

# LACERTA M-GEN

## Stand-Alone AutoGuider

### User's manual for Firmware 01.22

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Last updated: 21 July 2010

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# 1 About the Hardware

## 1.1 Parts of the device

The “LACERTA M-GEN Stand-Alone AutoGuider” (referenced as LMG) consists of the following parts:

- Handcontroller (referenced as HC). It has the whole user interface (buttons, indicator LEDs, LCD) and does the main functions like Autoguiding, Random Displacement, AutoExposure etc.  
The display is a graphic, 128x64 dot negative LCD with backlight. Previous versions have red while the new ones come with amber (orange) color due to the much better contrast.



The connector panel is located at the bottom of the HC box:



These are the following from left to right:

- o Canon EOS compatible shutter output (3.5mm stereo jack conn.)

- o Camera port (RJ-45 type female conn., can be used any low resistance UTP cable too but the supplied cable is preferred. Note: **NEVER** try to use a **UTP cross cable!**)
  - o DC power input (5.5/2.1mm size) (12V nominal, 9-15V), **tip positive** (polarity-protected)
  - o ST-4 compatibles autoguider output (RJ-12 type female conn.)
  - o PC communication port (USB-B mini 5-pin conn.)
- Camera (head). This is a special device, can be used only with the LMG Handcontroller. It's function is imaging and doing several image processing steps.



To attach the Camera to the guider telescope there is a 4-5mm thick T2 inside screw. Any T2? 1.25" adapter can be used for 1.25" (31.7mm) focusers. There is a 1.25" filter thread inside the T2 panel to attach some filter or "dust preventor".

At the back of the Camera there is the same type of connector as on the HC (RJ-45 female).

The sensor is a high sensitivity monochrome CCD from Sony (with ExView HAD technology). Due to its extremely low dark current (dark noise) and the enhanced sensitivity in near infrared it doesn't need cooling and saves energy. These with the low readout noise gives the ability of guiding on very faint stars or using small guidescope. The small pixel size allows using shorter focal length for guiding compared to other systems.

(For more information see the datasheet of the CCD, its part number is: ICX279AL-E. Some info can be found here:

<http://www.sony.net/Products/SC-HP/datasheet/90203/data/a6805282.pdf>)

Note: on the CCD there is the protector foil by default. You must remove it before the first use! Cleaning the CCD's glass is done as for any other optical surfaces. Try **not to scratch** it! Don't let any electrically conducting material or liquid fall into the circuit, on the CCD and its pins. (The foam around the CCD gives some protection.)

- Supplied cables:
  - 1 piece of Camera cable (black), similar to a straight UTP cable. Used to connect the Camera with the Handcontroller. It's length is around 1.8-2m.
  - 1 piece of "ST-4 autoguider" cable (white) to connect the Handcontroller and the mount with ST-4 compatible autoguider input. About 1.5 meters of length.
  - 1 piece of USB-A (PC side) / USB-B mini5 (HC side) cable to the connection with the PC. Used to update Firmwares, download data files or control the HC.
  - (Some release include an EOS shutter cable with 2.5mm and 3.5mm stereo jack ending, 2m length. (Can be used directly for Canon EOS 350D))

## 1.2 Powering the device

In normal use: (during autoguiding)

The device needs a nominal 12V DC power source on the HC's DC input connector, which is tip positive. This is essential for the Camera for imaging. 9-15V is also accepted but don't use higher voltage than 15V! The output power of the DC supply must be minimum 2.4W (12V, max. 200mA), typically 2W is enough.

Be careful choosing the type of the DC power source, it must be well stabilized or constant (ie. a battery)! An unfiltered, only rectified power may not supply the device properly, this could lead to sudden reset/turn-off of the device.

"Logic only" mode: (USB connection: Firmware update etc.)

If the Camera is not connected or will not be used for imaging the USB bus can also supply the device's logic circuit. All those functions are accessible that don't need analog power (imaging). Works for example: Autoexposure program, data file downloading, Firmware updating but autoguiding (star search, LiveView etc.) will not.

When the device gets power input (DC input or USB cable is plugged in) **a short flash of the four LEDs** indicates this. The flash is also present at the Firmware update process when the device is reset before the next update step.

## 1.3 Electrical characteristics

### 1.3.1 Specification of the HC and Camera

(Note.: currently there is no power saving features implemented.)

|                                  | Min. | Typical | Max. | unit | Notes       |
|----------------------------------|------|---------|------|------|-------------|
| DC power supply                  | 9    | 12      | 15   | V    |             |
| Active input current (no light)  |      | 110-116 | 200  | mA   | 1,2,3,4,5   |
| (full light)                     |      | 142     | 200  | mA   | 1,2,3,4,5,6 |
| HC only input current (no light) |      | 27      |      | mA   | 1,2         |
| (full light)                     |      | 56      |      | mA   | 1,2,6       |
| Power-down mode with USB         |      | 9       |      | mA   |             |
| w/o USB                          |      | 6       |      | mA   |             |
| ST-4 out. pull-down current      | 1.1  |         |      | mA   |             |
| Shutter out. pull-down current   | 0.5  |         |      | mA   |             |

- 1 'light' means the LCD backlight
- 2 the device may draw less current due to new MCUs
- 3 'active' meant with active Camera (autoguiding or LiveView)
- 4 the value changes as some parameters do (gain, exp.time)
- 5 there is a 200mA fuse in the HC
- 6 the value is for the red LCD backlight

Note.: values shown gray are only informational and derived from the design.

### 1.3.2 Imaging specification of the Camera

ADU means: Analog to Digital conversion Unit (step)

e<sup>-</sup> means: electron

RMS means: standard deviation (statistical); Root Mean Square

|                                               | Min.        | Typical | Max. | unit                   | Notes |
|-----------------------------------------------|-------------|---------|------|------------------------|-------|
| CCD active pixel area                         | 752 × 582   |         |      | pixel                  |       |
|                                               | 3.65 × 2.7  |         |      | mm                     |       |
| CCD pixel size                                | 4.85 × 4.65 |         |      | μm                     |       |
| Imaging depth                                 | 8           |         |      | bit                    |       |
| Image conversion speed                        | 2M          |         |      | pixel/sec              | max.  |
| Conversion (min. gain (1))<br>(max. gain (9)) |             | 70      |      | e <sup>-</sup> /ADU    | 1     |
|                                               |             | 1.75    |      | e <sup>-</sup> /ADU    | 1     |
| Readout noise at min. gain (1)                |             | 20      | 35   | e <sup>-</sup> (RMS)   | 1     |
| Readout noise at max. gain (9)                | 5.9         | 7.1     | 8.5  | e <sup>-</sup> (RMS)   | 1,2,4 |
| Average dark current                          |             | 3.9     |      | e <sup>-</sup> /px/sec | 1,2   |
| Pixel capacity                                | 16k         |         |      | e <sup>-</sup>         | 1     |
|                                               |             |         |      |                        |       |
| Operating temperature                         | -10         |         | 60   | °C                     | 3     |

- 1 the value is only informative but measured on some instances
- 2 at 25°C
- 3 violating the limits is the responsibility of the User  
The CCD and its environment heats itself a little bit if active (good for anti-dew).  
The power dissipated in the HC is also rather useful than problematic.
- 4 typical value (mean) measured on 22 pieces of 'random' Camera instances.  
The mean of deviation of this value between the instances is only 0.29 e<sup>-</sup>.  
The *limits* were measured in some "extreme" instances.

The gain of the CCD's analog output signal is called 'gain' generally and can be set in the HC as a parameter. The scaling of this is defined so that 2 steps means one magnitude difference in sensitivity. The full scale (from 1 to 9) cover 4 magnitudes. The table below shows the physical imaging parameters for each gain value (approximately):

| gain | conversion<br>(e <sup>-</sup> /ADU) | pixel saturation<br>(e <sup>-</sup> ) |
|------|-------------------------------------|---------------------------------------|
| 1    | 70.0                                | 16700                                 |
| 2    | 44.0                                | 10500                                 |
| 3    | 25.7                                | 6660                                  |
| 4    | 17.5                                | 4200                                  |
| 5    | 11.0                                | 2650                                  |
| 6    | 7.0                                 | 1670                                  |
| 7    | 4.4                                 | 1050                                  |
| 8    | 2.77                                | 666                                   |
| 9    | 1.75                                | 420                                   |

## 1.4 Tuning on and off the device

After the device is first supplied with power source it goes to sleep (power-down) mode, nothing can be seen and there are no output signals. The cables can be safely plugged in or out.

### Turning ON the device:

Press ESC button! The program will start in *application mode* if the HC contains valid Firmware. The version of it is displayed for 2 seconds, then the first screen appears (see later). You can skip 2 sec. waiting with pressing ESC one more.

If the device does not contain valid Firmware (or it was faulty) it starts in *update mode*, which is shown on the LCD. In the center of the display there is a "NO FIRMWARE" text indicating the case.

If ESC is pressed continuously for more than 1 second the device starts in *update mode*. Using this starting procedure is not required because the updater (PC application) will force to restart the device in this mode. If You happen to enter this mode, hold down SET for 1 second and the Firmware will try to start. This works until the device communicates through USB, after this only an USB command can start the application (PC application has a command line option to do this).

From Firmware ver. 1.21 (or later) the device starts on the date and time settings screen and the filesystem's screen after that. This is needed to make You remember to set or check the correct date and time at every startup and select a file to open if You want to store data about the night (guiding, events etc.). If You don't need these functions, two more ESC keypresses after startup leads directly to the main menu.

Turning **OFF** the device:

In *application mode*: Navigate back to the main menu (with pressing ESC some times) and select the **power off** item. It is essential to power off this way because it stops every functional part properly (Camera), closes the open file and stores the parameter settings.

WARNING: simply plugging out the power cable is **not recommended**, mainly if the Camera is actively working! Data loss or corruption in the open file or in the stored parameters may occur.

If the device is in *update mode* and **there is no operation in progress (mainly Firmware update)**, You can power-off the device with detaching the power cable(s). (Be sure there is no operation in progress shown by the PC application.)

**WARNING: never plug out the power/USB cable during Firmware update!** Doing so can damage the boot program and it may be required to reconfigure the device at factory (it's not the part of warranty).

## 2 New features in Fw. 01.22

A short list about the main features compared to the previous one (01.21):

- o The AutoExposure's state and outputs are also stored into the open file. The guiding curve ("drifts") is saved only when the AE is in the exposure state.

It belongs that the PC application version 1.22 generates a HTML format output when downloading a file, which contains for all the exposures separately the guiding curve as well as the spread of the guiding star positions and the approximated tracking error of the mount (derived from the autoguider signals). All the raw data is written into a CSV file for any user processing.

