A 1392x976 2.8μm 120dB CIS with Per-Pixel Controlled Conversion Gain

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Motivation

- To develop a 2.8um 120dB sensor with excellent light sensitivity and reduced ghosting artifacts in fast moving scenes (e.g. traffic scenes)

- OmniVision’s split-diode pixel technology is ghost free (IISW’13 and IISW’15), but difficult to scale down to 2.8um pitch (fill factor/QE)

- New scheme => DCG HDR combined with staggered HDR
Pixel circuit and readout chain

- HCG = 240μV/e⁻; LCG = 20μV/e⁻; C = MOS + diff + parasitics
- ADC: 12 bits; Tconv ~ 1.5 μs; Padc = 14.4 mW @ 1.2 V (excl. Vref)
- Again: 1x-2x-4x-8x (Vref)
DCG HDR CDS timing

- True CDS in both HCG and LCG readout
  - HCG: 1e- rms; LCG: 10e- rms
- DCG HDR achieves 94dB (120dB requires staggered HDR capture, not shown)
Chip architecture

90nm BSI Gen-2
3.3V / 1.8V / 1.2V

DCG combine outputs
16b linear value

20b DCG+staggered combine off-chip

12b
4-lanes
Measured SNR vs Light level (EMVA)

- **High FWC at low gain**
- **Low Noise at high gain**
- **Seamless connection, No SNR drop, No exposure difference/moving artifacts**

Light level (lux), 530nm, F1.6, 60fps
DCG HDR vs Staggered HDR mode

HCG (T1) + LCG (T1)
94dB scene

HCG (T1) + VS (T2)
94dB scene

No ghosting artifact

Ghosting artifact

Rem: Brightness difference is due to different tone mapping settings in the ISP
Measured readnoise distribution (1-CDF)

HCG@8x Again

Median value = 0.87 e- rms
Measured 2-frame Difference Histogram

-20e- | -10e- | 0 | 10e- | 20e-

PPM

HCG @8x Again

- Fit1 Gaussian onto 99.9%
- Fit 2 Gaussian Curve
- Fit 3 Lorentizan Curve
- Fit2+Fit3
- Measured Data
Measured Quantum Efficiency

- QE improved 3x to 58% @ 850nm
- Visible region cross-talk not changed
Image comparison

850nm

Baseline

Improved NIR version

- No IR image degradation
- Showing no negative MTF impact @ 850nm
Performance summary

<table>
<thead>
<tr>
<th>Performance</th>
<th>Value</th>
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<tbody>
<tr>
<td>Pixel Size (um)</td>
<td>2.8</td>
</tr>
<tr>
<td>Resolution and FPS</td>
<td>1.3M/60</td>
</tr>
<tr>
<td>FWC (e-)</td>
<td>50K</td>
</tr>
<tr>
<td>Sensitivity (e-/lux.sec)</td>
<td>31K</td>
</tr>
<tr>
<td>Max QE (% R/G/B/IR)</td>
<td>(79/84/76/58)</td>
</tr>
<tr>
<td>Xtalk (%)</td>
<td>14</td>
</tr>
<tr>
<td>PRNU (%)</td>
<td>0.4</td>
</tr>
<tr>
<td>RN (e- rms, 8xgain) @HCG</td>
<td>1.0</td>
</tr>
<tr>
<td>DC (e-/sec) 60C</td>
<td>20</td>
</tr>
<tr>
<td>Lag (%)</td>
<td>0.1</td>
</tr>
<tr>
<td>SNR1 (lux) 3200K; 60fps</td>
<td>0.19</td>
</tr>
<tr>
<td>SNR1 (Photon/pixel) @ 530nm (EMVA)</td>
<td>2.0</td>
</tr>
<tr>
<td>DR (dB) DCG/Staggered mode</td>
<td>94/120 w/30dB minSNR</td>
</tr>
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Thank You!