G0 and G1 CCD Camera

Operating Manual

moravian instruments

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Introduction

Thank you for choosing the Moravian Instruments CCD camera. These cameras were developed to be small, lightweight and easily operated. Despite their compactness and simplicity, they are very sensitive for use in low-light imaging applications in astronomy, microscopy and similar areas.

G0 and G1 cameras digitize image with 16 bit precision to fully exploit CCD chip dynamic range. Still the pixel digitization rate reaches 8 Mpx/s in fast read mode – downloading of image containing hundreds thousands pixels takes only a small fraction of a second. Slow read mode on the other hand ensures very low read noise, approaching the read noise limit of the CCD chip itself, and still provides more than 2.5 Mpx/s digitization speed.

Also important design goal of G0 and G1 cameras was USB-powered operation. Camera is attached to the host computer only via single USB cable, which provides both camera-to-host communication and camera power. No separate power supply is used with G1 cameras.

Both G0 and G1 series of CCD cameras provide also the RJ-12 connector beside the USB-B connector, which allows direct connection of the camera head and the telescope mount equipped with the standard “autoguider” port. This connector (together with other camera features like very fast download, compact and lightweight construction, USB powered operation etc.) makes using of these cameras for guiding of telescope mount very simple. Using of G0 or G1 CCD for guiding is described later in this manual.

Simplicity, compactness and quick image download took precedence to some other features, so G0 and G1 series of CCD cameras lack mechanical shutter and filter wheel. Also power provided by USB cable is not sufficient for power-hungry thermoelectric (Peltier) coolers. This is why the CCD chip in these cameras cannot be cooled below ambient temperature. However, G1 cameras employ a small fan, which forces air flow inside the camera head and removes the heat generated by camera electronics. The CCD temperature can be lowered by many degrees Celsius compared to sealed designs, which results to lowering of CCD thermal noise by a factor of two or more.

Please note the G0 and G1 CCD cameras are designed to work in cooperation with a host Personal Computer (PC). Computer is necessary for operation control, image download, processing and storage as well as for guiding. To operate G0 or G1 CCD camera, you need a computer which:

1. Is compatible with a PC standard.

2. Runs a modern 32 or 64-bit Windows operating system.

   Drivers for 32-bit and 64-bit Linux systems are also provided, but camera control and image processing software, supplied with the camera, requires Windows operating system.

3. Provides at last one free USB port.

   The G0 and G1 CCD cameras are designed to operate with USB 2.0 high-speed (480 Mbps) hosts. Although they are fully backward compatible with USB 1.1 full-speed (12 Mbps) hosts, image download time can be significantly longer if USB 1.1 connection is used.

   A simple and cheap device called USB hub can expand number of available USB port. Typical USB hub occupies one computer USB port and offers four free ports. Make sure the USB hub is USB 2.0 high-speed compatible.

   But keep on mind that if more USB devices connected to one hub need to communicate with a host PC, USB hub shares its single up-link line to the host PC. Although G0 and G1 CCD cameras can operate through a USB hub, it can negatively affect the camera performance, like download time etc. It is recommended to connect other USB devices through USB hub (e.g. the mouse) and to provide the camera a direct USB connection to the host PC.

   Also note the G0 and G1 cameras are powered from the host PC through the USB cable. Unpowered USB hub may not provide enough current to operate the camera. Always use USB hub with its own power supply to connect the camera. G0 and G1 camera power considerations are described later.

4. Alternatively it is possible to use the Gx Camera Ethernet Adapter. This device can connect up to four Gx cameras of any type (not only G0 and G1, but also G2, G3 and G4) and offers 1 Gbps and 10/100 Mbps Ethernet interface for direct connection to the host

PC. Because the PC then uses TCP/IP protocol to communicate with the cameras, it is possible to insert e.g. WiFi bridge or other networking device to the communication path.

The G0 or G1 CCD camera must be connected to some optical system (e.g. the telescope) to capture images.

G1 cameras are equipped with CS-thread adapter, which allows usage of CCTV lens with C/CS thread with the camera (it is necessary to use 5 mm distance ring for C-mount lenses). Adapter for 1.25” telescope focuser is screwed into the CS-thread adapter adapter.

G0 cameras are designed to be attached to the 1.25” telescope focuser only and CCTV lenses cannot be directly used.

Camera Technical Specifications

The G0 series of CCD cameras comprises of the following models:

Model	**G0-0300**	**G0-0300C**	**G0-0800**	**G0-0800C**
CCD chip	ICX424AL	ICX424AQ	ICX204AL	ICX204AK
Resolution	656×494	656×494	1032×778	1032×778
Pixel size	7.4×7.4 μm	7.4×7.4 μm	4.65×4.65 μm	4.65×4.65 μm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.9×3.7 mm	4.9×3.7 mm	4.8×3.6 mm	4.8×3.6 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	**G0-2000**	**G0-2000C**
CCD chip	ICX274AL	ICX274AQ
Resolution	1628×1236	1628×1236
Pixel size	4.4×4.4 μm	4.4×4.4 μm
Read mode	Progressive	Progressive
Dimension	7.2×5.4 mm	7.2×5.4 mm
Color mask	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0

The G1 series of CCD cameras comprises of the following models:

Model	**G1-0300**	**G1-0300C**	**G1-0301**	**G1-0301C**
CCD chip	ICX424AL	ICX424AQ	ICX414AL	ICX414AQ
Resolution	656×494	656×494	656×494	656×494
Pixel size	7.4×7.4 μm	7.4×7.4 μm	9.9×9.9 μm	9.9×9.9 μm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.9×3.7 mm	4.9×3.7 mm	6.5×4.9 mm	6.5×4.9 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	**G1-0800**	**G1-0800C**	**G1-1200**	**G1-1200C**
CCD chip	ICX204AL	ICX204AK	ICX445ALA	ICX445AQA
Resolution	1032×778	1032×778	1296×966	1296×966
Pixel size	4.65×4.65 μm	4.65×4.65 μm	3.75×3.75 μm	3.75×3.75 μm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.8×3.6 mm	4.8×3.6 mm	4.9×3.6 mm	4.9×3.6 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	G1-1400	G1-1400C	G1-2000	G1-2000C
CCD chip	ICX285AL	ICX285AQ	ICX274AL	ICX274AQ
Resolution	1392×1040	1392×1040	1628×1236	1628×1236
Pixel size	6.45×6.45 μm	6.45×6.45 μm	4.4×4.4 μm	4.4×4.4 μm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	9.0×6.7 mm	9.0×6.7 mm	7.2×5.4 mm	7.2×5.4 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

CCD Chip

Sensitivity is an important feature of any CCD camera, no matter if it is used as an imaging camera or automatic guider. Imaging camera must not waste light gathered by the optical system to provide images with as good signal/noise ratio as possible. Achieving of sufficient S/N ratio in rather short time is also important to allow perfect guiding – the necessity to accumulate light for many minutes is often unacceptable for high quality guider. This is why the G1 cameras utilize sensitive Sony CCDs.

- The CCD quantum efficiency exceeds 50%.
- The CCD read noise is very low and reaches 5 to 10 electrons RMS.
- G1 cameras support 16-bit digitization, significantly enhancing the dynamic range compared to 8-bit cameras.
- Strong anti-blooming protection keeps even bright stars round, without blooming streaks.
- G1 cameras also provide very fas readout – pixel digitization speed is 8 Mpx/s in fast read mode.

Model G0-0300 and G1-0300

G0/G1-0300 model uses progressive-scan VGA (640×480 pixels) Sony ICX424AL CCD chip.

Resolution	656 × 494 pixels
Pixel size	7.4 × 7.4 µm
Imaging area	4.9 × 3.7 mm
Color mask	Not present

Model G0-0300C and G1-0300C

G0/G1-0300C model uses progressive-scan VGA (640×480 pixels) Sony ICX424AQ CCD chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	656 × 494 pixels
Pixel size	7.4 × 7.4 µm
Imaging area	4.9 × 3.7 mm
Color mask	RGBG (Bayer mask)

Model G1-0301

G0/G1-0300 model uses progressive-scan VGA (640×480 pixels) Sony ICX424AL CCD chip.

Resolution	656 × 494 pixels
Pixel size	9.9×9.9 µm
Imaging area	6.5×4.9 mm
Color mask	Not present

Model G1-0301C

G0/G1-0300C model uses progressive-scan VGA (640×480 pixels) Sony ICX424AQ CCD chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	656 × 494 pixels
Pixel size	9.9×9.9 µm
Imaging area	6.5×4.9 mm
Color mask	RGBG (Bayer mask)

Model G0-0800 and G1-0800

G0/G1-0800 model uses progressive-scan XGA (1024×768 pixels) Sony ICX204AL CCD chip.

