Scopedog

with eFinder

Advanced Alt-Az 'GoTo++' Telescope drive and tracking system

User Manual

mk3_6eF Version

Manual contents

System Description

ScopeDog is an add-on drive kit for Dobsonian or AltAz telescopes

The ScopeDog mk3 system includes,

- High resolution optical encoders on each axis
- Encoder interface box & WiFi access point (Nexus DSC Pro[1])
- Stepper motor drives engaging through a gearbox and toothed belt
- ScopeDog Control Box
- CMOS camera and 50mm lens
- Hand-box
- Cables

An additional user interface is via a pc, tablet or smartphone running SkySafari or an equivalent planetarium software[2]. This device connects to ScopeDog via WiFi managed by the Nexus DSC Pro unit.

The ScopeDog system utilizes the Nexus DSC Pro to drive the optical encoders, perform initial two-star alignment, and calculate scope RA & Dec. These functions are independent of the rest of the ScopeDog system and can be used stand alone as a “push-to” configuration.

In full servo mode the ScopeDog controller receives telescope RA & Dec from the Nexus DSC Pro and calculates and applies the appropriate Alt & Az tracking rates. The drive is accomplished by micro-stepping stepper motors with integral planetary gearboxes. These engage through a final drive to the telescope via a toothed belt and pinion.

GoTo commands from the planetarium software are transferred by the Nexus DSC Pro to the ScopeDog controller, which converts the commanded RA & Dec to AltAz coordinates and drives the telescope to the required position through a cycle of acceleration, fast slew and deceleration. At the end of the first slew operation the controller checks the accuracy of the achieved position and if necessary, makes further small slew motions. The Nexus DSC Pro can also initiate a GoTo directly.

If no Nexus DSC is found on start-up, the Lite version of ScopeDog will start. (mk3ef ver 3_16_5 or later)

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[1] Original Nexus DSC is also supported

[2] Currently supported Apps and programs are all those that support LX200 mount connection protocol. These include SkySafari (Plus & Pro), Starry Night, Cartes du Ciel, TheSky, AstroPlanner. Not all have been tested in practice.

The ScopeDog hand-box includes a joystick to allow the telescope to be manually controlled. The hand-box provides three speeds of movement in any direction. The slowest speed direction is normally reversed in azimuth to match the view in the eyepiece. The hand-box has a long cable and can be handheld or attached near the eyepiece. The hand-box connects via standard USB cable allowing its length to be readily changed.

The stepper motor drive modules use adjustable current power control to maximize battery life while providing sufficient torque for any telescope size.

Two telescope configurations can be setup, with a simple switch selection at power up.

The mk3 ScopeDog differs from previous versions by the optional addition of eFinder. Images from a camera are plate-solved to derive the absolute position of the telescope so as refine the alignment, pointing and tracking.

Installing and Connecting ScopeDog

Do not plug or unplug the drive motors with ScopeDog powered. Damage may occur to the servo cards.

All components should be installed where they are protected from knocks and direct rain or dew. The ScopeDog system can be configured to suit most installations, if in doubt please contact scopedog@astrokeith.com . Final system performance depends on the accuracy with which the encoders and drive components are installed.