- o The calibration has been moved to a new screen, on which the directions, speeds and the orthogonality is displayed.
- o When starting the autoguiding the latest position is not rounded to pixel center but used the raw position directly for the new guiding center.

### 2.1 Previous version changes

From 01.21:

- o The menu structure has been changed a little bit. Some rarely used screen and parameter is pushed "down the tree" while (for example) the guiding screen is now accessible with only two SET keypresses from the main menu.
- o Complete file(system) menu screens: open, close, delete and create new, a short file list and file details screen. The date and time settings screen is also accessible now from menu.
- o In Autoexposure, selecting Start/Stop, Pause will change the selection to the more understandable item.
- o LCD contrast can be set (and is stored).
- o "AstroTimer mode": the Autoexposure's and Random Displacement's operation mode using an external shutter controller device. (This mode is fully compatible with AstroTimer.) The Autoexposure will have only one time value (period) to set while the external shutter is active and the shutter output will be only active when a Random Displacement is being made (the AE program is in wait state).
- o New RD mode: besides the default "uniform square" there is a new "square snake" pattern.
- o Exclusive autoguiding output signalling mode. ("Non-simultaneous signalling"). Only one axis can have autoguiding signal active at a time, that's why it is called "exclusive mode". Between different axis' signal there is a 62ms dead time. This

may be used with “old, touchy“ mount that don’t tolerate the default parallel signalling.

- o Bugfix: quitting from LiveView screen did not stop the imaging into the screen.
- o Bugfix: in some special cases the “guiding image” was drawn into false position – even if it was inactive.

From 01.20:

- o Stepping back in menu tree will hold the priously selected item. It’s easier to re-enter a screen if You had left it accidentally.
- o The method of calibration is modified: now it’s more immune to temporary star lose, position evaluation bettered and the result’s precision (axis direction) is displayed.
- o Modified RD method: it does not move the guide star to an exact position, instead it moves it only “close to it” to minimize the dead time between the exposures (that was rather long in wind or at bad seeing/parametrization).
- o Real-time clock (0.1s resolution) and date to timestamp the data stored in the open file.
- o Basic filesystem (and selection only at startup). The open file will store the guiding “drifts” and the calculated autoguider output signal lengths. To download the files use the PC application v1.22.
- o Bugifx: some more-byte parameters were not stored correctly at power-off.

From 01.12:

- o Three *profiles* available now to store parameter settings individually. Can be used as “presets” for separate guiding configuration (off-axis, guide scope(s) etc.);
- o AG speed can be set independent for each axis with 0.01 step size (any non-standard correction speed can be set);
- o The “drifts” history diagram is now displayed scaled to the tolerance value;
- o Pause/Continue button added to the AutoExposure screen – during paused state the AE program parameters can be changed;
- o Additional wait time can be set between the guiding exposures letting the mount to react before the next exposure. (Useful to lower the chance for oscillation.) – will be obsolete, using the smart guiding method implemented soon.

From 01.11:

- o New “drifts” as a guiding display mode: the history of the drifts of the guiding star can be monitored for the previous 48 frames;
- o Increased LCD backlight PWM frequency, it has no effect on the Camera now (in LiveView had a tiny);
- o Bugfix: “Camera stop in cold” symptom has been corrected (in hardware too).

From 01.10:

- o LiveView function (1:10 size real time image for the entire CCD field);
- o The “threshold” parameter is now set in percentage;
- o Some parameters can be changed with LEFT or RIGHT buttons too;
- o Advanced method for StarSearch – overexposed stars are missed more rarely;
- o The brightness of indicator LEDs can be set individually;
- o Asking for stopping the guiding if it’s in progress and some function needs to have it stopped;
- o Autorepeat for all the buttons – makes the navigation or parameter change easier;
- o A 0.5s dead time for the buttons is inserted at the power off screen to avoid accidental power-off of the device.

From 01.09 and before:

- o Adaptation from the prototype circuit and software, hardware changes.
- o Indicator LEDs are now active;
- o Bugfix: AutoExposure did short “wake-up” signals periodically in wait state;
- o ...and much more tiny changes...

## 3 About the user interface

### 3.1 Buttons and LEDs

On the front panel of the HC there are 6 buttons and 6 so-called indicator LEDs next to them. The buttons are for navigation and controlling of the device while the LEDs indicate some action of it for visual checking.

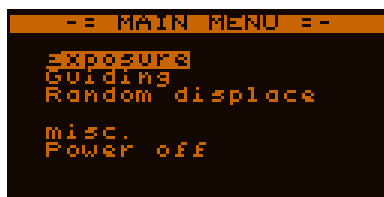
These are the following:

- o **ESC**  
Functions: [back](#), [cancel](#) or [exit](#).  
Main function: exiting from the current screen.  
blue LED indicator: [shutter focus](#) line active - feedback (default).
- o **SET**  
Functions: [enter \(into sub-menu\)](#), [choose](#), [set](#), [activate](#), [start editing](#).  
Main function: activating the selected item on the screen.  
green LED indicator: [shutter exposure](#) line active – feedback (default).
- o **UP, DOWN** (arrows)  
Functions: [select prev./next item](#), [inc./dec. digit \(in editing mode\)](#), [DEC manual guiding](#).  
Main function: navigation between the screen's items.  
red LED indicators: [DEC axis](#) correction line(s) active. (Shows what is physically on the autoguider output).
- o **LEFT, RIGHT** (arrows)  
Functions: [changing the value of the selected item](#), ([select prev./next item](#)), [moving the cursor \(in editing mode\)](#), [RA manual guiding](#).  
red LED indicators: [RA axis](#) correction line(s) active. (Shows what is physically on the autoguider output).

### 3.2 Main conception of the User Interface

The display and controlling of the device is menu-based. By default there is always an active screen, holding one selected item on it (for most of the screens). The selected item is always shown inverse. (This is something like a cursor for the actual screen items.) The selected item can be activated by pressing the SET button. Activating means entering to editing mode (to change its value) or doing some function. By default You can change the selected item (~"move the cursor") with UP and DOWN buttons and in some cases LEFT and RIGHT could also be used.

This "screenshot" below shows the main menu with the "Exposure" item selected on it:



Certain items behave differently. There are *number*, *time* and *text* types etc. Text type items can lead to a submenu or are to do some function (like a button), while other (*number* or *time*) types store a value that could be edited/changed and are called *parameters* or *variables*. These are to setup, parametrize the device, to control its behaviour.

For details of the method of changing the parameters see 3.2.2.

### 3.2.1 Menus

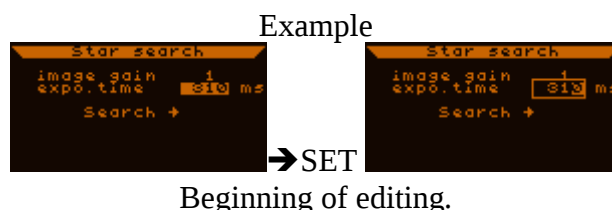
The HC has a fixed **menu tree structure**. From the main menu every submenu is accessible with a subscreen at the end that is for some specific function. If an item leads to another (sub)screen it is called *menu item*.

Exiting from a screen is done with ESC button. When entering into a subscreen, the selected item is memorized to set it as the selected item if You go back with ESC.

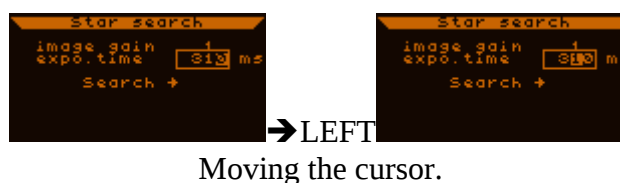
### 3.2.2 Variables (parameters)

There are many types of items on the screens. If an item holds a value its called *variable* or *parameter*. Their value can be changed in *editing mode*. For demonstration there are some examples:

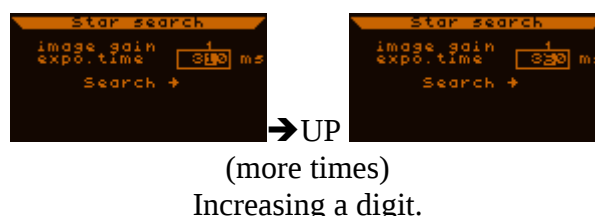
A variable item is selected on the screen. By pressing SET You can enter *editing mode* (if it is allowed to be changed). The bracket around the edited item indicates the *editing mode*.



In this mode there is always a *cursor* that selects one digit and is shown inverse. To move the cursor on the digits LEFT and RIGHT buttons can be used.



To change the value of the selected digit use UP and DOWN buttons. Use autorepeat of the buttons for faster changing of the digit value.



To store the new value press SET again. The new value immediately takes place in most of the cases. Doing so we also leave the *editing mode*.



To discard the new value edited (to hold the old one) press ESC. This exits *editing mode*.



Discarding the new value.

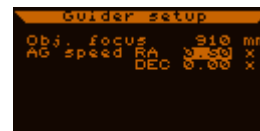
The editing process is always done on a temporary variable so it does not affect anything if You start an editing and then exit from it with ESC. During editing the device uses the old/original variable value.

Types of the items or parameters:

- *Decimal*  
An integer value representing something (meant in some unit or indexes different modes). Consists of fix number of digits (all these digit characters are shown inverse when selected as above in the example), has limits (minimal and maximal value). (If a limit is violated in editing mode by changing a digit's value the value is set to that limit independent of the edited digit.)  
The example above shows this type of parameter.

- *Real*  
Real value with two-digit fractional part. Edited the same as for the decimal type. Between the integer and fractional parts there is a dot character.  
For example:

The selected “AG speed RA” item in this screen is real-type with a value of 0.5.



- *Time*  
The default time-type variable is always meant in 0.1 sec unit and is displayed this way.  
For example:

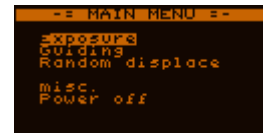
The selected “exp.time” item on this screen is time-type with a value of 3 minutes and 15.2 seconds.



In editing mode it behaves as the decimal type except that some digit's maximum is only 5 (ie. 59 for the minutes) and there are dot and double dot characters between the digits.

- *Text*  
This type can not be edited as the other. Holds a fix text or the ‘value’ (state) of it can be changed with the SET button. So the text can show the value or state of a parameter.

Can be a so-called *button* item that does/starts some function. Can be a *submenu* item to enter a new screen (down in menu tree).  
For example the main menu consists only of this type of items.



Can be a so-called *switch* that can be altered by the SET button. (This is a two-state parameter item.)  
For example: enabling functions or modes are controlled by this type of items. Commonly a ‘-’ character indicates the OFF and a ‘✓’ char. the ON state.



Can be a special parameter that can have a few number of fix values, displayed as a text.  
For example on LiveView screen this item can have only the “max.” and “avg.” values.



