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Biometric-Aware Pixel Fused Crossbars

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Background: biometric data for security

+ Biometric data is more secure compare to conventional keys and passwords:

    Unique biometric features

+ Convenient:

    You carry it with you every time

    Memorization is not required

- Requires sensory data processing and storage:

    Vulnerable to software based attacks

    Requires energy

Solution: storing and processing biometric data in energy-efficient hardware

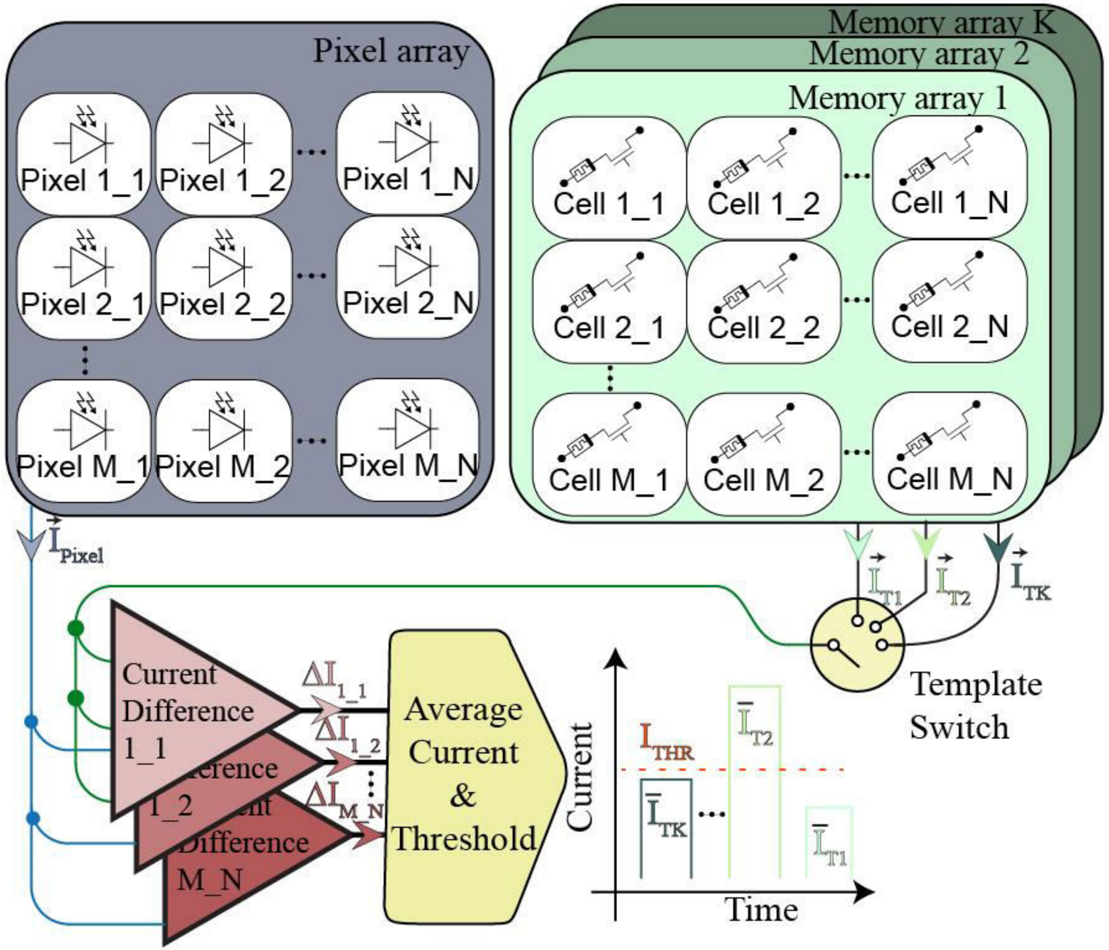
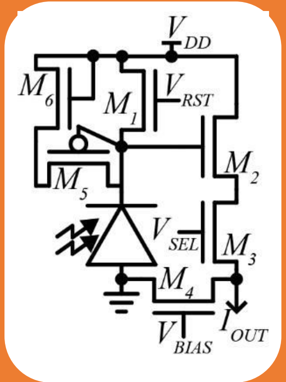


