPS, sent over the serial connection. For instance, in Cartes du Ciel, a user can select an object or point in the sky with the cursor, and command the telescope to slew to that object.

Unfortunately, not all of the MTSCP commands are implemented correctly in all versions of the LX200GPS firmware. For instance, the command :SBn# (where n is a single ASCII digit between 1 and 9) is supposed to set the baud rate of the connection between the LX200GPS and the external device. However, I have found that issuing this command to a scope running firmware 1.6b destroys the connection with the telescope (that had been working perfectly). Once this command is issued, communication with the telescope cannot be reestablished until the telescope is rebooted by powering it off and on again.

The MTSCP commands that are needed for guiding applications are those that set the tracking rate and slewing rate, and those that move or stop the telescope. These are presented in Table 1.

Problems with MTSCP

As indicated by the fourteen-page listing of the MTSCP offered by Meade, the command set is robust, offering the opportunity to perform most of the handbox commands remotely. If all commands worked as they are described by Meade, the MTSCP would be adequate for developing guiding and autoguiding software. Unfortunately, such has not been the case. Web Dove, Dan Johnson, I and others have tested many of the commands with firmware versions 1.6b, 2.0i and 3.0d and found that a number of the commands either don't work as they are described in the MTSCP, cause complete loss of communication with the telescope until it is rebooted (power down and power up again), or don't work at all. Following is a description of the problems that may affect guiding operations (slewing and guiding commands).

East and West Movement Commands Reversed

In at least one firmware version (1.6b, I think), the commands to move east or move west at the current slew rate (:Me# or :Mw#) are reversed. Commanding an eastward slew produces a westward slew instead.

Increment/decrement Tracking Rate Doesn't Work

As described in the MTSCP, the commands :T+# and :T-# are supposed increase or decrease the tracking rate of the telescope. Based on a model where a 60.0 Hz synchronous motor causes perfect sidereal tracking, these commands are intended to increase or decrease the tracking rate by 0.1 Hz. In my testing of firmware 2.0i and 3.0d, these commands had no effect. In fact, none of the commands below the horizontal line in Table 1 have any discernable effect on a LX200GPS running either firmware 2.0i or 3.0d.

Tracking Pauses After Slew Command

In versions 1.6b and 2.0i (and probably earlier versions), there is a slight pause of the sidereal tracking (the RA drive) immediately following execution of the :Me# or :Mw# command.[1] The pause is short, just a few hundred milliseconds. Nonetheless, it causes an apparent eastward drift of the target of several arcseconds. (This effect has been described as "ruberbanding" because a guide star behaves as if it is attached to a rubber band stretched from the east side of the FOV.) This is not a concern for visual use, but is a big

[1]Because each :Md# command is followed by a :Qd# command at the end of the intended slew interval, it is likely that the pause actually follows the :Qd# command.

Table 1. MTSCP Commands Potentially Used for Remote Guiding of LX200 Telescopes

Commands that work correctly in firmware 2.0i and 3.0d

:Mn#	Move telescope north at current slew rate*
:Ms#	Move telescope south at current slew rate*
:Me#	Move telescope east at current slew rate*
:Mw#	Move telescope west at current slew rate*
:Q#	Halt all current slewing*
:Qn#	Halt current northward slewing*
:Qs#	Halt current southward slewing*
:Qe#	Halt current eastward slewing*
:Qw#	Halt current westward slewing*
:RC#	Set Slew rate to Centering rate (2nd slowest)
:RG#	Set Slew rate to Guiding Rate (slowest)
:RM#	Set Slew rate to Find Rate (2nd Fastest)
:RS#	Set Slew rate to max (fastest)
: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)
:STtt.t#	Sets the current tracking rate to tt.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.

*Although these commands work correctly, guiding motions requested by these commands (*e.g.*, :Mw# :Qw#) are followed by a pause in tracking with firmware version 2.0i. The pause does not occur in firmware 3.0d.

