Sigma Delta Camera Testing

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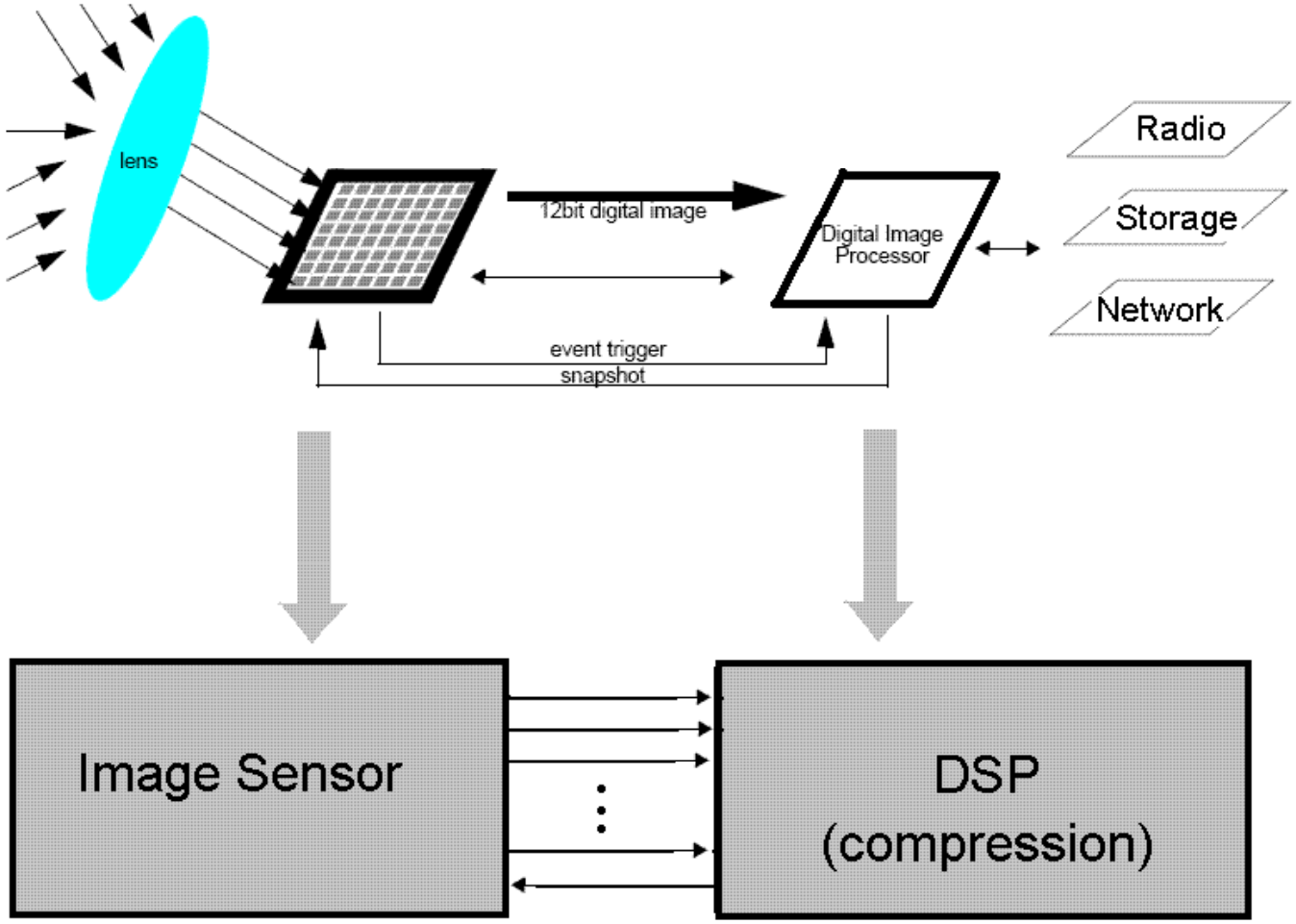
Motivation

- Exploring CMOS camera-on-chip architectures based on SD imager
- Unconventional low power image processor that exploits 1-bit pixel readout
- Existing SD Imager Testing

