COMPACT CCD GUIDER CAMERA FOR MAGELLAN

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Abstract: The Magellan guider camera uses a low-noise frame transfer CCD with a digital signal processor based controller. The electronics feature a compact, simple design, optimized for fast settling times and rapid readout rate. The camera operates (nominally) at –20 ºC with thermoelectric cooling. Multiple operating modes are supported, with software selectable binning, exposure times, and subrastering.

Key words: guider camera

The design objective for the Magellan guider camera was to build simple, low-power hardware with enough flexibility to operate in full-frame imaging mode, subrastered guiding mode, and Shack-Hartmann wavefront sensing mode.

The guider camera uses a Marconi CCD47-20 1024×1024×13 μm pixel, low-noise, back-illuminated, frame transfer CCD with a digital signal processor (DSP) based CCD controller. For reduced complexity, most of the digital logic functions are concentrated in the DSP and its internal peripherals, and a programmable logic chip (EPLD). A block diagram of the CCD camera is shown in Figure 1.

The CCD controller for the guider camera has a number of interesting properties. It features a programmable DSP56303 digital signal processor, which allows for software control of image size, subraster, binning, clock voltages, dual-slope signal processing, and exposure times. The circuit designs use simple op-amp and analog switch components for the clock driver and signal processing circuits[1]. The preamplifier[2] and signal processing circuits are optimized for fast settling times (less than 100 ns) to maximize the pixel readout rate. The design has dual signal processing channels with 14-bit, 1.2 ìs conversion time analog-to-digital converters. Clock and bias voltages are set by digital-to-analog converters. The controller features temperature monitoring of the CCD, and digital control of TE cooler current. The on-board DC-DC converters (with heavily filtered outputs) generate +3.3V, ±5V, ±12V and +28V from 48V DC input.

In operation, the CCD system is controlled by commands and program code sent over the data link. The DSP is fast enough to directly generate the sequences used for the CCD parallel and serial transfers from on-chip memory[3], and write them to the sequence register. Each bit controls one of the CCD clock lines, with a clock driver to translate to CCD-level voltages. The DSP controls the dual-slope integrators and analog-to-digital conversion, extracts the signal pixel-by-pixel and multiplexes the digitized data onto an RS-485 serial link at 20 Mbps for up to 100 meters. Each of the ADCs, DACs, sequence register, and data link peripherals are memory mapped in the DSP to simplify the software design.

The basic sequence patterns programmed into the DSP memory (serial shift, parallel shift, read pixel, flush pixel) are combined to read out the array. With the appropriate sequences the CCD can be read out through one or both output amplifiers.

Table -1. Detector and readout specifications

Property	Value	Units
Image size	1024 × 1024	Pixels
Pixel size	13	µm
Read noise	5	e- (slow scan)
Readout rate (slow)	5.0	µs/pixel
Readout rate (fast)	2.5	µs/pixel
Dark current (-20 C)	2	e-/pixel/s
Frame rate (binned 4×4)	4	fps
Subraster rate (32×32 pixels)	40	fps

Table -2. Power estimate

Circuit block	Value	Units
Digital electronics	1.05	
Clock drivers	1.60	
Signal processing	2.50	
Preamplifiers	0.35	
TE cooler	6.50	
TOTAL	12.0	watts

Figure 1. Magellan guider camera block diagram.

Physically, the guider camera consists of six circuit boards (DSP timing generator, signal processing, clock driver, power supply, backplane, and CCD header boards), and occupies a volume of less than 3.75 × 3.5 × 6.0 inches. An additional PCI interface board is used in the host computer.

The CCD is enclosed in a sealed, dry gas filled housing with an off-the-shelf two-stage thermoelectric (TE) cooler. The CCD temperature is monitored with an off-chip sensor (AD590) mounted inside the housing. An adjustable current source provides up to 3 amps to the TE cooler, which is rated for $\Delta T = 83$ ºC under ideal no-load conditions. In practice, a $\Delta T \approx 40$ ºC is achievable with a TE current of about 2 amps.

A liquid-cooled heat sink removed heat from the TE cooler hot side. Even at low flow rates (a few lites per minute), the entire CCD housing can be rapidly chilled to the fluid temperature (nominally 10 ºC at the telescope). The TE drive transistor is mounted on the heatsink as well, to prevent it overheating.

OCIW has open-sourced the design information for the guider camera, which is available at www.ociw.edu/~burley/ccd/guider.html. The on-line information contains a complete design description, including all schematics, pcb layouts, EPLD code, dsp source code, C subroutine library, and test results.

The guider cameras are in regular use on the two Magellan 6.5-m telescopes at Las Companas Observatory.

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