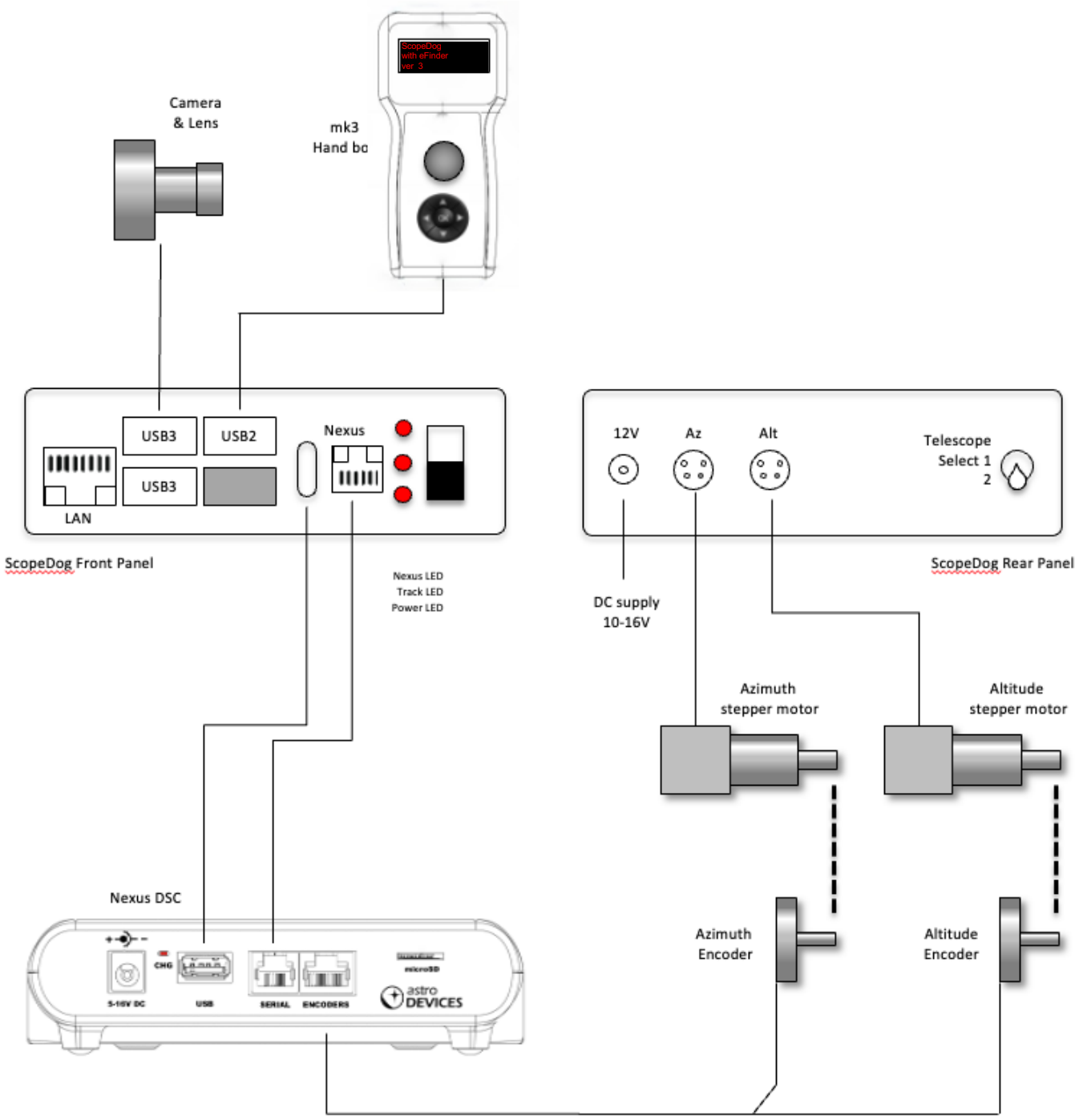
The diagram opposite illustrates how the ScopeDog components are interconnected. The power supply cable and motor drive cables should be kept as short as practical.

The hand box may be plugged into any available[3] USB port. The supplied cable may be changed for an alternative length by removing the back cover of the hand box.

The camera can be mounted via a suitable finder shoe and bracket. The camera needs to have a clear 6° field of view. It should be plugged into one of the USB 3 ports[3] (blue inserts) for optimum performance using a USB3 cable.

[3] Do not attempt to use the lower USB socket furthest from the LAN socket. This is reserved for internal connections.

ScopeDog mk3 System Interconnections



Adjusting the camera lens

The camera aperture should be set to maximum. Using either the eFinder GUI application on an attached pc or tablet, or ASICAP (download from the ZWO ASI website), adjust the lens focus to achieve sharpest image. Use locking screws on the lens to fix the aperture and focus positions.

Parameter setup

ScopeDog needs to have a number of mount and user preference parameters set before use. This is described on page 13.

The eFinder function also has some parameters which are pre-set, but these can be adjusted via the handset.

Initialisation

Select via the back panel switch, the telescope configuration, 1 or 2.