The value of most of the parameters or variables are stored into EEPROM memory of the HC at power-off. At the next power-on they are initialized from here.

### 3.2.3 Profiles

*Profile* means the value of a set of variables / parameters, these are called *profile variables*. The value of these can be set in each profile independently. Changing the active profile will change the value of all these profile variables.

There are 3 separate profiles (number 0, 1 and 2). The active profile can be changed in the misc. menu screen. If doing so the old profile setting is stored into memory and the new one is loaded into the profile variables. The change of these takes effect immediately and so there may be a question to stop the current autoguiding because all the guiding parameters are profile variables.

A profile can be interpreted as a ‘trimmed’ set of parameters for each guiding solutions, for example profile 0 for a guiding telescope, profile 1 for off-axis system and so on.

Non-profile (*global*) variables are not affected by a profile change. The parameters of the AutoExposure program are of this global type for example. Profile variables are generally for those variables that are needed for autoguiding.

## 4 Parts of the software, functional units

There are some well defined functional units in the device. In the next sections You can read about these functional units for the sake of a better transparency.

### 4.1 AutoGuiding function (AG)

The main function of the device is Autoguiding. It has its own process (runs independently of the other (including the User Interface)), handling the Camera is it's job exclusively so the program of the Camera is the part of this functional unit.

The guiding star's image is processed by the Camera. The guiding program in the HC uses the calculated star position to control the mount with the ST-4 compatible autoguider port. There is a dedicated screen for Autoguiding, on which everything can be controlled that directly affects guiding. This is the *guiding screen*, can be reached with two SET keypresses:

(Main menu) Guiding ? (Guiding menu) Current guiding ?

*Guiding screen* is indicated by a "GUI" text in the top right corner and a 48x48 pixel window monitoring something on the left of the screen. There are more pages of this screen, more on this later.

Important notes:

- o If the Camera is active and there is a star in its *guiding window* (an area on the CCD field), it will follow the star with repositioning the guiding window even if the autoguiding is not started. Because of this the monitored image of the guiding star (within the 48x48 pixel window) may be shown as replaced 'immediately' but this does not affect anything, it is only made by display.  
This *star following* is a part of the software, can't be turned off.

If the followed star is lost (gets too dim by clouds or jumps out of the guiding window by a mechanical push), the guiding window stays and waits for the star appearing again in it (no automatic re-search is done). The user may search for the star again (with LiveView or Star Search).

This could happen often if You touch and push the mount / telescope (or the DSLR) by hand and it is not stable enough. After this the star may stabilize in its old position (in guiding window) but the window may be repositioned as it wanted to follow the star and that's why the star is lost.

This is done the same way if the autoguiding is active, but the device tries to correct the position if there is any. If the star is lost (temporarily), no autoguiding signals are put out. At permanent star lose no automatic re-search takes place.

- o If You started to use the Camera once, do not just pull out the Camera-cable, for example to detach the Camera from the guide scope. Stop the Camera before, which can be done only with powering off the device currently.

The Firmware handles the lose of the Camera but it is not safe to power-off it that way, it might damage some circuit part in the Camera.

## **4.2 AutoExposure function (AE)**

The Autoexposure functional unit is also a separate part of the software. On its dedicated screen can be set up, started and stopped etc. The shutter signals generated by this functional unit appear on the 3.5mm stereo jack output connector and can be directly connected to a Canon EOS 350D or similar DSLR with such a shutter input (“open-collector” line). The AE’s function is to shutter Your DSLR synchronized with the device’s functions.

The AE program runs totally independently of the other units by default. In this case it can be used as a single automatic shutter device too, can be powered only from USB as well. The only case when the AE is synchronized with other functional units is the Random Displacement function enabled and the Autoguiding active.

The shutter program has two operational modes:

- o Normal mode (default): all the shutter program parameters can be set and used (wait time, mirror lockup time etc.), the DLSR shutter is controlled fully by the LMG device.
- o “AstroTimer” mode: this mode is mainly for cooperating with the external shutter device called AstroTimer but other external device may be used.  
In this mode the device does not generate shutter signals but other: the shutter output is only active when the Random Displacement function is moving the telescope, so it indicates the time when the external shutter device must wait.

In this mode there is only one parameter that can be set, the time period between two RD movements. It is shown as the ‘exposure time’ of the program.

## **4.3 Random Displacement function (RD)**

Also known as “dithering”. It’s goal is to move the telescope (with relocating the guide star) randomly between the imaging exposures, avoiding to image the object time to the same sensor surface each time. This has several advantages:

- Some untouched or ‘temporary’ hot pixels can be eliminated automatically at the combination (‘averaging’) of the single frames. These pixels will be located at different position on each frame relative to the object (after registering / alignment).
- Similar to this, overcompensated pixel caused ‘black holes’ are eliminated also and the noise effect of ‘wrong’ dark frame subtraction is smoothed.
- The non-uniformity of pixel sensitivity causes extra noise pattern that can be suppressed (smoothed) too.
- Using very short focal length objective and a sensor with Bayer-matrix color filter can cause false coloured star spots as they are easily imaged into a single pixel. By moving the image over the filter matrix will lower this ‘color noise’.

On photos taken without RD some small pattern of the background noise is a typical effect. This may be caused by the changing gravitational flex in the system (using a guide scope and a separate imaging telescope) or image movement (rotation) around the guiding star due to not enough precise polar alignment.

Some effect of using a 'noisy' flat field is also smoothened by RD.

RD works together with the Autoexposure and Autoguiding functions, if enabled. At disabled state it does not affect any part.

## **4.4 Filesystem (FS)**

As its name shows it is a data storage function of the device. There is 2.088.960 bytes of free Flash memory for the files' data.

In the filesystem there can be a maximum of 16 file entries. Only one of those can be opened at a time, which is accessed by all the processes (for data inserting). The open file stores several types of data –dependent of the parameter settings- to store one or more night's events to make statistics, search for 'bugs' or just check the accuracy of the autoguiding (or its parameters). May be used to optimize Your parameters 'offline'.

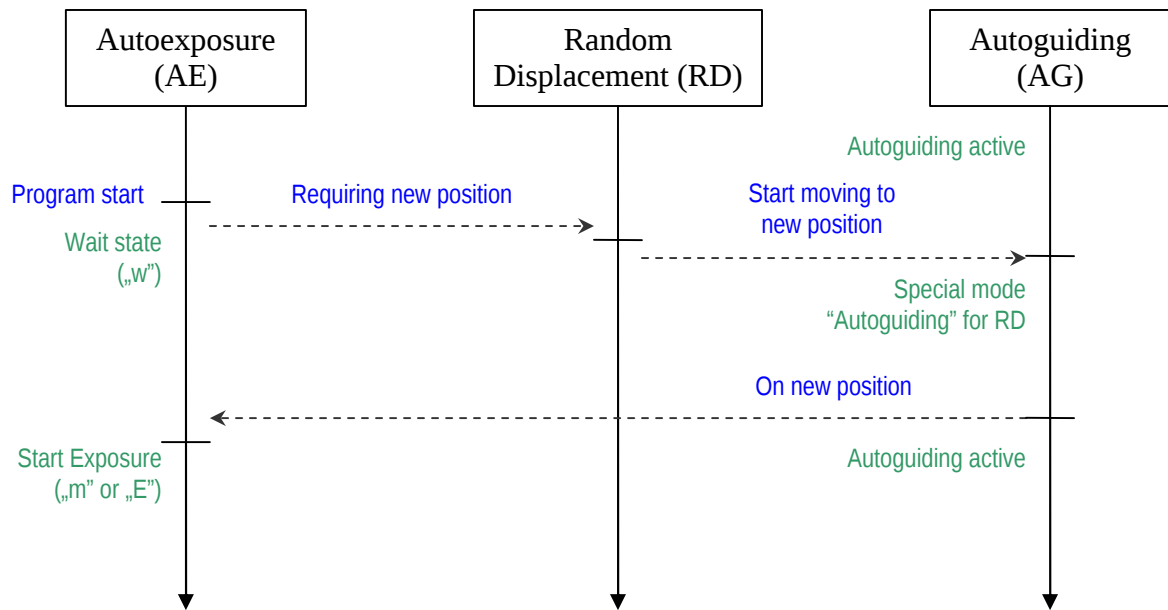
The files have their own menu, where details can be seen (size, dates, downloaded state), new file can be created, file deleted, opened or closed. It is advised to download these files to PC as frequently as possible (with the PC application) to make enough free space for the forthcoming nights.

There is a date and time settings screen, where the realtime clock (with date) is to be set. This is essential for timestamping the files' data to a proper identification of the stored data later. After power-on this screen appears, after then the file menu when You can open a file, for example the last opened or a new one. (If You skip opening a file, every function will work but no data will be saved.)

The current version of Firmware stores only one type of data into the open file: if the Autoguiding is active the guiding star's drift and the calculated correction signal length is stored. This is the "guiding curve", currently in one huge data stream. (Later versions will separate these data for each exposures, and the accumulated guiding star image too as a new feature. Position storing without Autoguiding will give a measurement tool of PE and other. The PC application will interpret and display these data in HTML format.)

## **4.5 Cooperation of the functional units**

The three main functional parts (AG, RD, AE) need to work synchronized if the RD is enabled. This communication is shown below in a simple diagram (the time axis goes downside):