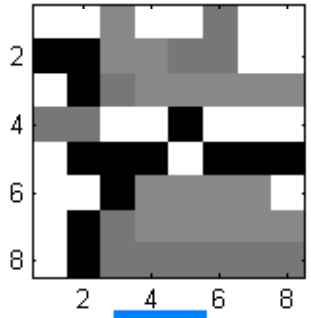
Camera Architecture



[1] Kodak, KAC-9618 image sensor

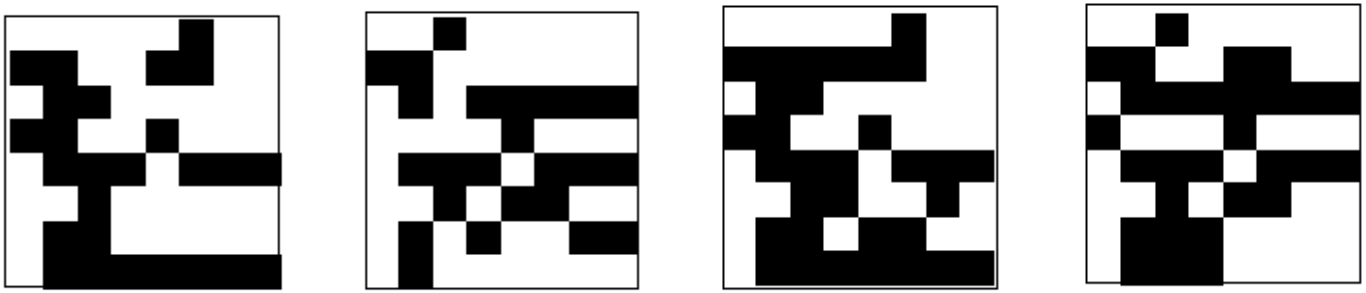
Sigma Delta Image Sensor

