

# A flexible 4-channel CCD controller - not only for BUSCA

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## Abstract

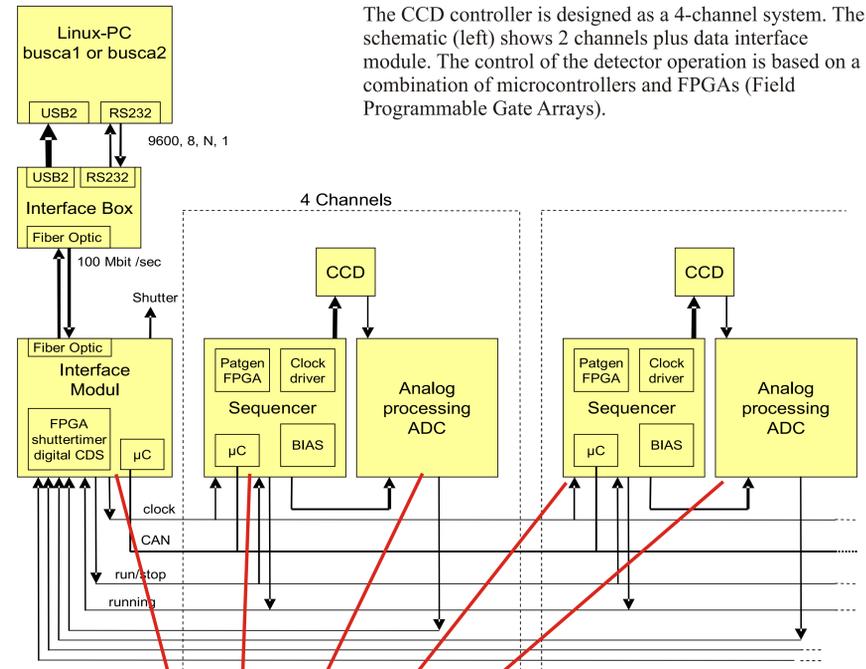
We have developed a new 4-channel CCD control electronics. In early summer 2008 it was implemented in the Bonn University Simultaneous Camera (BUSCA) at the Calar Alto 2.2m telescope. Given the limited budget of a University institute we aim at a high end/low cost solution that may be of interest also for other institutes or observatories.

Main characteristics and performance parameters are:

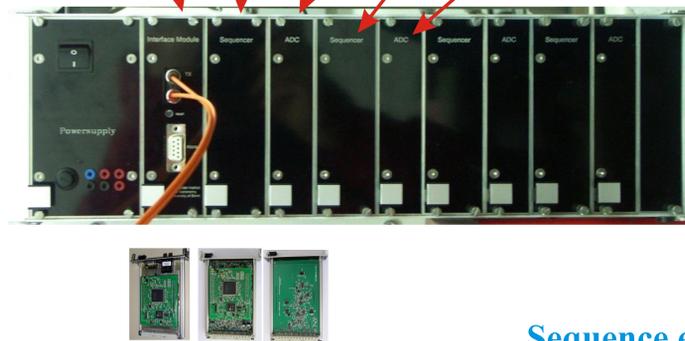
- A new concept for pattern generation in the FPGA.
- Number of CCD channels scalable.
- Complex read out modes are possible.
- Multiple window mode with overscan window, free size and position, shift correction.
- Up to 30 different patterns can be uploaded and stored in the FPGA.
- Programmable bias and clock voltages (14bit resolution).
- Programmable pattern, 20ns time step, 15 fast clocks/channel.
- Read out rate from 50kPix/sec to 250kPix/sec.
- Read out noise (with one of the new CCDs) is between 3 and 3.5 electrons.
- CDS is implemented digitally (FPGA).
- TDI mode is possible.
- USB2.0 data interface with Linux drivers.
- Highly compact sequencer design.

A new concept for the pattern generation was realized. A sequence processor was developed as a FPGA core. The patterns consist of a set of instructions residing in the FPGA's RAM. The instruction set is very "reduced" but it does allow to define sophisticated patterns in a very compact manner e.g. by means of a loop instruction. Each instruction takes one 50MHz cycle (i.e. 20ns) and does consist of a 16Bit word. All sequencer modules (one per CCD channel) are driven by the same master clock and are started by a common control line. Thus synchronous operation is guaranteed. A sequence editor with a debug/emulation mode and graphical output was developed.

## Multi channel CCD controller layout

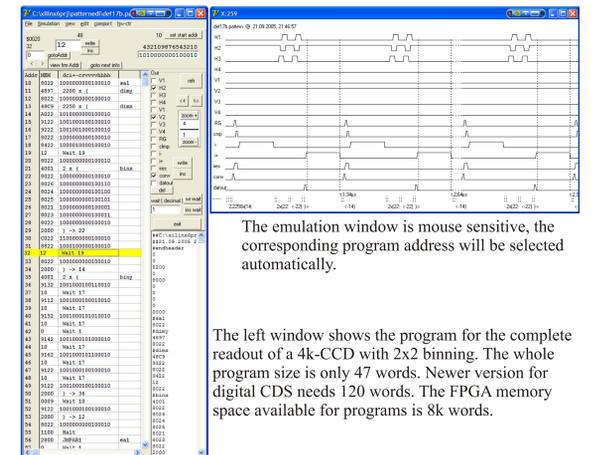


The CCD controller is designed as a 4-channel system. The schematic (left) shows 2 channels plus data interface module. The control of the detector operation is based on a combination of microcontrollers and FPGAs (Field Programmable Gate Arrays).



