Rochester Imaging Detector Laboratory

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Σ–Δ Analog to Digital Converter for CMOS Image Sensors

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Background

- After fabricating an imaging sensor it needs to be characterized and the performance measure.
- Imaging sensors need digital clock signals and DC bias voltage inputs unique to each type of detector based on its readout design.
- Proper testing configuration is important for evaluating the operation of an imaging sensor.

Goals

- Evaluate imaging sensor characteristics and performance

Plan

- Design and fabricate interface to supply clocks and biases to the imaging sensor
- Verify successful operation of the Σ-Δ analog to digital converter
- Measure the electrical and optical characteristics of the CMOS image sensor

Device Operation

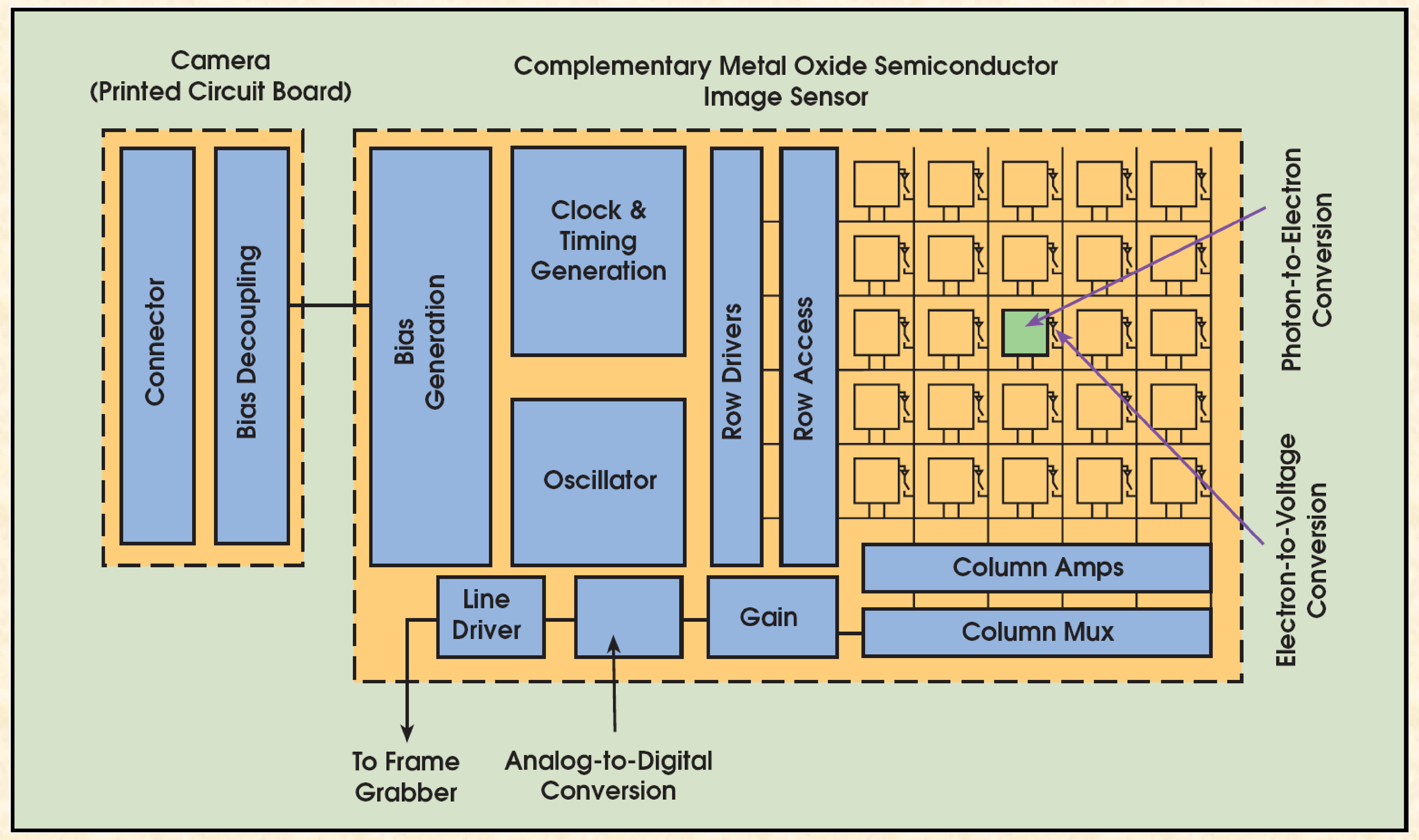

Figure 1: Generic architecture of a CMOS image sensor. CMOS image sensor consists of an array of pixel sensors, each pixel containing a photo detector and an active amplifier.