Resolution	1032 × 778 pixels
Pixel size	4.65 × 4.65 μm
Imaging area	4.8 × 3.6 mm
Color mask	Not present

Model G0-0800C and G1-0800C

G0/G1-0800C uses progressive-scan XGA (1024×768 pixels) Sony Super HAD ICX204AK chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	1032 × 778 pixels
Pixel size	4.65 × 4.65 μm
Imaging area	4.8 × 3.6 mm
Color mask	RGBG (Bayer mask)

Model G0-2000 and G1-2000

G0/G1-2000 model uses progressive-scan UXGA (1600×1200 pixels) Sony ICX274AL CCD chip.

Resolution	1628 × 1236 pixels
Pixel size	4.4 × 4.4 μm
Imaging area	7.2 × 5.4 mm
Color mask	Not present

Model G0-2000C and G1-2000C

G0/G1-2000C uses progressive-scan UXGA (1600×1200 pixels) Sony Super HAD ICX274AQ chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	1628 × 1236 pixels

Pixel size	4.4 × 4.4 μm
Imaging area	7.2 × 5.4 mm
Color mask	RGBG (Bayer mask)

Model G1-1200

G1-1200 model uses progressive-scan HD (1280×960 pixels) Sony ICX445ALA chip. The ICX445 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in red and near infra-red portion of the spectrum. Also absolute quantum efficiency of this CCD chip very high, comparable to ICX285 based models.

Resolution	1296 × 966 pixels
Pixel size	3.75 × 3.75 μm
Imaging area	4.9 × 3.6 mm
Color mask	Not present

Model G1-1200C

G1-1200C model uses progressive-scan HD (1280×960 pixels) Sony ICX445AQA chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure. The ICX445 detector is manufactured using so-called ExView HAD technology with absolute absolute quantum efficiency comparable to ICX285 based models.

Resolution	1296 × 966 pixels
Pixel size	3.75 × 3.75 μm
Imaging area	4.9 × 3.6 mm
Color mask	RGBG (Bayer mask)

Model G1-1400

G1-1400 model uses progressive-scan SXGA (1280×1024 pixels) Sony ICX285AL chip. The ICX285 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in red and near infra-red portion of the spectrum. Also absolute quantum efficiency of this CCD chip is highest from all detectors used in other G1 camera models.

Resolution	1392 × 1040 pixels
Pixel size	6.45 × 6.45 μm
Imaging area	9.0 × 6.7 mm
Color mask	Not present

Model G1-1400C

G1-1400C model uses progressive-scan SXGA (1280×1024 pixels) Sony ICX285AQ chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure. The ICX285 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in read and near infra-red portion of the spectrum.

Resolution	1392 × 1040 pixels
Pixel size	6.45 × 6.45 μm
Imaging area	9.0 × 6.7 mm
Color mask	RGBG (Bayer mask)

Camera Electronics

16-bit A/D converter with correlated double sampling ensures high dynamic range, in fact exceeding the pixel well capacity of the used CCD. Fast USB interface ensures image download time within a small fraction of second.

Maximum length of single USB cable is 5 m. This length can be extended to 10 m by using single USB hub or active USB extender cable. Up to 5 hubs or active extenders can be used in one connection.

Gx Camera Ethernet Adapter device allows connection of up to four Gx cameras of any type through Ethernet interface and TCP/IP network. Because TCP/IP protocol can be routed, the distance between camera and host PC can be virtually unlimited.

ADC resolution	16 bits
Sampling method	Correlated double sampling
Read modes	Fast (8 Mpx/s)

	Slow (2.5 Mpx/s)
Computer interface	USB 2.0 high-speed
	USB 1.1 full-speed compatible

1. Camera driver allows arbitrary software binning up to 4×4 pixels of downloaded images.

Image download time and system read noise depends on the CCD chip used in particular camera model and on the read mode.

Camera model	G0/G1-0300	G0/G1-0800	G0/G1-2000	G1-1400
Download time (fast mode)	0.05 s	0.1 s	0.25 s	0.18 s
Download time (slow mode)	0.15 s	0.32 s	0.8 s	0.58 s

1. Download times are valid for USB 2.0 host and may vary depending on host PC. Times stated here were measured on 1.5 GHz Pentium M based laptop computer.
2. Download times can be significantly longer when connected to USB 1.1 host.

Some electronics characteristics like system gain or system read noise cannot be determined without knowledge of some CCD parameters (e.g. output node sensitivity), which are not published by Sony.

CCD Chip Cooling

The G0 and G1 series of CCD cameras does not use active cooling with Peltier TEC modules, so the CCD cannot be cooled below ambient temperature.

Working electronics (including the CCD chip itself) produce quite amount of heat, which rise the camera internal temperature many degrees above ambient temperature. Because the CCD thermal noise typically doubles every 5 or 7 °C, the thermal noise can be significantly higher after some time of camera operation.

The G1 series of CCD cameras contain small fan, which efficiently removes the heat from the camera body and keeps the CCD temperature as close to ambient temperature as possible. The fan operation can be controlled from the software.

G0 and G1 cameras also include the embedded temperature sensor, which measures the current CCD temperature. This feature enables controlling of the CCD temperature and ensuring the used dark frame was taken in the same or similar temperature as the light exposure etc.

Power Supply

G0 and G1 cameras are powered from the USB cable. No external power supply is necessary.

The current limit for single USB device is 500 mA from 5 V supply. The current required by G1 CCD cameras varies depending on the camera operation mode. The following table summarizes camera consumption. Either way, G1 cameras do not reach the allowed 500 mA limit, defined in USB specification.

Camera operation mode	Required current
Idle, fan off	185 mA
Idle, fan on	260 mA
Image digitization, fan off	285 mA
Image digitization, fan on	360 mA

G0 cameras are not equipped with fan, so their power consumption equals to power consumption of G1 cameras with fan off.

1. If the camera is connected through non-powered USB hub, the current available for the connected devices can be as low as 100 mA, which is insufficient. Always use powered USB hubs when using G1 cameras.

2. Note the so-called “active USB extender cable” is in fact nothing more than standard USB cable with a hub with single USB connector on the far side. Such hub consumes some energy and may not work with G1 cameras.

3. Some USB cables incorporate very thin power lines with relatively high resistance. If the USB device consumes several hundreds milliamperes, the voltage drop on such cable can be around one volt. Although the G1 camera should work, some features (e.g. temperature measurement) may be negatively affected. Always make sure the used USB cable is as short as possible and with low-resistance power lines.

G0 Camera Mechanical Specifications

G0 camera head has just 40 mm diameter (approx. 1.6 inch) and 85 mm length (approx. 3.3 inch), including the 18 mm long 1.25” nose in the front part of the camera. All connectors (USB and autoguider) are placed on the rear side of the camera.

G0 cameras are designed to be attached directly to standard 1.25” telescope focusers. There is no C/CS thread available, so the G0 camera cannot be used with common CCTV lenses.

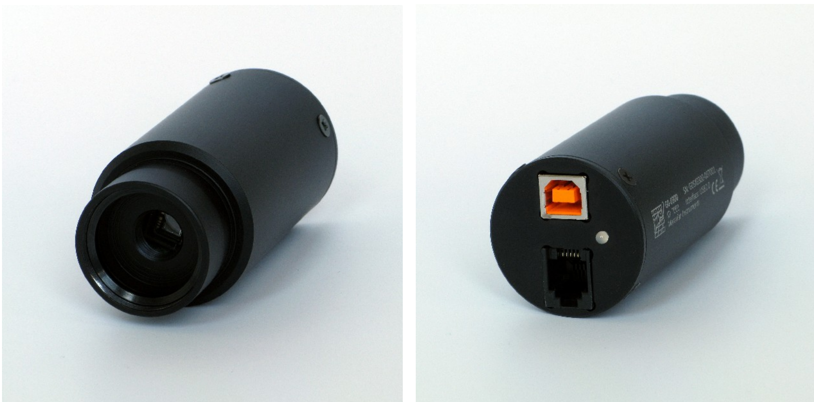


Illustration 1: G0 camera head

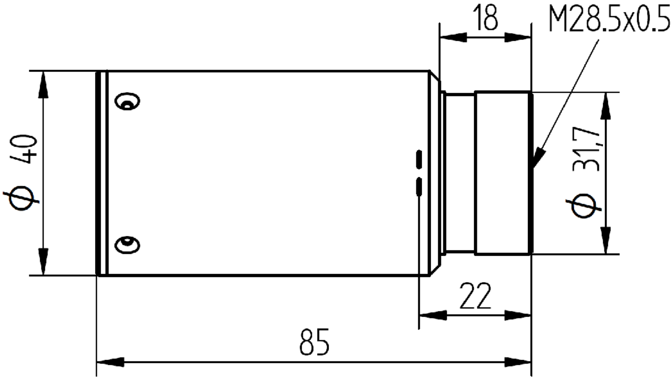


Illustration 2: G0 camera dimensions

The G0 cameras use Interline Transfer CCDs allowing electronic exposure control, so they do not contain mechanical shutter. But it is necessary to cover the telescope manually to take dark or bias frame.