Original image 8x8

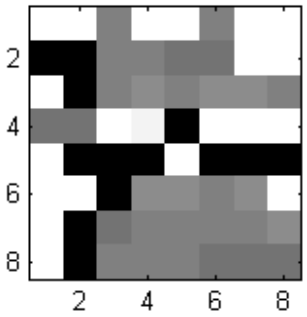


Oversampling OSR=4

Sigma delta output - 4 frames 1 bit per pixel



Reconstructed image



Log2(OSR) bits per pixel

Image accumulator architecture

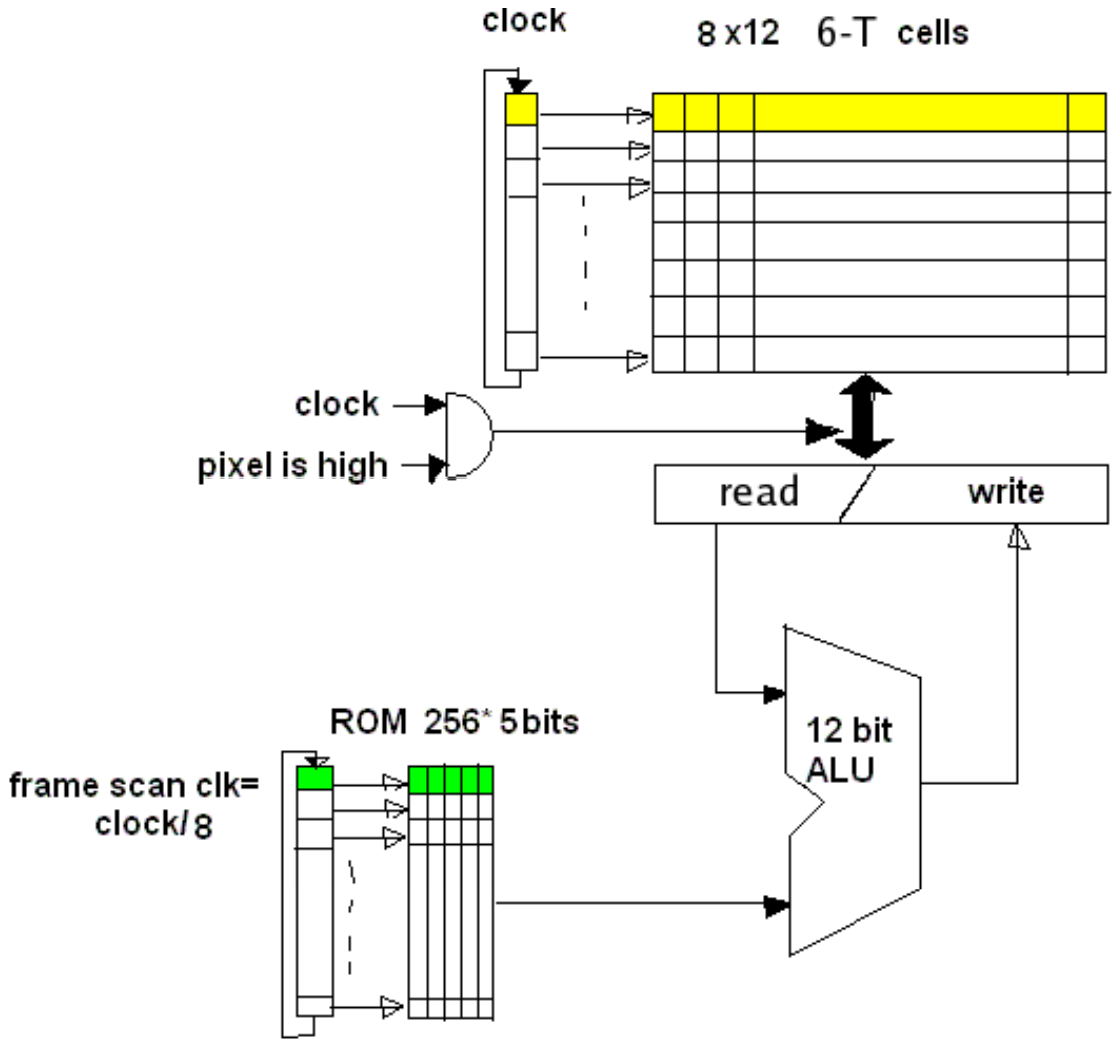
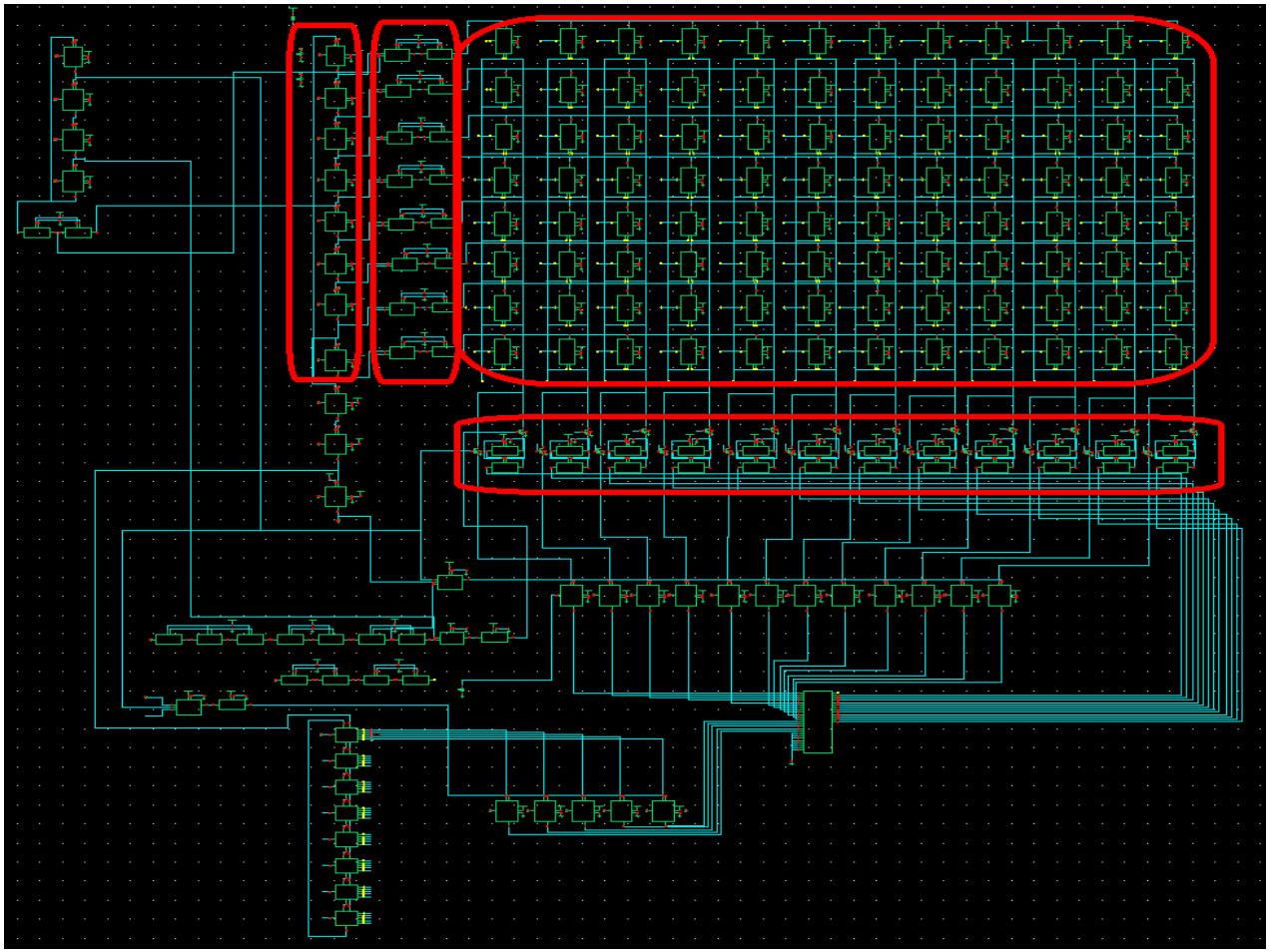
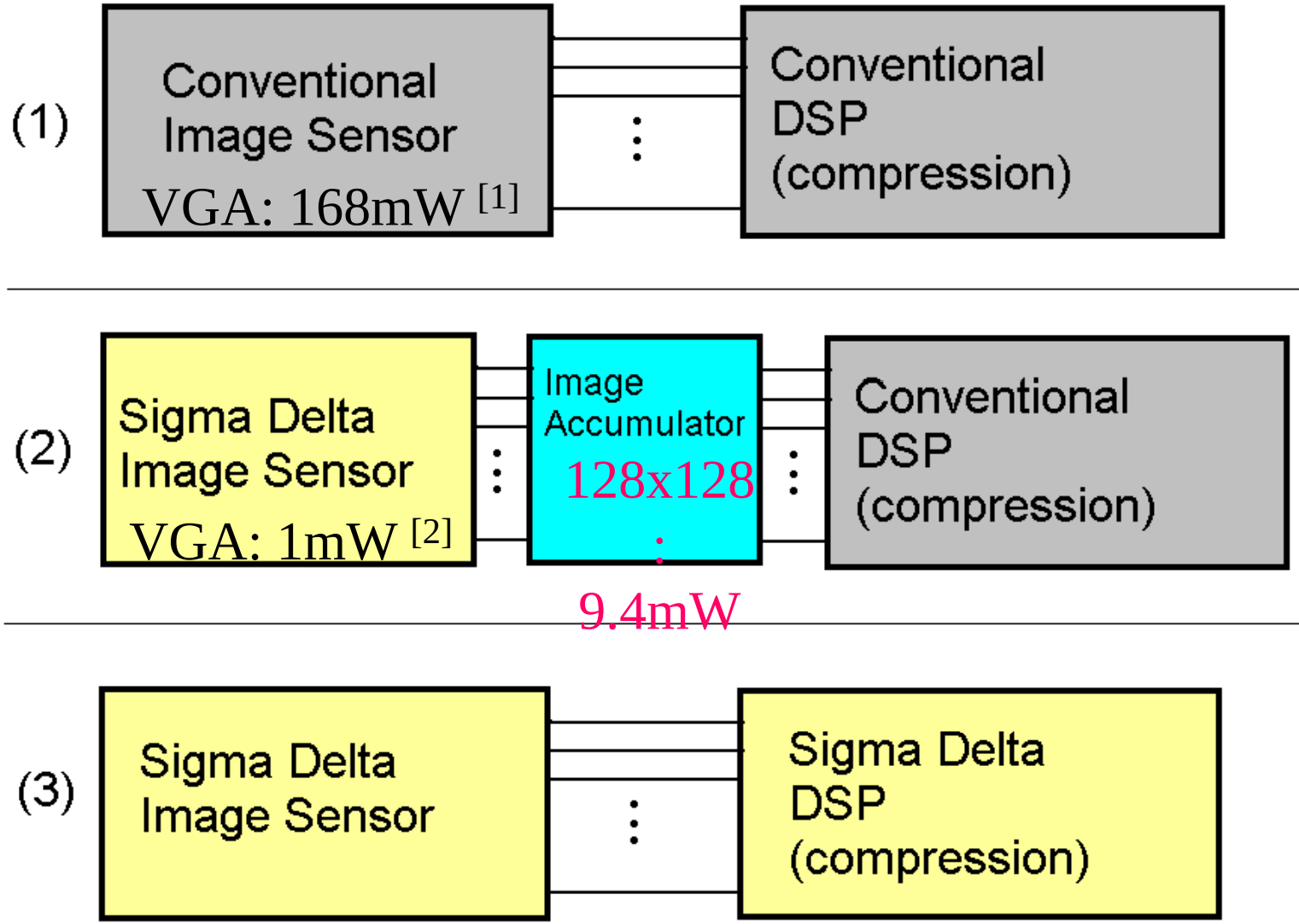