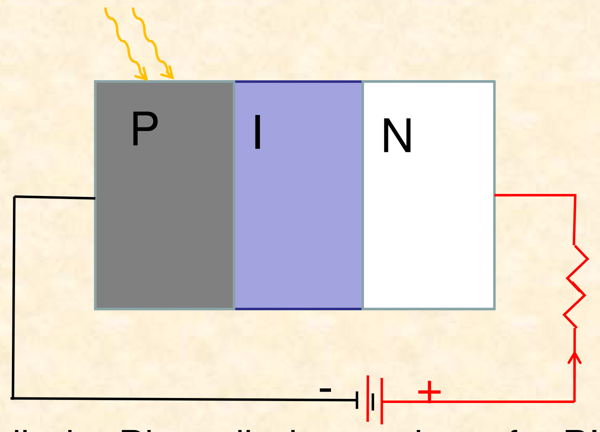

Figure 2: Diagram of a photodiode. Photodiode consists of a PIN junction operated in reverse bias mode. Each pixel on the ROIC is connected to a photodiode.

First Order Σ-Δ Modulator

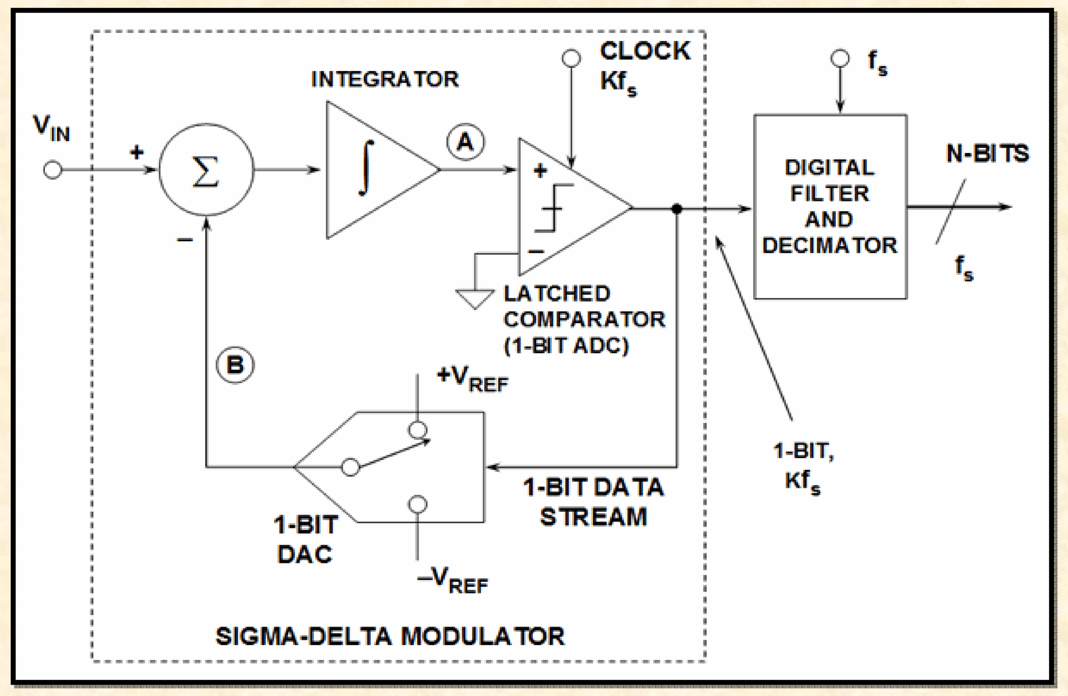

Figure 3: Configuration of first order Σ–Δ modulator. Input is fed to quantizer via integrator. Quantized output feeds back to the input signal.

Transfer function:
$x_Q[n]= z^{-1}.x[n]+(1-z^{-1}).e[n]$

- Persistent difference between input signal and quantized output accumulates in integrator and corrects output
- Average value of quantized signal tracks average input
- Density of "ones" at modulator output is proportional to input signal