Internal mechanical shutter	No
Shortest exposure time	0.000125 s
Longest exposure time	Limited by chip saturation only
Head dimensions	40 mm (diameter) × 85 mm (length)
Camera head weight	0.1 kg

G1 Camera Mechanical Specifications

Compact and robust camera head measures only 83 × 76 × 26 mm (approx. 3.25 × 3 × 1 inch). The head is CNC-machined from high-quality aluminum and black anodized.

The camera is supplied with CS adapter for connecting various CS compatible lenses. The C-thread to 1.25" adapter can be screwed into the head to attach the camera to any telescope focuser accepting standard 1.25" eyepieces.

Both C and CS standards use the same thread specification (C-thread with 1 inch diameter, 32 threads per inch). The difference between them is in the back focal distance – while the standard C-thread back focal distance is 17.5 mm, the CS back focal distance is 12.5 mm. Both variants are available for G1 CCD cameras.

Illustration 3: G1 camera head

The G1 cameras use Interline Transfer CCDs allowing electronic exposure control, so they do not contain mechanical shutter. But it is necessary to cover the telescope manually to take dark or bias frame.

Internal mechanical shutter	No
Shortest exposure time	0.000125 s
Longest exposure time	Limited by chip saturation only
Head dimensions	83 mm × 76 mm × 26 mm
Back focal distance	12.5 mm (CS standard)
	17.5 mm (C standard)
Camera head weight	0.2 kg

1. Camera dimensions do not include the CS-thread adapter. This adapter depth is 6.4 mm, so the camera depth including the CS-thread adapter is 32.4 mm.

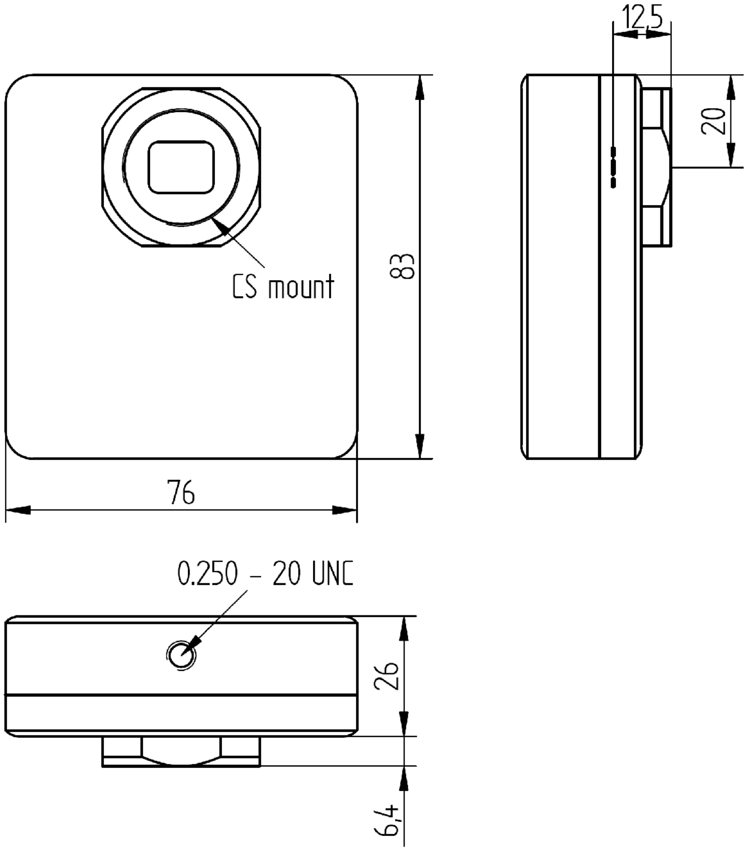


Illustration 4: G1 camera dimensions

Getting Started

If you intend to use the G0 or G1 camera for astronomy observations (be it imaging or mount autoguiding), it is highly recommended to install software and to make sure everything is working OK during day, before the first night under the stars.

The G0 and G1 CCD cameras can be in principle operated under various CCD control software packages (refer to our web site for available drivers), this manual demonstrates camera operation under the SIPS (Scientific Image Processing System) – camera control and image processing software suite supplied with the camera.

Camera System Driver Installation

Every USB device requires so-called “system driver”, incorporated directly into the operating system kernel. Some devices (for instance USB Flash Disk dongles) conform to some predefined class (USB mass-storage device class in this case), so they can use the driver already present in the operating system. But this is not the case of the G0/G1 CCD camera – it requires its own system driver to be installed.

Although 64 bit operating system can run 32 bit application without any problems, it is basically impossible to combine e.g. 64 bit process with 32 bit dynamic link library. The same is valid for operating system kernel - 64 bit kernel cannot use 32 bit system driver. This is why G0/G1 camera driver is supplied in two versions, one for 32 bit systems (marked x86 according to Intel 386, 486 CPUs) another for 64 bit systems, marked x64 (according to CPUs supporting 64 bit instructions marked x86-64 or only x64).

The simplest way to install G0/G1 CCD camera system driver is to run driver pre-installation package (“GxCam Drivers 32bit EN.exe“ or “GxCam Drivers 64bit EN.exe”, provided with the camera or downloaded from a web site) on the target computer. This package installs the driver for all Gx cameras on the particular computer. Then it is enough to plug in the camera and the operating system already knows which driver to use.

It is also possible to utilize Plug-and-play nature of USB devices and Windows operating system. Simply plug the camera to power supply and connect it to the host PC using the included USB A-B cable. Windows detects new USB device and opens hardware installation wizard. The system driver installation is slightly different on different Windows systems.

Individual camera types require different drivers depending on the CCD detector used. For instance. G1-0300 uses g1sx0300.sys driver, G1-2000 uses g1sx2000.sys driver etc.

However, G0 and G1 cameras are software compatible and they use the same driver (g1sx0300.sys works for both G0-0300 and G1-0300). Still, G0 cameras are supported from driver version 2.8 and higher. If the user have some older driver installed and then connects G0 camera, camera will not work. It is necessary to install newer version of the driver or to utilize "Update Driver..." menu in Windows Device Manager.

Windows 7 and 8 System Driver Installation

Windows 7 and 8 do not offer users the possibility to install system drivers using Plug-and-Play, like in the case of older Windows 2000, Windows XP and Windows Vista. It is necessary to pre-install all drivers, else the operating system only informs user that it cannot find appropriate driver for newly connected device.

We can only estimate reasons for this limitation of system functionality, probably it has something common with the inability of many hardware vendors to provide drivers complying to Plug-and-play standards (notification requiring installation of the software first and plugging of the device later is present on many devices).

Although the Plug-and-Play mechanism is hidden in Windows 7/8, it is possible to use it. Newly connected device appears in the "Device Manager" as "Unknown Device" (such device is usually marked by a question mark on yellow background icon). It is enough to click on such device by right mouse button to invoke pop-up menu and choose "Update Driver..." menu item. Operating system then opens driver installation wizard, basically identical to the one in Windows XP and Windows Vista.

Let us note that 64 bit versions of Windows 8, Windows 7 and Windows Vista require digitally signed drivers. Drivers without digital signature cannot be installed on these systems.

All G0/G1 camera drivers supplied by Moravian Instruments are digitally signed from the beginning of the year 2010.

Windows XP and Windows Vista System Driver Installation

The operating system notifies the new USB device was plugged in the "Found new hardware bubble". The system then opens the "Found New Hardware" Wizard.

1. The wizard offers searching for suitable driver on Windows Update site. Reject this offer (choose "No, not this time") and click "Next" button.
2. Choose the "Install the software automatically" in the next step.

   Insert the CD-ROM into the drive and the wizard will continue by the next step.

   It is not necessary to install files from CD-ROM. It is possible to copy the folder containing driver files e.g. to shared network volume, USB Flash Disk etc. Then it is necessary to choose the "Install from a list or specific location" and to define the path to driver files.
3. The wizard starts to copy files. But Windows XP checks for driver file digital signature. If it cannot find the signature, it notifies the user by a message box. Click "Continue Anyway", the digital signature is only an administrative step and does not influence the proper functionality.
4. The wizard then finishes the installation and the G0/G1 CCD camera is ready to work.

Please note the Windows system keeps the information about installed devices separately for each USB port. If you later connect G0/ G1 CCD camera to different USB port (different USB connector on the PC or through the USB hub), Windows reports "found new hardware" again and asks you to install the software. Repeating the installation again brings no problem, but you can also point Windows to use the same "oemXX.inf" (in the “\windows\inf” folder) and e.g. “g1sx0300.sys” (in the “\windows\system32\drivers” folder) files, which are already installed.

SIPS Software Installation

The Scientific Image Processing System (SIPS) software package is designed to operate without the necessity to be installed in any particular folder. The package can be even run directly from USB Flash Drive or CD-ROM.