Commands that do not work in firmware 2.0i and 3.0d (and probably other versions)

:T+#	Increment Manual rate by 0.1 Hz
:T-#	Decrement Manual rate by 0.1 Hz
:TM#	Select custom tracking rate
:TQ#	Select default tracking rate
:TDdd.ddd#	Set manual tracking rate to ddd.dd (units are not specified)

problem for imaging. Not only does the pause move the target off center (blurring the image), it makes it extremely difficult to accurately return the target to the desired position. Returning the target to center with MTSCP commands can only be accomplished by purposely overshooting the eastward slew to account for the following tracking pause. Obviously, this makes guiding with MTSCP commands during imaging infeasible.

How Do Problems with Firmware Implementation of MTSCP Affect Autoguiding?

In order to understand how these problems affect attempts at software-driven autoguiding using MTSCP commands sent via the LX200GPS RS-232 port, it is necessary to consider how autoguiding is performed. Briefly, autoguiding software performs the following tasks:

1. Locate the centroid of a guide star in an image frame (from the guide camera)
2. Calculate how far the centroid is (in the x- and

y-directions[2]) from desired position
3. Calculate the duration of slews (x- and y-directions) required at the current slew (guiding) rate to return the star to the desired position.
4. Issue command(s) to the telescope to slew in the direction(s) required
5. Stop the slew(s) after the calculated duration(s).
6. Repeat the process.

The duration of the slew may be altered (usually by an "aggressiveness" setting) to over- or undershoot the required slew in steps 4 and 5. Generally, the position errors induced by improper tracking (periodic error, inaccurate sidereal rate, or poor polar alignment) are much smaller than the sidereal rate. In other words, the errors that must be corrected are much less than 15 arcseconds per second. At a guiding frequency of 1 Hz, the errors are typically a few arcseconds or so (depending on seeing).

Typically in the past, MTSCP autoguiding for LX200 telescopes has attempted to use the :Md# and :Qd# commands (where d is the direction of slew). For a LX200GPS using a guiding rate setting of 66% (about 10 arcseconds per second) and a guiding frequency of 1 Hz. This means that the required slewing movements (at the guide rate) are typically 300 milliseconds or less. The software would calculate the duration of the slews (both x- and y- directions), issue :Ms# and :Me# commands (for a guide star that had moved southeast of the desired position), then issue :Qs# and :Qe# commands at the proper times.

In firmware version 2.0i and below, the :Qe# command is followed by a pause of the sidereal tracking, variously reported as 200 to 500 milliseconds. Imagine the effect this has on the process. The star has just been moved back on center (assuming an aggressiveness setting of 100%), but it is now allowed to drift eastward by three to eight arcseconds, *some of which may occur while the guide camera is acquiring the image that will be used to calculate the next corrections.* This drift has not been anticipated by the guiding software. When the next frame from the guide camera is analyzed, a large position error will be calculated and appropriate commands issued to return the star to the desired position. If the aggressiveness is set at 100% or higher, and if all of the tracking pause occurred before the guide camera image for the next iteration has been captured, the star will be moved back to the desired position, only to be once again immediately "knocked off position." The result will be oscillation of the guide star back and forth with each guiding iteration. However, if the aggressiveness is set to less than 100%, or if tracking pause has not been completed before the next frame is acquired by the guide camera, then the guiding software will not be able to fully move the star back to center. With each iteration, the star will move farther east and will quickly leave the frame.

This latter scenario is exactly what users of K3CCDTools2 v. 2.1.3 and below have experienced, as well as GuideDog users running versions 1.0.4 and below. The software was working correctly, but the telescope was not doing as commanded. (Ironically, this problem does not seem to have affected LX200 classic users.) Neither Peter Katreniak (author of K3CCDTools) nor Steve Barkes (author of GuideDog) have LX200GPS telescopes (although Steve has a LX200 classic), so they are both dependent on user reports to assess the performance of their software on our telescopes. Both Steve and Peter are aware of the LX200GPS problems, and have taken measures to address them (as described below).

But the plot thickens.....

Undocumented Command

In an attempt to figure out what the heck is going on with LX200GPS autoguiding, Web Dove used PortMon to log the commands that were being issued by autoguiding software through the serial port of his computer to his LX200GPS. He did this using Meade's Autostar Suite and GuideDog version 1.04. In doing so, he made an important discovery. GuideDog was using :Md# and :Qd# commands as described above to guide the scope. However, he discovered that Meade's Autostar Suite uses an undocumented command.

