CCD/CMOS Cameras for the Pi of The Sky Project and industrial applications

Grzegorz Kasprowicz
PERG
Plan of presentation

- Cameras for wide field astronomy
- Prototypes (K1, K2, K20, K30)
- Current version parameters and limitations
- Next generation of CCD cameras
- Summary
Wide field astronomy

Observation of variable objects
High time resolution (~1s)
Large areas of the Sky
Online processing of the data
Custom detectors required

=> Pi of the Sky
Camera requirements:

- Sensor: 2048x2048 pixels
- USB 2.0HS or Ethernet 1000T Interface
- Programmable exposure and readout time (1s-100s)
- uC software and FPGA upgrade via USB/Eth
- Peltier cooling of CCD
- Humidity and temp. measurement inside and outside chamber (CCD, case, ambient)
- Build-in mechanical shutter (10e6 cycles)
- Embedded on-line pre-processing

Power supply board

Main board

Top view

Side view

Installed in Las Campanas in Chile
K2 Camera Status

• 2 cameras installed in Las Campanas in Chile
• work since may 2004 collecting hundreds GB of data
• many optical flashes and other variable objects detected
• Spring 2008 – spectacular discovery of black hole birth

Problems:
• USB2.0 : Too short maximum cable length (5m)
• problems with transmission reliability
• problems with PC’s redundancy
• Solution: Gigabit Eth -> K20 camera
K20 camera with Gigabit Ethernet & USB2.0 HS interface (2006)
K20 during tests (without lens)

Status:

- 16 cameras produced, 16 cameras during mechanical assembly phase
- Further development seriously limited – too many custom solutions (firmware written in assembly)
- New approach needed -> K30
New generation of CCD cameras

K30 = K20 + Linux

Linux = ready to use network stack, application software, protocols, reliable operating system

Standardized tools and software interface = Further Development facilitated

Hardware:

• ARM9 200/400MIPS
• CCD readout same as K20 + programmable CCD biases
• Shared system and frame memory
K30 Cameras

2 prototypes produced
INDI server, Video for Linux **V4L2**
(M.Kwiatkowski)

Compatible with standarized tools
NEXT generation of CCD cameras

K30 is sufficient up to 1 frame/s due to 100mbit network bandwidth and processing power (200MIPS).

Pi of the sky requires 0.1...0.5 fps at the moment

New trends in astronomy require 10..100 fps with online processing (adaptative optics) and much higher sensitivity (EMCCD, CCD + oversampling)

50fps * 8MB = 400MB/s !! No way to store it continuously.
NEXT generation of CCD cameras

- K40 (?) = K30 + Linux + DSP + Power PC + FPGA + oversampling
- DSP: online processing, frame merging, gauss fitting, flash recognition
- Power PC with dual gigabit Ethernet–network interface, FPGA management, device control
- FPGA + SDRAM (~4GB) – pre-processing & storage
- Modular design – CCD/CMOS/IR FPA sensors
- Compact, built-in power supply
NEXT generation of CCD cameras

Power PC – assembled prototype

- 2* gigabit MAC
- Up to 1500MIPS
- 2* PCI Express
- 256MB SDRAM
- 1GB FLASH
- USB 2.0 HS
- EMIF with DMA (200MB/s)
NEXT generation of CCD cameras

Digital readout of CCD (P. Obroślak)

- Sample CCD signal just after the sensor
- CDS and filtering entirely in FPGA
- Great flexibility
- Ease of readout speed scaling
NEXT generation of CCD cameras

DSP accelerator (T.Klonowski)

• Ti Digital Media Processor
• Up to 5600 MMACs/s
• 256MB SDRAM
• Image Sensor IFC
• Host Port Interface
NEXT generation of CCD cameras

New mechanical design

- Compact 120x120mm case
- Vacuum chamber for CCD
- Embedded power supply 12-30V DC
- Up to 2 DSP modules
- Lower machining costs
NEXT generation of CCD cameras

New mechanical design

- case cross-section
NEXT generation of CCD cameras

New mechanical design

PCBs:
- Supply
- Drivers
- Analog (ADC)
- CCD
- DSP
- CPU
NEXT generation of CCD cameras

PCB designs
- Supply
- Drivers
- Analog (ADC)
- CCD
- DSP
- CPU
Plans for future:

• Readout noise reduction to less than 5..7e-Quad ADC readout to obtain 50+ fps
• Design and development of final DSP board with FPGA and SDRAM
• New custom, Frame Transfer CCD sensors from STA without dead time and mechanical shutter
• Implementation of over-sampling techniques and “Zero noise CCD” concept
• Mechanical development
Thank you