
IRACE

The ESO Controller for Infrared Arrays

(Infrared Array Control Electronics)

European Southern Observatory

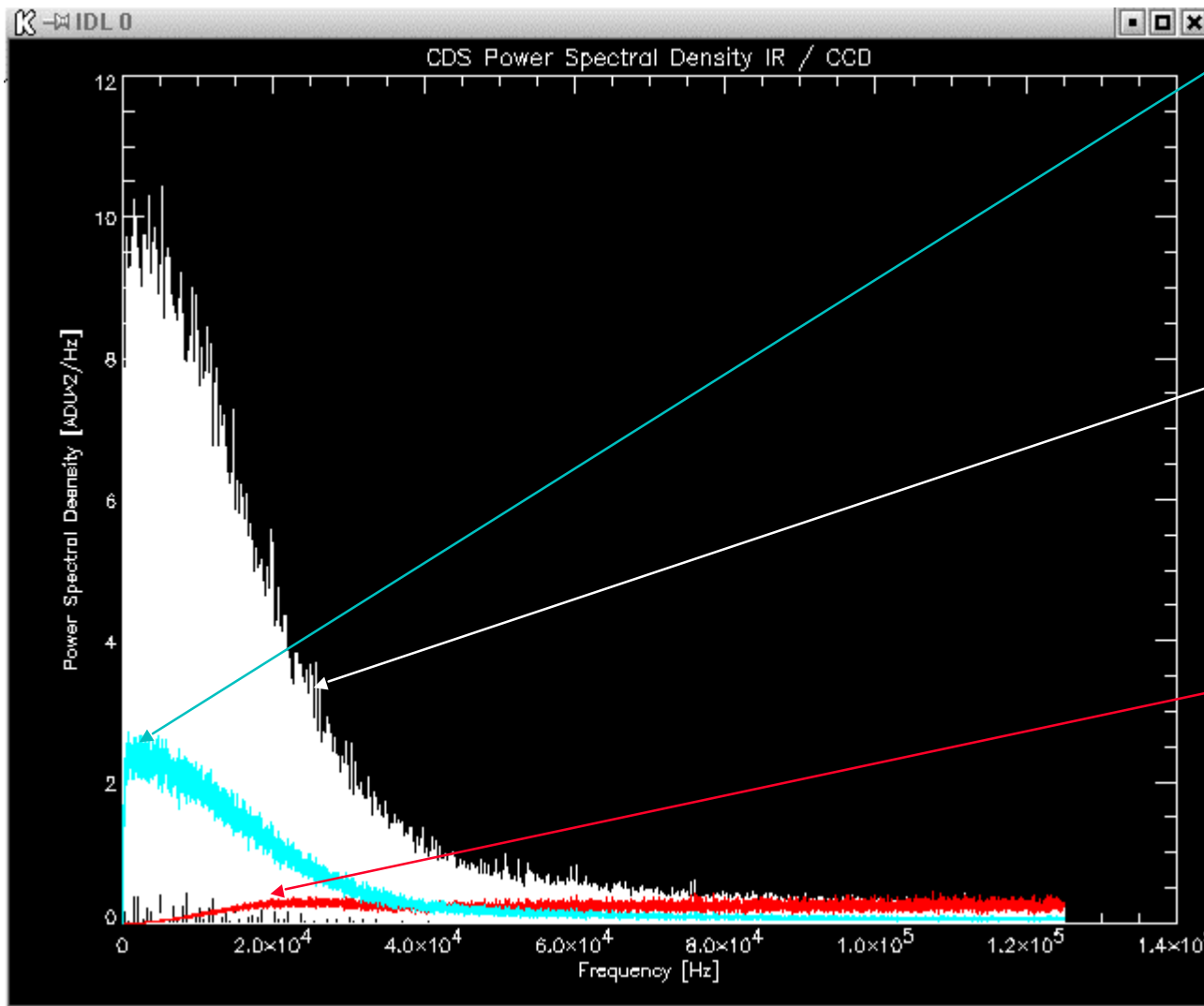
Manfred Meyer, Hamid Mehrgan, Joerg Stegmeier

Speaker: Gert Finger

Outline

- Special controller needs for IR detectors
- IRACE data acquisition system
- IRACE detector control software DCS

Double correlated sampling Infrared / CCD



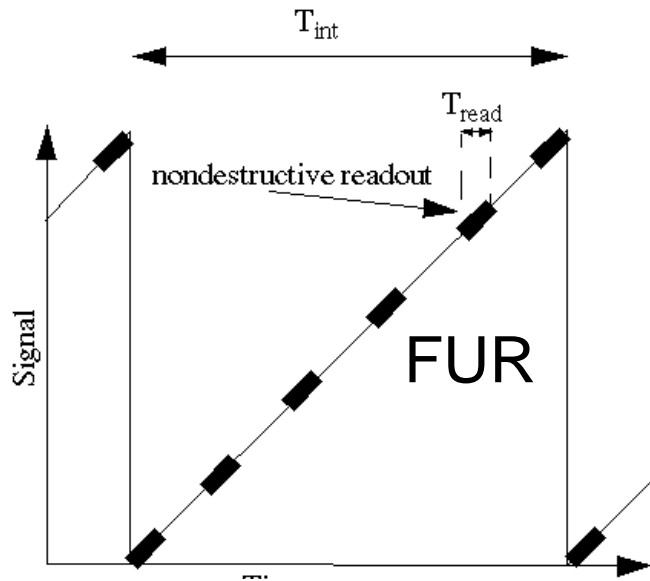
- Blue curve:
power spectral density of
Picnic 256x256 MBE

- $|N_{\text{CDS}}|^2 = |N_{\text{DET}}|^2 * |H_{\text{CDS}}|^2$
 $|H_{\text{CDS}}|^2 = [2 - 2\cos(2\pi f t_s)]$

- White Curve Infrared:
dc coupled
 $t_s = 1$ sec (can be >1000s)
fully sensitive to
1/f noise and 50 Hz

- Red curve CCD
 $t_s = 4$ μ sec
no 1/f noise and 50Hz

Noise reduction by multiple nondestructive readouts



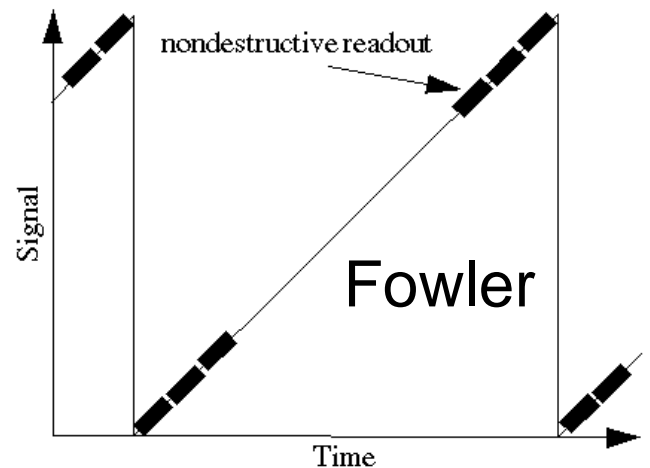
- Follow-up-the-ramp sampling (FUR):
at equidistant time intervals nondestructive readouts
least squares fit: slope of integration ramp

$$SNR_{FUR} = SNR_{DC} \sqrt{\frac{n(n+1)}{6(n-1)}}$$

- Fowler:
nondestructive readouts at start and at end of ramp
least squares fit: slope of integration ramp
for $n \gg 1$:

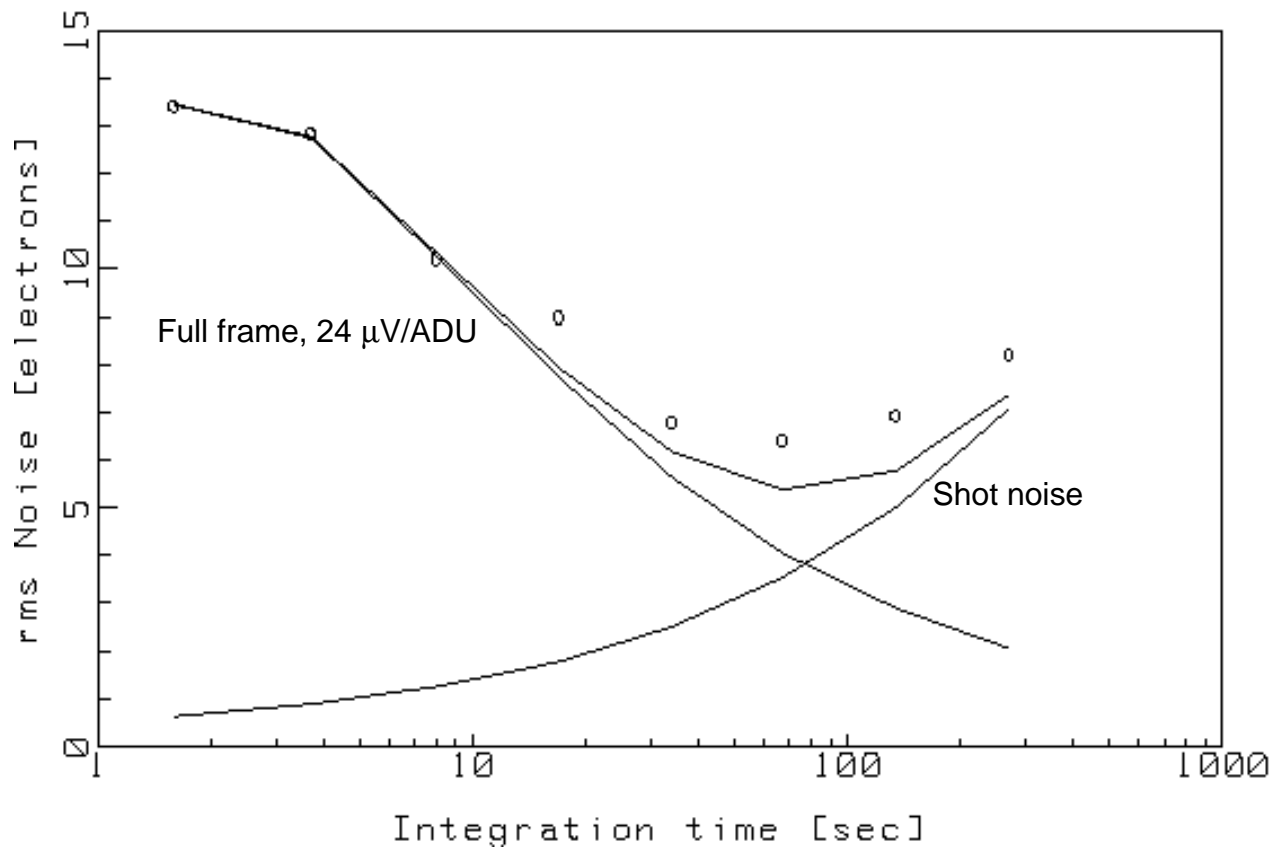
$$SNR_{Fowler} = SNR_{DC} \sqrt{\frac{n}{8}} \cong SNR_{FUR} \sqrt{\frac{6}{8}} \Leftrightarrow T_{int} = nT_{Read}$$

$$SNR_{Fowler} = SNR_{DC} \sqrt{\frac{n}{2}} \cong SNR_{FUR} \sqrt{3} \Leftrightarrow T_{int} \gg nT_{Read}$$