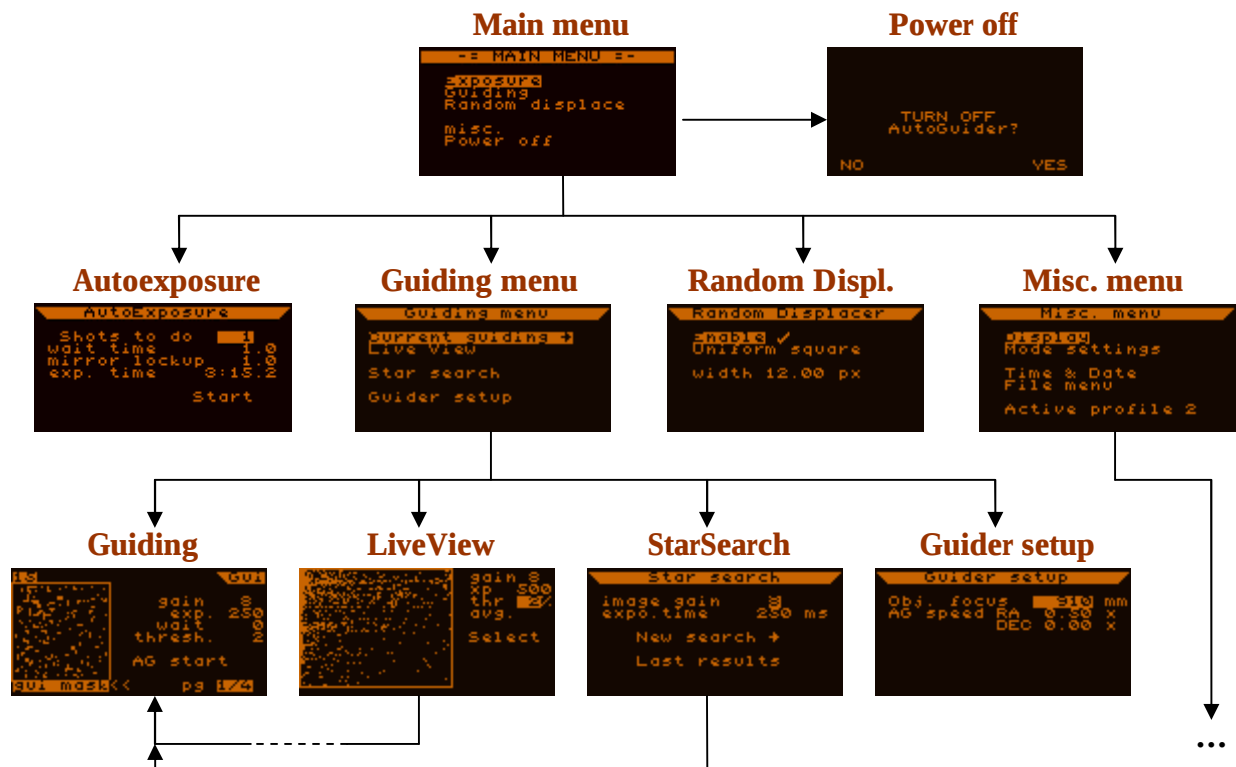
Some behaviour read from the diagram:

- If the RD is disabled ("Requiring new position" will fail) there is no synchronization between AE and AG.
- The RD as a program must be enabled only at one moment (the only horizontal line), the movement is done using parameter values at that time moment. Changing the parameters (or enabling/disabling it) any other time will not affect anything.
- The Autoguiding works in a special mode when a displacement is in progress. It starts to autoguide to the new position automatically with the current parameters but the guiding is stopped right after both of the correction signals (axes) got inactive at least for a moment since the start of the movement. The new star position (that is not the exact calculated position) is then measured for max. 2 seconds and the guiding is continued in that position and the Autoexposure is left to go on. (This method shorten the displacement time and gives more for imaging).

## 5 Menu tree

The menu is structured around the function units. From the main menu You can access these main functional units' control screens, besides other subscreens and menus.

Here is the menu structure except for the “misc. menu” that will be detailed later at the screen descriptions.



To navigate in the menu use SET and ESC buttons. SET is to enter a subscreen while ESC is to exit the current one. The previous screens and their selected items are stored in a stack, by going back to them will hold the previous selection. By entering a new one will have the default item selected on it.

To go to the main menu press ESC more times or keep it pressed (autorepeat).

## **5.1 Screens and functions detailed**

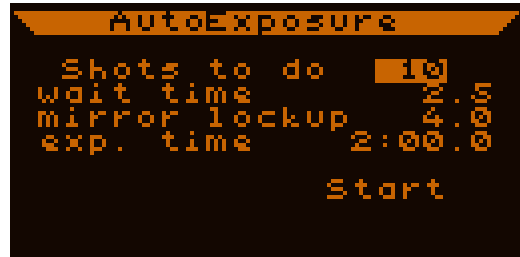
Some explanation for the next (screen-descriptor) sections and its items:

- With **blue** color the item as it apperas on the screen;
- after it in caret, separated with comma (if it has):
  - type of it (see 3.2.2);
  - limits (minimum and maximum);
- after the caret: information about the storage behaviour:
  - if nothing stays here the item value (if any) is not stored anywhere;
  - global = the variable item is stored at power-foff but independent of the profiles;
  - profile = the variable item is a profile variable, stored at power-off, changed by profile change.

For each screen description section there is a screenshot from the device (right to the section title) to identify the items more easily.

### 5.1.1 Autoexposure (AE) screen

To control the EOS-compatible shutter output lines (3.5mm stereo jack). One program can be set up at a time on this screen, started, paused/continued and stopped.



The screen items are the following:

- **Shots to do:** (*decimal*, 1 ... 999) global  
The number of images to take in series.
- **wait time:** (*time*, 0.5 ... 99:59.9 sec) global  
Minimal wait time between the exposures. (The mirror lockup is a part of the exposure.) This wait time could be more in real than the set value due to other functions like enabled Random Displacement.  
The **very first wait time** (before the first **shutter exposure** signal) is always **1 second**.

Note: right before the end of the wait time the **shutter focus** line is active for the last 0.3 seconds to wake up the DSLR if it was in standby.

- **mirror lockup:** (*time*, 0 ... 20.0 sec) global  
"Mirror lockup" means: if the DSLR has a mirror lockup option and is active it will only move the mirrors out of the optical path for the first shutter signal and the next signal will start the real exposure. The 'lockup' of the mirrors can cause the telescope/mount to oscillate for a short time.

If ML is activated in the DLSR this must be also set up in the device to be in synchron. This item is to do this. The mirror lockup time is always 0.2 second then the device is waiting in the remaining time.

If this item is set to 0.0 it means the ML is disabled.

Note: independent of the value set the ML time (including wait phase) is **at least 0.5 second**, except if disabled (0.0).

- **exp. time:** (*time*, 0.1 ... 99:59.9 sec) global  
The desired exposure time.
- **Start** or **Stop:** (*button*)  
Used to start or stop the program. At stopping the program is interrupted regardless to its current state and the shutter lines go inactive immediately.  
It is possible to stop the program while it and the DSLR is in ML state. In this case they will be out of synchron, but the DSLR may timeout from ML state and the synchron is okay from that time.
- **Pause** or **Continue:** (*button*)  
The program can be paused in the wait state (between the exposures). This item is only shown when the program is running. If Pause is activated, a "P" character at the left bottom part indicates that the program will be paused after the current exposure

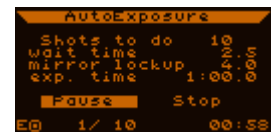
ended. The item text will be 'Continue'. The paused state gets active at the last 0.1 second of the wait state of the program.

At the paused state the program variables can be changed. (Meanwhile a running program it is not allowed.) The 'remaining time' will stay at 1 second at paused state.

Activating 'Continue' will clear the paused state or the signal to pause before the next exposition. If it was in paused state, the next exposure starts immediately.

Note: if the RD function is enabled the next movement is started before the program reaches paused state.

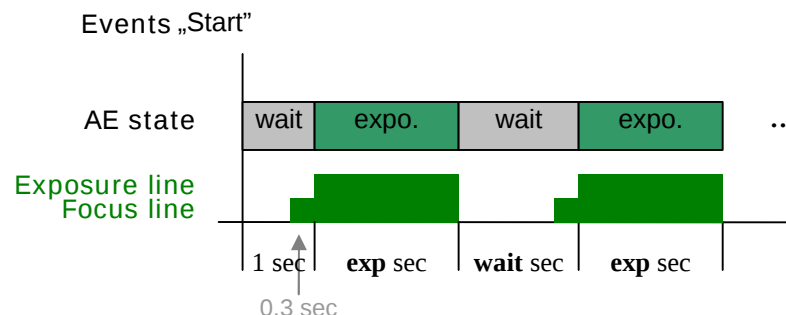
If an AE program is running the bottom line there is information about the current state:



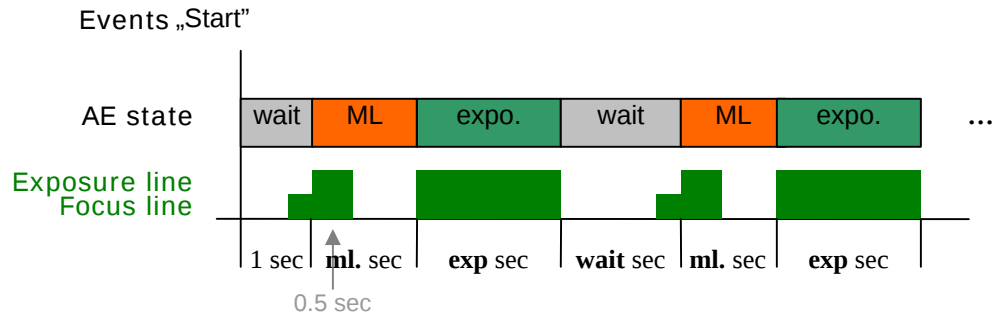
- at left:
  - one character showing the current state of the AE program
    - w = wait time (is counted down);
    - m = mirror lockup time (is counted down);
    - E = exposure time (is counted down).
  - and the next one the actual (physical) shutter signals:
    - *nothing* = both shutter signals / lines are inactive;
    - ○ = only the **shutter focus** line is active;
    - ⊙ = both lines are active.
- on the middle:
  - the next or current exposure's index and the exposures to do (although it can be read above at the item).
- at right:
  - the remaining time of the current state, in seconds (rounded up).

Below there are some example diagrams for the running of the AE program in different cases. (Time axis is the horizontal line.)

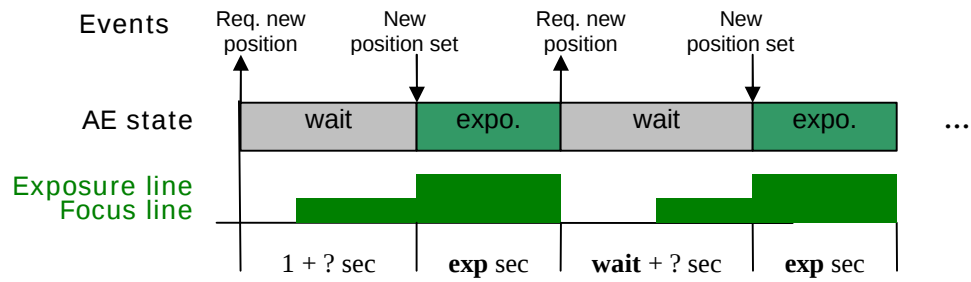
- Operation without ML ("mirror lockup" = 0.0)



- Operation with ML



▪ Operation without ML but with enabled Random Displacement



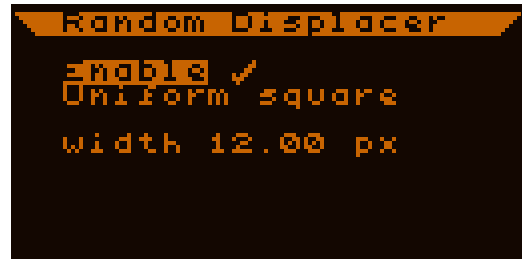
With ML the case is almost the same because ML can be interpreted as a part of the „exposure” state.

See more in 4.5 about extra waiting due to RD.