[2] Some autoguidng software defines "x" and "y" axes. Normally, the x-axis is aligned with the RA axis, and the y-axis is aligned with the declination axis.

Apparently, Meade has added the command :Mg*dnnnn*# to the MTSCP and didn't tell anyone about it. This command instructs the telescope to move in direction *d* at the current guiding rate for *nnnn* milliseconds. It is the perfect command for autoguiding because it does not require a follow-up command to halt the movement, and therefore does not rely on the timing of commands issued over the RS-232 interface.

This second point is important. While personal computers have highly accurate timing, this does not mean that they have the ability to issue signals over the COM ports at precise times. This is because the COM port traffic timing is affected by system interrupts. For one reason or another, the system resources needed to handle COM port traffic may not be available at the precise time that the software wishes to send it. When this occurs, the signal may be delayed until the resources are available. As a consequence, the interval between a :Md# and a :Qd# command may be shorter than expected (if the :Md# command was delayed) or longer (if the :Qd# command was delayed). The :Mgdnnnn# command solves this problem by providing both the slew direction and duration information in a single command. It is left to the timing of the LX200GPS processor to accurately implement the command. Presumably, this is a much more accurate method.

Steve Barkes has already implemented :Mgdnnnn# into GuideDog version 1.0.6. Peter Katreniak and Axel Canicio have released beta testing versions of K3CCDTools2 and Astrosnap Pro (respectively) using the :Mgdnnnn# command.

Two Problems Solved by Meade, But....

In early October 2004, Meade released firmware version 3.0d for the LX200GPS. In this version, Meade has *finally* eliminated the 200-500 millisecond tracking pause following slew commands. This important correction means that guiding using the :Md# and :Qd# commands can be expected to work, at least to some degree.

In firmware version 3.0d, Meade also solved another important problem related to guiding. Firmware version 2.0i, unfortunately, did not apply the anti-backlash feature during guiding. This, in conjunction with the retrograde motion exhibited by most LX200 telescopes, made declination guiding very difficult.

As usual, though, when Meade giveth with one hand, they take away with the other. In version 3.0i, it is not possible to reload the user's Periodic Error Correction tables to the LX200GPS using the Autostar Updater utility.[3] This means that, if a user clears or overwrites a good PEC curve, there is no way to restore the previous data. Hopefully, the next firmware version will correct this, without removing another important feature.

ASCOM

The Astronomy Common Objects Model is a set of standards for scriptable/programmable low-level control of astronomical instruments and related devices. In practical terms, ASCOM acts like a universal driver set for astronomy software to use to communicate with ASCOM-compliant telescopes, observatories, *etc.* In order to achieve this, ASCOM must include telescope-specific drivers. The ASCOM platform includes several drivers that are potentially relevant to LX200GPS telescopes. The driver most closely matching the LX200GPS is Meade.Telescope, which is selected in the ASCOM dialog as "Meade LX200 and Autostar."

Just like any other software, however, the ASCOM platform must use the MTSCP to command the LX200GPS. The version of the ASCOM platform that is current as of this writing (version 3.03) uses the :Md# and :Qd# commands for guiding movements; it does not use :Mgdnnnn:. In testing I have done with the ASCOM platform, I found that many of the commands included in the ASCOM specification do not work properly with the LX200GPS. ASCOM is still in its infancy. There is an ongoing attempt to develop drivers for many telescope and mount types simultaneously, so errors and omissions are to be expected. Fortunately, the ASCOM platform includes a "blind command" function, which passes a command string literally and without interpretation

[3]Although PEC tables may not be uploaded using the Autostar Updater, Dick Seymour reports that Andrew Johansen's PEC Editor has already overcome that obstacle. See the references section for a link to download Andrew's program..

to the telescope. This allows programmers who find errors in the ASCOM driver for a particular telescope to send the proper commands through ASCOM.

Popular software such as Cartes du Ciel and GuideDog use the ASCOM platform.[4] K3CCDTools2 does not (yet) use ASCOM, but instead issues MTSCP commands directly to the LX200-compatible telescopes.