Readout Noise versus number of nondestructive readouts

Readout & Shot Noise of Rockwell 1024x1024 MCT Array



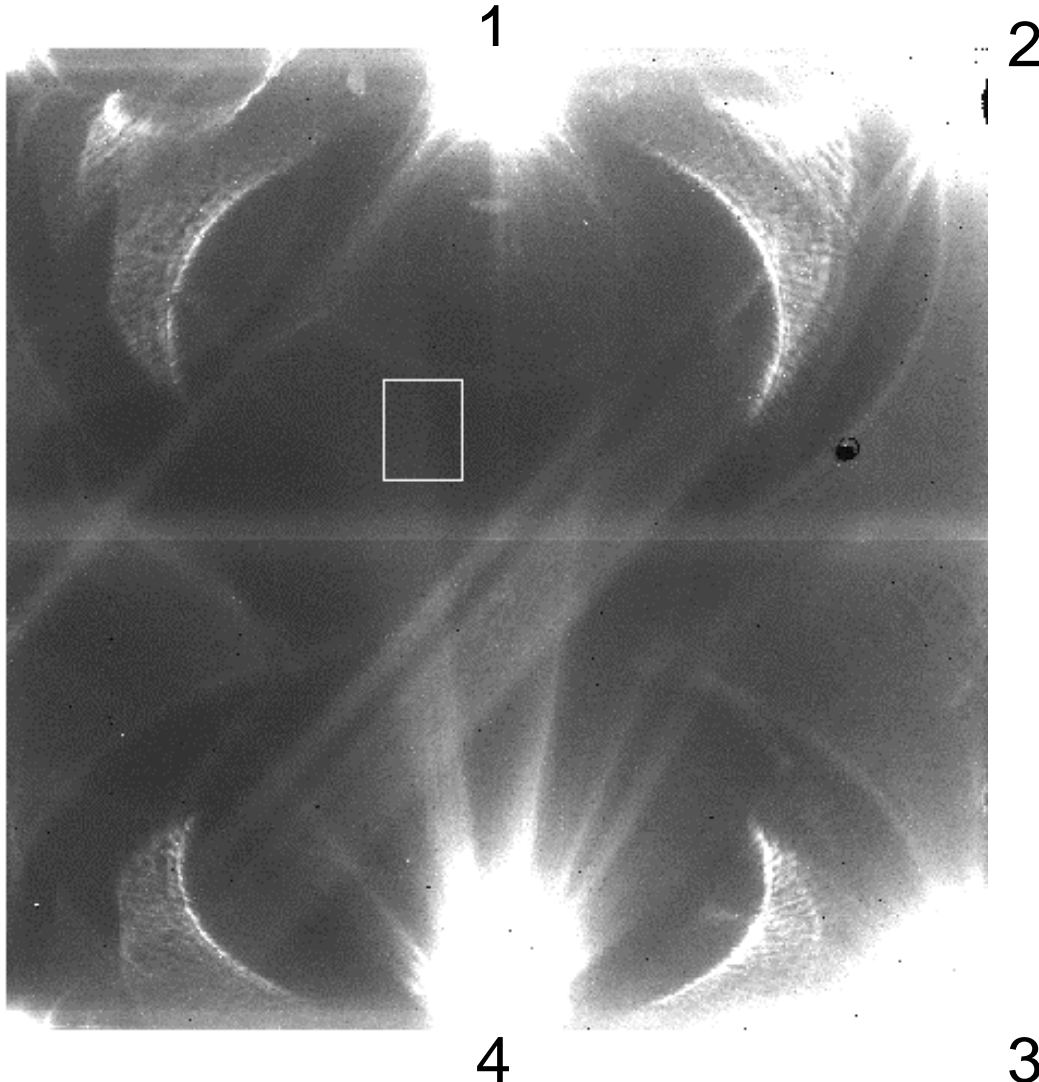
Follow-up-the-ramp sampling:
number of readouts n
proportional to integration time

$$\sigma_{\text{mult}}^2 / \sigma_{\text{dc}}^2 = 6(n-1) / (n(n+1))$$

frame rate 1Hz, 64 nd samples
integration time 67 sec
rms noise 6.3 electrons

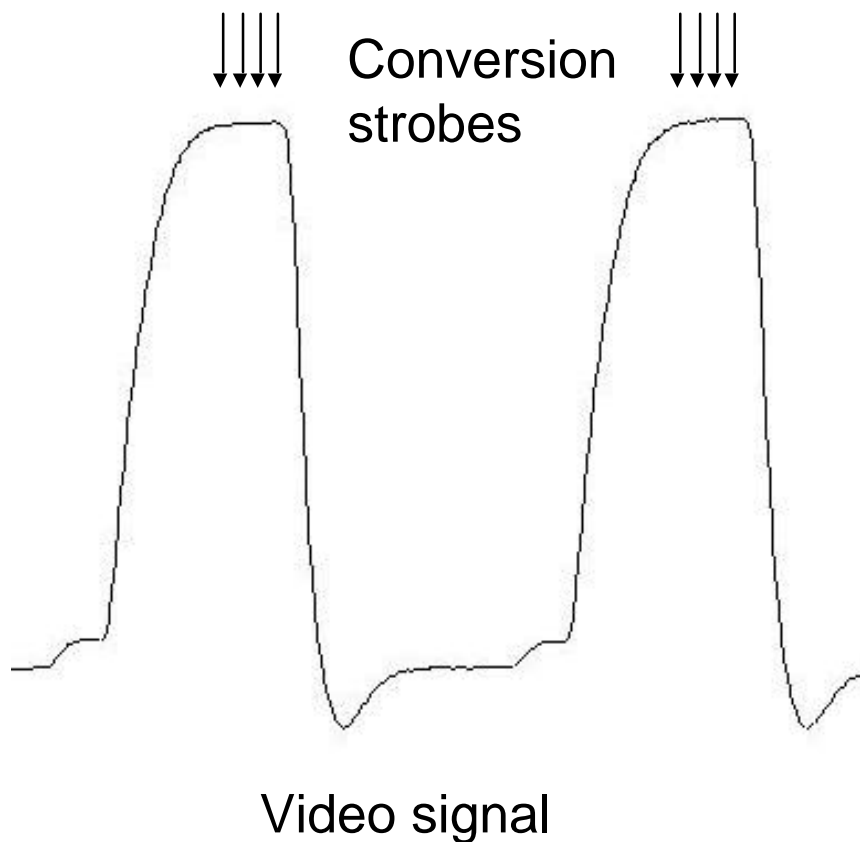
darkcurrent of 30 e/hour too small
for shot noise

Shot noise of shift register glow



- shift register glow localized at four points on edges (1,4) and in corners (2,3)
- Remark: arcs are due to reflection of light emitted by glow centers

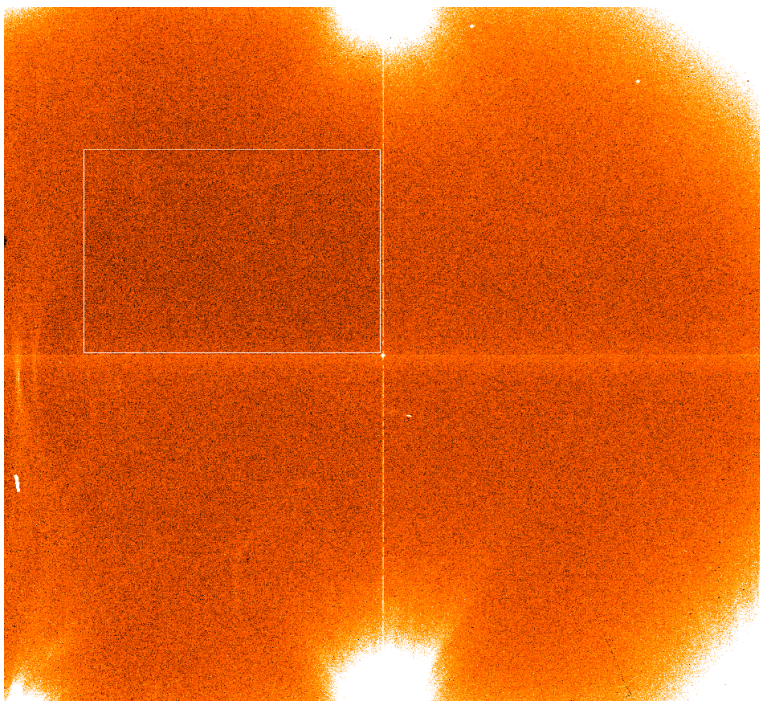
Subpixel sampling to reduce shift register glow



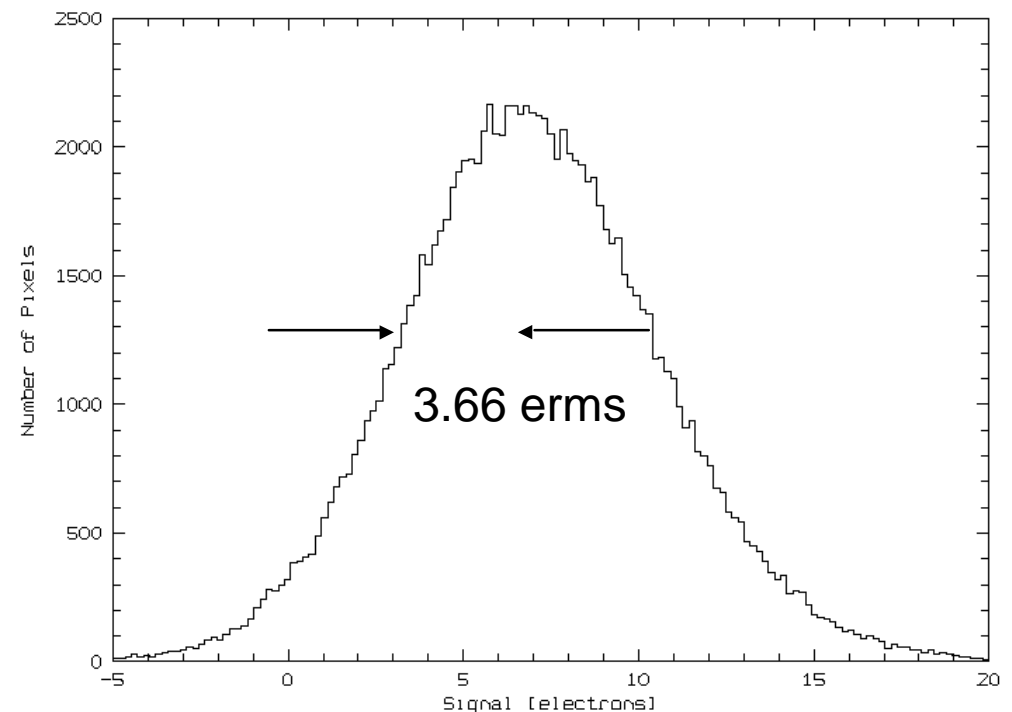
- On-chip amplifiers not used: no glow
- only source of glow is addressing of pixels
- reduce addressing (number of readouts)
- increase number of conversions per pixel
- sufficient samples to beat down noise without glow penalty

Noise of Hawaii LPE raw image on stabilized integration ramp

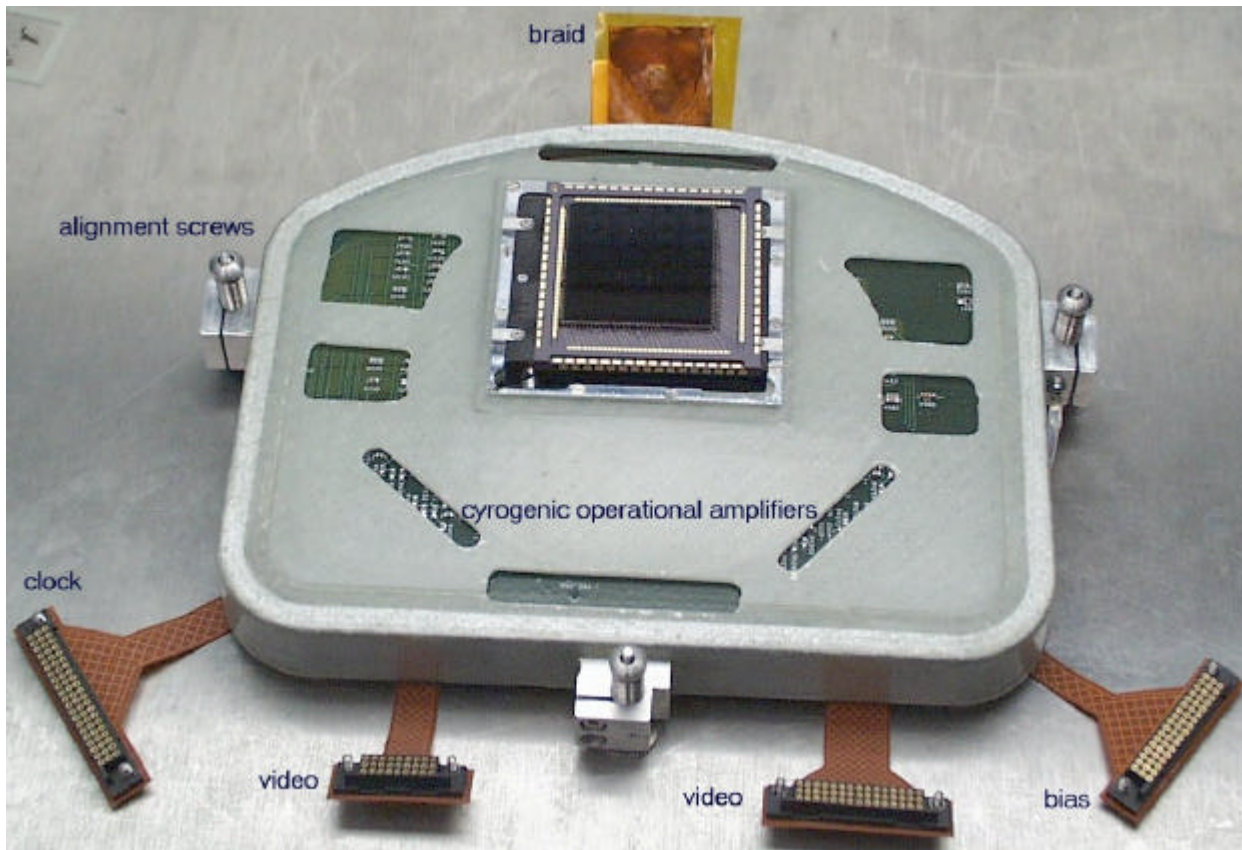
- Introduce delay > 30 s after reset
- with 32 fowler pairs uniformity of raw image 3.66 e rms pixel to pixel
- no difference required : equivalent noise of 2.6 e rms
- discontinuity at quadrant borders: < 4 electrons