Image accumulator layout



Alternative Architectures



[1] Kodak, KAC-9618 image sensor: VGA, 30fps, 3.3V, 62dB, 2007

[2] A 0.88nW/pixel, 99.6 dB Linear-Dynamic-Range Fully-Digital Image Sensor
Employing a Pixel-Level Sigma-Delta ADC, Z. Ignjatovic, M.F. Bocko, University of Rochester

Sigma Delta image compression

•Wavelet transform is linear transform – apply wavelet to every 1-bit picture frame and then accumulate with the image buffer

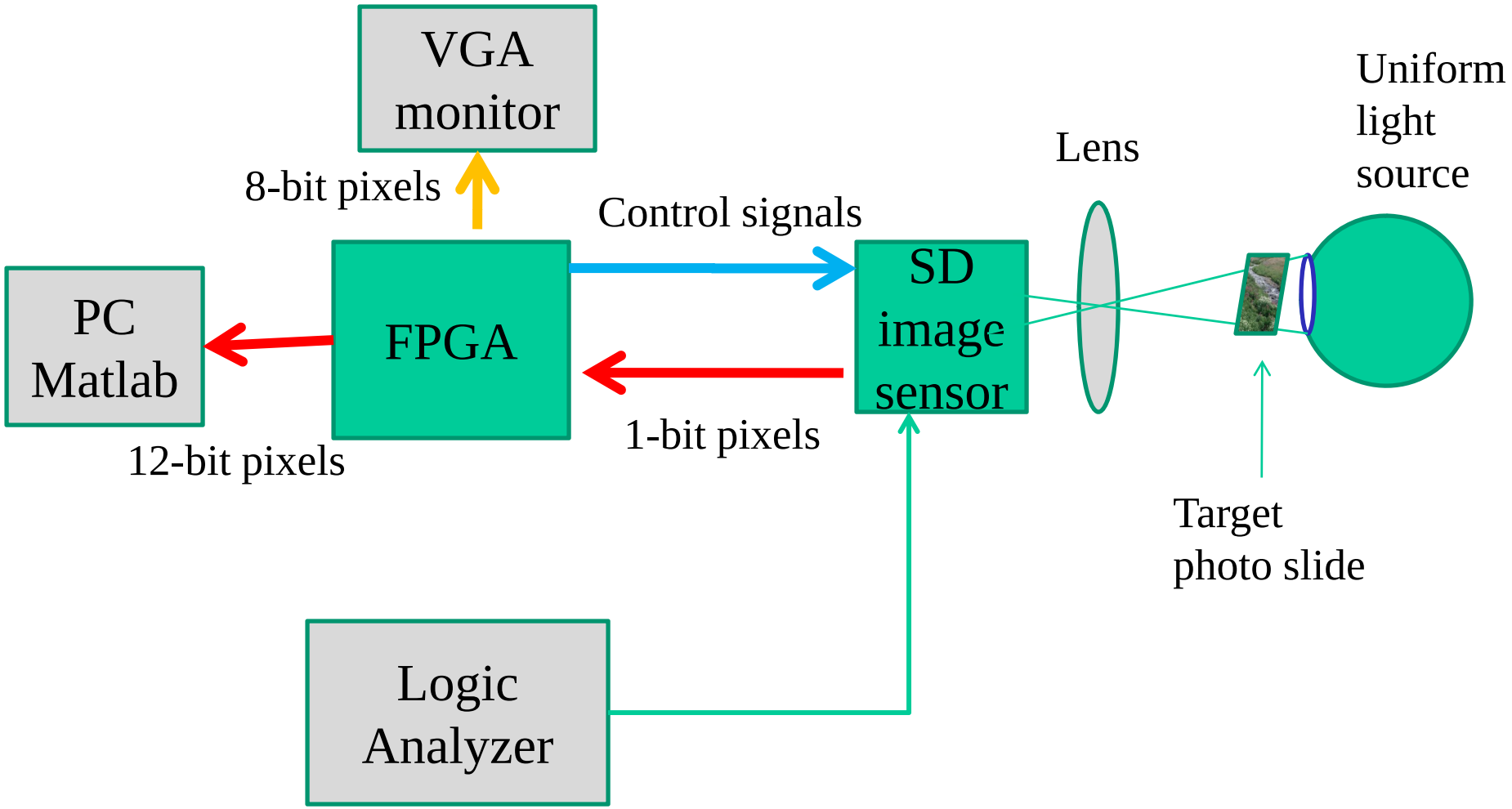
•Wavelet filtering needs additions and subtractions of wavelet coefficients only – no multiplications