SIPS needs the Microsoft Visual C++ 2008 libraries to work. These libraries are already installed on many Windows PCs, because they are used by a lot of other applications. But if they are not present, it is necessary to install them first. The best way how to do it is to run the “Microsoft Visual C++ 2008 SP1 Redistributable Setup” package (executable file 'vcredist_x86.exe'). This package can be downloaded from the Microsoft web site and it is also supplied on the USB Flash Drive shipped with the camera,

SIPS package is distributed in the two forms:

1. In the form of the executable installation package 'SIPS_EN.exe'. Running of this package installs SIPS similarly to any other Windows application. The user does not need to care whether other libraries or packages are installed, the setup process installs everything necessary.

   If the SIPS is installed this way, then it can be easily uninstalled from the application management of the Windows operating system.

2. In the form of so-called “portable version” on the USB Flash Drive or CD-ROM. The directory called “SIPS” contains SIPS image (set of EXE and DLL files, as well as auxiliary INI files etc.), which can be directly executed. The image can be copied to computer local drive into the (possibly newly created) directory chosen by the user.

   The portable version can be also downloaded in the form of ZIP archive (file 'sips.zip') from the web site. Again it is enough to unzip the archive into chosen directory.

Uninstalling of the SIPS portable version is also quite easy – just delete the SIPS folder.

No matter how is the package installed, the software is run by launching the 'SIPS.exe' main program file.

SIPS configuration files

The software package distinguishes two types of configuration:

- Global configuration, common for all users.
- User-specific configuration.

Global configuration defines which hardware is used and which drivers controls it. The configuration is stored in the simple text file "sips.ini", which must be placed in the same folder as the "sips.exe" main executable. The file may look for example like this:

```
[Camera]
Gx Camera on USB = gxusb.dll
Gx Camera on Ethernet = gxeth.dll
Legacy G2 camera = g2ccd2.dll
ASCOM Camera = ascom_camera.dll

[GPS]
GarminUSB = gps18.dll
NMEA = nmea.dll

[Telescope]
NexStar = nexstar.dll
LX200 = lx200.dll
ASCOM = ascom_tele.dll

[Focuser]
ASCOM = ascom_focuser.dll

[Dome]
ASCOM = ascom_dome.dll
```

Individual sections define which driver would be loaded and asked to enumerate all connected devices of particular type (CCD cameras, GPS receivers, telescope mounts).

SIPS package already contains this file containing all included drivers. This file is not modified programmatically, so it is necessary to edit it manually if a new device driver, not included into basic package, is to be installed.

User-specific configuration is stored in the file named also “sips.ini”, but this file is placed in the “\Documents and Settings\%user_name %\Application Data\SIPS\” folder. Number of setting is stored in this text file, beginning from the position and open state of individual tool windows, to the preferred astrometry catalog and parameters for searching stars in images.

G0/G1 CCD Camera Driver for SIPS

SIPS is designed to work with any CCD camera, providing the driver for the particular camera is installed. The drivers for G0/G1 CCD cameras are included into SIPS package – it is not necessary to install it separately.

Both G0/G1 cameras use common driver 'gxusb.dll' when connected directly to the host computer or 'gxeth.dll' when connected trough the Gx Camera Ethernet Adapter.

Common drivers for all Gx cameras were introduced in SIPS version 2.3, previous SIPS versions used different drivers for G0/G1 and for G2/G3/G4 cameras. G0 and G1 cameras used the 'g1ccd.dll' driver, but it was replaced with the 'gxusb.dll' common driver.

G0 cameras are supported from version 2.0 of SIPS. Previous versions did not support G0 cameras.

The G0/G1 camera requires no configuration. The driver is capable to recognize all G0 and G1 cameras connected to the computer and to provide necessary information to the SIPS software package.

Camera Connection

Camera connection is pretty easy. Plug the camera to the computer USB port using the supplied USB cable.

Camera LED state indicator

There is a two-color LED on the camera back side just close to the USB connector. The LED is functional only upon camera start-up not to influence observations.

Camera firmware finishes initialization by signaling the USB speed, on which it is currently operating.

- USB 2.0 High Speed (480 Mbps) is signalized by 4 short green blinks.
- USB 1.1 Full Speed (12 Mbps) is signalized by 4 short red blinks.

Working with Multiple Cameras

It is possible to connect multiple CCD cameras to single computer, be it directly to USB ports available on the computer I/O panel or through the USB hub. The operating system assigns unique name to every connected USB device. The name is rather complex string derived from the device driver GUID, USB hub identifiers, USB port number on the particular hub etc. Simply put, these identifiers are intended for distinguishing USB devices within operating system, not to be used by computer users.

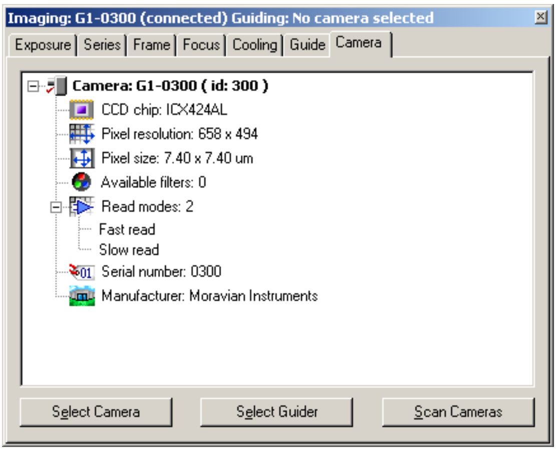


Illustration 5: Camera Id number is displayed in brackets after camera name in SIPS

But the user always needs to distinguish individual cameras – for instance one camera should be used for guiding, another for imaging. This is why every camera has assigned unique identifier (ID number). This number is engraved into camera body and it is also displayed in the list of all available cameras in the CCD Camera tool in SIPS. This enables the user to select the particular camera he or she needs.

Camera Operation

Camera operation depends on the software used. Scientific cameras usually cannot be operated independently on the host computer and G0 and G1 CCD cameras also needs a host PC (with properly installed software) to work. Camera itself has no displays, buttons or other controls. On the other side, every function can be controlled programmatically, so the camera is suitable for unattended operation in robotic setups.

Plug the camera into computer USB port and run the SIPS program. Open the CCD Tool (choose the “Tools” menu and click the “CCD Camera...” item or click the  tool button). The camera name (e.g. “G1-0300”) should be displayed in the title bar of the tool window.

If you run the SIPS before the camera was plugged, program does not know about it and it is necessary to scan for available cameras. Select the “Camera” tab and press the “Scan Cameras” button. The G0/G1 CCD camera should appear in the displayed tree. Select it (click its name by mouse – its name should be highlighted) and press “Select Camera” button.

If the G0/G1 CCD does not appear in the tree of available cameras, check the following items:

1. Check the USB cable – make sure both connectors are properly inserted to PC (or USB hub) and to camera head.
2. Check if the camera system driver is properly installed. Refer to the “Camera System Driver Installation” chapter for information about system driver installation.

Camera and the Telescope

The camera needs some optical system to capture real images. It depends on the telescope adapter to which telescopes (or lenses) the camera can be connected. Standard 1.25" barrel adapter allows camera connection to vast majority of astronomical telescopes.

CCTV lens with C-thread or some small refractor is the best optical system to start experimenting with the camera. If you are using some bigger telescope at home for the first experiments, make sure the telescope can be focused to relatively nearby objects in the room.

Temperature Control

The following chapters provide only a brief description of G0/G1 camera operation under SIPS (Scientific Image Processing System) program, supplied with the camera. Refer to the SIPS User's Guide (click “Help” and “Contents” from the SIPS main menu) for thorough description of all SIPS features.

The G1 cameras do not provide active chip cooling, which means the CCD temperature cannot be lowered under the ambient temperature. This is because the USB does not provide enough electrical power to run thermoelectric (Peltier) cooler. However, there is a small fan, which forces air flow inside the camera head and removes the heat generated by camera electronics. The CCD temperature can be lowered by many degrees Celsius compared to sealed designs, which results to lowering of CCD thermal noise by a factor of two or more.

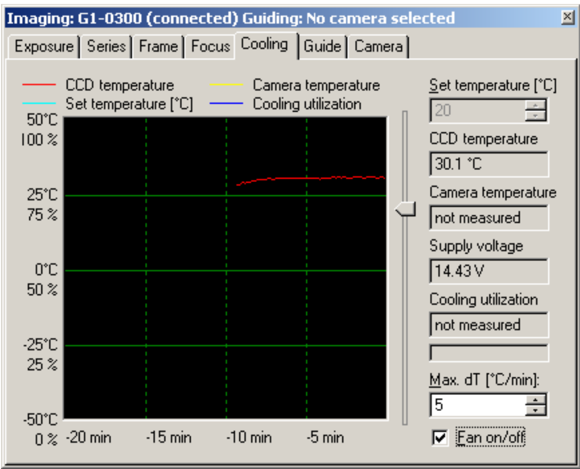


Illustration 6: Cooling tab shows CCD chip temperature

Fan operation can be controlled from the "Cooling" tab of the CCD Camera tool. Controls like "Set Temperature" cannot be manipulated if G1 camera is connected, but a check box "Fan On/Off" can be set/reset to switch the fan on and off.