Dit = 60 s , Cuts -5 / 40 electrons



Hawaii2 2Kx2K LPE HgCdTe engineering grade

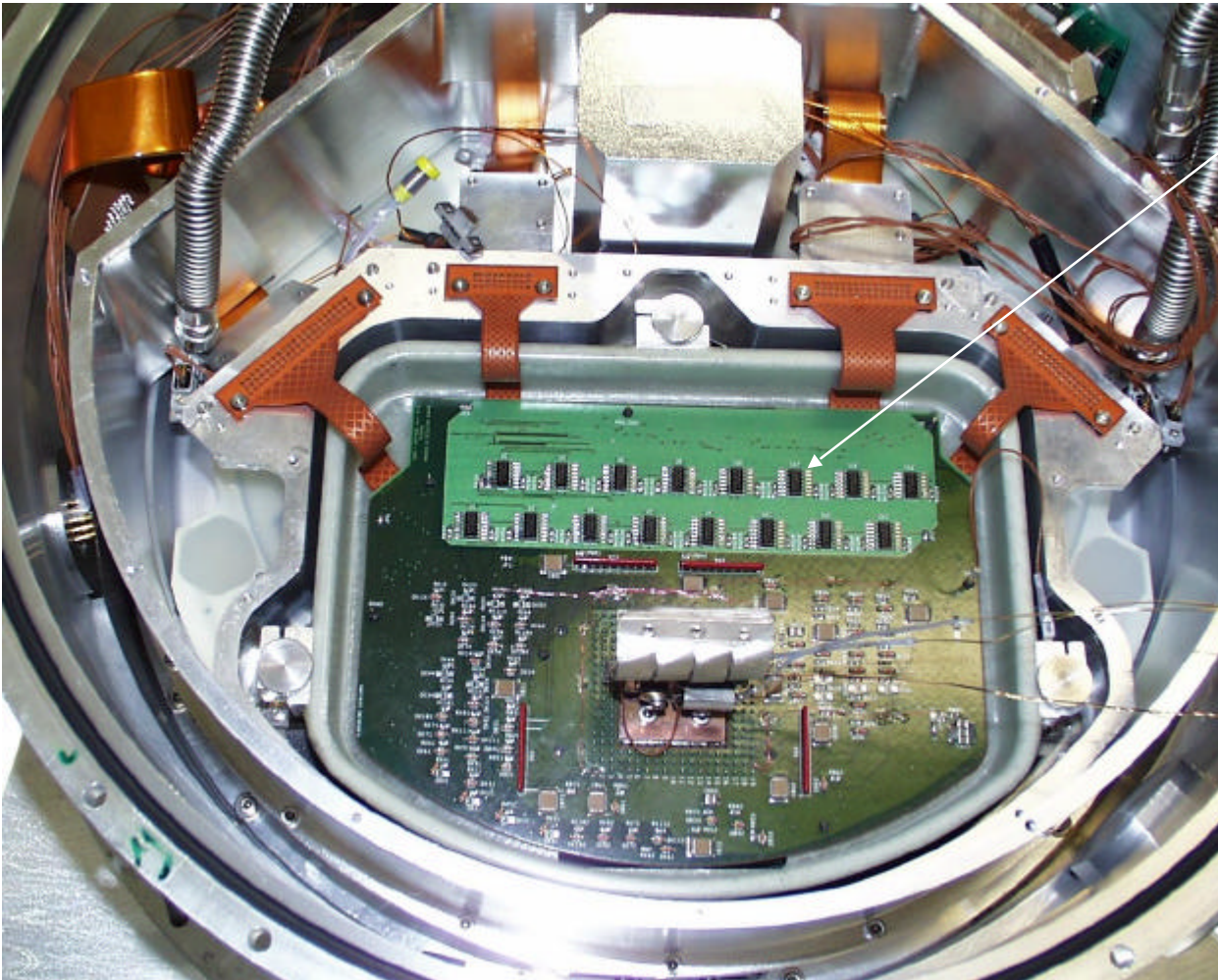


- Hawaii 2Kx2K LPE HgCdTe engineering grade array
- 32 video + 4 reference channels
- Readout time: 800 msec
- RON : 10 erms double correlated
- QE H-Band : 0.81

Status:

- engineering grade array delivered and tested
- science grade array delivered
- cryogenic clamp circuit for 4 reference outputs manufactured

Hawaii2 2Kx2K LPE HgCdTe engineering grade

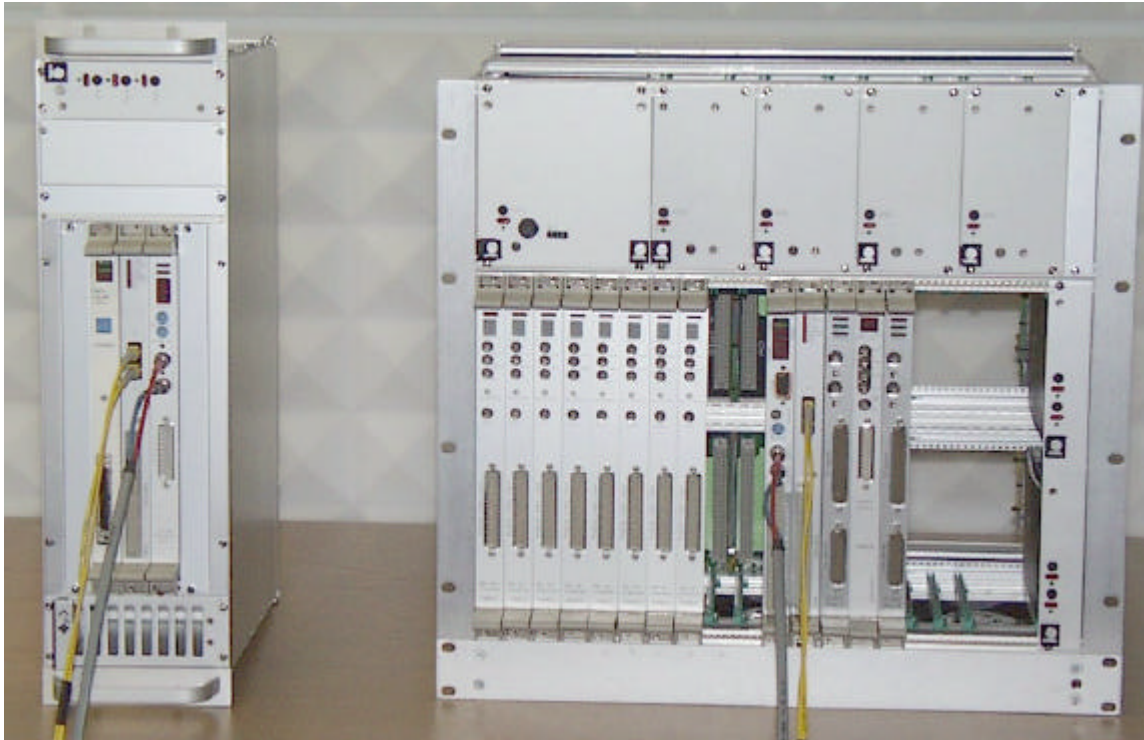


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IRACE 144 channel version



Interface
to Ultrasparc

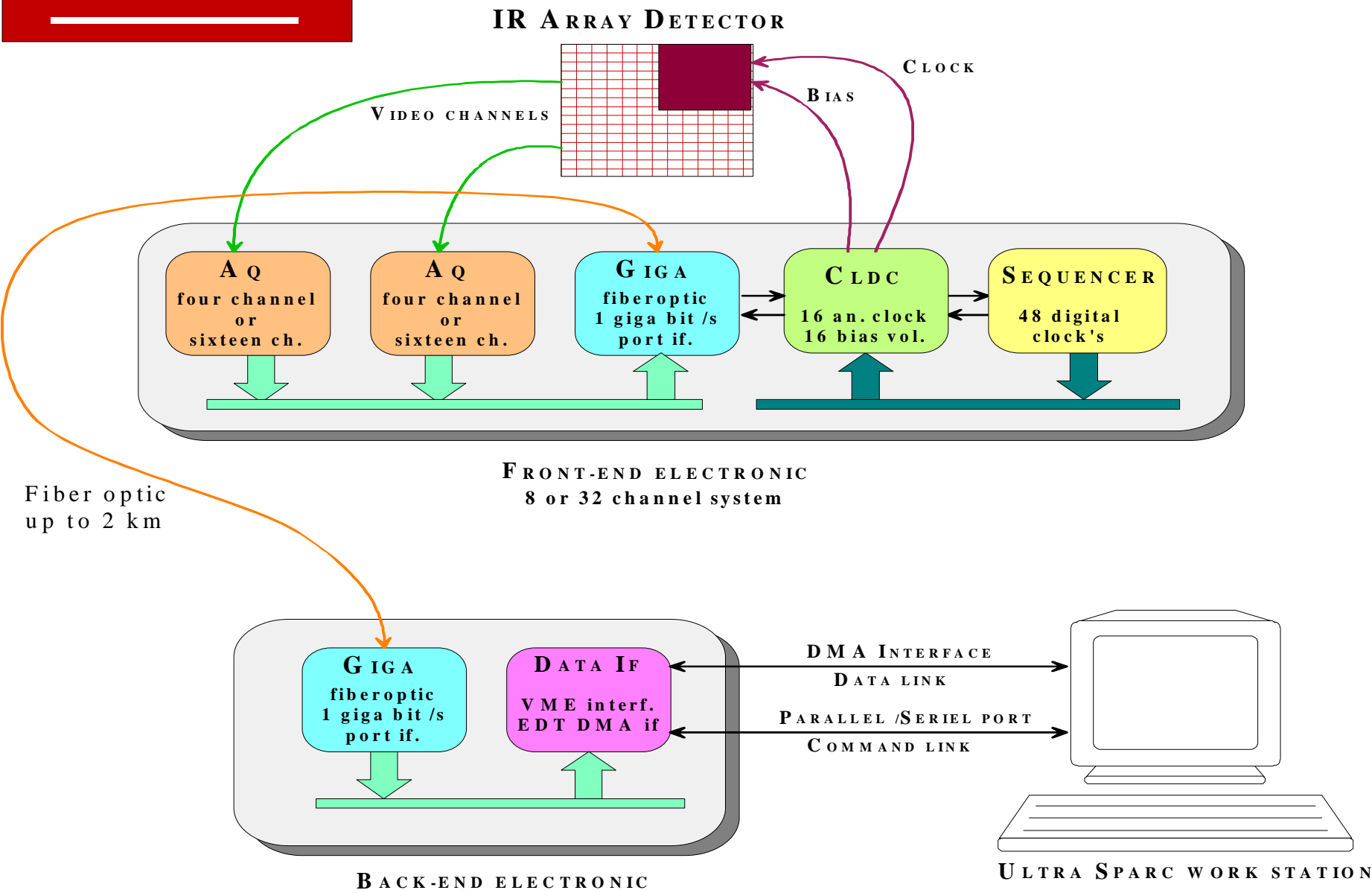
Detector front end
mounted on Instrument

- Nirmos has four 2Kx2K arrays each having 32 video channels and 4 reference channels
- new ADC boards:
16 channels / board
16 bit 500KHZ
16x9 = 144 channel system
- readout of 4Kx4K array in 1.3 sec