•Haar wavelet even more simple – coefficients are -1 and 1

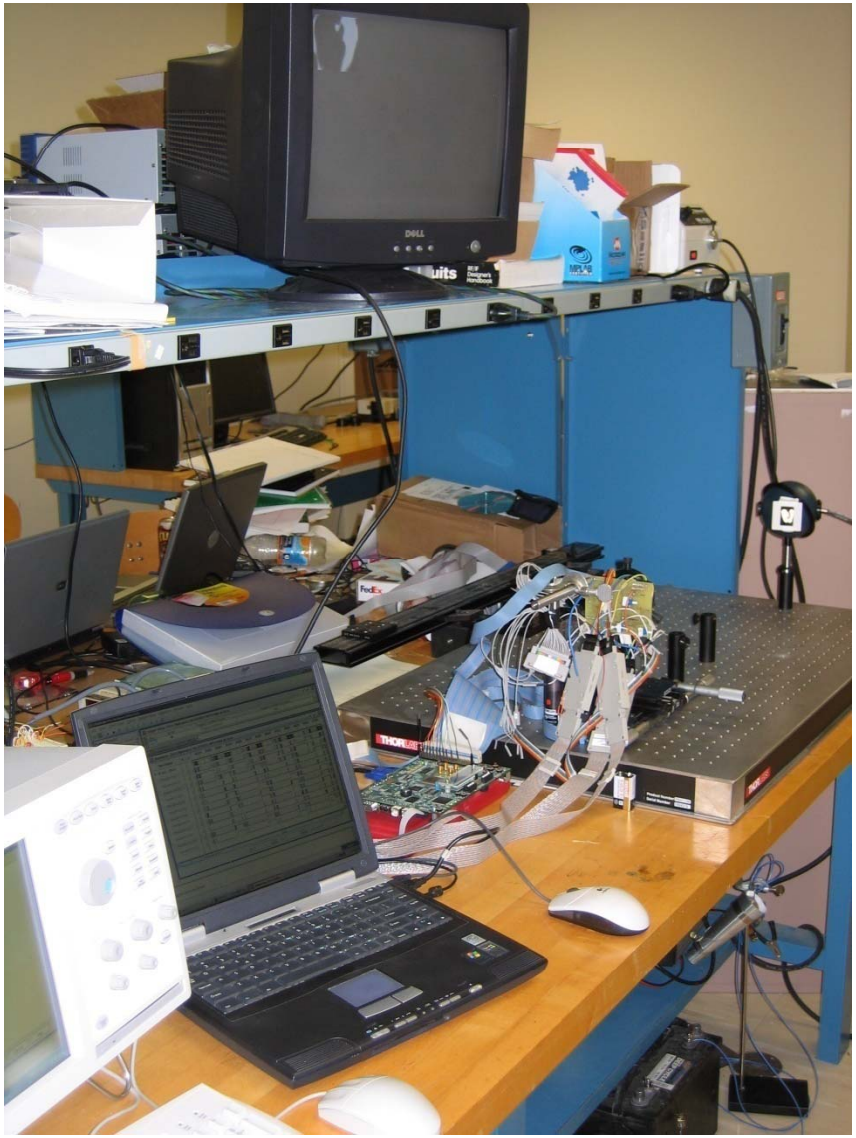
SD Imager Testing

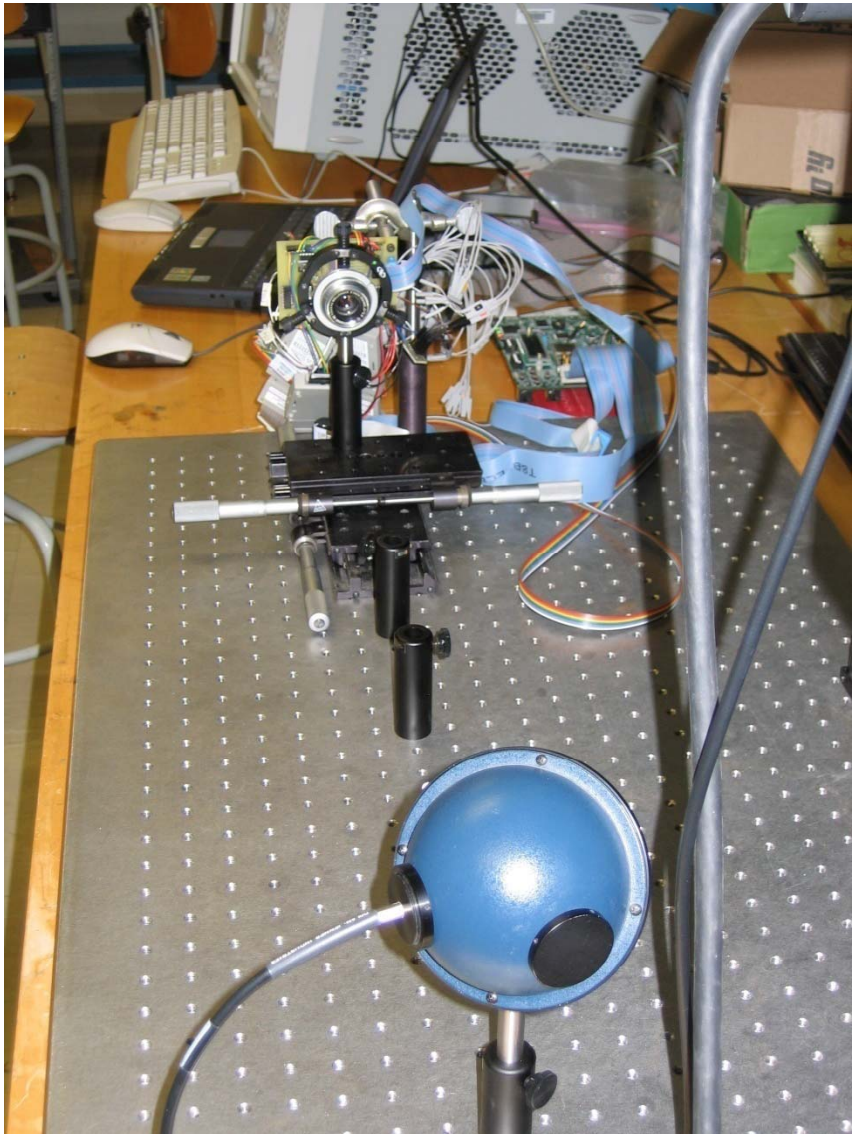
- Lab setup
- FPGA components
- Results

Lab Setup


VGA monitor
8-bit pixels
Control signals
Lens
Uniform light source
PC Matlab
FPGA
SD image sensor
12-bit pixels
1-bit pixels
Target photo slide
Logic Analyzer