One of the great benefits of the ASCOM platform is that once a problem with a driver for a given telescope or mount is solved in ASCOM, that fix will be applied to all software installed on a user's computer that uses ASCOM to command the user's telescope.

Declination Guiding - A Bigger Challenge

As LX200GPS users are all too aware, the LX200GPS exhibits significant backlash and retrograde motion in the declination drive. While this is a mechanical problem that cannot be resolved with software or firmware, the significance of the problem can be reduced. Meade has provided a method to quickly take up the backlash when reversing declination motion direction by making appropriate settings through the telescope's firmware. Although the backlash can be somewhat annoying for visual use, the anti-backlash feature makes it tolerable. As mentioned above, firmware versions 2.0i did not apply the anti-backlash feature during guiding in polar mode. This, in conjunction with the retrograde motion exhibited by most LX200 telescopes, made declination guiding very difficult.

In firmware version 3.0d, the anti-backlash feature is active during guiding. This means that, if guide star drift correction requires a reversal of declination slew direction, the backlash will be taken up by the drive before the correcting slew is performed (assuming declination backlash correction is turned on). Unfortunately, the retrograde motion is still present, so the star goes through some wild gyrations before settling in the new position - but at least the gyrations occur quickly and the star can be successfully directed back to the proper position.

The effect of declination backlash on autoguidng can be minimized. Unlike RA tracking, the declination axis is not moving while tracking a target. Movements in declination should only be required to account for inaccurate polar alignment. The target may be deflected northward or southward due to seeing, but attempts to chase the seeing are futile. Declination corrections for imperfect polar alignment should only be needed in one direction. Therefore, the following suggestions should help minimize or eliminate declination direction changes:

1) After any motions have been made in declination (*e.g.* to center a new target), guide the LX200GPS in declination (either autoguiding or manually) for several minutes before starting the next exposure. This should be sufficient time for the direction of declination drift to be established and for the declination drive to take up backlash from the last direction change.[5]

2) Set the minimum adjustment large enough that the autoguider does not try to chase the seeing. The software should be issuing all northward or all southward declination guiding movements. (You can check this using PortMon software. Or, if you are using GuideDog, carefully watch the direction buttons at the lower left of the program window. The buttons will blink when a corresponding motion is commanded.) It is important to avoid overshooting the desired position, thus requiring a direction reversal.

3) If your autoguider software allows it, set the declination to correct in one direction only, or set the aggressiveness much lower for the direction that is not needed to correct for imprecise polar

[4] In GuideDog, Steve Barkes has made extensive use of the ASCOM blind commands to make use of Meade's undocumented :Mgdnnnn# command for more accurate guiding.of the LX200GPS.

[5] Some users have suggested purposely misaligning the telescope by a *small* amount in order to ensure a small declination drift and avoid declination direction reversals. It is important that the misalignment be very small, in order to avoid field rotation.

alignment.

Conclusions

Six months ago, successful autoguiding of the LX200GPS via the RS-232 port was essentially impossible, having been thwarted by an uncommanded tracking pause that followed guiding command sequences (*e.g.*, :Me# followed by :Qe#). That problem has been corrected within the last month with the release of LX200GPS firmware 3.0d. As a result, any properly-coded and correctly-used software should be capable of autoguiding LX200GPS telescopes through the RS-232 port *if the telescope is running firmware 3.0d*.

However, the undocumented commands :Mgdnnnn# have been incorporated into the LX200GPS firmware since at least version 2.0i. These commands do not require a subsequent halt command, and are not followed by a pause in tracking. Any properly-coded and correctly-used software that uses the :Mdnnnn# commands should be capable of autoguiding LX200GPS telescopes running either firmware version 2.0i or above.

The :Mgdnnnn# commands have some clear advantages over the documented move/halt command sequences, because they eliminate the possibility of timing errors introduced by serial communication between computer and telescope. Therefore, I recommend using autoguiding software that uses these commands. Steve Barkes' GuideDog version 1.06 has already incorporated these commands, and versions of other popular applications will do so in the upcoming weeks and months.

Successful autoguiding the LX200GPS through the RS-232 port has arrived.

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