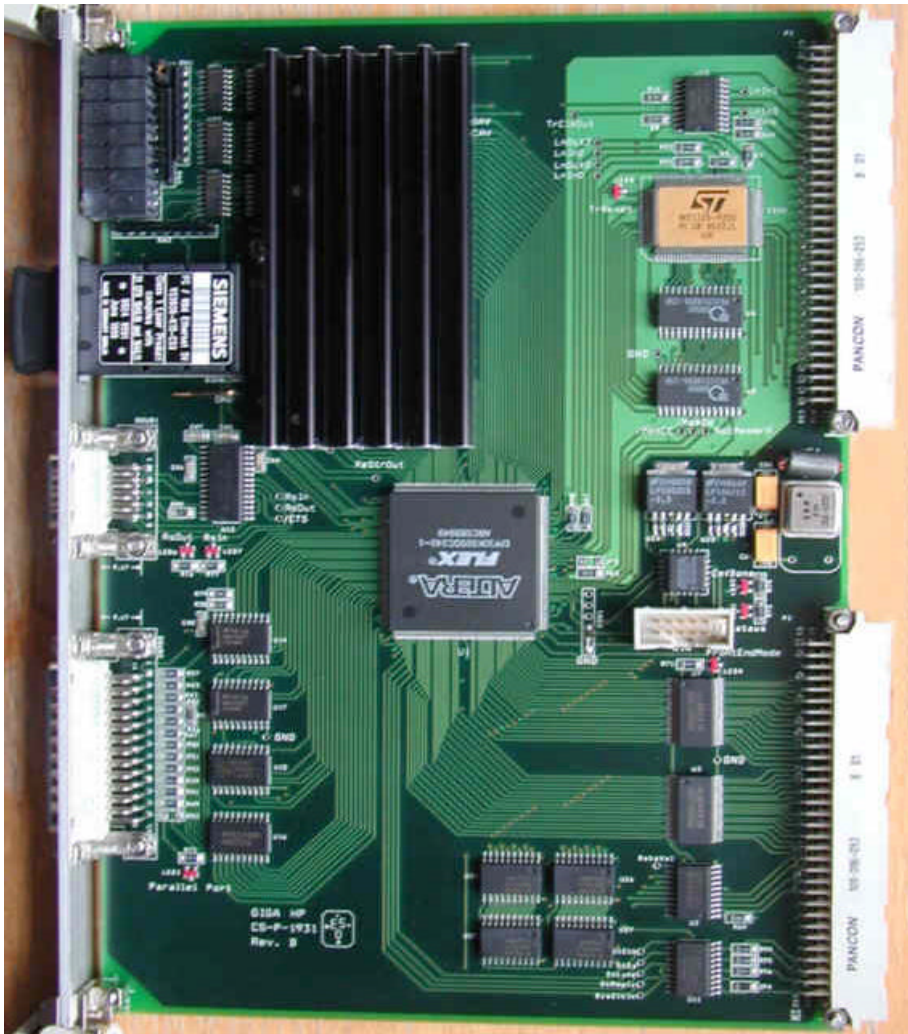
Status:

- tested with Hawaii 2Kx2K array
- 144 channel prototype tested

IRACE



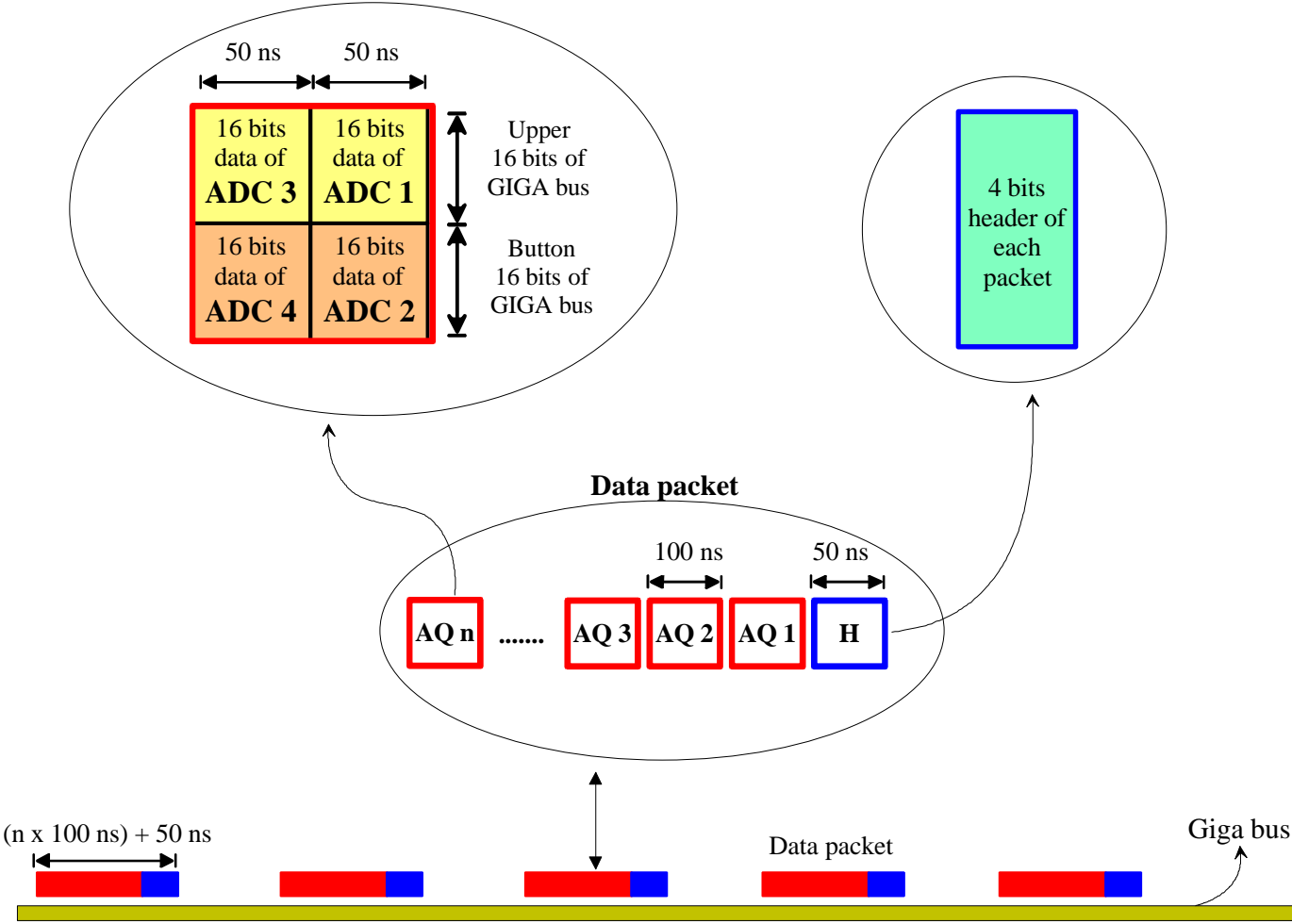
GIGA



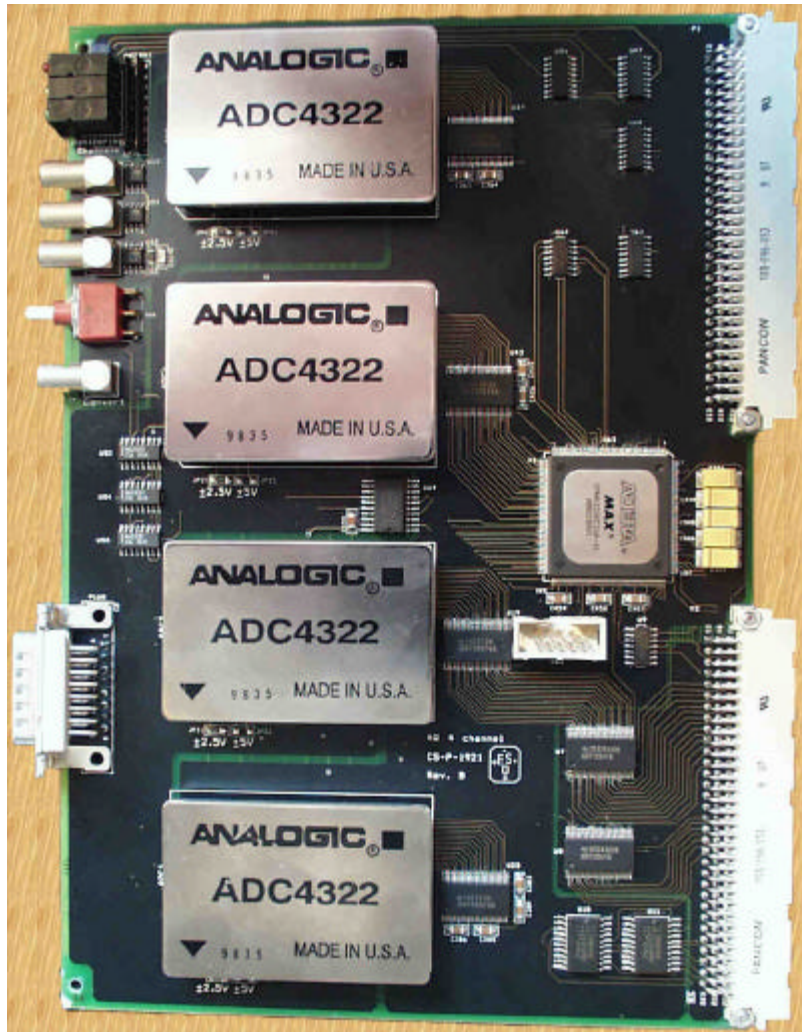
- Fiber optic transceiver data rate of 1 Gigabit/s
- 80 MB/s data bus on P2 connector
- Parallel and serial port interface
- VME bus compatible