Figure 1. Proposed circuit level block diagram for fingerprint recognition and classification

Algorithm of operation:

1) Feed the output currents from pixel array and selected memory array into current difference circuit
2) Normalize obtained current differences
3) Select the memory array which produces the lowest averaged current difference with current input as winning pattern
4) Any input pattern producing averaged current difference above current threshold will be invalidated

Pixel and memory arrays



Optical CMOS sensors allows to capture accurate representation of biometric data – **fingerpint.** Lin-Log pixel cell is selected for adequate dynamic range

Figure 2. Lin-Log CMOS active pixel sensor

Figure 3. Fingerprint captured by optical fingerprint sensor. From FVC2000

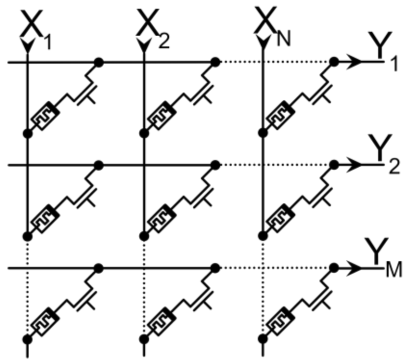


Figure 4. Memristive crossbar

Memristor is emerging resistive memory device that can be used as energy efficient storage for collected fingerprints

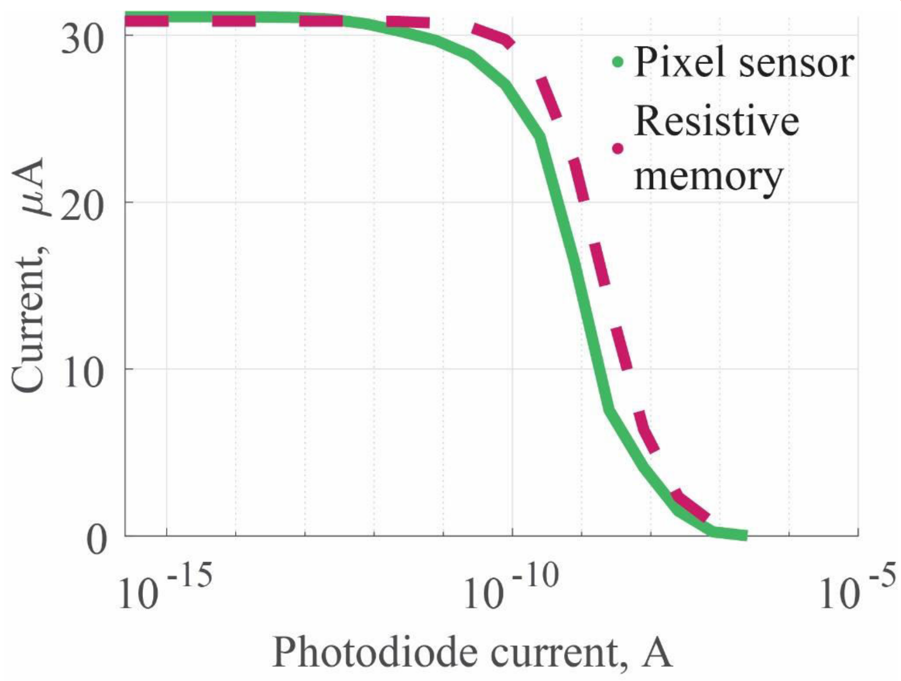


Figure 5. Output currents of CMOS pixel sensor and memristive cell similarity

Due to the similarity in output currents responses, both currents could be directly fed into the current averaging circuit