### 5.1.2 Random Displacement (RD) screen

About the meaning of RD see 4.3.

Below are the screen's items and detailed descriptions:



- **Enable:** (*switch*) profile  
To enable or disable the RD function.  
If enabled, right after the currently running exposure (in AE) has ended this generates a new guiding position for the guide star.
- **Uniform square** or **Square snake:** (*text*) profile  
The used method to generate the positions. The two above can be set.
- **width:** (*real*, 0.01 ...99.99) profile  
The width or size of the patterns. It is interpreted differently by the two modes.

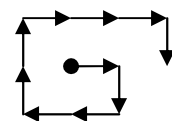
#### Uniform square mode:

It means a quasi uniform distribution of points within a square. The pattern is predefined and is designed to cover the whole area uniformly even at low number of exposures.

The “width” stands for the width of the square’s sides, the unit is pixels (in the Camera). (Note: the physical pixels are not exactly square shaped so the Y coordinates (size) are scaled to be equal to X, which is the horizontal axis.) For example width=16 means a [-8..8] pixel interval for each axis relative to the autoguiding center (where the AG has been started).

#### Square snake mode:

This pattern is not random but the pattern shown at right. It steps on a square grid, the step size is always the same. The first step is to right (RA axis) and the next steps are counterclockwise around the previously used positions.



In this mode “width” is interpreted as the grid distance or one step’s size. This has an other scale than the other mode, be careful and check the size every time You change between the modes.

Knowing the directions of RA and DEC axes the generated position are mapped to this coordinate system, so X movement will always mean moving in RA, Y will mean moving in DEC.

Each new guiding position coordinate is limited to 16 pixels close to the CCD surface’s border, to avoid star lose.

A new displacement is generated by the Autoexposure program when it goes into wait state. In this case the AE waits until the new position has been stabilized and continues the program after it (see the example at the end of section 5.1.1).

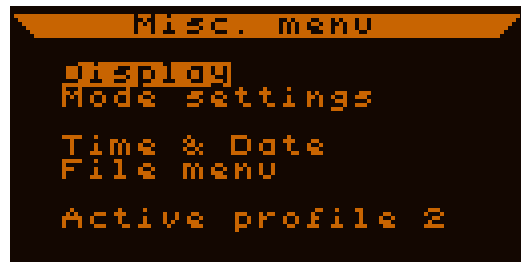
The RD positions are fix so reproducible. The positions are indexed in the device that starts from 0 at power-on. This first position (offset) is always (0,0). Later the index grows but can't be reset to 0 currently. If You stop the autoguiding and restart again, remember that the star may be located somewhere but not where it was at starting the autoguiding. In this case the autoguiding center changes and the new RD movements are done around that point.

The display of the RD positions (prev. and next ones) and the ability of changing the position index will be included in a later Firmware version.

The RD movement is not done exactly. The new position may differ from the calculated one a little bit. This behaviour is to save time at RD movement, letting more time for the exposures.

### 5.1.3 Misc. screen

This screen holds every menu and settings that may be accessed rarely.



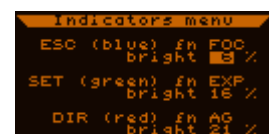
- **Display:** (*submenu*)  
Leads to LCD and LED indicators' settings.
- **Mode settings:** (*submenu*)  
This submenu contains switches for the different modes of operation of the functional units.
- **Time & Date:** (*submenu*)  
The realtime clock (with date) in the device can be set up here. The filesystem uses this for timestamping.
- **File menu:** (*submenu*)  
Handling the files in the DataFlash memory is done from here.
- **Active profile:** (*decimal, 0...2*) global  
The currently active profile's index. Changing this value will replace all the profile variable's values. The current settings are stored into EEPROM memory before the replacement.

#### 5.1.3.1 Display settings screen

The LCD and LED indicators' settings are here:



- **LCD backlight:** (*decimal, 0...99 %*) global  
The intensity of the LCD backlight brightness. The value is used in application mode of the device, the LCD backlight is always on full in update mode.
- **contrast:** (*decimal, 0...9*) global  
Contrast for the LCD. By default it is 5 and is optimal in most of the cases.
- **Indicators' setup:** (*submenu*)  
Here You can set the LED's brightness for each color (function). On this screen every LED will be lit to check their brightness in place.



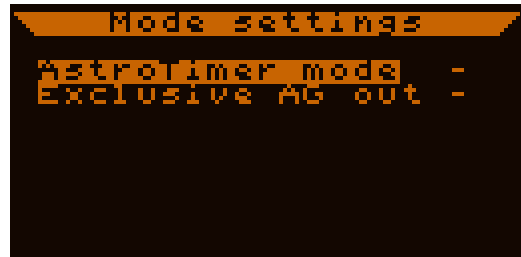
Currently the indicated events or states are constant, can't be changed:

- ESC (blue): **shutter focus** line active
- SET (green): **shutter exposure** line active
- directions (red): the RA autoguiding signals horizontal (left-right), the DEC signals vertically (up-down).

Each brightness can be next to the **bright** item in percentage of the full light.

### 5.1.3.2 Mode settings screen

Here are some switches for the behaviour of the functional units. These are:



- **AstroTimer mode:** (*switch*) profile  
Used to cooperate with AstroTimer shutter controller unit. If enabled, the Autoexposure and so the EOS shutter output signals behave differently. The description of this mode see 4.2.
- **Exclusive AG out:** (*switch*) profile  
Meaning of the item: "exclusive AutoGuiding output signals for the axes". If enabled, only one axis is signalled for correction at a time. If the device wants to signal both axes, the RA will be signalled first and the DEC after then, in other words the RA axis is in priority to the DEC.

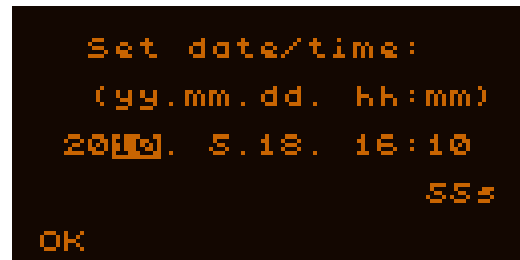
Note: it may occur that the correction (guider imaging) frequency is so frequent that both of the correction signals could not be put out fully. In this case the new correction signal gets active and the current is interrupted. It may delay the DEC corrections if the RA must be corrected continuously.

Note: there is a 62ms dead time between the two axes' signals to let the circuit of the mount to react on them.

### 5.1.3.3 Date and time screen

You can set the realtime clock and date here. The format is displayed on the screen: year-month-day and hours:minutes.

The seconds are also displayed but can't be changed. After setting a new date the device checks it and limits the day value. Always recheck the displayed date after changing it.



This screen appears right after power-on (from Firmware 01.21). If the filesystem is to be used set the date and time properly, timestamps will be inserted into the file.

Note: changing the date and time items takes place immediately. If a file is open and data is being stored into it the timestamps will change suddenly causing the data flow getting a bit confused. Only set a new date or time when no file is open or do it properly only once after power-on.

### 5.1.3.4 Filesystem's screen(s)

This screen is for showing and controlling the files. After startup and the date and time setting screen this screen appears. If you don't want to store data into file press ESC again to exit into main menu. (The meaning of the files can be found in 4.4.)



Files list screen: (the screenshot above)

There can be 16 file entries at a time. The list of the used file entries is shown in the first 6 rows of the screen. If there are more than 6 of them the list could be scrolled, an up- or downward triangle shows on the left where the list can be scrolled.

The content of the rows:

- Date and time of creation. Might make the identification of files easier.
- At right (optionally) a sign about the state of the file. These can be:
  - o L: this file is the last opened one (there is no open file)
  - o OP: this is the currently open file
  - o \*: the file is broken (has error). (Can not be opened, but a part of its content may be downloaded.) This can occur when an open file has not been closed or written properly, for example at a sudden power loss. (Checking the type of the error the PC application can be used.)

At the bottom (above the functions of the buttons) the free memory is displayed in kilobytes and in percentage of the whole memory. (This is not refreshed, shows the state at entering this screen.)

The files in the list are **ordered** by their **unique ID**. This value is constantly increasing with every new file creation and gives the ability to identify all new files from the older ones (from even those that were downloaded to PC and then deleted). *The newest file is always the first file in the list (at the top of the other) regardless to its creation time value.*

#### When there is no open file:

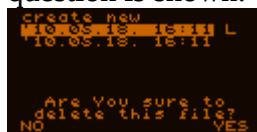
..and there is space for a new one, the first line will be “create new”, which will create and open a brand new file by activating it (pressing SET if selected). This case is shown at the screenshot. After a new file has been created the device exits the filesystem screen.

If there is no more space (free entry) for a new file, this option will be missing.

The “last opened” flag (“L”) can be used to identify which file has been used previously. If the device was turned off and then on, open this file to continue data storage into a single file. (It is advised to use one file for each night if possible.)

If a file entry’s row is selected the following options appear for the buttons:

- SET button: display the file’s details (new screen)
- LEFT button: delete the file (with confirmation). This question is shown:

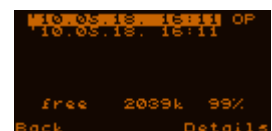


With pressing SET You can confirm the deletion while ESC cancels it.



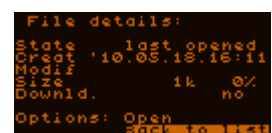
#### If there is an open file:

...then this screen at right can be seen, there is no “create new” option. The “OP” (“open”) flag shows which file is currently open. The open file can’t be deleted at this moment but the others can.



#### File details screen:

To see the details about a file press SET on it in the files list screen. An example of the details screen is shown at right. The displayed data is the following:

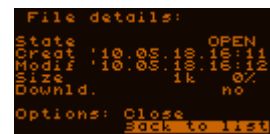


- State: the actual state of the file that can be:
  - o last opened: this file was opened last time (currently there is no open);
  - o OPEN: this is the currently opened file;
  - o closed: the file is closed (and so can be continued / reopened);
  - o broken: the file’s data is broken, can not be continued / reopened.
- Creat: the date and time of its creation.

- **Modif:** the date and time of its last opening (“modification”). If this row is empty the file was open (created) only once yet.
- **Size:** the size of its data content in kilobytes and in percentage of the whole memory (rounded).
- **Downld.:** the downloaded state of the file. After downloading the file with the PC application it gets the value “yes”, otherwise it is “no”. Opening a downloaded file will reset this state to “no” value to show it contains new data appended to it.

The operation that can be done on the file is shown after “Options”:

- If there is no open file, selecting the “Open” item and pressing SET button You can open this file, except if it is broken.
- If this file is open “Close” is shown and is used to close the file. Data storage will be interrupted.



```

File details:
State      : 10.000100 OPEN
Crc32      : 10.000100 16:11
Modif      : 10.000100 16:12
Size       : 1K 0%
Downld.    : no
Options:   Close
           500 10 11 13
  
```

Or You can go back to the files list screen with perssing ESC or activating the default “Back to list” item. The device goeas back to the files list screen automatically also after an “Open” or “Close” operation.