Transport of data over the giga bus

IRACE with AQ 4-channel

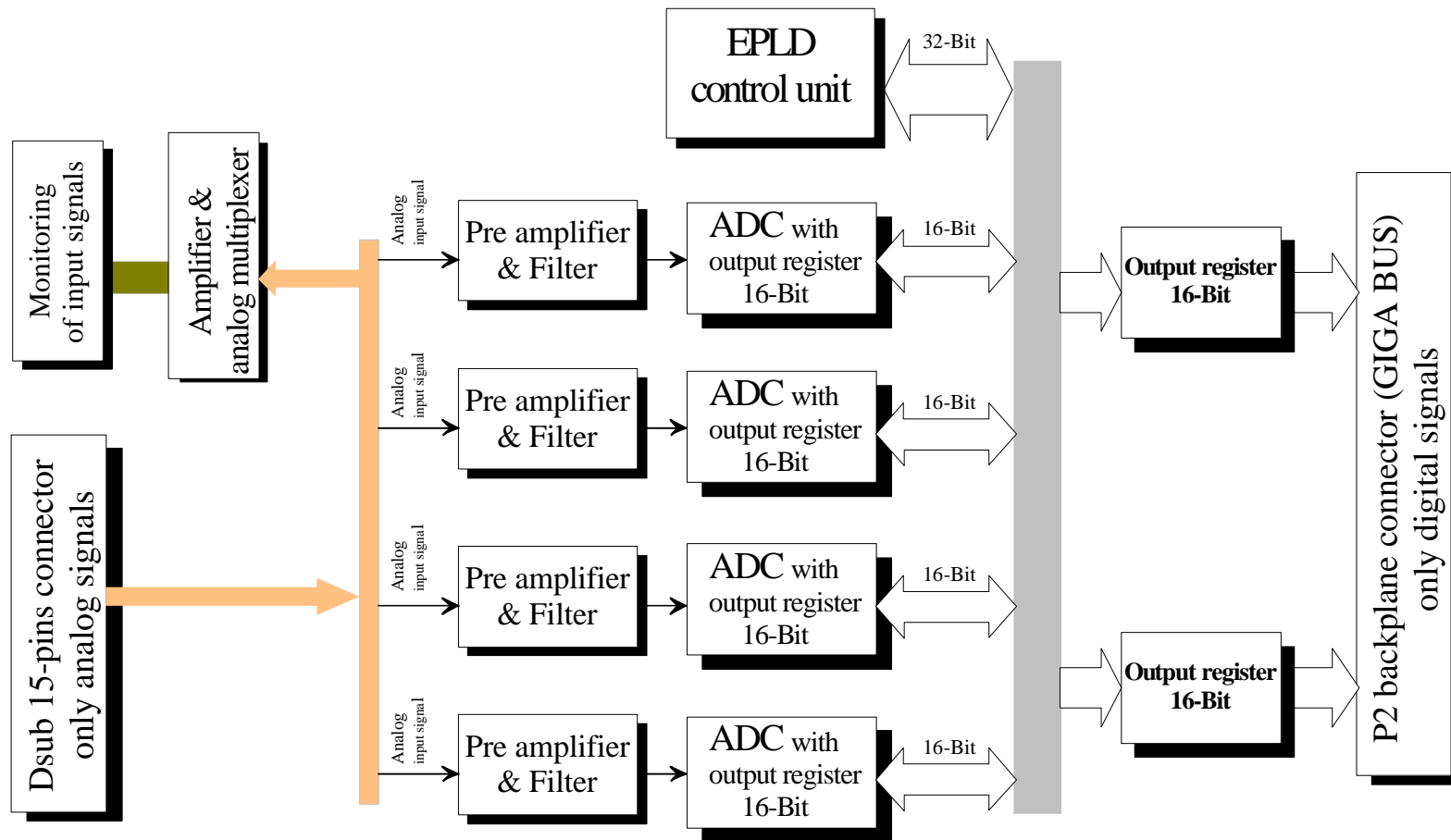


AQ 4-channel

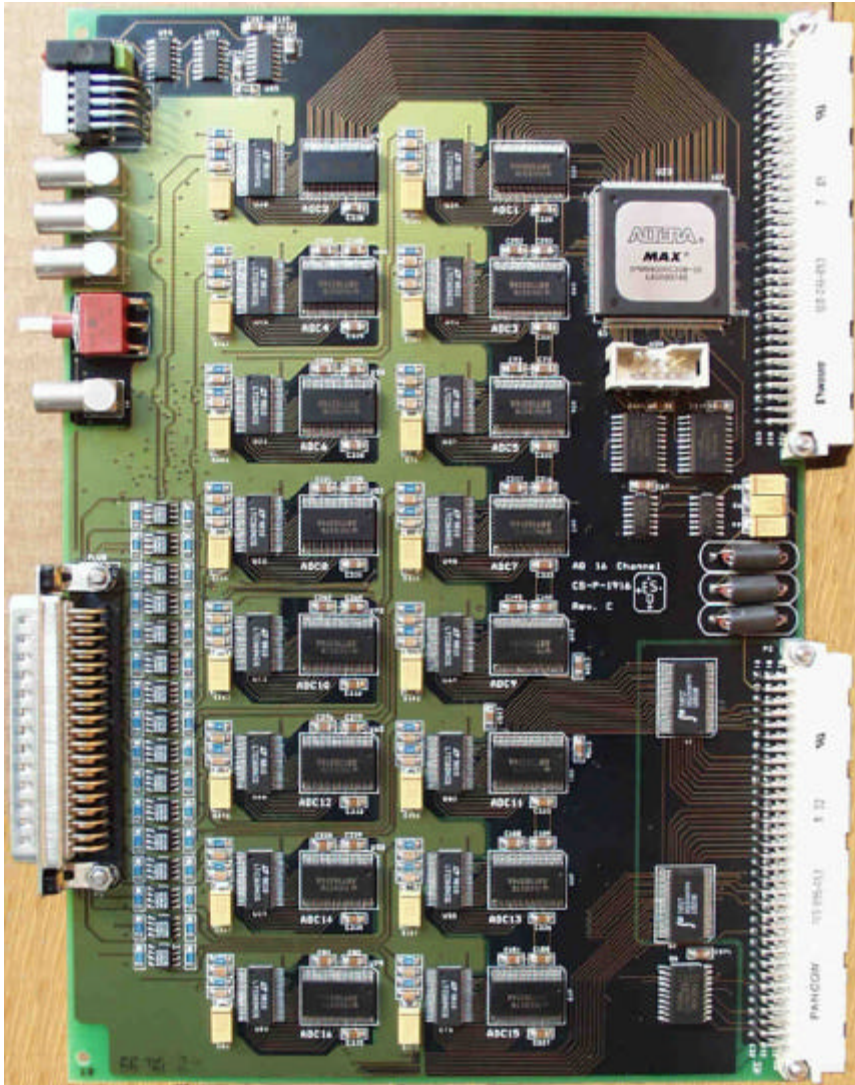


- 4 fast ADC's
ADC 4322: 16 bit 2MHz
- 8 boards = 32 channel system
1Kx1K array: frame rate 16 Hz
- True differential analog inputs
- VME compatible I/O pin
- Monitoring of video input signals
- 80 MB/s data bus on P2
- Delay of conversion strobe
in 50 ns steps
- On board ADC-emulator

AQ 4-channel

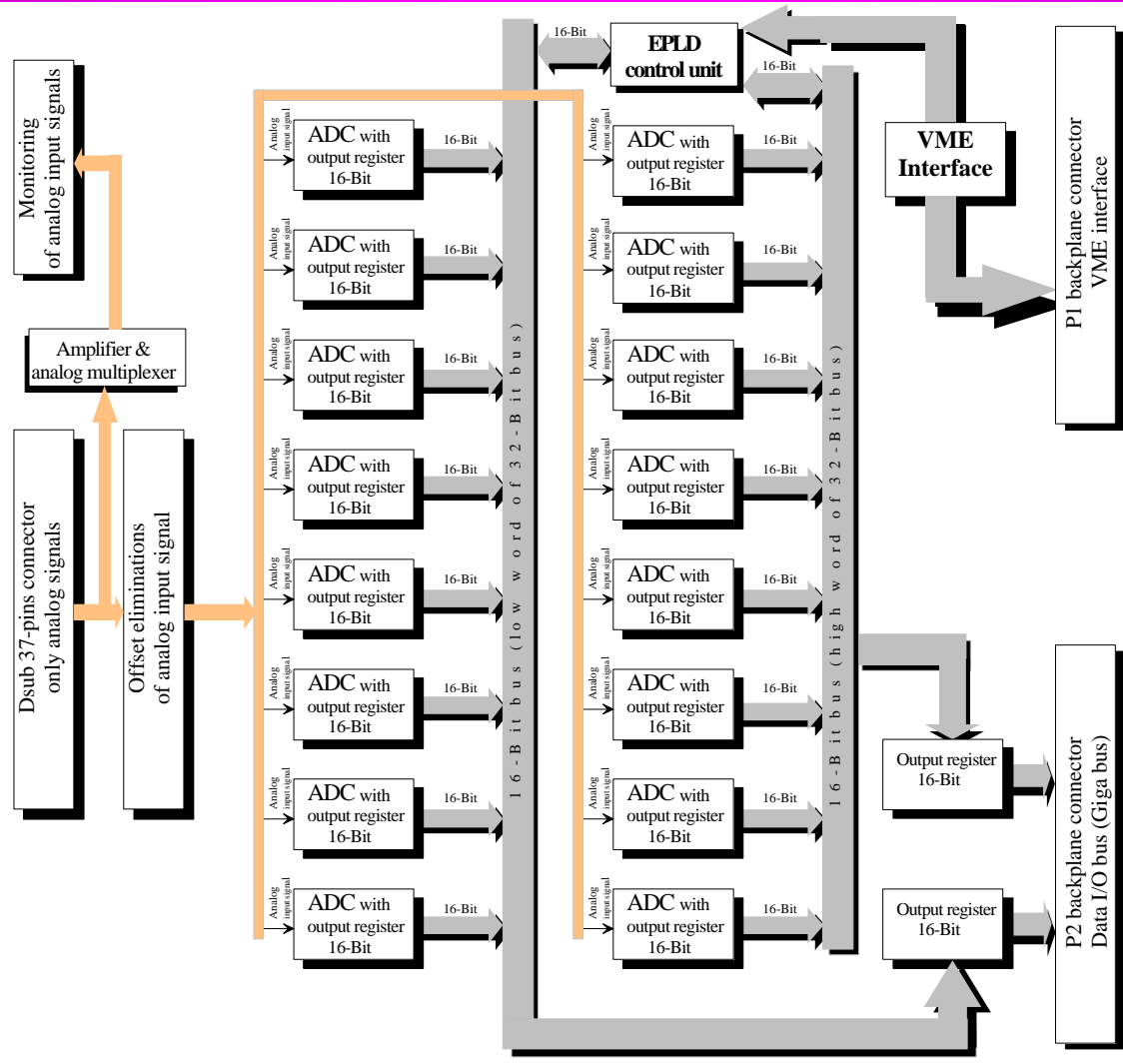


AQ 16-channel

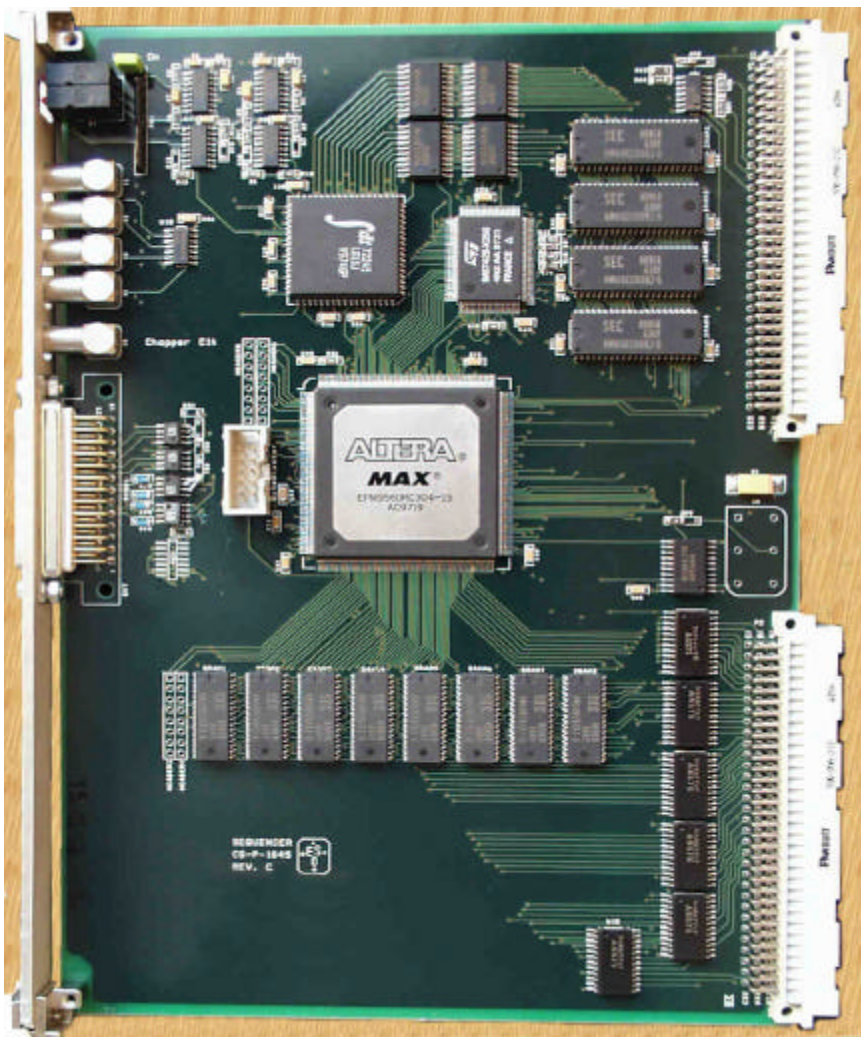


- 16 ADC's
LTC1608 16 bit 500 KHz
- 9 boards = 144 channel system for
4Kx4K array: frame rate 1.25 Hz
- True differential analog inputs
- True VME bus interface
- Monitoring of video input signals
- 80 MB/s data bus on P2
- Delay of conversion strobe
in 50 ns steps
- On board ADC-emulator