G0 cameras are not equipped with a fan so switching it on and off has no effect.

The CCD Camera tool also displays the current CCD chip temperature ant its 20 minutes long history.

The value "Supply voltage" does not display the real USB cable voltage, but one of the internal camera voltages. It should be between 14 and 15 volts. If it drops below 13.5 volts, the power provided by the USB line is not sufficient. It is recommended to use shorter USB cable or USB cable with thicker power lines.

The "Supply voltage" value is not measure on G0 cameras.

First Images

Actual exposure is performed from the "Exposure" tab of the CCD Camera tool.

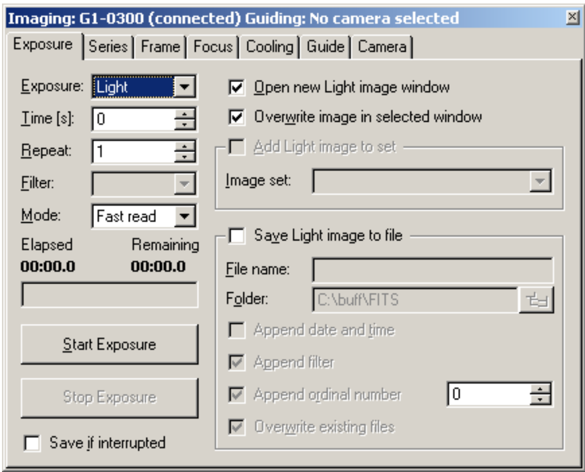


Illustration 7: Exposure tab of the CCD Camera Control tool

It is necessary to define few parameters before the first shot. First, it is necessary to define the image type – choose “Light” from “Exposure” combo box. Then choose the exposure time. If you experiment during daytime, it is possible to start with exposures as short as 0.001 second. Do not forget to review the image handling options on the right side of the “Exposure” tab. Let the “Open new light image window” and “Overwrite image in selected window” check-boxes checked, uncheck other options for now (we do not plan to save our first images).

Then click the “Start Exposure” button. Camera will perform the exposure of required length and download the image. Image is then opened in new image window. If this is the first shot, it will probably be far from sharp focused image. Alter the focuser and try again.

Notice that options determining the new image handling on the right side of this tab changes with every change of the exposure type. SIPS remembers these options for every exposure type separately. So it is possible e.g. to define separate folders for dark frames and for flat fields.

Always check whether image processing options are defined properly before you start any exposure.

If you choose “Dark” or “Bias” from “Exposure” combo box (remember the image handling options on the right side changes – make sure they are properly defined), SIPS will prompt you co cover the telescope/lens, because the G1 cameras lack the mechanical shutter. The captured image will represent the thermal noise, generated by the CCD chip itself, combined with the CCD chip and camera electronics read noise. Such images are subtracted from normal images during image calibration to reduce the dark current effects.

Brightness and Contrast – Image Stretching

The G0/G1 CCD dynamic range spans 65 536 levels. But only imaging of perfectly illuminated and perfectly exposed scenes can result in images with pixels spanning this range. Usually only a fraction of this range is used, e.g. the black background can have values around 1000 counts and the brightest part of the image can have around 10 000 counts. If we assign the black to white range to the full possible range (0 to 65 535), the image with 1000 to 10 000 counts will be displayed only in dark gray tones. This is why image brightness scale should be “stretched” before they are displayed.

Open the “Histogram ans Stretch” tool .

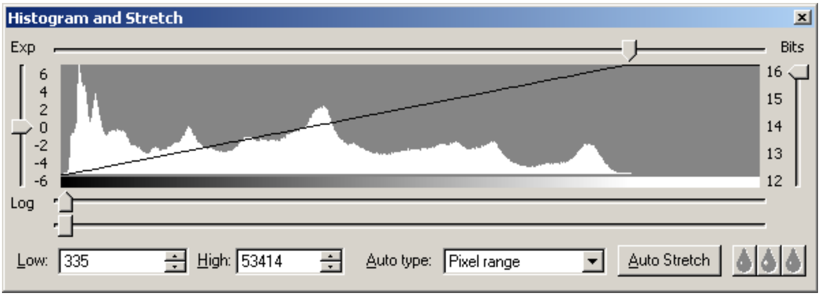


Illustration 8: Histogram and Stretch tool

The exact meaning of the histogram chart is explained in the SIPS software documentation. Now only try to play with “Low” and “High” count-boxes or better with the related horizontal sliders. Observe how the image view is changed when you alter these values.

The best positions of Low and High control are as follows: the Low count should be on the count value representing black on the image. Any pixel with value lower than this count will be displayed black. The High count should be on the count value representing white on the image. Any pixel with value higher than this count will be displayed white.

Similar adjustments are usually called brightness and contrast adjustments.

- Brightness is changed by moving both Low and High values together up and down. Try to move both values using the second slider below the histogram chart.
- Contrast is changed if the relative distance between Low and High values changes. Try to narrow or widen the distance between Low and High values.

But astronomers often need precise control of Low and High values so the terms brightness and contract are not used within SIPS.

Calibration

If you preform short exposure of bright object, the signal to noise ratio of the image is very high. Image artifacts related to CCD chip (like hot/cold pixels or thermal noise) almost do not affect the image. But all unwanted effects of unevenly illuminated field, CCD thermal noise etc. significantly degrade image quality when imaging dim deep-sky objects for several minutes.

This is why every CCD image should be calibrated. Image calibration basically consists of two steps:

1. **dark frame** subtraction
2. applying **flat field**

Image calibration is supported by the “Calibration” tool in SIPS .

The raw image downloaded from the camera contains not only the information desired (the image of the target field), but also CCD chip thermal noise.

Note the brighter background of the upper left corner of long exposure images taken by G0/G1 cameras. It is caused by the electro-luminescence of the CCD chip output amplifier and it is inherent to this type of CCD detectors. This artifact appears on low-light images exposed for many seconds. It must be removed by dark-frame subtraction.

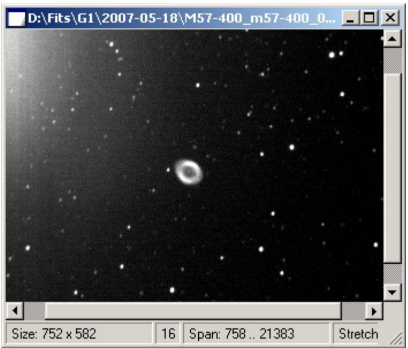


Illustration 9: The raw image downloaded from the camera

The Dark frame is taken with the same exposition time at the same CCD chip temperature. Because hot pixels are less stable than normal pixels, it is always better to take more dark frames and to create resulting dark frame as average or median of multiple dark frames.

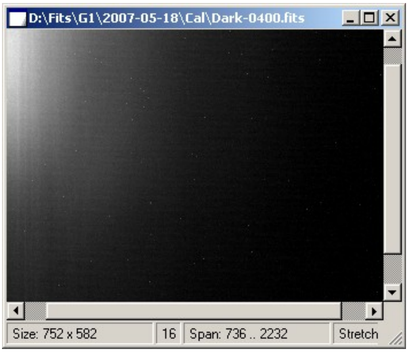


Illustration 10: The dark frame corresponding to the above raw image

Then it is necessary to subtract the dark frame from the raw image. This operation removes hot (bright) pixels es well as image gradient caused by electro-luminescence of CCD output amplifier.

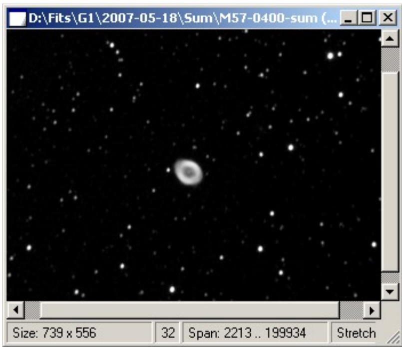


Illustration 11: Image with subtracted dark frame

CCD image calibration is described in detail in the SIPS User's Guide. Refer to the “Introduction to CCD Imaging” and “Calibrate Tool” chapters for calibration description in theory and in practice.

Color Images

Color images can be obtained using camera with monochrome CCD detector by acquiring three different exposures through red, green and blue filters. This way is preferred by professional astronomers from number of reasons – monochrome CCD detectors are much more sensitive (high-end CCD detectors with 80+ % quantum efficiency are available only in monochrome variant), they provide freedom in choosing filter (e.g. narrow-band filters, IR or UV filters etc.), they allow binning, time-delay integration etc.

G2/G3/G4 cameras contain filter wheel (be it inside the camera head or external one), which makes imaging through separate filters quite easy. G1 cameras were developed with other design goals, so they lack filter wheel and changing filters, screwed into the telescope adapter, is time consuming. It also requires focusing after filter change etc.

