Future Developments of Infrared Controllers at ESO

Gert Finger
# Next Generation IR Detectors

<table>
<thead>
<tr>
<th>Detector</th>
<th>Format</th>
<th>Outputs</th>
<th>Pixel Time [µs]</th>
<th>Frame Time [ms]</th>
<th>Baud Rate Gbaud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawaii-2RG MBE HgCdTe</td>
<td>2Kx2K</td>
<td>32</td>
<td>0.2</td>
<td>26</td>
<td>2.6</td>
</tr>
<tr>
<td>Si:As BIB</td>
<td>640x480</td>
<td>32</td>
<td>0.3</td>
<td>2.8</td>
<td>1.7</td>
</tr>
<tr>
<td>ORION 2Kx2K InSb</td>
<td>2Kx2K</td>
<td>64</td>
<td>1.5</td>
<td>100</td>
<td>0.7</td>
</tr>
<tr>
<td>Adaptive optics sensors</td>
<td>256x256</td>
<td>32</td>
<td>0.2</td>
<td>0.41</td>
<td>2.6</td>
</tr>
</tbody>
</table>

- need 5 MHz 16 bit ADC’s
- need 3 Gbaud fiber link
Future Requirements for IRACE

- Large format mosaics of 4x4x2Kx2K IR arrays each having >= 32 parallel video outputs (VISTA)
- Subpixel sampling by digital filter in EPLD
- Reference unit cells for true differential signal chain
- Interpolated digital clamp of reference unit cell
- Embedded real time pre-processing in high level programming language such as IDL (cosmic ray rejection)
- Guiding on science frame
- Diagnostics, self test of acquisition system, on line help
- Audio DAC’s to control clock slopes?
- Put detector front end in ASIC close to focal plane
Large Format: VISTA

- 4 meter telescope, field 1.67 deg
- Mosaics of 4x4x2Kx2K IR arrays

Slide provided by Mark Casali / UKATC
Eight filter units, each containing sixteen filters, each 54mm square

- With HAWAII2 mux use four quadrants for tracking, guiding and wave-front sensing
- With HAWAII2-RG use guiding feature built into detector

Large Format: VISTA

Slide provided by Mark Casali / UKATC
VISTA focal plane

IR imager
focal plane module

16 detectors

2 boards and 2 external connectors per detector

- 16 2Kx2K arrays each having 32 parallel outputs
- 512 channel IRACE system
- readout time 1.3 s

Integrate cryo-opamps and filters in flex board

Slide provided by Mark Casali / UKATC
Digital filter in EPLD of AQ16

- process subpixel samples in EPLD
- parallel processing
  1 processor /AQ board
- digital filter of video signal

AQ 16 board

Conversion strobes

Video signal
Reference unit cell (Hawaii2)

- 8 video outputs / quadrant
- 128 pixels in fast direction
- reference pixel for thermal drift is 129\textsuperscript{th} pixel on 9\textsuperscript{th} output
- 36 channels / detector required

![Diagram of Hawaii2 unit cell]

![Graph of Video and Reference Signal at end of Row]

<table>
<thead>
<tr>
<th>Time [s]</th>
<th>Video</th>
<th>Reference</th>
<th>CLK1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.48E-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.50E-03</td>
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<td></td>
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<tr>
<td>1.52E-03</td>
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</tr>
<tr>
<td>1.60E-03</td>
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</tr>
</tbody>
</table>

[Signal values: Video 0.00-5.00 V, Reference 0.00-5.00 V, CLK1 0.00-5.00 V]

Graph labels:
- Video
- Reference
- CLK1
External reference with Hawaii1

- No reference output provided on chip
- External reference has to be used

Gain = 1 + 2R_F / R_G
On chip reference cell of Hawaii2

- Reference pixel for thermal drift compensation and suppression of pickup is 129th pixel on 9th output
- Reference pixel not available while reading pixels
- Clock first to reference pixel
- Clamp reference pixel with cryogenic sample and hold
- Read pixels of row with clamped voltage at reference input of cryo-opamp

\[ \text{Gain} = 1 + 2R_F/R_G \]
On chip reference cell of Hawaii2-RG

- Reference pixel for thermal drift compensation and suppression of pickup on 9th output, but
- Reference pixel available while reading pixels
- Read pixels of row with voltage of reference cell at reference input of cryo-opamp
- Best suppression of noise pickup

Gain = 1 + 2R_f / R_G
50 Hz pickup of Hawaii2 without clamp of reference

- Multiple sampling reduces readout noise and requires lower pickup noise
- Clock each row once and read once
- Reference output (129\textsuperscript{th} pixel on 9\textsuperscript{th} output) is not used
- 32 channels / detector required
50 Hz pickup of Hawaii2 with digital clamp

- Clock each row once and read once
- read reference after reading row and and subtract reference signal for each pixel
  \[ \text{sig}_{nk} = \text{pix}_{nk} - \text{ref}_{na} \]
- 36 channels / detector required

![Graph showing video and reference signal for Row n-1 and Row n]
50 Hz pickup of Hawaii 2 with interpolated digital clamp

- Clock each row twice and read once
- read reference before and after reading row and interpolate reference signal for each pixel
\[ \text{sig}_{nk} = \text{pix}_{nk} - (\text{ref}_{nb} - (\text{ref}_{nb} - \text{ref}_{na}) \times (k-1)/127) \]
- 36 channels / detector required
- reference allows rejection of low frequency pickup and compensation of thermal drifts

![Video and Reference Signal of Hawaii 2 at end of Row](image)
Aladdin #3 & #4

#5: QE H = 0.82
   darkcurrent = 0.017 e/s

(ISAAC)

#4:  QE H = 0.86
    darkcurrent = 0.004 e/s
Monitor temperature drift using dead pixels

- Triangles: measured integration ramp
- Diamonds: dead pixels
- Open In bump bonds are used to monitor drifts
- Squares: drift corrected integration ramp
- Darkcurrent at 28.5 K: 0.017 e/s/pixel
Temperature drift of dead pixels in Aladdin array

- Temperature drift: 1700 electrons / K
- Required temperature stability of array: 6 mK
- Temperature drift will be monitored with reference unit cell of Hawaii-2RG
Elimination of cosmic rays by multiple sampling

Warm pixels
continuous integration ramp

Cosmic rays create charge burst and step in integration ramp
Cosmic Ray Correction

- At Paranal (altitude 2600 m) 2038 pixels / hour are hit
- Maximum charge injected by cosmic ray 
  \~ 2 \times 10^4 \text{ electrons} < \text{full well} (1 \times 10^5 \text{ electrons})
- Correction by multiple nondestructive sampling and real time processing in IRACE number cruncher using idl routines
- At present more warm pixels than cosmics, but arrays may improve (MBE)
Parallel Processing of Detector Data in IRACE

- mark digitized video signal with different headers
- process video signal in IRACE number cruncher (ULTRA-SPARC) for science frame
- process subwindow in PowerPC on VME bus for real time applications
Mosaics of 2Kx2K arrays are coming
need 5 MHz 16 bit ADC’s and 3 Gbaud fiber link
use of unit cell reference for true differential signal chain
more real time image processing with faster processors
General purpose ASIC needed for ground based applications