AQ 16-channel

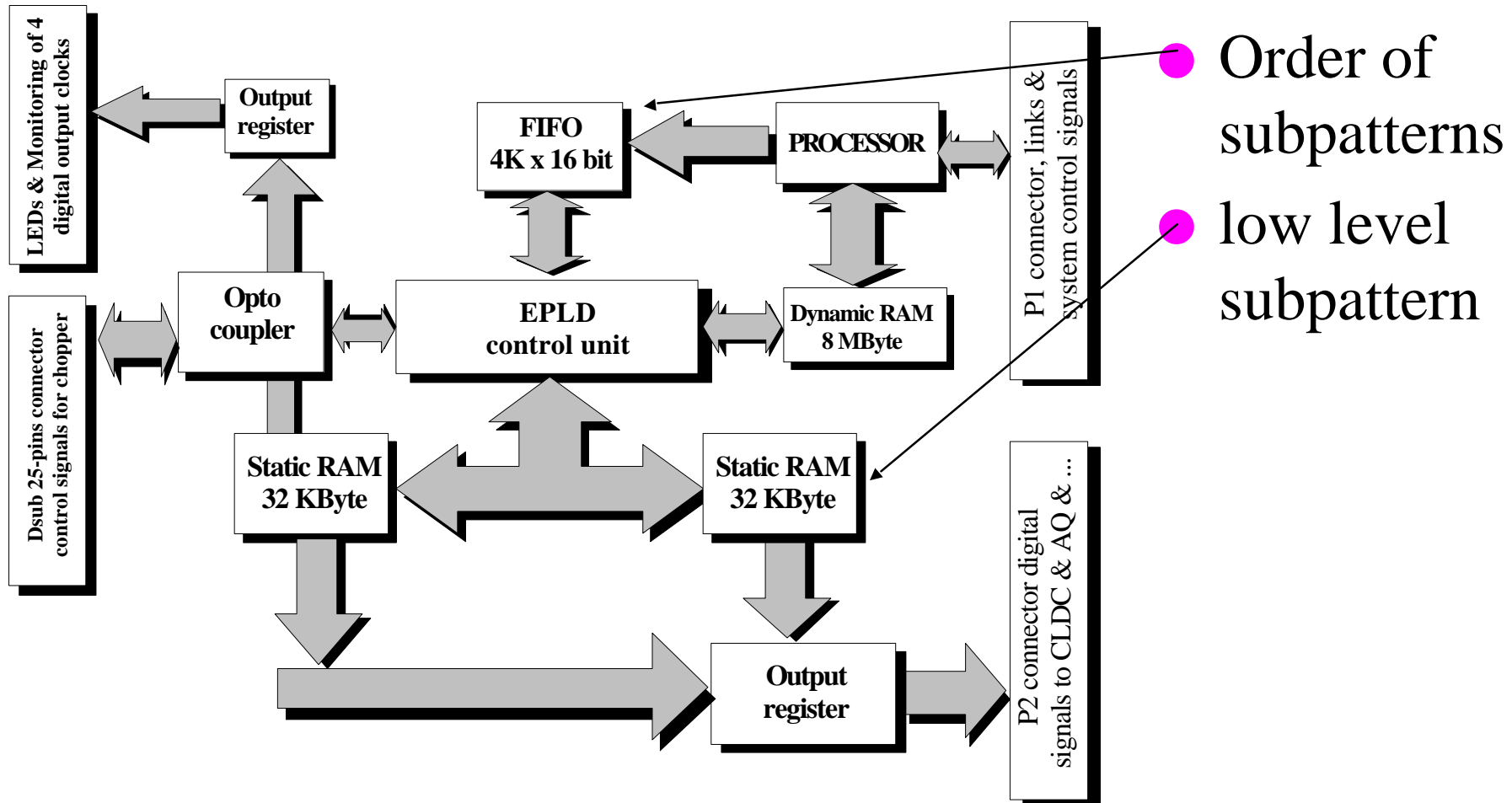


Sequencer

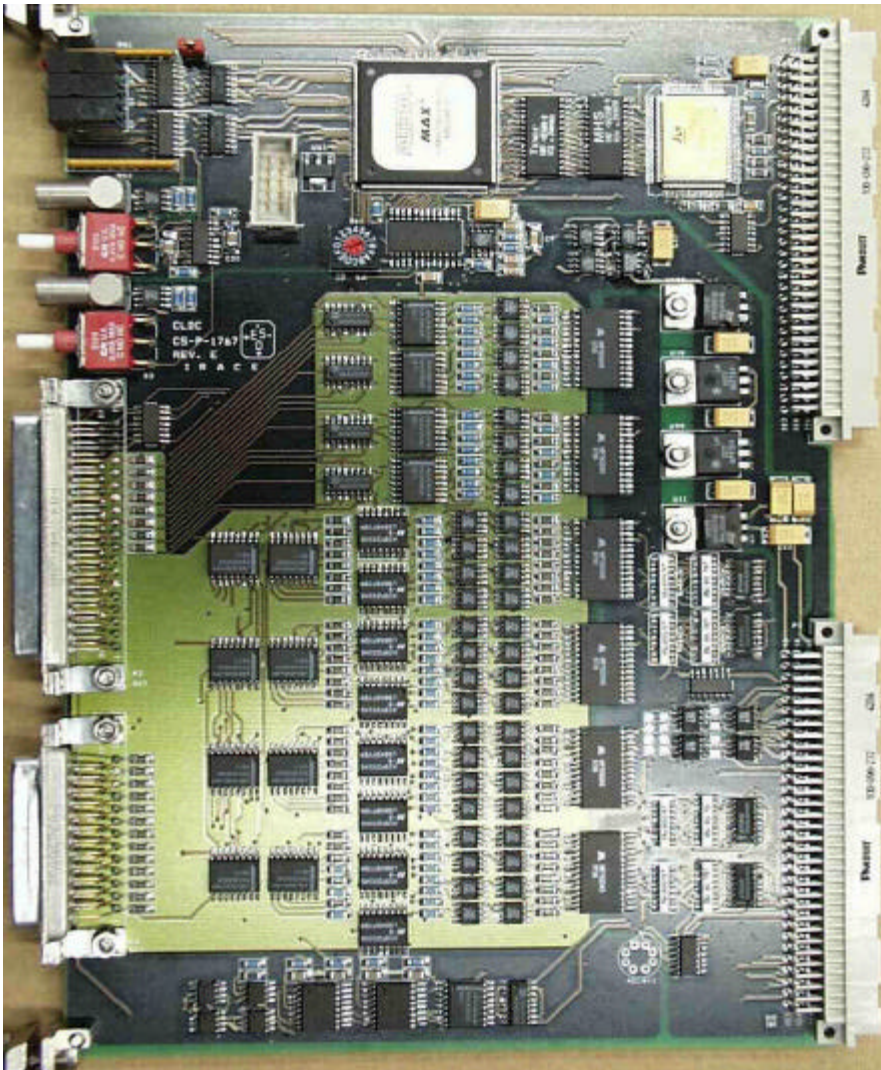


- 48 digital clocks
- Min. pulse width of 50 ns
- Flexible mapping of clocks on output pins
- On board monitor for all clocks
- Control input signal for external synchronization
- 8 MB DRAM

Sequencer

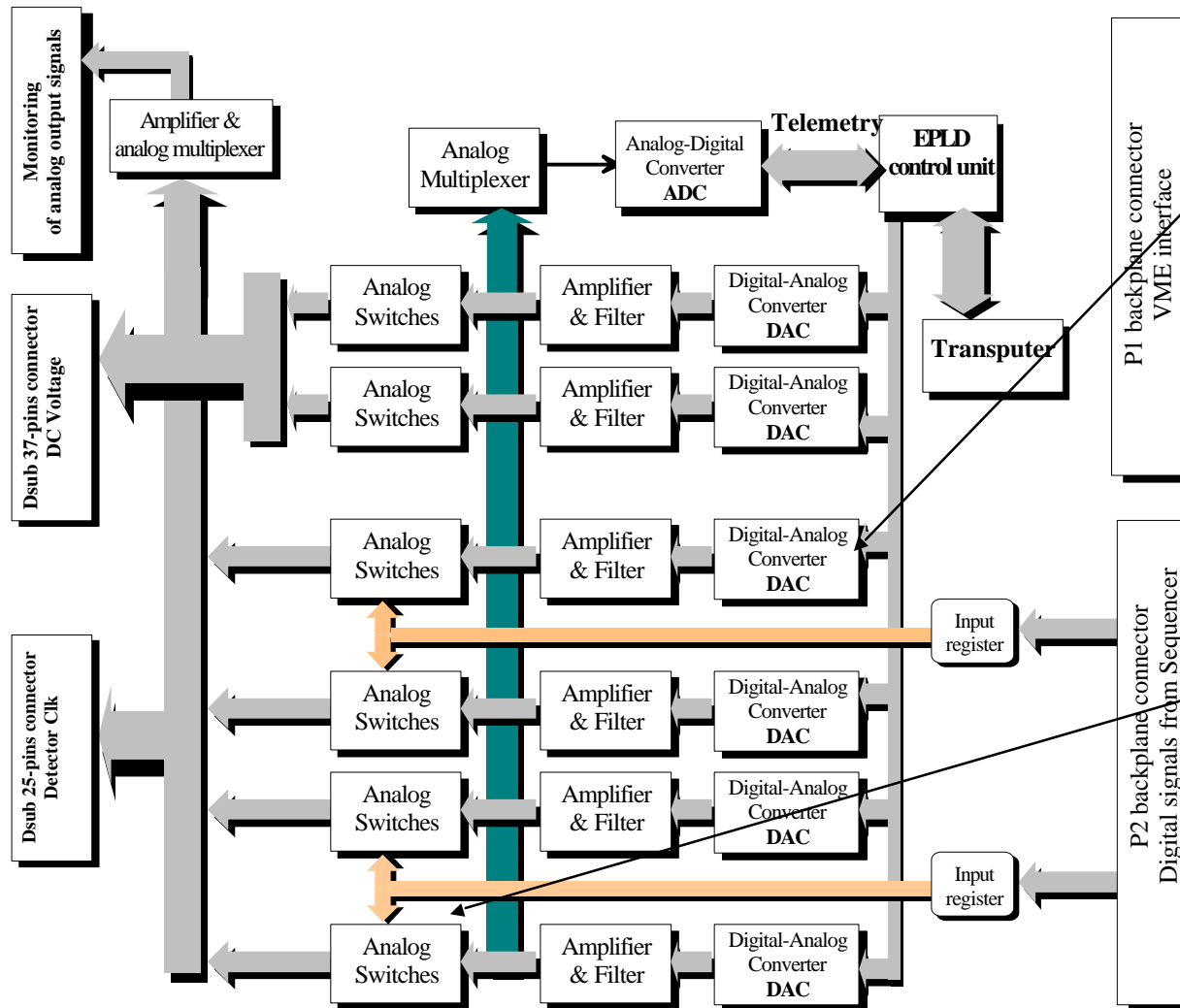


CLDC



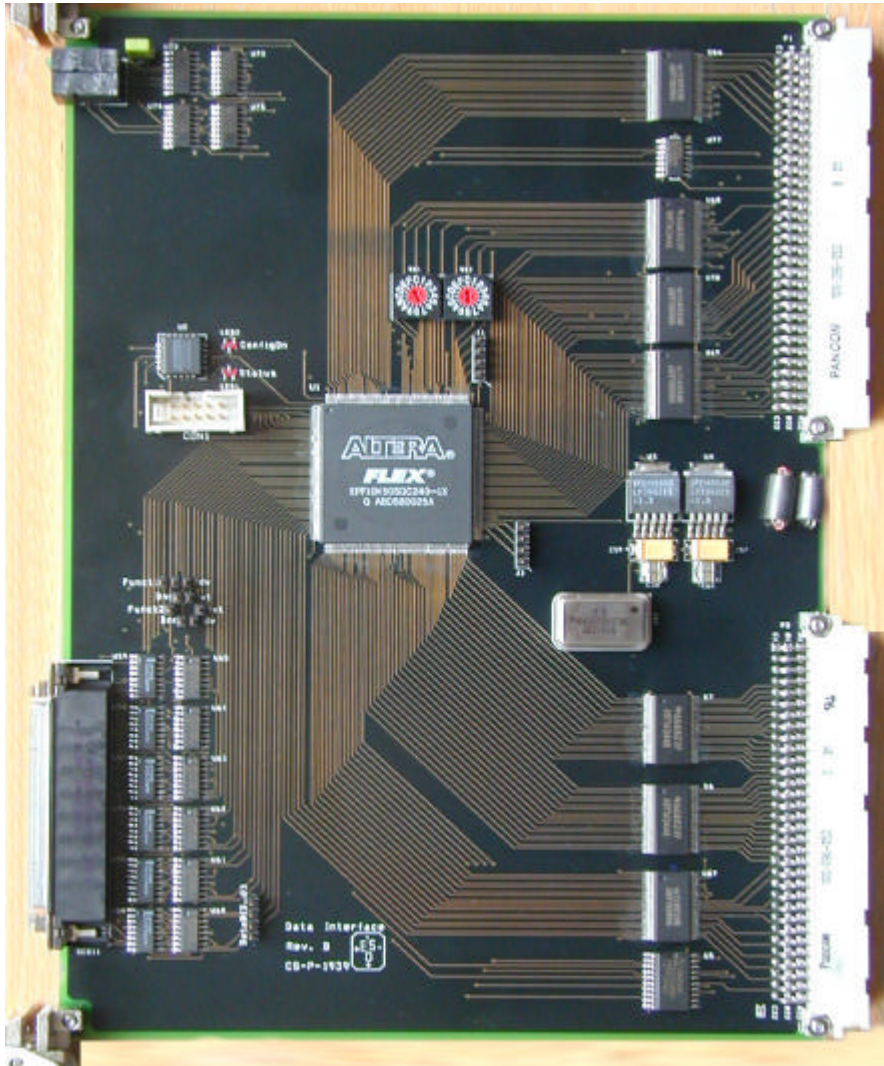
- 16 low noise analog clocks
- 16 low noise bias voltages
- Telemetry of clock and bias voltages
- Monitoring of analog clocks
- Integrated temperature measurement of detector