Let us note that imaging through separate color filters is close to impossible in some cases. For instance taking images of some fast evolving scenes, like planet occultation by Moon, imaging of fast moving comet etc. There is no time to take separate exposures through filters, because the scene changes between individual exposures. Then it is not possible to combine red, green and blue images into one image. In such cases using a single-shot color camera is necessary.

Single-shot color cameras use special CCD detectors with red, green and blue color filters applied directly on individual pixels. G0/G1 CCD cameras can be equipped with such detectors (the name of the camera is then followed by the letter "C" to indicate color CCD).

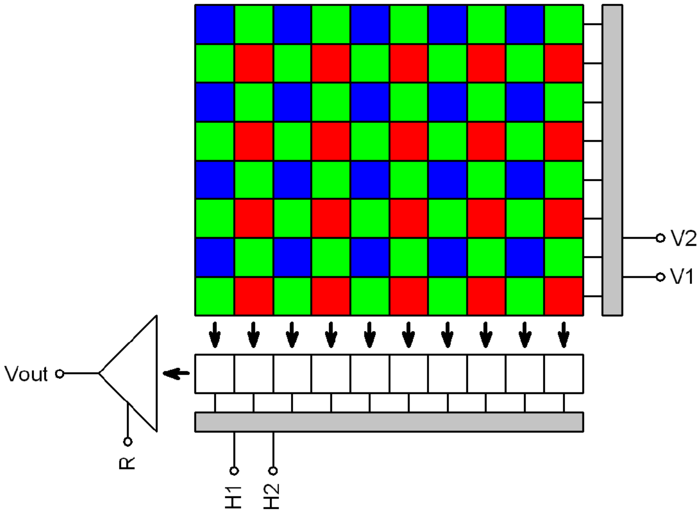


Illustration 12: Schematic diagram of color CCD detector

Every pixel receives light of particular color only (red, green or blue). But color image consists of pixels with all three colors specified. So it is necessary to calculate other color from the values of neighboring pixels.

Covering pixels with such color mask and subsequent calculations of remaining colors was invented by Mr. Bayer, engineer working at Kodak company. This is why this color mask is called Bayer mask and the process of calculation of missing color is called Debayer processing.

There are several algorithms for calculating missing color components of individual pixels – from simply using of color from neighboring pixels (this method provides quite coarse images) to more accurate methods like bilinear or bicubic interpolation. There are even more sophisticated algorithms like pixel grouping etc.

No G0 or G1 camera performs the Debayer processing itself. The raw image is always passed to the host PC and processed by control software. It is also possible not to perform Debayer filtering and save images in the raw form for processing by some other software packages.

SIPS software implements bilinear Debayer interpolation. It is possible to perform Debayer processing immediately when the image is downloaded from the camera (color image is then immediately displayed and/or saved and no raw monochrome image is shown) or to perform this processing anytime later.

Debayer processing can be performed from “Image Transform” tool (to open this tool click  button in the tool-bar or choose “Image Transform” from the “Tools” menu). Check box “Debayer new images” allows immediate Debayer processing of images downloaded from the camera. The  button performs Debayer processing of currently selected image.

The Bayer mask displayed on the schematic image above begins with blue pixel. But there are no rules specifying the color of the first pixel – in principle there can be also green pixel from the blue-green line on the upper-left corner as well as green pixel from the green-red line or red pixel.

There is no way how to determine the Bayer mask organization from the image. This is why the “Image Transform” tool provides two check-boxes called “Bayer X odd” and “Bayer Y odd”. Combination of these check-boxes allows specification of Bayer mask organization on the particular CCD.

State of “Bayer X odd” and “Bayer Y odd” check-boxes are always updated when you connect camera with color CCD according to the information provided by the driver. Is is necessary to update them manually only if the raw color image is loaded from the disk file and needs to be processed without connected camera.

Wrong definition of these two flags results in wrong color calculation. Proper settings can be easily determined by the try-and-error method. But Debayer processing discards the original raw image so it is always necessary to backup the original raw image.

Also please note the settings of the “Bayer X odd” and “Bayer Y odd” check boxes must be altered when any geometric transformations are applied to the raw image (e.g. mirroring, rotation, etc.). Some transformations (e.g. soft binning or resampling) cannot be performed on raw image at all. It is always better to Debayer images first and process them later.

Also note that stacking of raw color images results in loss of color information. Stacking algorithms align images regardless if the particular pixel is red, green or blue. SIPS allows also sub-pixel stacking, which can mix pixels of different colors. Images must be Debayer processed first and then stacked.

Balancing colors

CCD chip sensitivity to red, green and blue light is different. This means the exposure of uniformly illuminated white surface does not produce the same signal in pixels covered with different color filters. Usually blue pixels gather less light (they have less quantum efficiency) then green and red pixels. This results into more or less yellowish images (yellow is a combination of red and green colors).

The effect described above is compensated by so-called “white balancing”. White balancing is performed by brightening of less intensive colors (or darkening of more intensive colors) to achieve color-neutral appearance of white and/or gray colors. Usually is one color considered reference (e.g. green) and other colors (red and blue) is lightened or darkened to level with the green.

Automatic white balancing can be relatively easy on normal images, where all colors are represented approximately uniformly. But this is almost impossible on images of deep-space objects. For instance consider the image of emission nebula, dominated by deep-red hydrogen alpha lines – any attempts to lighten green and blue color to create color-neutral image result to totally wrong color representation. Astronomical images are usually color balanced manually.

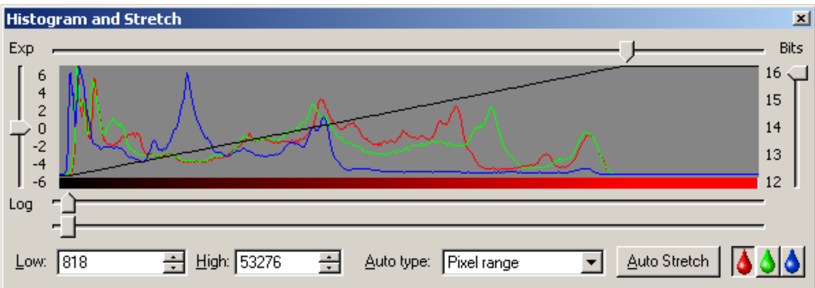


Illustration 13: Histogram and Stretch tool shows histograms of individual colors

As already described in the “Brightness and Contrast – Image Stretching” chapter, image can be visually brightened by altering its stretch limits. SIPS “Histogram and Stretch” tool displays and also enables altering of stretching curve limits and shape for red, green and blue color individually.

Guiding

No astronomical mount is precise enough to keep the star images perfectly round during long exposures without small corrections. Astronomical CCD cameras and digital SLR cameras allow perfectly sharp and high-resolution images, so even a small irregularity in mount tracking appears as star image deformations. G0 and G1 CCD cameras were designed especially with automatic mount guiding on mind.

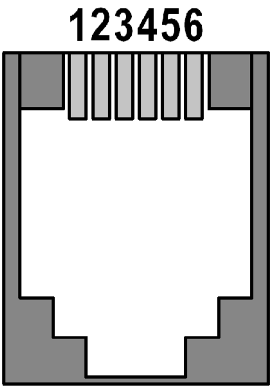
The G0 and G1 cameras were designed to operate without any mechanically moving parts (with the exception of magnetically levitating fan used in G1 cameras). Electronic shutter allows extremely short exposures and also obtaining thousands of images in a short time, which is necessary for quality guiding. CCD chips used in G0 and G1 cameras are sensitive enough to capture even a faint stars within few seconds. The limiting magnitude of G0 and G1 cameras is much higher compared to the most sensitive TV or Web cameras.

G0 and G1 cameras work in connection with a host computer (PC). Guiding corrections are not calculated in the camera itself, it only sends acquired images to the PC. The software running on the PC calculates the difference from required state and sends appropriate corrections to the telescope mount. The plus side of using a host PC CPU to process images is the fact, that current PCs provide overwhelming computational power compared to any embedded processor inside the guiding camera. Guiding algorithms then can determine star position with sub-pixel precision, can match multiple stars to calculate average difference, which limits the effects of seeing, etc.

Calculated corrections can be sent back to mount using PC-to-mount link, but more accurate guiding can be achieved using so called “Autoguider” port. It is enough to connect the G0 or G1 camera and the mount using 6-wire cable and guide the mount through the camera.

Illustration 14: Bottom side of the G0 and G1 camera heads with USB and Autoguider connectors

The Autoguider port follows the de-facto standard introduced by SBIG ST-4 autoguider. The pins have the following functions:



1. R.A. + (Right)
2. Dec + (Up)
3. Dec – (Down)
4. R.A.– (Left)
5. Common (Ground)
6. Not connected

The maximum sinking current of each pin of the G0 or G1 camera is 100 mA. If the mount does not treat the autoguider port as logical input only, but switches the guiding motors directly by these signals, a relay box must be inserted between the camera and the mount. The relay box ensures switching of currents required by the mount.