Current differentiator circuit implementation

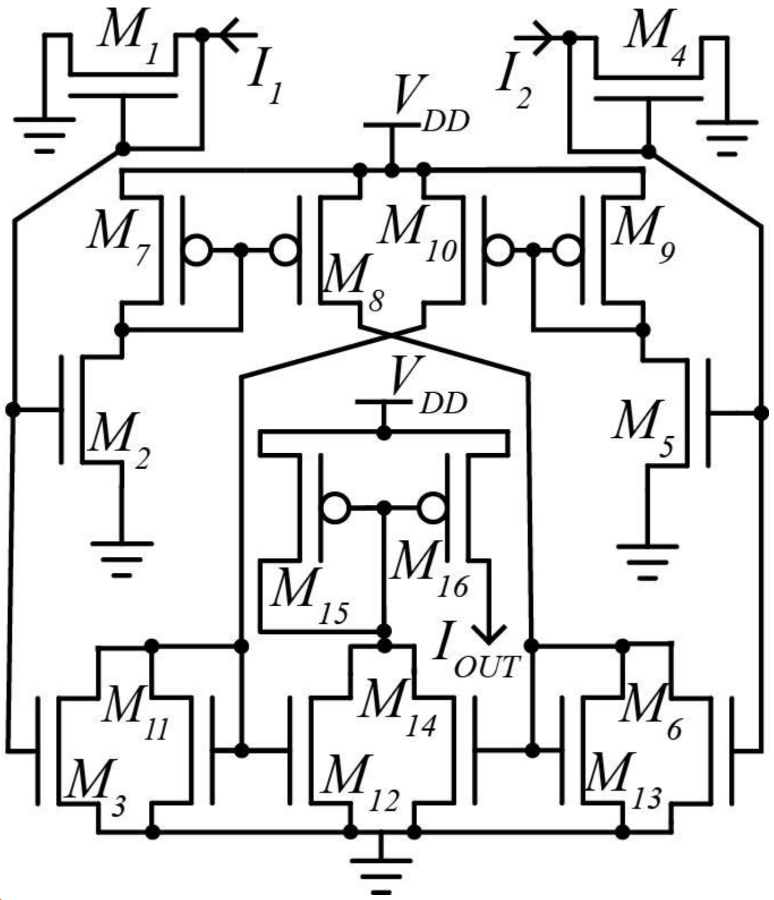


Figure 6. CMOS circuit for current differentiator circuit

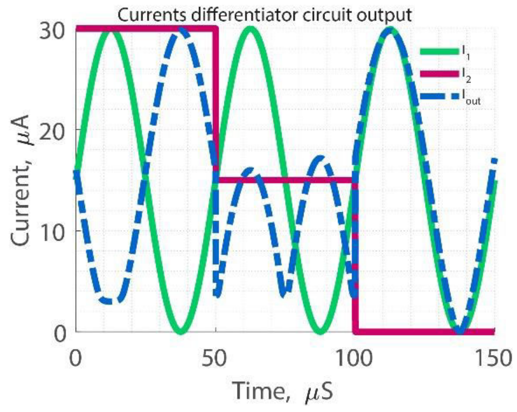


Figure 7. Generated output current

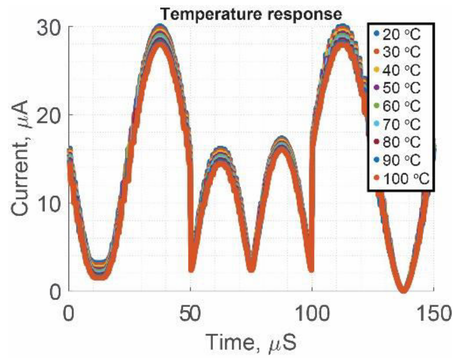


Figure 8. Temperature sensitivity

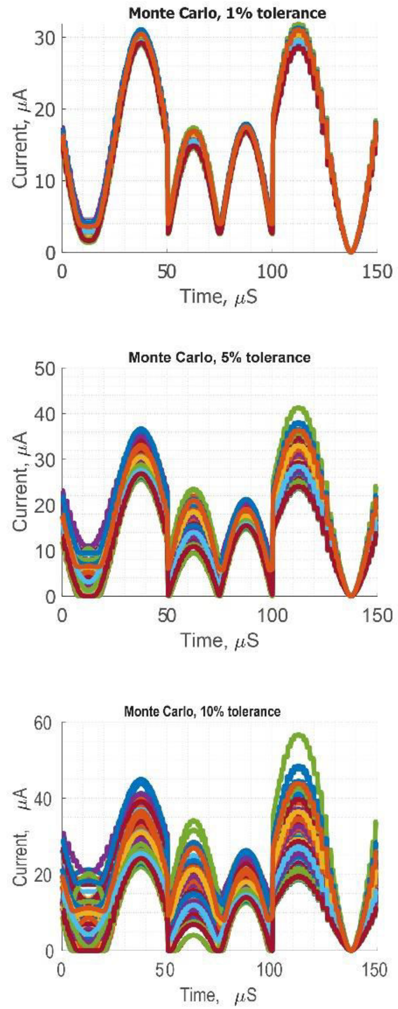


Figure 9. Monte Carlo analysis