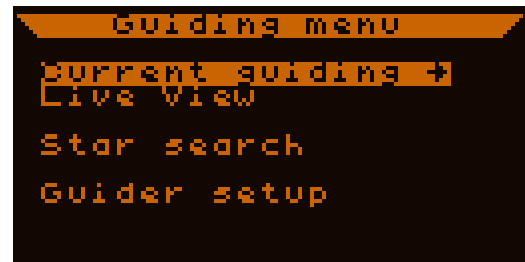
#### 5.1.4 Power off screen

This asks for power the device off (SET) or not (ESC). Power off makes everything go inactive. This is the advised mode to stop the device (before plugging out power cable(s)) because it closes the open file (if any), saves the parameter settings, stops the Camera properly etc.

There is a half a second dead time before the device gets any button press to avoid unwanted power-off. With ESC You go back to main meu.

### 5.1.5 Guiding menu screen

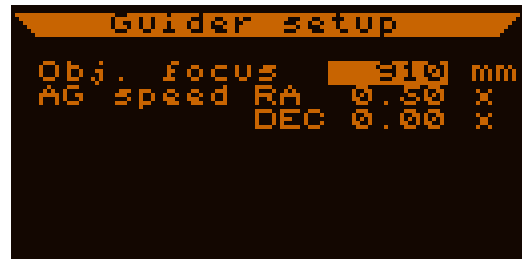
This screen (and its subscreens) holds all the functions and settings for autoguiding.



- **Current guiding:** (*subscreen*)  
This leads to the main Guiding screen (5.1.9.1).
- **Live View:** (*subscreen*)  
To enter LiveView screen, where the full CCD surface can be monitored in realtime.
- **Star search:** (*subscreen*)  
Leads to the automatic star searching function's screen. Compared to the LiveView this is more immune to single hot pixels and finds faint stars.
- **Guider setup:** (*submenu*)  
Holds the parameters of the guiding optics and the mount's autoguiding settings.

### 5.1.6 Guider setup screen

This screen holds the parameters of the guiding optics and mount, so “guider” in this context does not mean the autoguider device. These values are needed by some function that does not know anything about the used system and giving the values (approximately) helps them. Calibration is such a function.



- **Obj.focus:** (*decimal*, 50 .. 60000 mm), profile  
The focal length of the guider optics used with the Camera, in millimeters.
- **AG speed RA/DEC:** (*real*, 0.00 ... 1.00), profile  
The correction (autoguiding) speed (relative to sidereal rate) set in the mount's controller. Any non-standard rate can be set with 0.01 step size.  
The RA speed can't be set under 0.01x while for DEC it is allowed and means that DEC speed always equals RA speed. (See the screenshot for the case.)

Changing the values take effect immediately if no calibration is in use. If there is no calibration data, the operation mode below is active:

#### Axis aligned, manual setup:

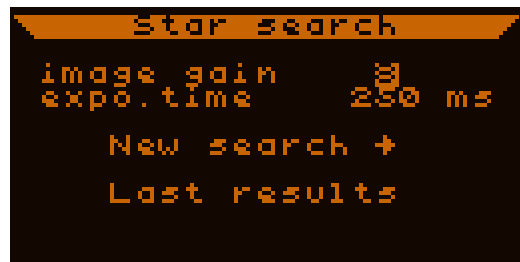
If You want to set up the autoguiding manually, You can skip using calibration. In this case this screen's values give information about the actual correction speeds. The RA direction must be horizontally (X axis) and the DEC vertically (Y axis) aligned.

The actual RA speed ( $\text{spd}_{\text{RA}}^*$ ) changes as a function of the object's DEC coordinate (DEC). This RA speed must be calculated and set up by the user manually. The formula is the following:

$$\text{spd}_{\text{RA}}^* = \text{spd}_{\text{RA}} \cdot \cos(\text{DEC})$$

### 5.1.7 Star Search screen

After setting some guiding parameter (that You want to use) an automatic star searching function can be started from here. The guiding parameters are the imaging parameters like analog gain and the guiding exposure time. These two main parameters are responsible for the limiting magnitude and the precision of determining the star position. These values are typically constant for a well tested system.



- **image gain:** (*decimal*, 1...9) profile  
The analog gain value of the CCD's signal. (See the table at 1.3.2)
- **expo.time:** (*decimal*, 50...4000 ms) profile  
The exposure time for the star search and later for the guiding, in milliseconds. The maximum is 4 seconds, there is no reason to increase this limit.
- **New search:** (*button*)  
Starts a new star search with the given parameters. If the Camera is not working it is started (taking some seconds) then the exposure time plus about 2.5 seconds for the search procedure elapses. "Searching stars" text is displayed meanwhile.
- **Last results:** (*button*)  
Shows the last search's results again, goes to the search result screen, which appears after each new search. Hold valid information until some other Camera function was not used.

The search result screen appears after a star search, which can be seen at right.

The top left big rectangle shows the entire CCD area. Every active point (pixel) on it represents a found star, these are the hits. At top right is the index of the currently selected hit and the number of them. (The first 16 are memorized and shown only.) To select the next or previous hit, press UP or DOWN buttons. The selected one is displayed with a tiny rectangle (see on screenshot). The index orders the found stars nearly by their brightness. The first index must be the brightest star found.



At bottom left there should be information about the brightness of the selected star but forget it now, this Firmware has a display bug here unfortunately.

To start following the selected star press SET button ("See ? "). Then You can monitor the star on the Guiding screen (5.1.9) where this action jumps.

Note: the smaller rectangle is for live viewing of the selected star's CCD part, currently not used, always empty.

If the search was inefficient, this is shown. You can start a new search with the same parameters by pressing the SET button ("New search") or go back to the Star Search screen by pressing ESC and change the parameters.

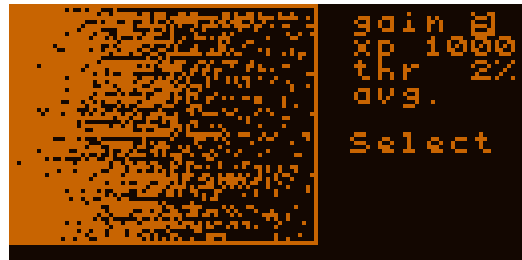


Other notes:

The automatic star search method uses a 32 pixel width window. Stars having this huge image or defocused spots may not result in a hit point or more points close to each other. Double stars within this size are also identified as single stars.

### 5.1.8 Live View screen

The screen does that it's name suggests. The entire CCD surface is monitored on the LCD in realtime so far as a two-state display can: there are on- (bright) and off- (dark) pixels on it. The on-pixels show that the given part of the CCD is brighter than a threshold value.



Each displayed pixel corresponds to a 10x10 pixel field on the CCD surface, its 'brightness' is derived from those. The method of calculation the brightness is described later.

- **gain:** (*decimal, 1...9*) profile  
The same variable as the "image gain" at the Star Search screen. (They are identical, changing one makes the other change too.) (See at 1.3.2)
- **xp:** (*decimal, 50...4000 ms*) profile  
The same variable as the "expo.time" at Star Search screen, this is the exposure time. (They are identical, changing one makes the other change too.)

Note: the frequency of refreshing the LiveView image can be higher than it would by the exposure time set. This is because reading the 10x10 pixel field is done with 10 rows added in hardware and therefore it is more sensitive than at normal resolution. So the used real exposure time in LiveView is always shorter than the desired value but shows the same sensitivity as would at autoguiding.

- **thr:** (*decimal, 1...99 %*)  
Threshold value to discriminate the resulting pixels for display. The percentage is meant to the 8-bit depth (50% will mean 128). The used threshold value is calculated by an addition of the minimal value of the full LiveView image and this "thr" variable's value.  
Generally a low threshold value can be used to show faint stars but not the background noise. On the screenshot above only the background noise can be seen.
- **avg.** or **max.:** (*special switch*)  
As written above, each resulting displayed pixel is derived from a 10x10 CCD-pixel field. The 10 rows are added in hardware but there are different modes of processing the 10 'horizontal' pixels values, and the resulting pixel value will be:
  - **avg.:** the average of the 10 'horizontal' pixels;
  - **max.:** the maximum of the 10 'horizontal' pixels.

The 'average' mode gives the best "resized" image content and is smooth enough but it can suppress tiny stars that consist of only some pixels. So may hot pixels also be suppressed.

The 'maximum' mode is for displaying every tiny or single pixels, which can be a faint star so as a hot pixel, use this mode carefully. Moving slightly the telescope will

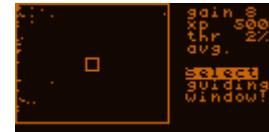
show which pixel is due to a star (it moves with the scope) and which is a hot pixel (stays in place).

- **Select:** (*button*)

Activating it a little window appears on the LiveView image (inverted) that can be moved along the CCD area with the direction buttons. (“Select guiding window!” text is shown.)

This window selects the guiding window’s position when SET is pressed again. The following of the star in it (if any) is started and the Guiding screen is activated.

By pressing ESC You can exit this selection mode.



The LiveView function is especially useful to roughly focus the guiding optics. If a star’s big spot is made to be small enough, selecting it will allow the focusing to be finalized on the Guiding screen’s window in normal resolution.

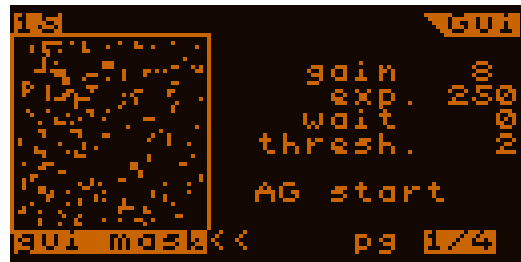
The LiveView can be used for “manual star search”, in some cases it may be more comfortable to do it in here than with the automatic StarSearch function.

If You change to the Guiding screen by selecting an area, the gain and exposure time values are copied to the guiding parameters, as well as the threshold value but this is set at a minimum value of 10 (avoiding background noise surely).

Note: there is some higher dark current present in the ‘vertical register’ of the CCD that affects the read image. (The rows have growing offset.) This is compensated by software and that’s why some horizontal ‘pattern’ (steps) may be seen on the LiveView image at low threshold values. Don’t bother with it, it won’t affect guiding performance.

### 5.1.9 Guiding screen

One of the most important screens is this one. From here You can start, stop, parametrize the autoguiding, run the calibraton etc. Due to the much function and parameters this screen is splitted into pages that is displayed at the right bottom as “pg ?/4”. Changing the page is done with this item (LEFT or RIGHT/SET buttons).