Guiding using SIPS software package

There are two guiding algorithms implemented in SIPS:

- **Single star guiding.** The PC calculates the centroid of the brightest star on the image acquired by the guider. The centroid position is calculated to the fraction of pixel precision, so the guiding can be very precise even when the guider is connected to the telescope with short focal length.
- **Plate solution guiding.** The PC performs basically the same operation like in the case of sub-pixel matching of multiple exposures or astrometry reduction. Number of triangles are created from the brightest stars and they are matched to triangles on reference frame.

  Although triangle matching requires at last three stars on the guiding image and thus is suitable either for short focal length guiders or for rich star fields, the image shift is calculated from multiple star positions and is less sensitive to random errors like seeing, radiation spikes etc.

SIPS can also guide through telescope link (e.g. through the Meade LX-200 or Celestron NexStar protocol), so no autoguider cable may be necessary. But the specialized device like the guider camera can control the mount with much better precision compared to commanding of the mount through serial interface. Serial interface (COM port) can introduce significant delays to the guiding commands and the guiding precision is compromised.

SIPS allows controlling of attached cameras in the CCD Camera tool. This tool enables selection of two cameras – one camera for imaging, another camera for guiding. There are no limitations which camera can be used for imaging and which for guiding. Any camera capable to work under SIPS can work as imaging as well as guiding one (cameras are selected in the "Camera" tab of this tool – see the "Working with Multiple Cameras" in the "Getting Stared" chapter for details).

Guiding itself is rather complex task and requires lot of parameters on the one side and also provides the user with information about mount performance, guiding reliability etc. on the other side. This is why the CCD Control tool offers two guiding-related tabs:

- **Guiding Setup** tab allow definition of guiding parameters like guider camera sub-frame, exposure time, binning, calibration parameters etc.
- **Guiding** tab itself allows to start and stop guiding, calibrate guider, shows the history guiding pulses as well as the log of guider activity.

“Guiding Setup” tab of the CCD Camera control tool

There are two guiding algorithms implemented in SIPS:

- **Single star guiding**. The PC calculates the centroid of the brightest star on the image acquired by the guider. The centroid position is calculated to the fraction of pixel precision, so the guiding can be very precise even when the guider is connected to the telescope with short focal length.
- **Plate solution guiding**. The PC performs basically the same operation like in the case of sub-pixel matching of multiple exposures or astrometry reduction. Number of triangles are created from the brightest stars and they are matched to triangles on reference frame.

Although plate solution requires at last three stars on the guiding image and thus is suitable either for short focal length guiders or for rich star fields, the image shift is calculated from multiple star positions and is less sensitive to random errors like seeing, radiation spikes etc. On the other side, it is much more CPU demanding.

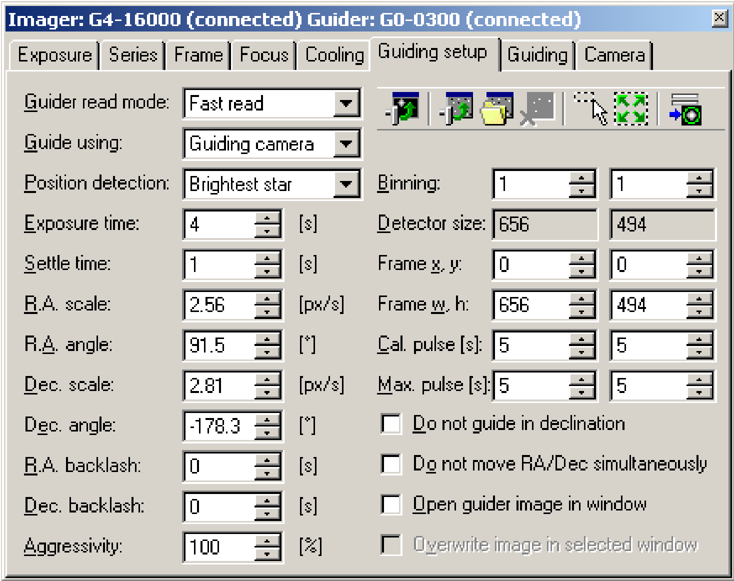


Illustration 15: "Guiding Setup" tab of the SIPS CCD Camera tool

Individual parameters have the following meaning:

- **Guider read mode**: mode for reading of guider images (enabled only if the particular camera used for guiding provides more than one read mode).
- **Guide using**: only guiding through guider camera "Autoguider" port and proper 6-pin cable is currently supported. Support for PC-to-telescope link is planned, but currently not implemented.
- **Position detection**: allows choosing between single (brightest) star match and astrometry plate solution.
- **Exposure time**: is the time to take single guiding image.
- **Settle time**: is the time to wait after moving of the telescope before next guiding exposure begins.
- **R.A. scale**:, **R. A. angle**: and **Dec. scale**:, **Dec. angle**: calibration parameters. These parameters are filled automatically after successful calibration.

- **R.A. backslash**:, **Dec. backslash**: time to move the telescope in addition to calculated correction pulse length if the movement direction changed from the last movement.
- **Aggressivity**: the correction pulse can be shortened compared co calculated length. Setting of this parameter to approx. 80% eliminates to possible overshots of guiding corrections.
- **Binning**: bin the guiding images. If the camera used for guiding does not provide hardware binning, software binning is used instead.
- **Frame x, y**:, **Frame w, d**: sub-frame of the image used for guiding. If the particular camera used for guiding supports sub-frame readout, only this sub-frame is read from the camera. If the camera supports reading of the whole frame only, image is clipped by software to the sub-frame size. This allows elimination of unwanted stars on the image.

  Note selecting of a sub-frame around the chosen bright star is essential for reliable guiding. Subframe should be small enough so there are no similarly bright star in the field of view and big enough to keep the selected star in the frame even if the mount makes strong movement.

  Sub-frame is almost never selected by filling of these count-boxes. It is much easier to mark a selection frame in image by mouse and use the  tool to define readout subframe from the selected frame.

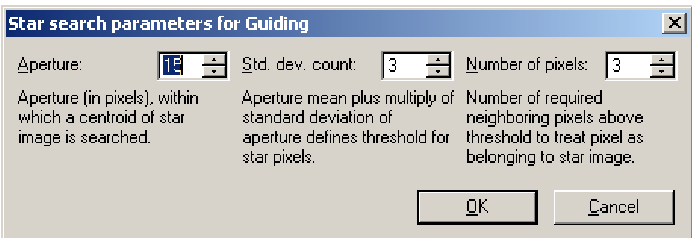
- **Cal. pulse**: length of the pulse used to calibrate the guider (measure speed and angle for both R.A. and Dec.). Make sure the pulse is long enough to measure the difference in star position and short enough not to move the star (or triangles) out of image or selected frame.
- **Max. pulse**: maximum length of the pulse, considered proper drive error measurement. If e.g. some radiation particle trace, brighter than the guiding star, appears in the image, SIPS does not perform telescope move if the distance from the reference star leads to longer guiding pulse then defined here.

A toolbar offers the following commands:

-  – read guider image. Note image is not displayed, if the "Open guider image in window" option is not checked.
-  – read guider dark frame.

If dark frame should be subtracted from the guiding image, it must have the same size. This means it makes sense to capture dark frame only after the proper sub-frame is selected. Capturing dark frame with full guider camera frame and then selecting only a sub-frame causes no dark frame will be subtracted.

-  – load guider dark frame from file. Storing guider image in file makes sense only if no sub frames are used (see the warning above).
-  – clear dark frame. If some dark frame is exposed or loaded, this commands clears it and no dark frame will be subtracted on subsequent guider image read.
-  – copy selection frame from guider image into sub-frame coordinates. Next guider image read will be only defined sub-frame.
-  – clear sub frame, next guider image read will be full resolution frame.
-  – define parameters for guiding star(s) search. Command opens dialog box, which allows definition of parameters.



The dialog box allows definition of just three numbers, but these numbers are very important for star search algorithm.

Aperture is the diameter of pixel area, in which a centroid is searched. General rule is the star image should well fit in the aperture else the star will be not recognized. Too big aperture on the other side covers more pixels than necessary. Aperture 11 pixels is a good value for typical well-sampled CCD image.

The **standard deviation** is calculated for the aperture and if some pixel is a certain multiply of standard deviation above the aperture average, it is considered a star pixel. Multiply of 2 works well on typical CCD image.

To eliminate hot pixels, at last a certain **number of neighboring pixels** should also be above the threshold limit. Requiring of 3 neighboring pixels above the threshold is a good value, but this number can be lowered for undersampled images.

Previous SIPS versions (prior to v2) maintained only one set of star search parameters. These parameters were used for image alignment, astrometry plate solution and also for guiding. But guiding camera/telescope often provide quite different star FWHM, different S/N ratio etc. So beginning in SIPS v2, guiding parameters are defined (and stored) separately from parameters used to search stars in images captured by main telescope/camera.