Lab Setup

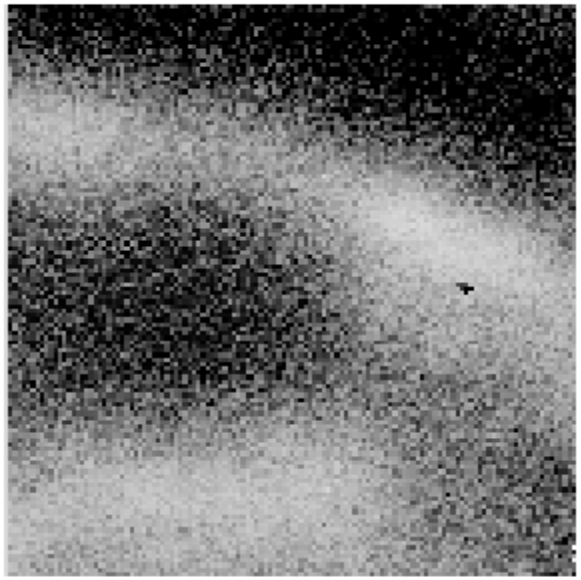




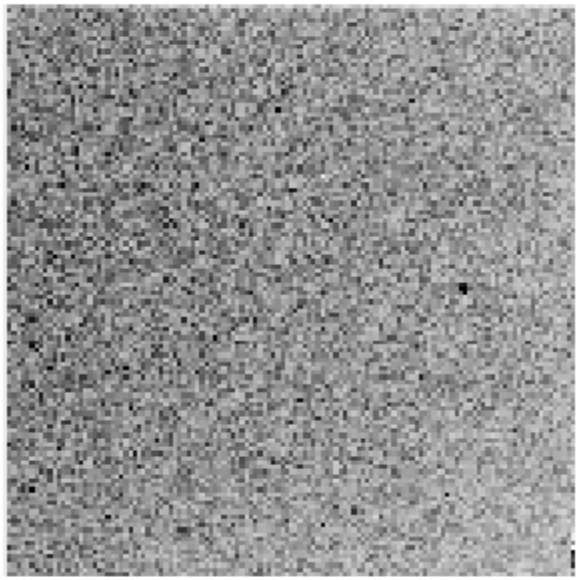
FPGA components

- Accumulator:
  - 12 bit adders
  - image buffer memory
  - windowing coefficients in ROM
- Control – state machine with ROM that contains the control sequence (1-60MHz)
- VGA component to read the image buffer
- PC interface to download the image from the FPGA