On the Guiding screen there is always the guiding star (or other) monitored in the window on the left. This is a 48x48 pixel window in a frame.

Below the frame its content type is shown, which can be one of the following: (Changing it is done with the “<<” item next to it.)

- gui mask

The “image” of the guiding star. Those pixels are shown lit (bright) that belong to the guiding star and are involved in the calculation of the star position. (This image is a real sized part of the CCD.)

This display mode can be seen at the screenshot above (showing only a background noise).

Note: due to an automatic hot pixel suppression single hot pixels are not shown in this image and so don’t disturb the guiding.

- maxY

A “vertical profile” of the raw image. The maximum pixel value of the columns of the raw image is calculated and shown in a “diagram”. The ‘zero’ (dark) level is near the top and the saturated pixel level is on (or near to) the bottom. The screenshot shows a single hot pixel causing one column to be “saturated”. The other columns does not contain hot pixel so they only show some background noise.



Note: the diagram is NOT a histogram but a “vertically projected map” of the raw image. This mode is used to trim the focus precisely. If the diagram shows a wide ‘hump’ the star may be out of focus. The focus is the best if the thickness of the hump is the smallest and the rise of the sides are the highest.

Note: using long exposure time more hot (or warm) pixels could be on the raw image and so in this display mode too. If these are located “far” from the guiding star and can’t be seen on the “gui mask” mode, they don’t affect guiding.

- drifts

This is a time diagram (or history) of the drifts of the guiding star, relative to the guiding center where the star



should be held. The latest 48 drift values are shown for the latest 48 frames, for each axis. One time step (one frame) is one pixel horizontally while vertically the drift values are scaled to the tolerance limit set. The tolerance is shown right next to the frame with two short lines, the size of it is  $\pm 2$  pixels to the zero. As the tolerance value is changed so changes the appropriate axis' drift diagram's scaling.

This diagram is called *guiding curve* too.

Note: the screenshot example does not show a real guiding curve on a star but on the background noise only.

At the top left of the screen there is a counter increasing or staying (between 0 and 63). This is the frame number from the Camera. If it is changing time by time, the Camera is working, following a star (or nothing). If the counter is still, the Camera does not work in guiding/following mode (or is not powered) so don't expect any reasonable image.

In the guiding window (that means also a 48x48 pixel area on the CCD surface), there must be only one star at a time, or maybe some close doublets. Stars appearing partially or temporarily in the window will disturb the position-determination so choose stars that have no other close to them almost with the same brightness. (You can check this at the automatic Star Search but even at LiveView.)

Modified star following method will be inserted in later Firmwares as an option to avoid such cases.

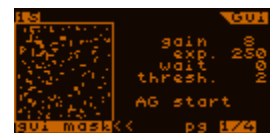
The guiding window "follows" the actual star in it (as written earlier). If the star closes some edge of the window, the window is relocated to center the star in it. This star-centering happens some time ie. during the calibration procedure. Don't bother with it, it has no effect on the guiding.

This star-following behaviour is always active until the star is suddenly lost somehow or the star drifts off the CCD surface.

#### 5.1.9.1 Main imaging page (1/4)

This page contains the parameters of imaging and the autoguiding can be started and stopped from here.

(Currently only this page allows to change the display mode in the guiding window on the left.)



The screen items are the following:

- **gain:** (decimal, 1...9) profile  
The same variable as the "image gain" at the Star Search screen. (They are identical.) More on this value at 1.3.2. Changing the value takes effect immediately (at the next exposure).
- **exp.:** (decimal, 50...4000 ms) profile

The same variable as the “expo.time” at Star Search screen. (They are identical.) The used exposure (integraton) time for taking images for autoguiding.

- **wait:** (*decimal*, 0...250 ms) profile  
Wait time between the guiding exposures. The mounts’ reaction time is never ideal for the autoguider signals. If there is a bright enough guiding star, this wait time can be used to wait some until the mount can react. Using good guiding parameters (and later a new guiding method) this value can be constantly 0.
- **thresh.:** (*decimal*, 1...99 %)   
The threshold value to discriminate star and non-star pixels. The value means the percentage to the saturation relative to the background pixel value (the minimum of the noise suppressed background for each frame).

Generally a value of 10% is useful and is above the readout noise at any gain. If some pixels randomly appear at the edge of the star (“gui mask” display mode), increase this value until the star’s edge is no more ‘noisy’.

If there is a fainter star close to our guiding star, this threshold can be also increased until the faint star does not appear even for a moment. This is not advised if the difference of their brightness is less than about 2 magnitudes.

- **AG start** or **AG stop:** (*button*)  
To start or stop the autoguiding.  
When starting, the latest star position will be the *guiding center*, where the star is to be held. Later the *guiding center* can be overwritten with a new value (for example by the RD function). The position is always a fractional (any “subpixel” position is allowed).

The autoguiding can’t be started if there are no star (pixel) in the guiding window.

- **<<:** (*button*)  
The display mode of the window at left is changed by this item (presing SET on it), see display modes at 5.1.9.
- **pg ?/4:** (*button*)  
By selecting this item and pressing LEFT, RIGHT or SET the active page of the Guiding screen can be changed. This item can be found on each page at the same position.

### 5.1.9.2 Camera orientation (and calibration) page (2/4)

The Calibration’s function is to determine the relationship between the sky axes and the Camera coordinates and the actual correction speeds for both sky axes. It is required to make the device know how the mount will react on the autoguider signals and know how the guiding star will move on the CCD. This screen contains the main elements of setting this ‘camera orientation’ data.



The screen items are the following:

- **Invert RA, invert DEC:** (*switches*)  
When enabled they invert the appropriate axis' autoguider signal direction. It is important to know that these inversions are made just before putting them physically to the output and so they will invert all the signals generated by any part of the unit. If a calibration data is used, these need to be disabled. Inverting one of them may be necessary after a meridian-change of the mount (pointing to the same point of the sky but physically differently).  
  
At manual autoguiding setup (when the Camera's horizontal (X) axis is parallel to the RA of the mount) this can be used to set the polarity of the image. For example using a mirror will need one axis to be inverted.
- **Manual:** (*button*)  
By pressing it the autoguider signals stop and the direction buttons can be used to control them manually. On the screen a "MANUAL, ESC to quit" inverted text indicates this manual control mode. You can exit this mode with pressing ESC. May be used for checking the axes' directions or for manual guiding for some purpose.
- **Calibration:** (*submenu*)  
Enters the Calibration screen to show and start or delete the current calibration data.

#### 5.1.9.2.1 Calibration screen

The screen displays all of the current calibration data if there is one. (The "Calibration" inverted text on the top indicates this screen.) If there is no calibration data present, "no data" text is shown (see screenshot at right) and only one option is possible: starting a new calibration with the **Calibrate** button.



The calibration procedure is the following:

First the DEC axis is moved according to the settings given in "guider settings" screen (AG speed DEC value). (This helps the calibration to move the desired amount without a knowledge.) If the star moved a little (no backlash is on the DEC now) the measurement of the DEC direction and correction speed is started. After it the RA axis' direction and speed can be measured now easier, the device supposes that the actual RA speed is equal or less than the DEC's. (Less due to the actual DEC coordinate where the mount points to.)

After all is finished, both the directions and speeds are stored as the calibration data. The correction speeds precision can't be checked directly but the directions can. In an ideal case these directions (vectors) are orthogonal to each other but during the measurement the star may drift some due to polar alignment failure or due to the periodic error of the RA axis. (The constant speed drifts are mostly corrected by the measurement method.)

After the calibration the orthogonality measure is displayed on the screen as "ortho.", in percent. The interpretation of the resulting value is described later.

The calibration procedure can be interrupted by pressing ESC. The mount will stay in the position where it was stopped. The mount is tries to set back to its original position only after all the calibration steps has run.

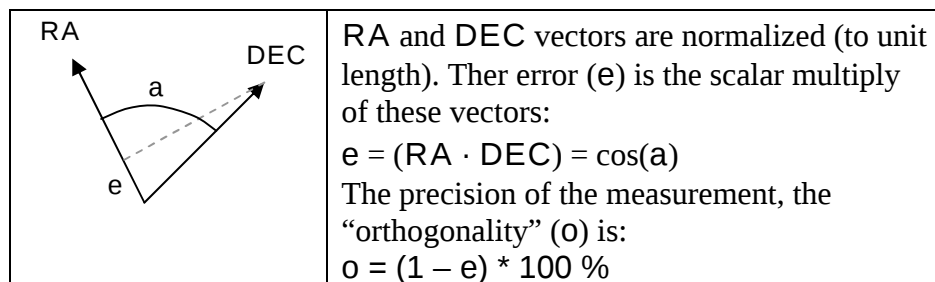
If a calibration has run with no error, a calibration data is present. The data consists of the directions (on the CCD's surface) of the two axes (RA and DEC) and their actual correction speeds. This is displayed on the screen as on the screenshot at right:



- The two directions are shown in the “guiding window” that is now used for displaying only these vectors. Both are normalized to equal length displayed.

Note that these may seem not orthogonal to eachother due to the CCD's and LCD's pixel aspect ratios but it shows the real moving directions when the guiding star is being monitored.

- RA and DEC's correction speeds are shown at top right, in pixels per second unit (px/s).
- The next row shows the orthogonality measure of the two axes' vectors. This is calculated as follows:



The o value is displayed on the screen as “Ortho”, in percent. If this is 100% the orthogonality of the two direction vectors is perfect. The value can be selected but does not have any function yet.

The error in optimal circumstances (no wind, good mount) is generally under some percent. The orthogonality is well enough above 90%, this means that the angle between the axes is less than 6 degrees. This has almost no effect on the guiding performance, even higher errors may be useful for an accurate guiding.

In wind using weak or overloaded mount the value could be 85-60% only. It is not advised to accept them (a new calibration should be started) except when so bad circumstances make it almost impossible.

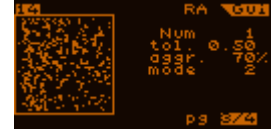
The **Delete cal.** button can be used to delete the current calibration data. It is required before a new calibration proceure can be started.

Note: the CCD sensor's pixel acpect ratio is not exactly 1:1. The device corrects the vertical (Y) corrdinates to the horizontal so the pixel size can be interpreted as 4.85 micrometers and its shape as square. (Only the real images displayed on the LCD are not

corrected, they could be seen a bit longer vertically due to the pixel aspect ratio and also by the LCD-pixels' aspect ratio.)

### 5.1.9.3 Guiding parameters page (RA and DEC: 3/4 and 4/4)

The next two pages have the same items, one page is for the RA and one for the DEC axis' parameters. These settings are independent. These parameters define the guiding behaviour of an axis. The parameters can be experienced with time and should be only trimmed later for some fix guiding configurations.