CLDC



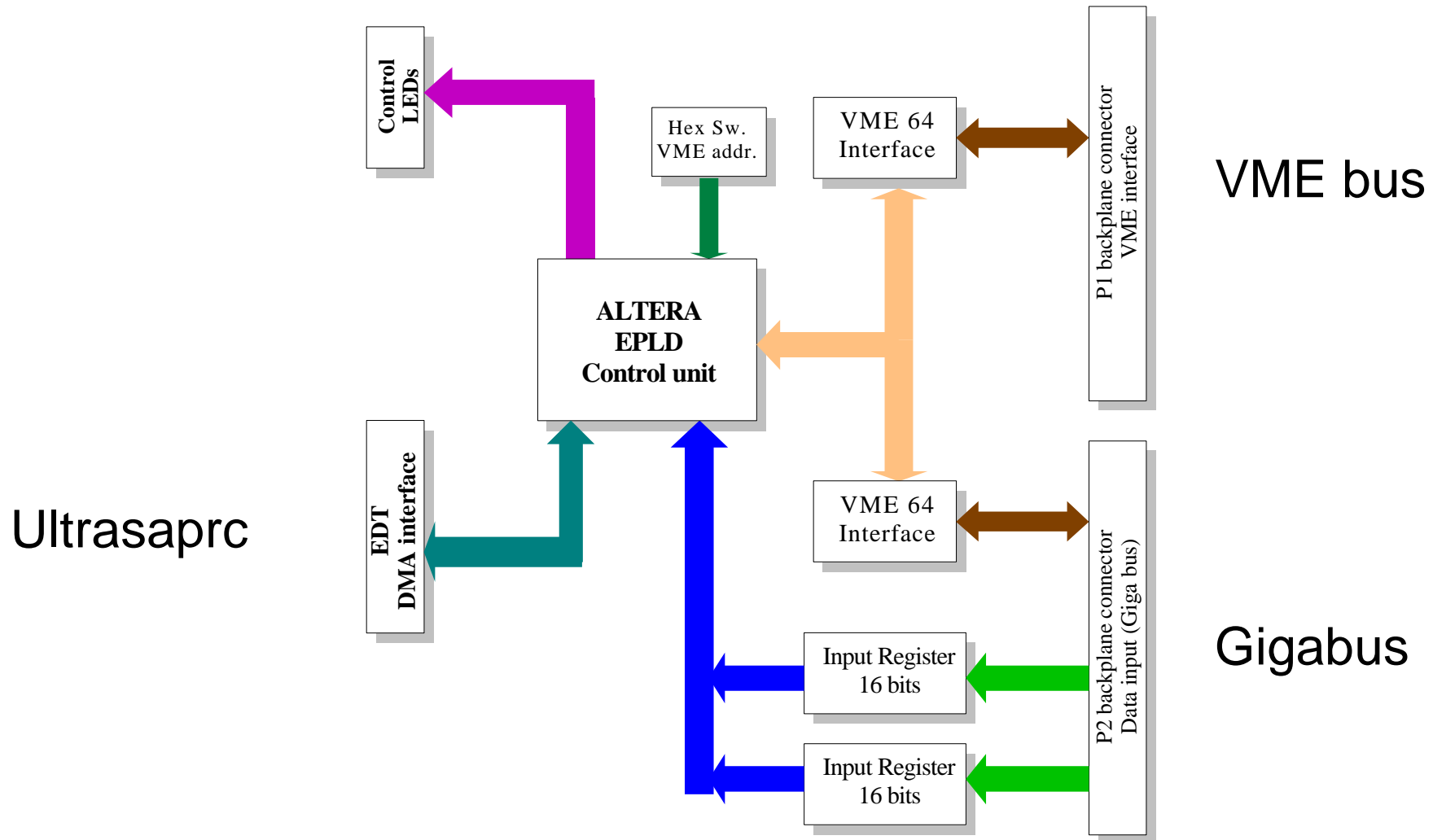
- Programmable bias and clock voltages
- change of voltage settings possible during reading out of detector
- Analog switch Harris HI-201HS

Date interface

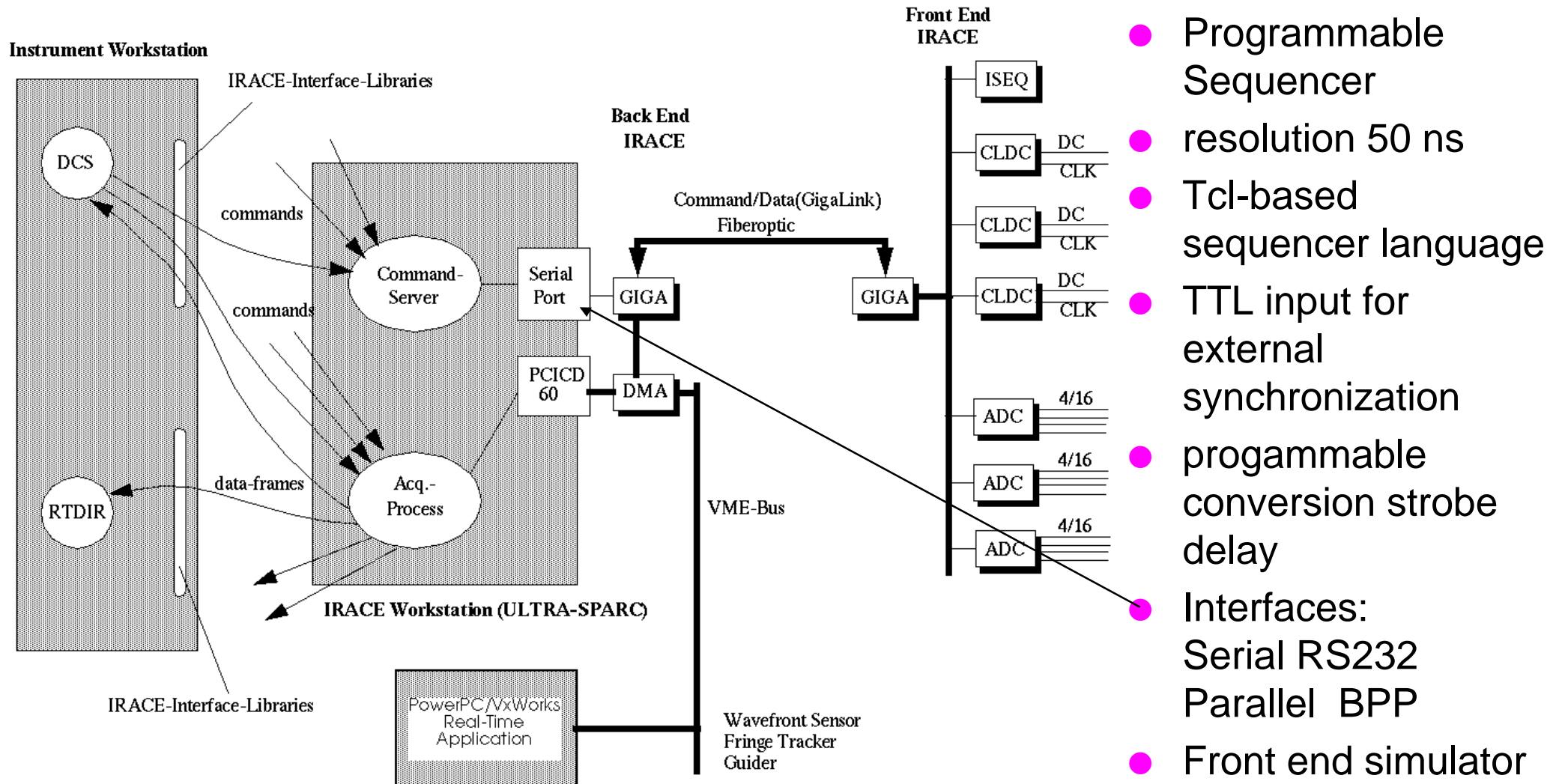


- EDT SCD 60 interface with a transfer rate of 60 MB/s
- VME 64 bit interface
- minimum DIT
with semaphore: 150 μ s
(power PC on VME)
without semaphore: 3 μ s
- VME interrupt and board ID are programmable by software