Turn on the Nexus DSC Pro and if it hasn't been used for a while, wait for it to get a gps lock. Then turn on the ScopeDog control box. If required, connect your controlling device (tablet, pc, etc) to the Nexus DSC via WiFi.

If no camera is connected, ScopeDog will function as a conventional drive without any plate-solving features.

Calibrate offset
ScopeDog mk3 includes a semi-automatic routine to measure, save and use the offset between the eFinder camera and the main scope sightline.

Navigate to the 'OK Offset star' menu screen. The current offset values are displayed, in arc minutes.
Accurately point the main scope at a bright star, ideally Polaris. Use a reticule eyepiece if possible. If required the scope drive can be disabled for this alignment using the option on the Tracking Rate Screen.
Enter 'OK' on the handset. An image is captured and the brightest star identified. Its name is displayed along with the offset in arc minutes. You just need to check the star name is the one you expected. The offset value is saved and used for all subsequent actions. It is overwritten if the calibration is repeated, or the 'Reset' option is used.

Having completed offset calibration, whenever the eFinder takes and solves an image, the reported RA & Dec is that of the main scope sightline, and not the eFinder image centre. However, this will be affected by any flex in the telescope OTA or its components, eg secondary mirror holder.

Note: the offset is *'dx,dy'* in arc minutes which relates directly to the image seen in the eyepiece. *dy* is equal to altitude angle, but *dx* is not the same as azimuth. As the apparent value of an azimuth angle decreases with altitude (becomes zero at the zenith) it is more convenient to use *dx*.

Initial 2-star alignment

Next step is to complete a 2-star alignment with the Nexus DSC. There are three ways of doing this. The third is unique to ScopeDog mk3 and provides the most convenient and accurate method.

1. Use Nexus DSC Pro standalone. As described in the Nexus DSC Pro manual.
2. Use SkySafari. The Nexus DSC Pro will take the first two alignment commands it receives from an external device as if they were the first two alignment stars. Thereafter they are taken as Local Sync points. Thus point the main scope accurately at an object, select that object on the SkySafari display, and then select 'align'. repeat for a second object, with a good separation in azimuth.
3. Use the eFinder. Navigate to the 'OK Align' menu screen. The page should be showing 'Nexus not aligned' and 'ANO'[4]. Point the main scope at a clear region of sky at around 45° altitude. Enter 'OK'. The eFinder images, plate solves and sends the main telescope position to the Nexus DSC Pro, as if it was 'virtual star'. Repeat on a second clear part of sky, with a good separation in azimuth. The display should now show the top line as 'OK Syncs' and AT2[5] as the Nexus report.

When both alignments have been completed the ScopeDog control box will automatically start to read the scope RA & Dec and the motors will be driven at tracking rate. (remember to turn drives back on if disabled for offset measurement)

The front panel of ScopeDog has three LEDs to indicate status;

Power	Steady when power switched on
Serial	Flashes at 2Hz as ScopeDog & Nexus communicate
Tracking	Pulses at 1Hz when ScopeDog program is tracking

If not already done, open SkySafari (or equivalent) and connect to the telescope. The display should now correctly depict the position of the telescope sightline.

[4] ANO = AltAz mode, Not tracking (ie not aligned yet)
[5] AT2 = AltAz mode, Tracking, 2 star aligned.

Observing

Joystick Control

The hand-box has a light-touch joystick that allows the scope to be driven manually at a choice of three speeds. The Planetarium software display will continually update to show the current position of the telescope.

Speed: The current speed is always shown at the bottom right corner of the handpad display. The speed is changed by pressing the joystick paddle to sequence through the range:

	Speed
1	Slow, normally used when looking through the eyepiece for small corrections
2	Medium
3	Fast Slew

The drive speeds can be specified via the ScopeDog configuration page, described on page 13 of this manual. The maximum slew speed is first set for both axes. This setting is used for GoTo and joystick Fast Slew. The medium and slow joystick speeds are then set as a fraction of the fast speed. The choice of fast slew speed will largely depend on telescope mount dynamics, whilst the medium and slow speeds will be down to personal preference when observing.