Image out of focus

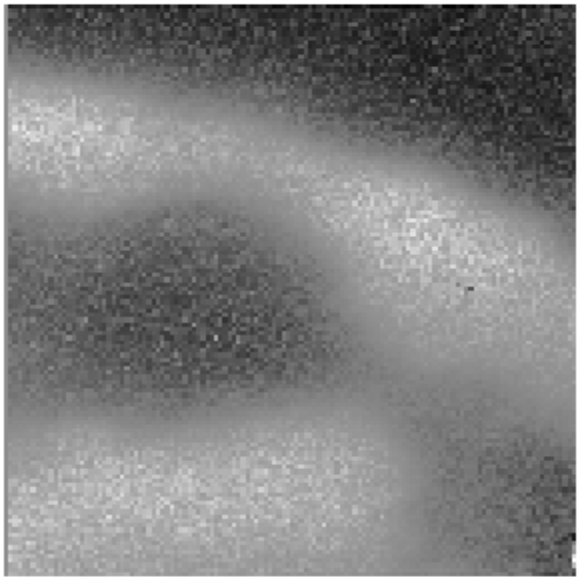


128x128 at OSR=256

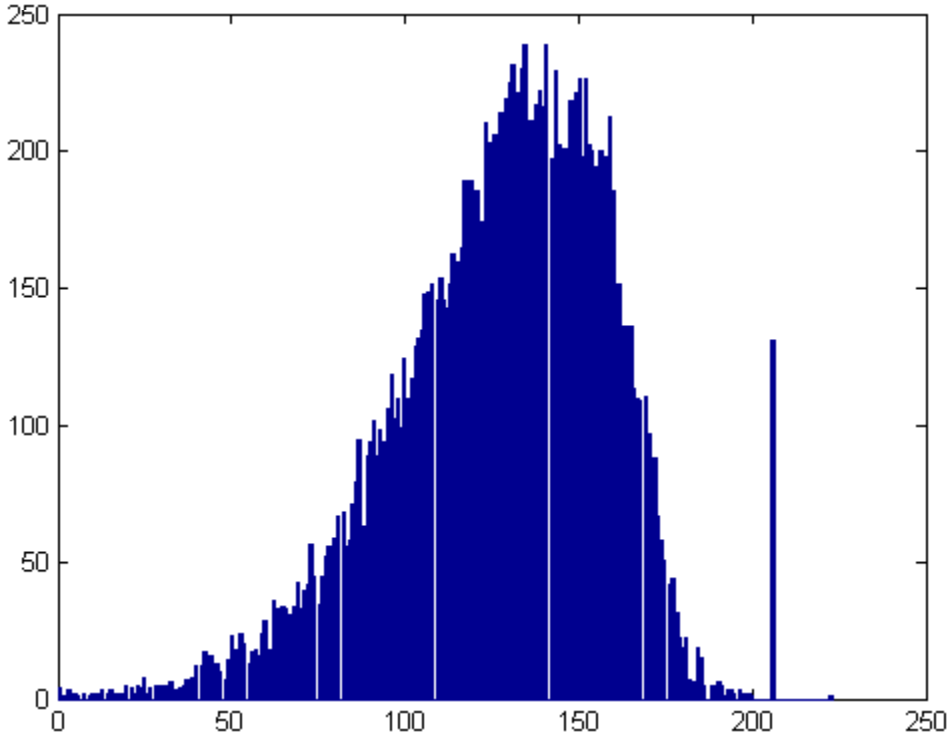


Uniform image at OSR=256

Post processing



Uniform image subtracted



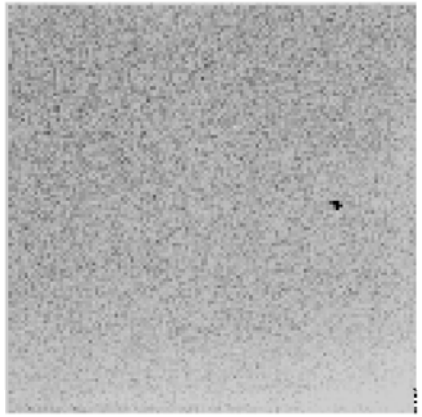
Histogram of the uniform image

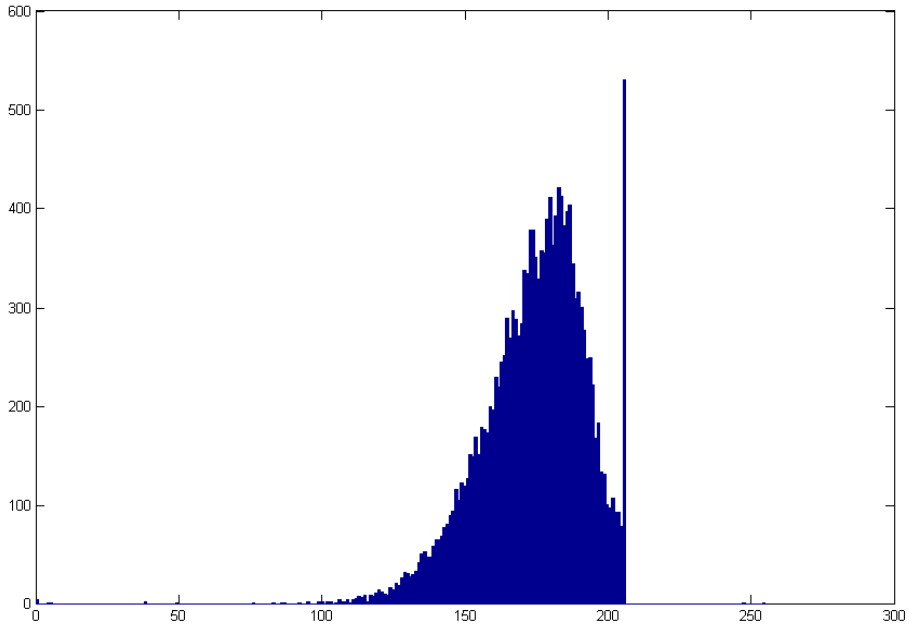
Image in focus

Original

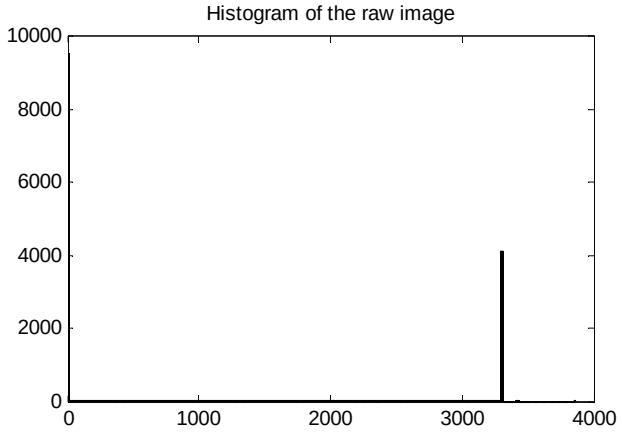
Post processed

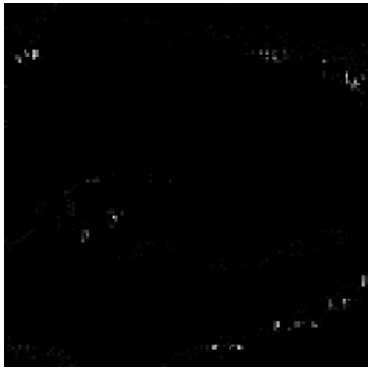
Lighter uniform image

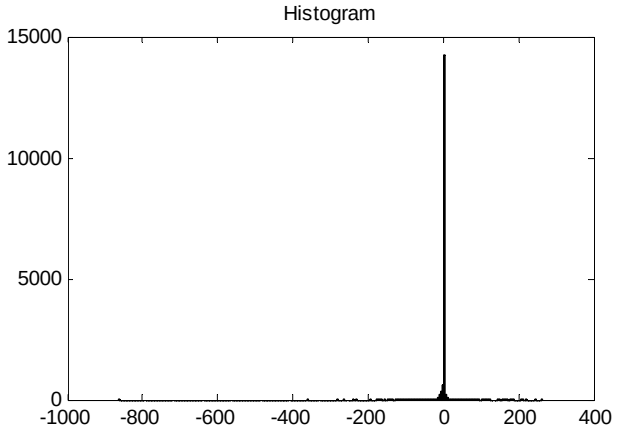




Noise between 2 snapshots







PSNR=46dB between two consecutive images captured

Future testing

- Estimate the pixel light response characteristics using different light intensities

- Estimate the variation of the response characteristics between the pixels when uniform light is applied, at different light intensities

Conclusions

- DAC voltage level can be reduced
- Imager control sequence adjusted
- Layout redesign: smaller pixels – less capacitance