The items for an axis:

- **Num:** (*decimal*, 1...99) profile  
The number of frames (or star positions) that should be averaged before a new correction signal is calculated and sent to output. With this item it is possible to lower the correction frequency or to increase the effective integration time.  
For the RA axis this value is generally 1 causing no averaging and calculating correction signal after each new frame. For the DEC axis the averaging may be used, because there must be only low and constant drifts here. Averaging avoids chasing the seeing on DEC.
- **tol.:** (*real*, 0.01 ... 9.99 pixel) profile  
Abbreviation for “tolerance”. This is a threshold value in both directions to the center (zero drift) that means an interval in which the device handles the drift with ‘tolerance’. There are more modes of behaviour inside the tolerance interval, which is described later.
- **aggr.:** (*decimal*, 1...200 %) profile  
Abbreviation of “aggressivity”. This is a scalar factor that multiplies the calculated correction signal's length. This item trims the guiding “strength”, avoids oscillation and compensates other anomaly (a wrong calibration) if set carefully.

At manual guiding parametrization (no calibration data is present) this allows the User to set RA correction signal lengths according to the objects DEC coordinate. That's why the value is allowed to be over 100%.

Note: with calibration, using long exposure time (over 1 second) the typical value is 70-100%, using shorter correction frequency requires to lower this value to overcome oscillation around the zero drift point. Be careful not to chase the seeing, use as much integration time as your mount's errors allow.

- **mode:** (*decimal*, 0...2) profile  
Some different guiding policy is available, this can be given by this item. These are:
  - 0 Inside the tolerance interval there will be no correction signal but outside of it the device will try to correct the drift to zero.
  - 1 Inside the tolerance interval there will be no correction signal but

outside of it the device will try to correct the drift back to the tolerance border only.

- 2 The same as mode 0 but this singals even inside the tolernace border as a function of the current drift to remove low-frequency component of the guiding curve (the drift's history).  
This mode is more liable to cause oscillation, it may be compensated by lowering the aggressivity or increasing the tolerance a little bit.

There is an “emergency” action for both axes. If the drift is beyond **3 times the tolerance** limit the averaging is turned off and correction signal is generated immediately. This is for the case that the star is suddenly moved out of its position and is needed to get it back to zero drift as fast as possible. Other causes can be wind, backlash and mechanical errors in the mount. Currently this “emergency” behaviour is always active.

## 6 Practical examples

### 6.1 Assembly and startup

- Fix the Camera to the guider telescope or other optics. Try to put it near in focus.
- Connect the cables (advised in this order):

DC power cable into the HandController (nominal 12V), can be charged.

Camera and HC with the black 8-wire cable (UTP like).

The mount's ST-4 compatible autoguider input and the HC's output with the white 6-wire cable.

(Then the DSLR and the shutter output of the HC.)

**Note: don't plug** the ST-4 cable (6-wire) into the Camera port (8-wire) because the connector may bend the two extra connector pins at the sides and so the Camera will not be accessible by the HC. This is why the order of the assembly should be followed. (The bended pins could be repositioned but needs some practice doing this.)

- Turn on the device (press ESC).
- Set the current date and time, exit the screen and open a file. If You don't need data storage press ESC again.

### 6.2 Focusing using live views

- Set the guider telescope to a bright star (above 5 magnitude must be enough)!
- Navigate to the LiveView screen (5.1.8)! (From main menu: **Guiding / Live View**.) Set the exposure time for some seconds, the threshold to a low value (10% for example). Increase gain until the defocused big spot appears on the screen. After this focus the scope until the spot gets the smallest possible. As the star closes to focus, You can lower the gain and/or the exposure time to be able to focus more precisely (the overexposed image will not allow to get the spot smaller than a quite big one). If the spot is the smallest (has some or one pixel width) rough focusing is done.
- Select the roughly focused star for the guiding star, then You get to the Guiding screen (5.1.9). On the 1<sup>st</sup> page select "maxY" display mode. Set the imaging parameters (gain, exposure time) so that the star's hump could be easily seen but not reaching the bottom of the window. Focus the telescope gently until the shape of the star is the thinnest and rises the most at the edges ("sharp"). If this is also done, the focusing is done precisely enough. (You can mark this position of the focuser for later uses.)

Note: precise focus is not essential for guiding but could help increase the limiting magnitude and the position-determinization is more accurate. Except if You use a

sharp and short focal length optics because this easily maps the star into one or only some pixels that is not enough for detecting the position in fractions of a pixel. In this case slight defocusing of the guiding star will help.

### 6.3 Example for setting up and starting an autoguiding

- Navigate to the “guider setup” screen! (From main menu: **Guiding / Guider setup**.)
- Enter the real values into the screen’s items. The focal length is enough to be given roughly. For the actual autoguiding speed used, see Your mount’s (hand)controller.
- Navigate to the LiveView screen (5.1.8)! (From main menu: **Guiding / Live View**.) With changing the imaging parameters, find a star in the field of view (the brightest possible but above magnitude of 4 might be way too bright...). Check with slightly pushing the tube that the seen spot is a real star and is not a hot pixel structure (the star must move by the pushing). Choose one of the stars and You get to the Guiding screen (5.1.9).

As an alternative You can use the automatic star search function also (5.1.7) that may take more time but is more comfortable and immune to single hot pixels.

- On the 1<sup>st</sup> page of the Guiding screen (5.1.9.1) You can optimize the imaging parameters (gain and exposure time). This can be done the following way:
  - Set the display mode to “maxY”;
  - Change the parameters so that the star covers the full dynamic range (the profile of the star reaches the bottom of the window), it’s not a problem if the bottom is only near to it or sometimes it saturates in some columns. Take care of the followings:
    - the exposure time should be as much as possible, as many as Your mount’s periodic error’s rate allows and as much as it smoothes the seeing enough not to chase that;
    - the gain should be as low as possible for the lowest readout noise.

(An automatic procedure will be included soon to do this without human interaction.)

- Change to page 2 (5.1.9.2)! Delete the previous calibration (if any) and start a new one. Re-run the calibration until an acceptable orthogonality is measured (over 90% is near perfect).
- Change to page 3 and 4 (5.1.9.3) and set up the guiding parameters for the axes as advised.
- Change to page 1 (5.1.9.1) and start the autoguiding!

Soon the first correction signals will be indicated by the red LEDs as short or longer flashes. By monitoring these signals You can trace what the guider is doing. If Your mount has some typical errors (as mine has) those can be observed easily by watching

the LEDs. If these LEDs are flashing sometimes (“rarely”), the autoguiding is working well. You may discover (and keep off) many symptoms, like:

- o Oscillation. The LEDs in the opposite directions (along one axis) will flash alternating left-right-left-.. and so on for example.
- o Backlash, stucked gears or ST-4 cable contact error: one LED flashes almost constantly in one directon and it never ends.
- o Etc.

## 7 Error codes

In some cases there are error codes generated in the device. These may not be fully interpreted yet in the current Firmware and displayed as a text but the error codes are. These are the following with a short description of the cause:

|                                             |                                                                                                                                                                                                                  |
|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ERR type: c0</b><br><b>CAM error: 40</b> | <b>Indicates Camera error</b><br><b>DC input power is too low or missing for the HC</b><br>(some below 9V)                                                                                                       |
| <b>CAM error: 01</b>                        | <b>Some analog supply for the Camera is too low</b><br>(failure in the power supply unit of the HC or in the Camera)                                                                                             |
| <b>CAM error: 02</b>                        | <b>Some analog supply for the Camera went critical</b><br>(too low or high: failure in the power supply unit of the HC)                                                                                          |
| <b>CAM error: 03</b>                        | <b>Camera is not connected with the cable</b><br>(Camera-cable contact error or not connected)                                                                                                                   |
| <b>CAM error: 04</b>                        | <b>Other Camera-connection error</b><br>(Camera-cable or Camera failure)                                                                                                                                         |
| <b>CAM error: 05</b>                        | <b>Initializing communication with the Camera failed</b><br>(Camera is not working properly or is in bad mode)                                                                                                   |
| <b>CAM error: 06</b>                        | <b>Connection lost with Camera...</b><br>(unknown error, the Camera is stopped somehow suddenly)                                                                                                                 |
| <b>CAM error: 07</b>                        | <b>Firmware version mismatch (HC and Camera)</b><br>(Camera has an other version of Firmware program than the HC needs.<br>The Camera can't be used.)                                                            |
| <b>ERR type: 90</b>                         | <b>Timeout during calibration</b><br>(communication was interrupted somehow with Camera)                                                                                                                         |
| <b>ERR type: 51</b>                         | <b>"Star lost" error</b><br>(The star was lost during a procedure. (because of clouds or wind blow))                                                                                                             |
| <b>ERR type: 82</b><br><b>ERR type: 81</b>  | <b>Calibration interrupted by the user</b><br><b>Coarse position error during calibration</b><br>(if the position is way too off from the expected. Badly set guider parameters<br>(focal length and AG speeds)) |
| <b>ERR type: 83</b>                         | <b>Orientation is inadequate during calibration</b>                                                                                                                                                              |

## 8 Planned developments

The Firmware for the device is continuously developed. There are planned functions that are not implemented yet so are missing from the current Firmware. The 'direction' of the development is influenced by the feedbacks from the users and the testers.

Currently the following (useful) functions are planned to implementation (not all listed)

- Besides the guiding drifts every other events to be logged into the open file. For a more readable statistics of the night(s).
- Automatic image processing at Guiding. Some variables like "threshold" will be automatized to free the user from taking care about them. (The option for manual setting will be held.)  
A new method for following and determining the star's position. Close, bright stars will not affect the evaluation of the followed guiding star. Along with this the real guiding image window size will be increased to follow the star more accurate, to lose it less probably.
- New guiding method, optionally selectable, a smarter method that considers the mount's theoretical reaction and its movements made for the previous autoguider signals. So it compensates (predicts) many things in the system and lowers the chance to parametrize an axis causing oscillation.
- Advanced Star Search function that makes automatic imaging parametrization after the search and chooses the most useful star in the field. May offer an 'optimal' guiding parameter setting (in each axes) for the selected star.
- Extending the Calibration function: separate window displaying the current calibration. It allows to calibrate only for the correction speeds to save time (if the Camera is not rotated).  
Optionally orthogonalization of the resulting direction vectors. If these result far from optimal every time, orthogonalization might help the 'wrong' calibration data to be much more useful.
- More user-friendly interface: all errors handled and displayed as a text, easier navigation between the main control screens and more comfortable parameter value editing.
- Optional power-saving modes implemented. Currently there are no such modes working in the Firmware but the dissipated power is not too high. (In cold it works as an anti-dew function.) Power-saving may reduce the required power noticeably.