Direction: Move the joystick in any direction, including a combination of both axes and the motors will be commanded accordingly.

It is usual for fast and medium speeds to set the joystick direction such that pushing the joystick left, moves the scope left. For slow speed, it is recommended to reverse the azimuth direction so as to make scope movement more intuitive whilst looking at an object in the eyepiece. Joystick direction for each axis and speed can be set via the scopedog.config file. See page 13.

ScopeDog will also respond to the telescope move buttons on SkySafari. The SkySafari rate select will change the slew speed.

Solve & Local Sync Control

From almost any screen, a short ‘OK’ will trigger an image capture and plate-solve at the current telescope position. If successful the display will show the delta in arc minutes dx,dy, between solution and the Nexus DSC readout. The ‘Sol’ screen shows the actual RA & Dec from the plate-solve.

From the ‘OK Syncs’ screen, a short OK will trigger the same capture and solve process except that this time the Nexus DSC will sent the solution and a Nexus DSC Local Sync requested. Thus the Nexus DSC is synced to true sky RA & Dec (valid for 10 degrees around the sync point). Note that if GoTo++ is enabled, this Local

Sync is automatically executed at the end of the first goto iteration, and is then followed by the GoTo++ refinement, (see GoTo Control section below).

From the ‘OK Syncs’ screen, a long OK will trigger the same capture and solve process except that this time the Nexus DSC will sent the solution as a new Target. This could be used by the observer if an interesting object is found, its position saved as a target, which would then cause a GoTo to return to that object.

GoTo Control

For SkySafari (similar functions apply in other planetarium programs), any object in the display may be highlighted and then the 'GoTo' command engaged. This command may also be done from the object search result.

A ‘GoTo’ command can also be initiated from the Nexus DSC Pro once an object has been recalled from an installed catalogue. On the Nexus DSC Pro press 'OK', twice. To stop the GoTo, press 'OK', then '9'.

ScopeDog will then calculate the required change of telescope position, smoothly accelerate the drives up to the fast slew speed, and decelerate as the computed target nears. When the first slew has been completed, ScopeDog reads the encoders (via the Nexus DSC Pro) to compare against the intended target. If necessary another small slew is performed to close any gap. This is repeated automatically until the target position (as measured by the encoders) is reached.

In normal use, a GoTo command should result in the target object being found in a wide field of view eyepiece. However, a number of factors strongly affect GoTo performance - mount stability, mount accuracy and initial alignment accuracy.

If at the 'Home' screen on the ScopeDog handset, a long press of 'OK' will repeat the last GoTo, whether it was Nexus DSC Pro or SkySafari initiated.

A GoTo can be stopped from the Nexus DSC Pro or SkySafari as appropriate, but also during a GoTo by pressing the joystick paddle (as if changing speed). This will decelerate the motion to a fairly rapid stop. A useful emergency stop facility to avoid collisions.

ScopeDog mk3 with eFinder has a GoTo++ feature. After completion of a conventional GoTo, the 'OK' button can be given a longer press. This causes the eFinder to image, plate-solve, local sync the Nexus DSC and command a repeat of the GoTo. Since the scope was very close to the target, this process effectively cancels out any encoder or mount errors. After completing this GoTo++ another image and plate-solve is automatically done and the distance (delta) between main

scope and target displayed in arc minutes. Depending on the telescope drive backlash, this delta should be around 1 arc minute or less. Note: this is the actual distance between the main telescope sightline and the target, not one inferred from encoders etc.

The GoTo++ action can be set to be undertaken automatically at the end of any GoTo.

This GoTo++ long press action is available from any menu screen page, except the home, align/local sync, offset calibration and reset. On the 'home' screen page, a long press causes a repeat of the last normal GoTo, without the GoTo++ enhancements. This can be useful to re-acquire a target having used the joystick to move the scope around.

During a GoTo, the hand pad displays the distance to be travelled during each iteration. At the end of GoTo, and GoTo++ if selected, the final distance from the intended target is displayed for 2 seconds.

eFinder plate-solver

From any menu screen, except align/local sync, offset calibration and reset, a short press of the 'OK' button will command an image, plate-solve and display of current absolute telescope position.