Second Order Σ-Δ Modulator

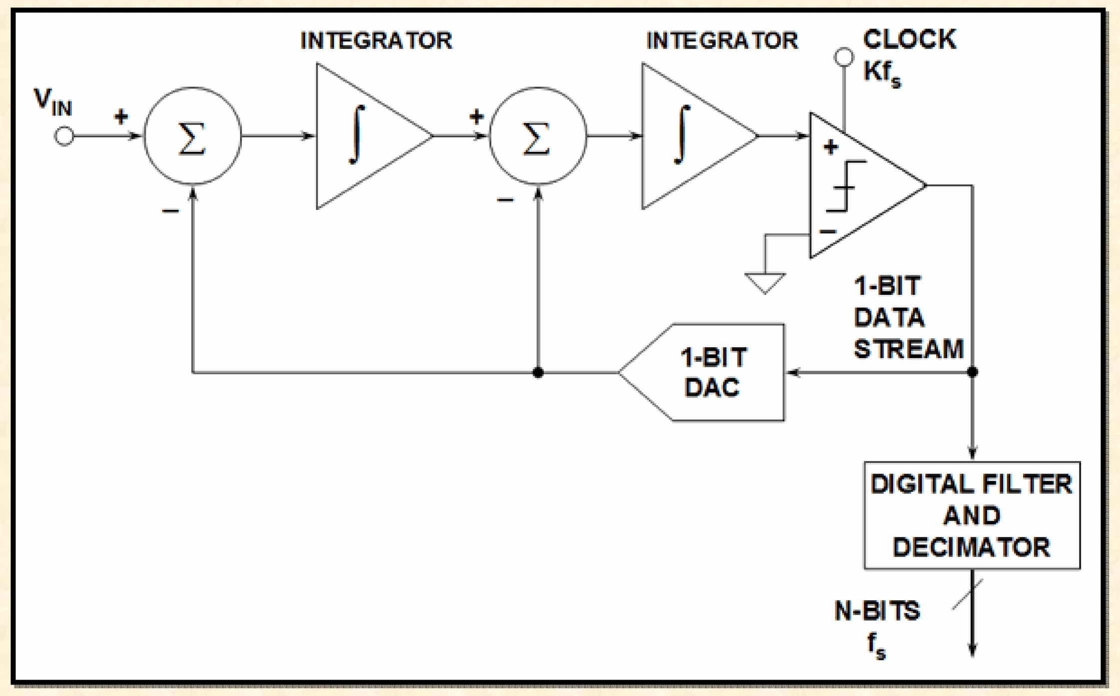

Figure 4: Configuration of second order Σ–Δ modulator. A second order Σ-Δ modulator structure is obtained by extending the first order Σ-Δ modulator with an additional integrator unit.

Transfer function:
$x_Q[n]=z^{-1}\cdot x[n]+(1-z^{-1})^2.e[n]$

Advantages over first order Σ–Δ A to D converter

- Noise is filtered with second order high pass filter
- Further suppresses quantization noise
- SNR increases by 15 dB or 2.5 bits when frequency doubles

Noise Shaping

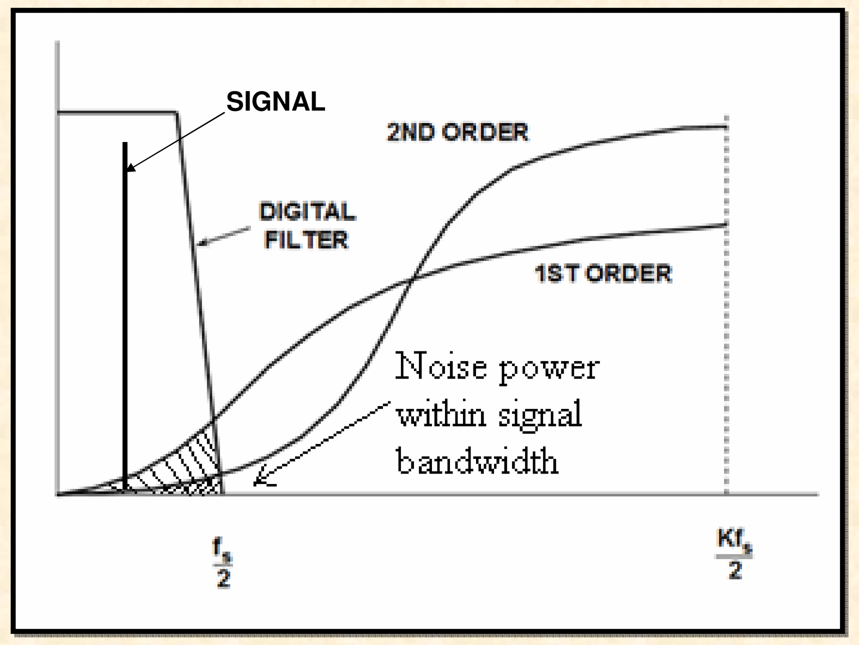

Figure 5: Response of first and second order Σ-Δ modulation

Noise shaping using Σ–Δ modulation

- Low pass filtration of input signal
- High pass filtration of quantization noise
- Most quantization noise is pushed into higher frequencies

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