Date interface

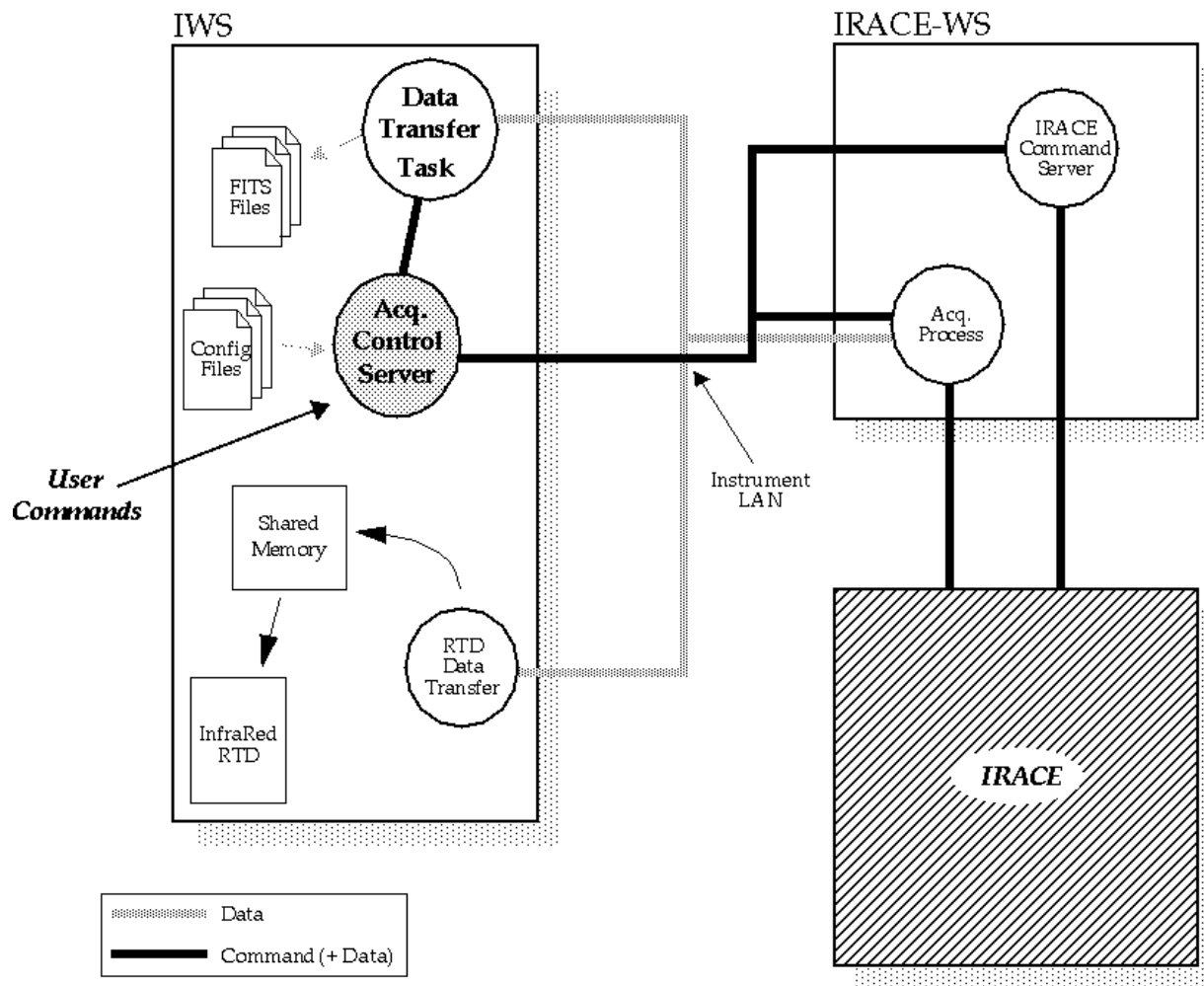


Detector Control Software DCS for IRACE front end



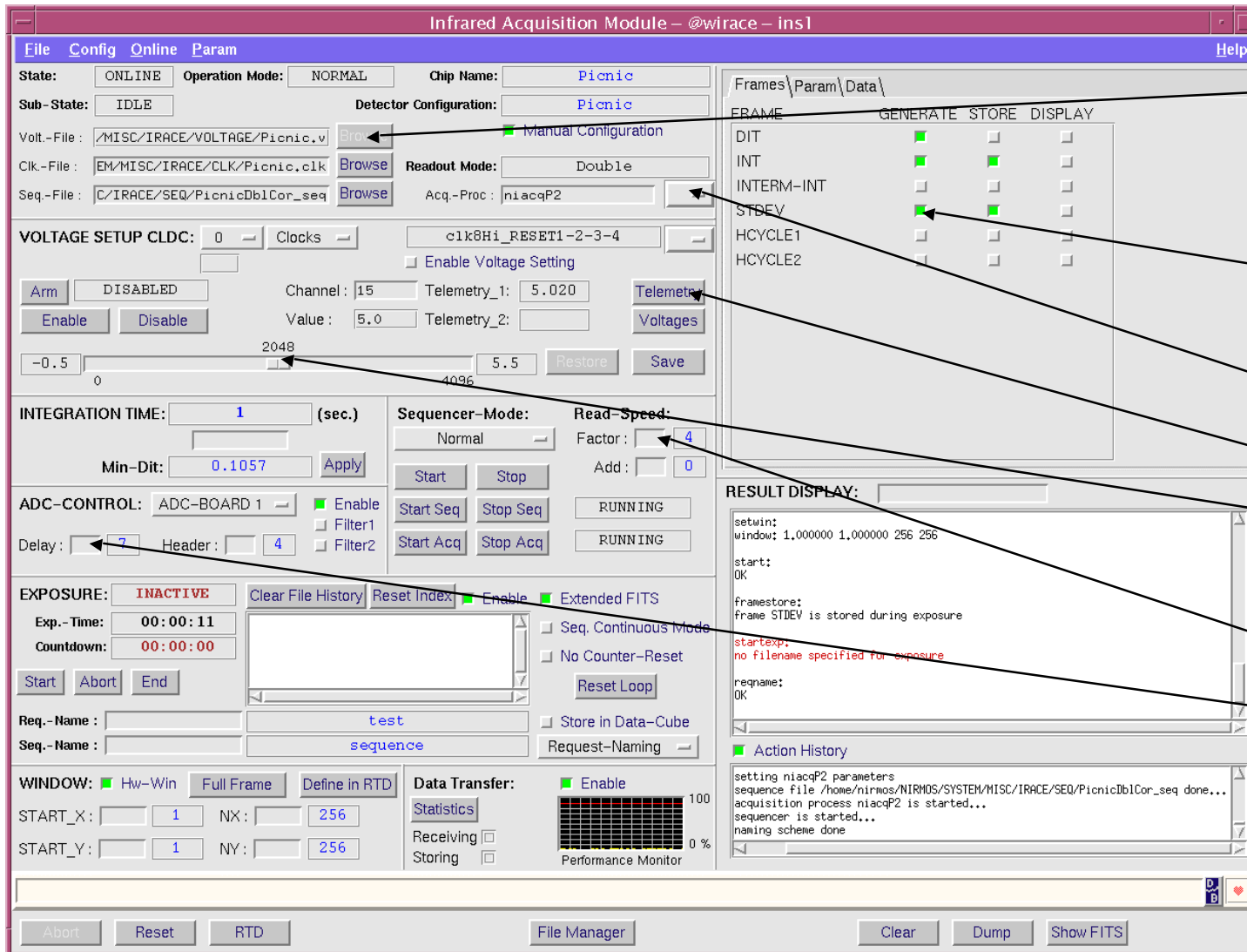
- Programmable Sequencer
- resolution 50 ns
- Tcl-based sequencer language
- TTL input for external synchronization
- programmable conversion strobe delay
- Interfaces:
 - Serial RS232
 - Parallel BPP
- Front end simulator

Detector control software DCS for Acquisition Process & server



- Acquisition Process
 - » Modular Architecture
 - » Parallel frame transfer to n clients
 - » up to 60 MB/s continuous data reduction flow
 - » built-in burst mode
 - » built in simulation mode
 - » Solaris real time threads with priority control
 - » VME bus interface: VxWorks driver for control loops
- DSC Control server
 - » Control Server and Data Transfer task support hooks
 - » Image postprocessing in data transfer task (flip, rotate)
 - » Engineering GUI with on line help
 - » supported: HP-UX, Solaris, Linux

IRACE DCS Engineering Gui



- Voltage file
- clock file
- sequencer file
- standard deviation
- intermediate INT
- readout mode
- telemetry
- slide ruler for voltage setting
- read speed
- ADC conversion
- strobe delay

IRACE DCS Engineering Gui

The screenshot displays the 'Infrared Acquisition Module - @wirace - ins1' GUI. The interface is divided into several functional areas:

- Top Panel:** Includes menu options (File, Config, Online, Param, Help) and status indicators for State (ONLINE), Operation Mode (NORMAL), Chip Name (Picnic), and Sub-State (IDLE).
- Configuration Section:** Contains fields for Volt-File, Clk-File, Seq-File, Detector Configuration (Picnic), Readout Mode (Double), and Acq-Proc (niacqP2).
- Voltage Setup:** Features a 'VOLTAGE SETUP CLDC' section with a slider for voltage (0 to 5.5) and buttons for Arm, Enable, Disable, Telemetry, and Voltages.
- Integration and Sequencer:** Includes 'INTEGRATION TIME' (1 sec), 'Min-Dit' (0.1057), and 'Sequencer-Mode' (Normal) with Start/Stop buttons.
- ADC Control:** Shows 'ADC-CONTROL' (ADC-BOARD 1) with checkboxes for Filter1 and Filter2, and buttons for Start Seq, Stop Seq, Start Acq, and Stop Acq.
- Exposure Control:** Displays 'EXPOSURE: COMPLETED' with 'Exp.-Time' (00:00:11) and 'Countdown' (-00:00:01). It includes a file list (test_1.STDEV.fits, test.fits) and buttons for Start, Abort, End, and Reset Loop.
- Window and Data Transfer:** The 'WINDOW' section has 'Hw-Win' checked and 'Full Frame' selected. 'Data Transfer' is also enabled, with a 'Performance Monitor' showing 0% activity.
- Parameter List:** A window titled 'Frames\Param\Data\' lists parameters such as DET.CHOP.CYCSKIP (0), DET.CHOP.NCYCLES (4), DET.CHOP.ST (0), DET.DITDELAY (0), DET.NC.DIT (1), DET.NC.HCYC (0), DET.NC.IINT (0), DET.NC.STDEV (1), DET.NC.NDIT (10), and DET.NDITSKIP (0).
- Result Display:** A text area showing status messages like 'startexp: no filename specified for exposure' and 'Action History' with logs of system events.

- Exposure parameters chopping
- window parameters for hardware window

IRACE DCS Engineering Gui

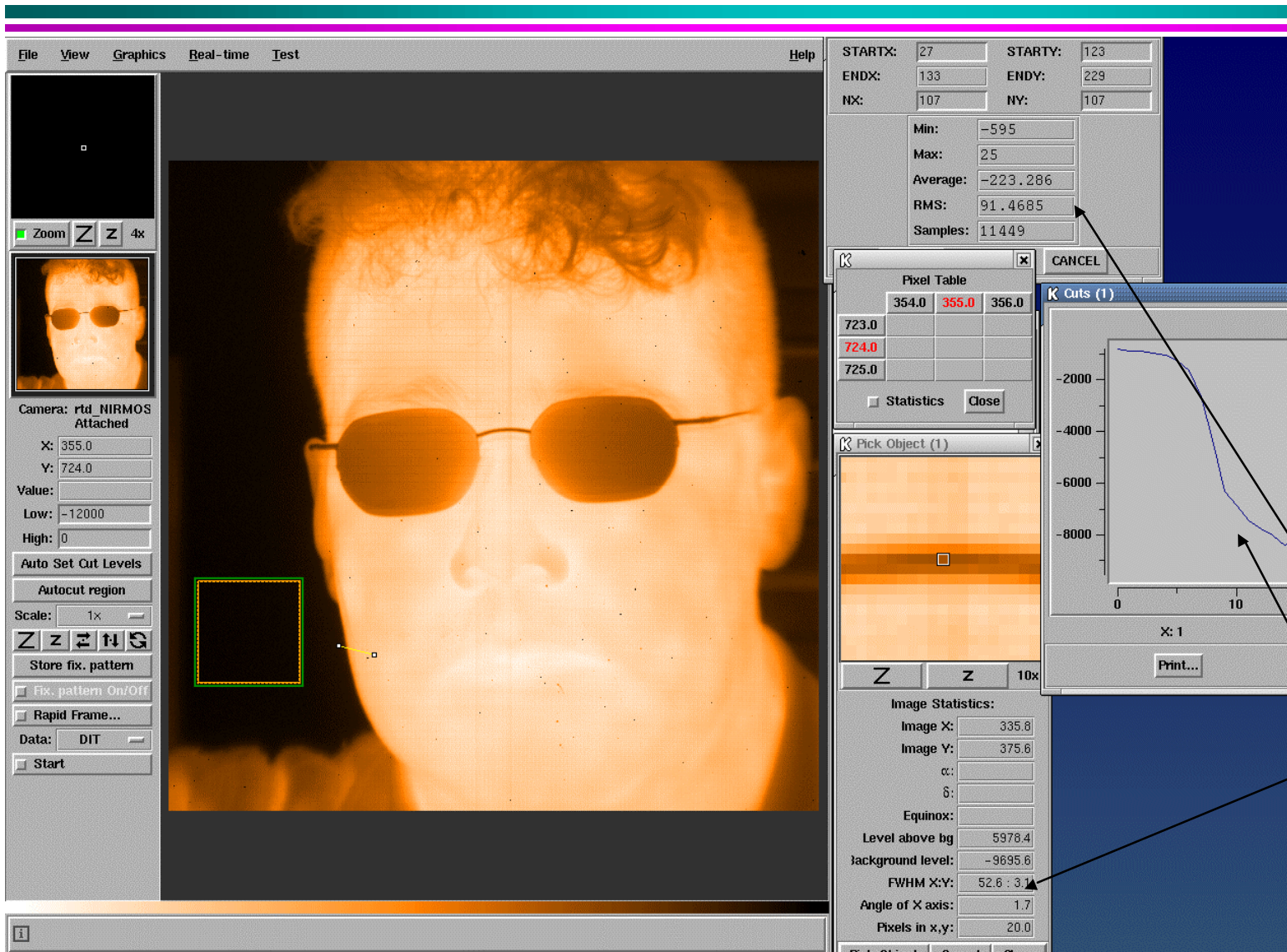
The screenshot shows the IRACE DCS Engineering Gui interface. The window title is "Infrared Acquisition Module - @wirace - ins1". The interface is divided into several sections:

- State:** ONLINE, Operation Mode: NORMAL, Chip Name: Picnic, Sub-State: IDLE, Detector Configuration: Picnic, Manual Configuration:
- VOLTAGE SETUP CLDC:** 0 Clacks, Channel: 15, Telemetry_1: 5.020, Value: 5.0, Telemetry_2: (empty), 2048 (range 0 to 4096), Restore, Save
- INTEGRATION TIME:** 1 (sec.), Min-Dit: 0.1057, Sequencer-Mode: Normal, Read-Speed: Factor: 4, Add: 0, Start, Stop, Start Seq, Stop Seq, Start Acq, Stop Acq, RUNNING, RUNNING
- ADC-CONTROL:** ADC-BOARD 1, Enable, Filter1, Delay: 7, Header: 4, Filter2
- EXPOSURE:** COMPLETED, Exp.-Time: 00:00:11, Countdown: -00:00:01, Start, Abort, End, Clear File History, Reset Index, Enable, Extended FITS, Seq. Continuous Mode, No Counter-Reset, Reset Loop, Store in Data-Cube, Request-Naming
- WINDOW:** Hw-Win, Full Frame, Define in RTD, START_X: 1, NX: 256, START_Y: 1, NY: 256
- Data Transfer:** Enable, Statistics, Receiving, Storing, Performance Monitor
- RESULT DISPLAY:** start: OK, framestore: frame STDEV is stored during exposure, startexp: no filename specified for exposure, reqname: OK, startexp: OK
- Action History:** iracq: fits header loaded, iracq: data transfer is started (no = 1), iracq: acquisition process niacqP2 is started..., iracq: sequencer is started..., iracq: start time is 2001-10-31T17:54:05.7791 (UTC) (MJD: 52213.74590022)

At the bottom are buttons for Abort, Reset, RTD, File Manager, Clear, Dump, and Show FITS.

● Flat field
● bad pixel mask

Real Time Display



- M band 4.6-4.8 μm
- 640x640 window of 1024^2 InSb array
- Integration time 27 msec

In Real Time:

- fixed pattern subtraction
- statistics inside subframe
- trace
- FWHM & centroid
- intermediate image

Conclusion

- IRACE is **modular**
flexible
scaleable to adapt to all detector needs
- IRACE has low noise: 3 erms with Hawaii1
by combining non-destructive and subpixel sampling
- IRACE is fast
0.77 frame/sec with 4Kx4K Hawaii2 (144 outputs)
16 frames/sec with 1Kx1K InSb (32 outputs)
6600 frames/sec for real time applications
(power PC on VME, fringe tracker, wavefront sensor,...)
- IRACE comes with integrated detector control software and
real time display offering a wide variety of readout modes