Hand pad display brightness

The OLED display will initially show at full brightness. This is convenient for setting up under any lighting conditions.

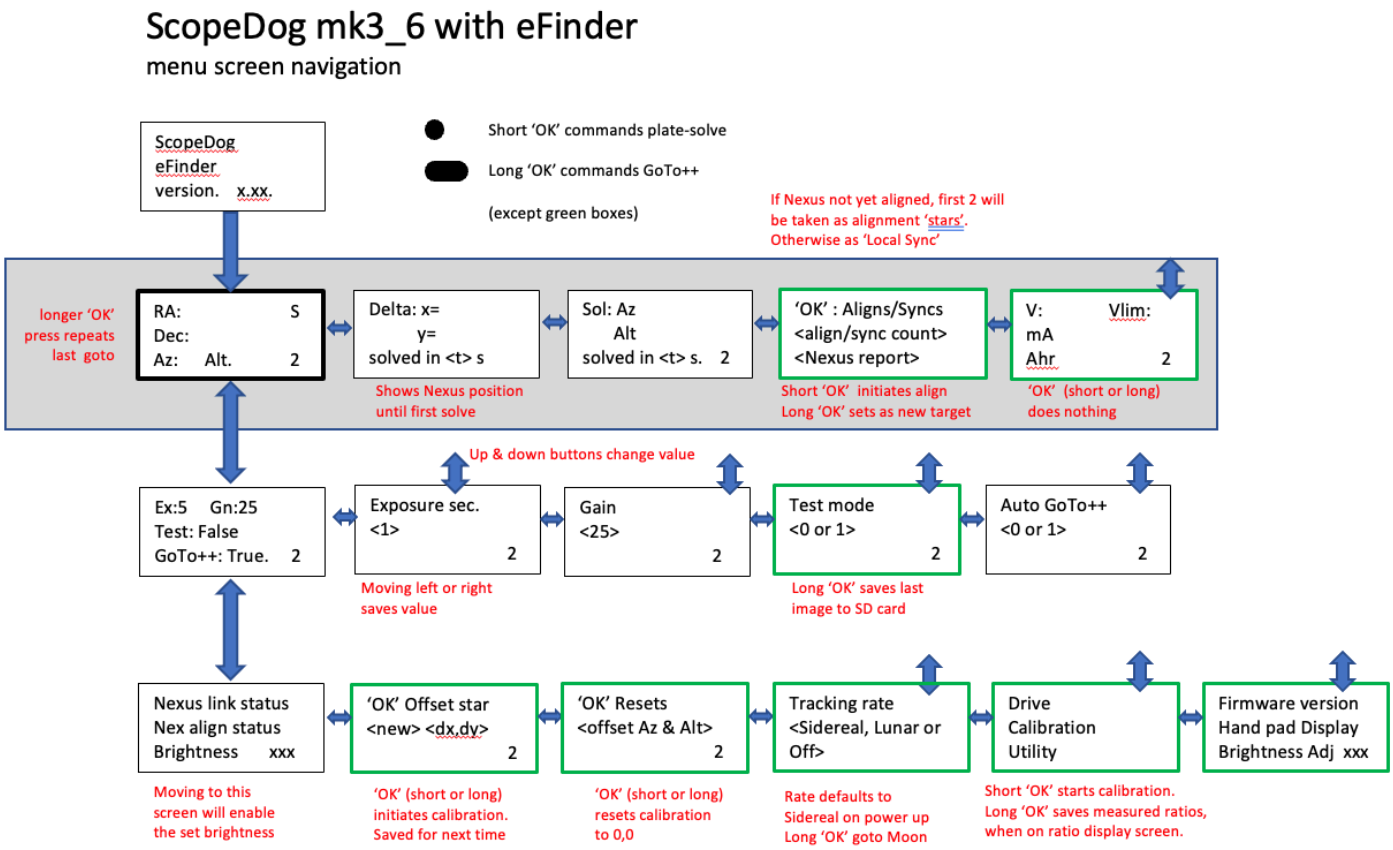
An 'observing' brightness level can be set. This level is implemented when the status screen is first displayed (two 🡻🡻 presses from the home screen). This lower level is pre-set using the Hand pad Display Adj screen.