Digital pattern generation module realized as piggyback board.

## Sequence editor

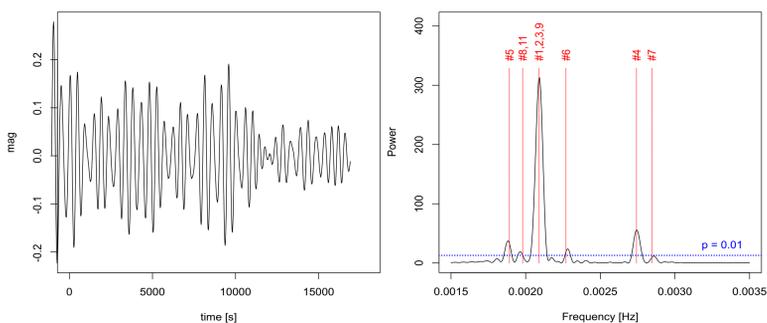


The emulation window is mouse sensitive, the corresponding program address will be selected automatically.

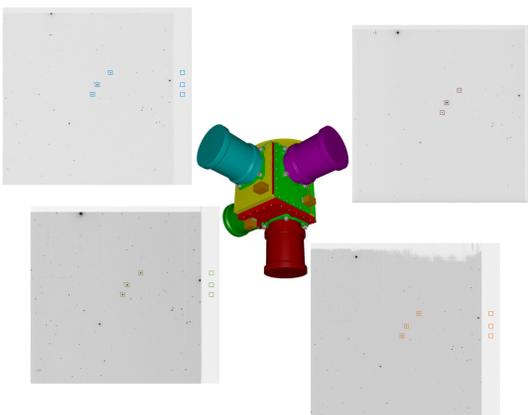
The left window shows the program for the complete readout of a 4k-CCD with 2x2 binning. The whole program size is only 47 words. Newer version for digital CDS needs 120 words. The FPGA memory space available for programs is 8k words.

The sequence editor emulates the sequence processors program run and shows the generated waveform.

## A typical application: Rapid (multicolor) time series of variable objects

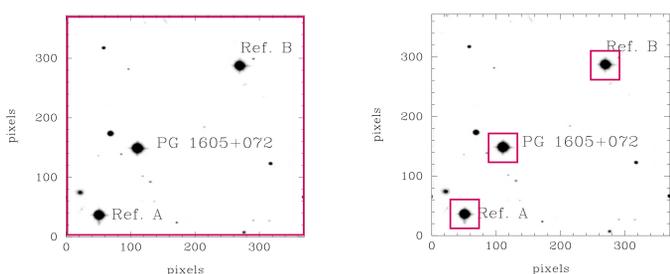


BUSCA takes images in four color bands simultaneously - separated by dichroics. In the 4 frames (4k x 4k) the windows around 3 selected stars are indicated plus overscan windows on the right hand site.



Positions of readout windows. The position offsets of the CCDs in the 4 color channels are visible.

Time series (left) of the V361 Hya class pulsating sdB star PG1605+072 (from Falter et al. 2003). The CCD readout time (=sample time) of 50s per frame of the first BUSCA controller limits those studies which is show in the periodogram (right). No all of the main 9 pulsation periods between 5 and 8 minutes (0.0033-0.0020Hz) can be detected with a confidence level of 99%.



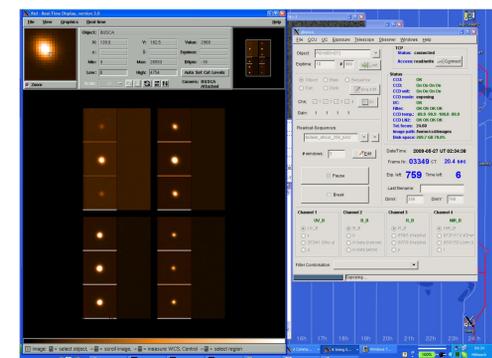
So far the read out window is usually tailored to include all reference objects (left). The new controller will not only allow higher read out speeds but also the read out of multiple windows (right). This will improve the detection of more than just the main periods.

## Reference:

Falter S., Heber U., Dreizler S., Schuh S. L., Cordes O., Edelmann, H., 2003, A&A401, 289-296 *Simultaneous time-series spectroscopy and multi-band photometry of the sdBV*

A special multiple window mode is implemented. It can correct the CCD position error (shift and rotation).

BUSCA takes images in four color bands simultaneously - separated by dichroics. The CCDs are not ideally placed in the light path, they are a little shifted and rotated with respect to each other. The readout windows will be shifted to different positions for each CCD and read out at the same time. Variables for shifting will be calculated by the control program before. Very small windows are possible with short readout time. Tested: 4 CCDs, three windows 50 x 50 pixel with overscan, readout time is 10.4 sec



Multiple window mode in action.

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