High dynamic range hybrid pixel sensor

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A new readout imaging system with enhanced dynamic range (DR) and low power consumption is presented. The DR is enhanced by using feedback to control the integration time of the sensor. The feedback is implemented within an in-pixel-level ADC. The power consumption is reduced by switching the bias circuit off when it is not needed for the system, this readout circuit is used for a hybrid sensor: the photodiode and the readout circuits are placed in two different layers, the interconnections are made through bond pads.

Introduction: Dynamic range (DR) in image sensors is defined as the ratio of the largest to the smallest light levels that can be measured, in reality being the ratio between the saturation level and the noise floor of the imager. In [1], the DR of the sensor is enhanced by having several integration times within one frame period. One sample of the image is read out after each integration. Because several samples need to be read in one frame period, the power consumption increases with increase in DR.

![Fig. 1 Conversion algorithm of proposed pixel-level ADC](image1)

Local transfer gate control method: In this method described in this Letter, the integration time for each pixel depends on the incoming light intensity. The conversion algorithm is shown in Fig. 1. There are two phases: coarse conversion and fine conversion. The coarse conversion period is used to choose the integration time (MSBs). The fine conversion period converts the voltage after integration using a single slope ADC (LSBs). The reset level is converted and stored before the first charge transfer for digital correlated double sampling (CDS). The generated photon current, $A$, is a comparison of the generated photon current, $A$, with only 2.2% additional power consumption. The final specifications of the pixel are shown in Table 1. The pixel size does not contain the photodiode as it is placed in a different layer as mentioned before.

![Fig. 2 Schematic diagram, and timing of pixel ADC](image2)

![Fig. 3 Simulated SNR curve of proposed ADC](image3)

Table 1: Pixel specifications

<table>
<thead>
<tr>
<th>Technology</th>
<th>0.18 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel size (without photodiode)</td>
<td>18 μm × 18 μm</td>
</tr>
<tr>
<td>ADC resolution</td>
<td>8 bits</td>
</tr>
<tr>
<td>Frame rate</td>
<td>1000 frames/second</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>1.8 V</td>
</tr>
<tr>
<td>Power consumption</td>
<td>63 nW/pixel</td>
</tr>
<tr>
<td>DR</td>
<td>85.29 dB</td>
</tr>
<tr>
<td>Peak SNR</td>
<td>38.91 dB</td>
</tr>
</tbody>
</table>

Conclusion: The proposed method enhances the DR of the sensor by generating local charge transfer control signal pulses based on the incoming light intensity. Because both the source follower and the comparator are switched off when they are not used, the DR can be enhanced by 7 bits with only 2.2% additional power consumption.

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One or more of the Figures in this Letter are available in colour online.
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References