Power Supply Monitor

If the power monitor hardware (INA260) has been installed, this screen displays the input voltage, current being drawn and power used since last power up. A minimum voltage limit can be set (up and down arrows) which will trigger a warning in all screens if the input voltage falls below the set value. This value is saved for future sessions.

The display is uodated every second and the current being drawn will be seen to vary a little. This is due to the ScopeDog unit drawing varying power as it cycles through various loops. The power used is displayed as Ah (amp hours) and gives an indication of how much battery capacity maybe remaining.

eFinder screen navigation



notes on the screens:

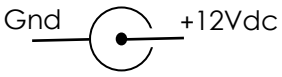
Main screens within grey frame

- The Home screen (Bold outline box above) display of RA, Dec, Az & Altitude is read from the Nexus DSC.
  Upper right corner is an 'S' for Sidereal or 'L' for Lunar tracking rate
- The Delta display is the difference between a solved image and the Nexus DSC derived position. Positive x means scope is to the right of Nexus, positive y means scope is above Nexus.
- After initial alignment, the 'OK' Align action will perform a local sync and cause the Nexus DSC position to be the same as the solved position.

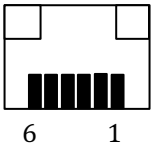
Delta and Offset numbers are in arc minutes. Offset is *'dx,dy'* (equivalent to 'delta x, delta y'). Delta y is the same as a delta altitude.
Delta x is the horizontal delta as would be seen in the eyepiece. ie it is
delta x = delta azimuth * cos(scope altitude)

Most screens show the slew speed in the bottom right corner.
1 = Slow, 2 = Medium, 3 = Fast

Connections

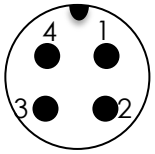


Nexus Serial port
socket view



1	Gnd
2	Serial Rx
3	Serial Tx
4	Gnd
5	Gnd
6	Not connected

Motor
socket view



Pin	Motor wire
1	Black
2	Green
3	Red
4	Blue

Specification

Encoder Resolution	>=10,000	will depend on encoders selected
Drive Speeds	Fast	Up to 6 deg/sec depending on telescope size and mount
	Medium	typically 1/3 of fast (user adjustable)
	Slow	typically 1/40 of medium (user adjustable)
Drive resolution steps	typically less than 1 arcsec, depending on final output drive ratio.	
eFinder accuracy	Typically 15 arc sec	
Power supply	10.5 -16 Vdc	
Power consumption	Typically 7-10W depending on scope size	
Motor Torque (max)	30kg-cm continuous, 80kg-cm for short periods	

Configuration Setup

Nexus DSC

The Nexus website (www.astrodevices.com/Downloads) has guides for checking the settings on the Nexus unit. Note that the Nexus DSC serial comms protocol is set to ScopeDog,19200,1,8,None and the USB protocol is set to LX200, 9600,1,8,None. If connecting ScopeDog via Wifi (ie no USB cable) set wifi protocol to LX200, 4060,JNow.

In the Align setup menu, ensure '2 star w/o Alt ref' is selected.

Ensure the latest firmware is installed on the Nexus DSC. (later than 1.1.14 for Nexus DSC and later than 1.1.20 for the Nexus DSC Pro)

ScopeDog

Access to ScopeDog configuration data is via wifi or LAN. These are the two methods.

Wifi

1. Wifi: Turn on ScopeDog which will generate its own wifi hotspot. Using your device, connect to the hotspot, SSID is scopedog, password ‘scopedog’. LAN: Use an Ethernet cable to connect ScopeDog unit to an existing LAN.
2. Open a browser on the device and enter scopedogmk3.local as the target address.
3. The configuration page will be similar as shown on the page 15 of this manual. Two sets of data will be shown, one for each telescope option.
4. Make a note of the current parameters before making any changes!
5. *Autostart* must be left at True for the ScopeDog to start at power up. If False, the code will exit allowing manual starting from the command line.
6. After making changes, save them using the button at the bottom of the page.
7. Changes take affect after a re-start.