Set of check boxes on the bottom of the window defines guiding options and guiding image handling:

- **Do not guide in declination** eliminates guiding in declination. Only differences in R.A. are corrected.
- **Do not move RA/Dec simultaneously** performs guiding corrections in R.A. and Dec. directions exclusively. This means the Dec. correction pulse begins only after the R.A. correction pulse finishes. This feature somewhat compromises the guiding accuracy, but there are telescope mounts, which require this feature. If the particular mount can move with guide speed in both axes at the same time, never check this option.
- **Open guider image in window** opens the image acquired by the guider camera in window.

- **Overwrite image in selected window** causes replacing of the image in currently selected image window by the image downloaded from guider camera. If no image window is opened, new window is created.

“Guiding” tab of the CCD Camera control tool

Guiding tab is used to start and stop guiding and to monitor guiding performance.

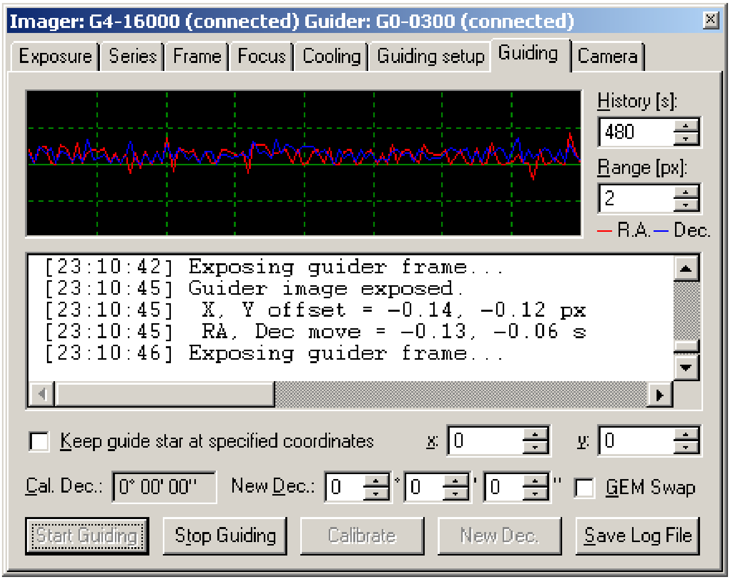


Illustration 16: “Guiding” tab of the SIPS CCD Camera tool

The first chart displays the detected differences between reference star position and detected star position in R.A. and Dec. Because different mounts have different worm period and also typical guiding differences can be only small fraction of pixel to many pixels, the chart time span and range can be defined by the user.

Following text box shows log of all guiding actions (calibration progress, performed corrections, etc.). The log can be saved to file and the analyzed, which can help to solve guiding-related problems (e.g. the log states that the reference star was not found when the clouds covered the field of view etc.).

The Keep guide star at specified coordinates option slightly changes the way the reference star position is determined. Normally, reference frame is taken upon guiding start, reference star position is measured and subsequent guiding images are compared to this position.

But when some object is observed during multiple nights, it is desirable to keep the observed star and reference star on the same camera pixels to achieve maximum photometric precision, which also means to keep the guiding star on the same pixel. Here comes the option to pick the guiding star, measure its position (only roughly) and let SIPS keep the reference star at defined position instead of taking reference frame first.

Note the reference star coordinates are always measured relative to the whole frame, not relative to defined sub-frame.

Calibration parameters are influenced not only by guiding telescope focal length, guiding camera pixel size, camera orientation etc., but also by the target object declination. SIPS allows storing of the declination on the object when the calibration is performed. If the telescope moves to different object with different declination, it is not necessary to calibrate the mount again, but it is enough enter new declination and the calibration parameters are recalculated.

Similar situation occurs when the GEM (German Equatorial Mount) is swapped. Checking the GEM Swap check-box recalculates the guiding parameters when the mount is swapped to opposite hemisphere compared to the hemisphere on which the calibration was performed.

Calibration of guiding subsystem

Every automatic guiding system must be calibrated before use. When the software detects that the reference star moved on the image, it must move the mount in the opposite direction to correct the tracking error. The mount movement is controlled by the length of the correction pulse. Proper pulse length is calculated from the known distance on the image (expressed in pixels) and the mount guiding speed (expressed in pixels per second).

The speed and direction of mount movement is in principle different in R.A. and in Dec. This makes setting of proper parameters somewhat complicated. So the software can automatically measure (calibrate) these parameters.

SIPS performs automatic calibration in several steps:

1. SIPS takes the first reference frame.
2. The mount is moved in R.A. for the period defined as R.A. Calibration pulse (the first one).
3. SIPS then takes another frame and calculates the difference between centroids of reference star on these two frames. The difference represents the mount reaction on the movement in Right Ascension. The speed (R.A. scale) and angle (R.A. angle) is then calculated.
4. The mount is returned back to the original position by moving it for the same time in reverse direction and another reference frame is taken.
5. The mount is moved in Dec. for the period defined as Dec. Calibration pulse (the second one).
6. SIPS then takes another frame and calculates the difference between centroids of reference star on these two frames. The difference represents the mount reaction on the movement in Declination. The speed (Dec. scale) and angle (Dec. angle) is then calculated.
7. The software then moves the mount back to the original position.

Because both R.A. and Dec. speed and angle are calculated independently, SIPS does not require any particular camera orientation. Guiding camera in any position on any telescope (mirroring the image or not) can be properly calibrated.

Some General Rules for Successful Imaging

Advanced CCD cameras caused a revolution in amateur astronomy. Amateurs started to capture images of deep-sky objects similar or surpassing the ones captured on film by multi-meter telescopes on professional observatories. While CCD technology allows capturing of beautiful images, doing so is definitely not easy and straightforward as it may seems. It is necessary to gain experience, to learn imaging and image processing techniques, to spend many nights mastering the technology.

Although CCD camera can convert majority of incoming light into information, it is not a miracle device. Keep on mind that laws of physics are sill valid.

- CCD camera does nothing more than converting image created on the chip by telescope (or objective lens) into information. A quality telescope and quality "photographic-class" mount is absolute must for successful imaging. If the mount cannot keep the telescope on track, image is always distorted and blurred.
- Focus image properly. Almost unnoticeable focuser shift affects star diameter. Focusing, especially on fast telescopes, is critical for sharp images. Electrical focuser is a huge advantage, because it allows focusing without shaking the telescope by hand and with precision surpassing the manual focusing.

  Keep on mind that the star images are affected not only by focusing, but also by seeing. Star images will be considerably bigger in the night of poor seeing, no matter how carefully you focus.
- Master image calibration (dark frame subtraction) and carefully calibrate all images. Various artifacts (thermal noise, hot pixels, gradients etc.) degrade the image and properly calibrated image always looks better. Take care to obtain dark frames for all

resolutions/binnings and take new dark frames if the CCD temperature changes more than several degrees.

- If the image is processed to be as aesthetic as possible, other processing than basic calibration can significantly improve its appearance. Nonlinear stretching (called "curves" in some image-editing packages), special filters (hot/cold pixels removal, noise reduction etc.) and other processing (e.g. deconvolution) enhances the image.
- A common saying "there is a science in every astronomical picture" is especially true for CCD images. Examine your images carefully, blink them with older images of the same object or field. There is always a chance some new variable star, new asteroid, new nova or supernova appear in the image.
- Be patient. Although many advertisements proclaim "capture images like these your first night out", they probably mean your first successful night out. Nights can become cloudy or foggy, the full Moon can shine too much, the seeing can be extremely bad… Number of things can come bad, but the bad luck never lasts forever. Start with bright objects (globular clusters, planetary nebulae) and learn the technique. Then proceed to more difficult dimmer objects.

If you are new to CCD imaging and terms like "dark frame", "read noise" and "image binning" sound strange to you, refer to the "Introduction to CCD Imaging" chapter of the SIPS software documentation. This chapter explains basic principles of CCD operation and their usage in astronomy, discusses color imaging, CCD chip dark current and camera read noise, chip resolution and pixel scales in relation to telescope focal length and explains basic image calibration.

Camera Maintenance

The G0 and G1 cameras require no special maintenance. However, it is a precision optical and mechanical instrument so it should be handled with care. Camera should be protected from moisture and dust. Always cover the telescope adapter when the camera is removed from the telescope or put the whole camera into protective plastic bag.

Changing the Telescope Adapter of the G1 Camera

The 1.25" telescope adapter is screwed into the camera CS adapter. If you intend to use the camera with some CS compatible lens or microscope with C-thread adapter, simply unscrew the 1.25" adapter.

There are two standards using the C-thread (C-thread has 1 inch diameter and 32 threads per inch), differentiated by the back focal distance. The C standard has 17.5 mm back focal distance while the CS standard has 12.5 mm back focal distance.

G1 CCD cameras can be supplied with either C or CS adapter. This usually has no importance if the camera is used with the telescope, because the telescope focuser can easily compensate the difference. But certain lenses are designed either for C or CS standard.

While it is possible to use the distance ring to prolong the CS adapter to C standard, it is not possible to use the CS lens with full length C adapter. The C and CS adapters used on G1 cameras can be replaced, but camera mus be returned to manufacturer for such exchange.