Introduction

Image sensors convert optical images into electric signals and are one of the most prevalent sensors in use today due to their unrivaled:

- Massively parallel data acquisition
- Sensitivity
- Selectivity

CMOS image sensors have several advantages over other imaging sensors:

- Ease of integration with other electronics
- Integrated signal processing
- Low cost
- Compatibility with lab-on-a-chip (LOC) systems

Our lab has developed specialized CMOS imagers with a focus on biosystems applications such as lab-on-a-chip systems, image plane processors, flight stabilization for unmanned aerial vehicles, and medical diagnostics.

Adaptive Floating Gate Imager

- Non-adapting current mode imager automatically removes fixed-pattern noise (FPN) from all pixels simultaneously.
- Floating gates were created to change locally at each pixel.
- The pixel exploits the negative feedback mechanism of the floating gate circuit.
- Floating gate adaptation reduces noise power 100 times at the calibration intensity and 10 times over 5 orders of magnitude at intensity.

Differential APS

- Differential structure reduces correlated noise at exposure of moderate increase in fundamental reset noise and multiplier noise.
- Offers a good design tradeoff for many applications, including small portable imaging systems.

Low Dark Current APS

- Standard 3-transistor APS element with feedback loop that clamps the photodiode voltage near zero and isolates the integration node from the parasitic capacitance of the photodiode, increasing the front-end gain.

Optical Comparator

- The sensor is comprised of a clocked comparator with enlarged data-substrate N-well junctions acting as photodiodes.
- One of the photodiodes is covered with metal to provide a dark current reference, and the bias current is varied to set the photodiode threshold.
- Changes in illumination due to a rotating fan blade at 100 Hz were successfully detected.

Passive quenching circuit for SPAD using off-chip quenching resistors achieves a timing resolution of 300 ps.

Single Photon Avalanche Diodes

- Motivation: Perimeter breakdown and high dark counts are the primary challenges to implementing single photon avalanche diodes (SPADs) in a standard CMOS process.
- Approach: a control gate placed over the perimeter of the junction effectively suppresses perimeter breakdown while suppressing dark current. In addition, lateral diffusion of n-well is used to further improve device performance by reducing the built-in electric field at the edge of the structure.

<table>
<thead>
<tr>
<th>Breakdown Voltage (V)</th>
<th>0.127 pW</th>
<th>4.38 pW</th>
<th>1000 pW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark count rate (cts/pH)</td>
<td>10^6</td>
<td>10^4</td>
<td>10^2</td>
</tr>
</tbody>
</table>

Experimental Data

- Measured detector sensitivity to Fura-2 in calcium free buffer
- Fura-2 is a common calcium indicator
- Accurately measured concentrations of Fura-2 from 100 to 30 μM
- "Accurately" = signal at least one standard deviation above noise floor

Single Photon Avalanche Diodes

- Standard 3-transistor APS element
- Modified 3-transistor APS element
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Acknowledgements

National Science Foundation (NSF)
Defense Intelligence Agency (DIA)
Maryland Industrial Partnerships (MIPS)
F. Hines, W. Weinberg of Weinberg Medical Physics