Drive Calibration Utility

Under a clear sky perform the standard offset caliibration and 2-star alignment. Then position the scope pointing approximately due South and at 45 deg altitude. From the Drive Calibration Utility screen, a short OK will trigger a specific measurement routine. First the drives will make a small movement to take up backlash, then follows a plate-solve to measure true telescope position. Then a large scope movement (+30° Az, +15° Alt) is executed finishing with another plate-solve. Finally the scope is driven back (-30° Az, -15° Alt) and another plate-solve.

The ScopeDog processes the measurements and displays (use up and down

arrows), measured axes gear ratios, axes drive backlash and Nexus error.

A long OK whilst on the Gear Ratio screen will save the new values to the scopedog.config file.

ScopeDog System Access

It is possible to login to the ScopeDog operating system via Wifi or LAN. This is only recommended for expert users and requires some familiarity with the Raspberry Pi Debian operating System and Linux.

Computer hostname is: scopedogmk3
Username is: scopedog
password is: scopedog

eFinder

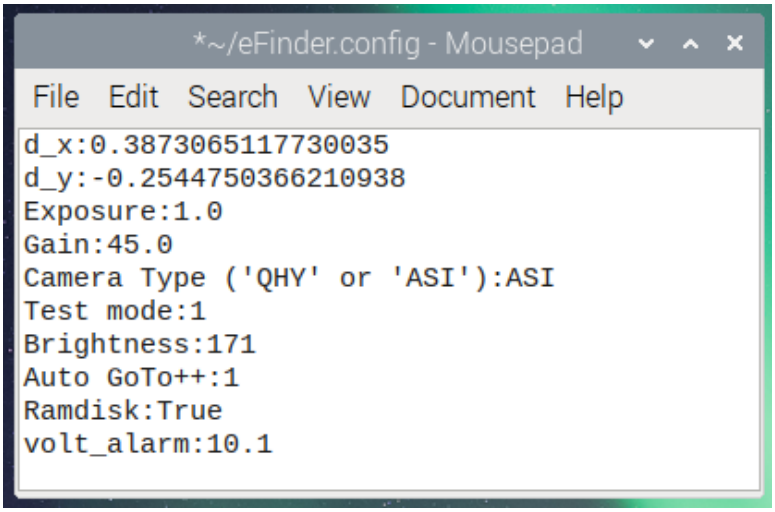
Access the eFinder set up summary menu page screen, (one 🡻press from the home screen). This will show current set exposure time (seconds), camera gain, test mode status, and GoTo++ status. Navigating 🡺 will access each of these 4 parameters in turn. At each one, the 🡹 and 🡻 buttons will change the value. Leaving that screen saves the value.

A map of the menu screens is shown on page 11. Once initial alignment is complete, the observer will generally just use the screens within the horizontal grey frame.

If test mode is set to '1', then the plate-solver either uses a pre-saved image of M31 instead of taking a camera image, or in offset calibration it uses a pre-saved image of Polaris. This provided a useful check of eFinder operation. A camera still needs to be connected however.

