A dual-core highly programmable 120dB image sensor

OUTLINE

- HDR: concepts and technical solutions
- HDPYX sensor architecture
- HDR Characterization results
- Perspectives
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Why HDR?

- HDR stands for High Dynamic Range:
- In Imaging, HDR is not a new concept

Ansel Adams, Snake River, 1942

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Why HDR?

- In nowadays digital imaging, the need of HDR surpasses digital photography.

- Is it a key issue for many applications such as:
  - Scientific
  - Space
  - Security
  - Automotive
  - …

- The dynamic of the scene is very variable / unknown.

- Several solutions have been developed through years.
HDR: what we are looking for?

- Constraints of scientific application:
  - No tone-mapping: HDR must extend sensor output dynamic
  - Linear solution
  - HDR image in one shot

- Furthermore:
  - A digital system
  - A fully integrated solution
# HDR: several exiting solutions

<table>
<thead>
<tr>
<th>HDR solution</th>
<th>Multiple integration times</th>
<th>Multiple resets</th>
<th>Logarithmic</th>
<th>Multiple readout gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linearity</td>
<td>Yes</td>
<td>PWL</td>
<td>log</td>
<td>Yes</td>
</tr>
<tr>
<td>CDS</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>SNR</td>
<td>+</td>
<td>-</td>
<td>--</td>
<td>+</td>
</tr>
</tbody>
</table>

### Complexity

- Pixel: Low-medium
- Readout: Low

### Main drawbacks

- Several asynchronous scene taken, several images to combine. Risk of motion blur, large memory needs
- Dispersion of the reset voltage can create artefact in reconstruction, if furtive event occurs during reduced well the signal is partially lost
- Low sensitivity at low light levels
- Higher area and power consumption

**HDPYX sensor solution**

But In one frame only

One output chain

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HDPYX: Sensor architecture

• A sensor designed for scientific imaging
• 2800x1088 actives pixels
• 10µm pixel pitch
• up to 100 FPS
• 20 bits parallel data
• **Processor based, instrument driven operating modes:**
  o Rolling shutter
  o Global shutter
  o Low noise global shutter
  o Global reset
  o Integrating while read out (RWI)
  o Triggered acquisition
  o Triggered read out

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HDPYX: Sensor architecture

Dual 32 bits processors with dedicated tasks
Using on-chip dual processor allows to perform on the fly image processing:

- Offset corrections
- Programmable digital gain and offset
- HDR Interpolation filter for saturated pixels compensation
- HDR reconstruction filter (internal compensation of dual integration and/or dual gain mode)
HDPYX: Sensor architecture

Dedicated peripheral for on-the-fly reconstruction
HDPYX: Sensor architecture

- **Pixel design:**
  - In pixel dual gain
  - 6T pixel based
  - Global or rolling shutter
  - 2 gains in pixel

  - Ensures charge conservation!
  - Automatically switching gain during readout
  - Single readout chain

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HDPYX: Sensor architecture

- Pixel design:
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⇒ 90dB linear dynamic range
HDPYX: HDR features

- **Dynamic range extension:**
  - Exposure time is changed line by line in a single image capture
  - Programmable integration time ratio
  - Interpolation filter to correct saturated values
  - Improves dynamic range up to 120dB

⇒ Single frame, single output, no post treatement required

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### HDPYX: performances

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low gain</th>
<th>High gain</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full well Capacity</td>
<td>85000</td>
<td>10500</td>
<td>e-</td>
</tr>
<tr>
<td>Temporal noise in darkness</td>
<td>25</td>
<td>2.6</td>
<td>e-rms</td>
</tr>
<tr>
<td>Conversion factor</td>
<td>12</td>
<td>125</td>
<td>µV/e-</td>
</tr>
</tbody>
</table>

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HDPYX: performances

- Noise (1/f limited at source follower):

  ![Graph showing Temporal Noise VS $I_{COL}$ in ERS, GH](image)

  - Trade noise for speed if needed
  - Nominal operating point

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HDPYX: performances

- SNR over single TinT: shot noise limited

![SNR graph](image-url)
HDPYX: performances

- Image lag: below 1 e-

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HDPYX: HDR images

Using only low gain
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Perspectives

- Sensor will be deployed in hyperspectral/multispectral systems

- Sensor platform offers wide variety of customization:
  - Back side thinning for UV enhancement
  - NIR enhancement
  - Thick EPI for direct Xray sensing
  - Color or Monochrom versions…
  - Custom packaging for specific applications
Future work

- Pyxalis is also working towards lower noise via a collaboration with the CEA-LETI (cf IISW 2015 paper). First measurements show temporal noise of 0.4 e- RMS

- Pyxalis will further develop processor based approaches in custom designs with for instance the possibility to upload proprietary code, new peripherals, etc.