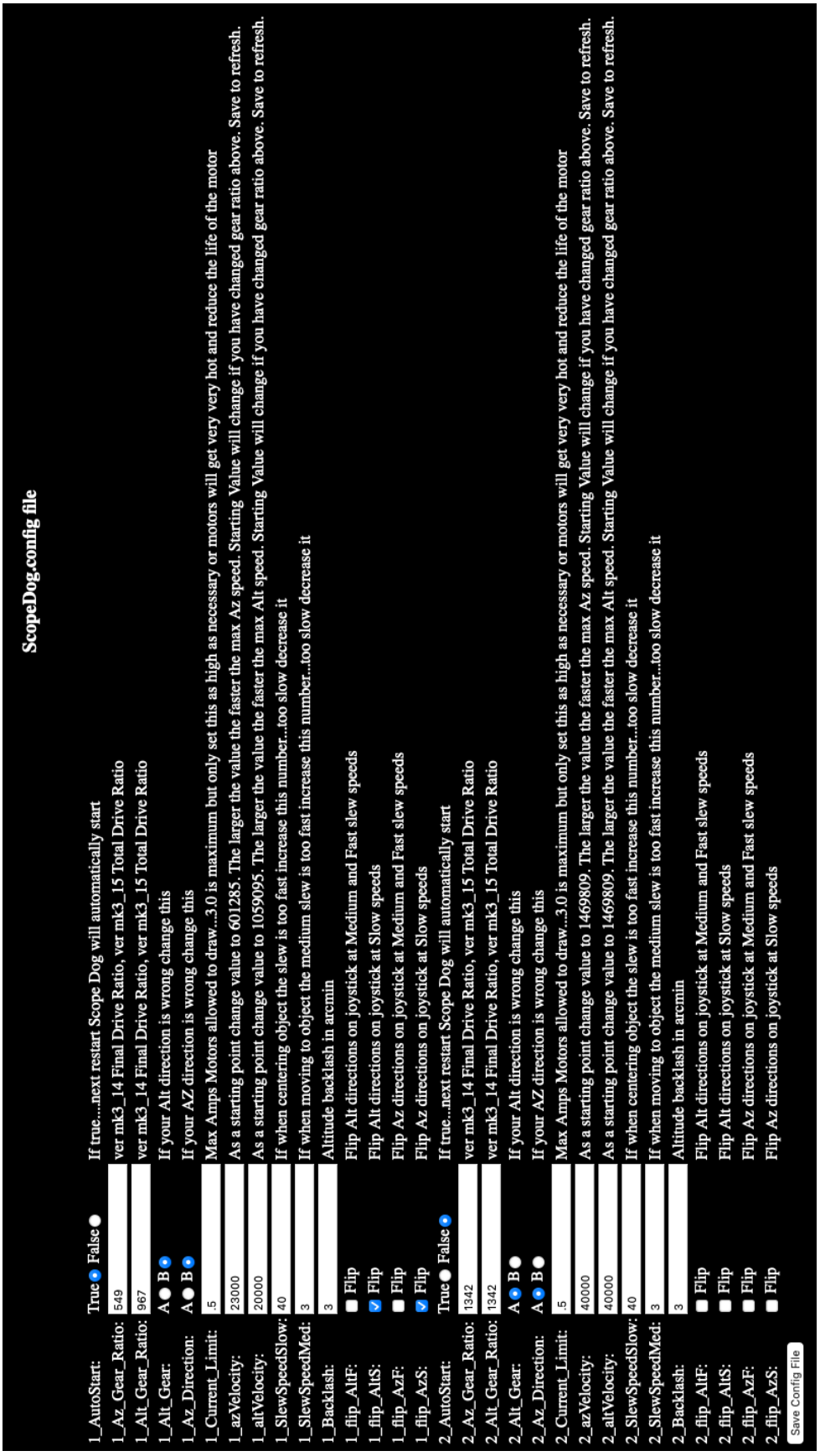
If Auto GoTo++ is set to '1', then after a normal GoTo, the system will automatically attempt a GoTo++ action, without user intervention.

There is a efinder.config file that contains eFinder parameters. Most of these can be changed from the hand box and will then be saved. d_x & d_y are the current saved offset calibration values in degrees.
Camera Type and Ramdisk are set at initial installation using a text editor tool.



ScopeDog Configuration Setup

Example screen, actual values will vary according to the installation.



Copy of User ScopeDog Parameters

Scope1	
Az gear ratio	
Alt gear ratio	
Alt Gear	
Az direction	
Current Limit	
Az velocity	
Alt velocity	
Backlash	
Slow slew speed	
Medium slew speed	
flip altitude fast & medium slew	
flip altitude slow slew	
flip azimuth fast & medium slew	
flip azimuth slow slew	
Scope2	
Az gear ratio	
Alt gear ratio	
Alt Gear	
Az direction	
Current Limit	
Az velocity	
Alt velocity	
Backlash	
Slow slew speed	
Medium slew speed	
flip altitude fast & medium slew	
flip altitude slow slew	
flip azimuth fast & medium slew	
flip azimuth slow slew	