Current averaging circuit implementation

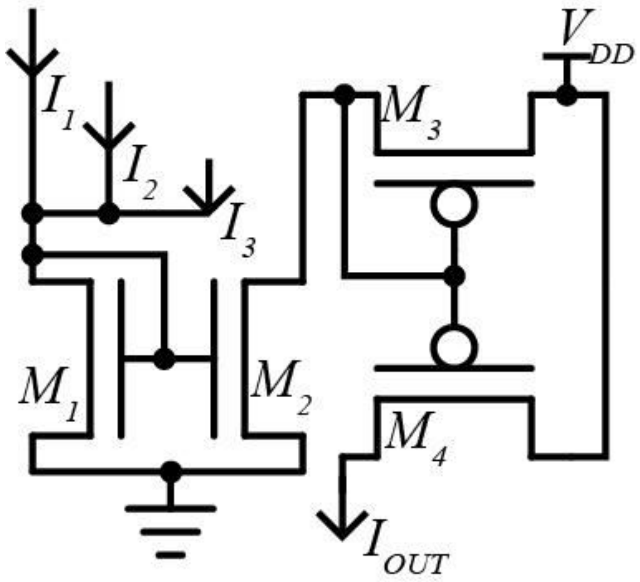


Figure 10. CMOS circuit for current averaging circuit

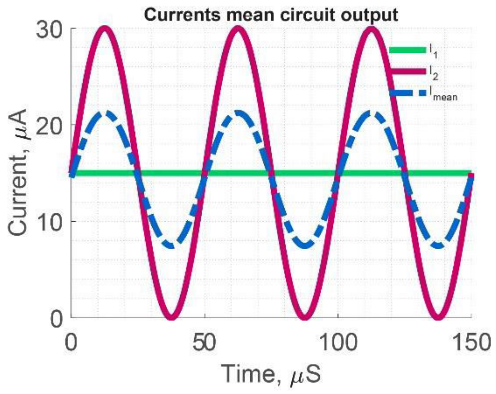


Figure 11. Generated output current

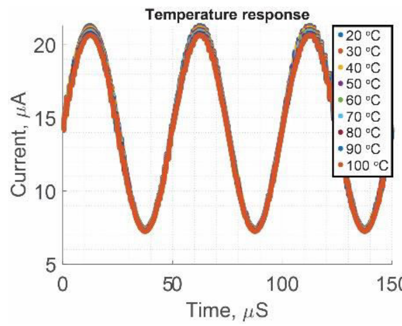


Figure 12. Temperature sensitivity

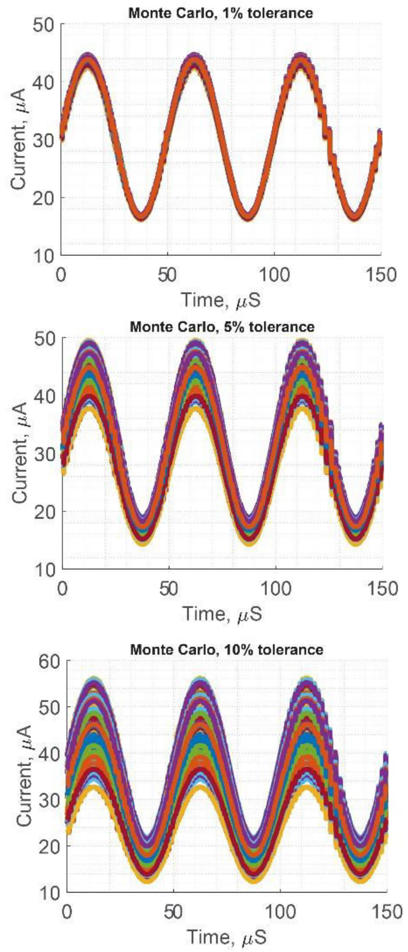


Figure 13. Monte Carlo analysis

Current thresholding circuit implementation

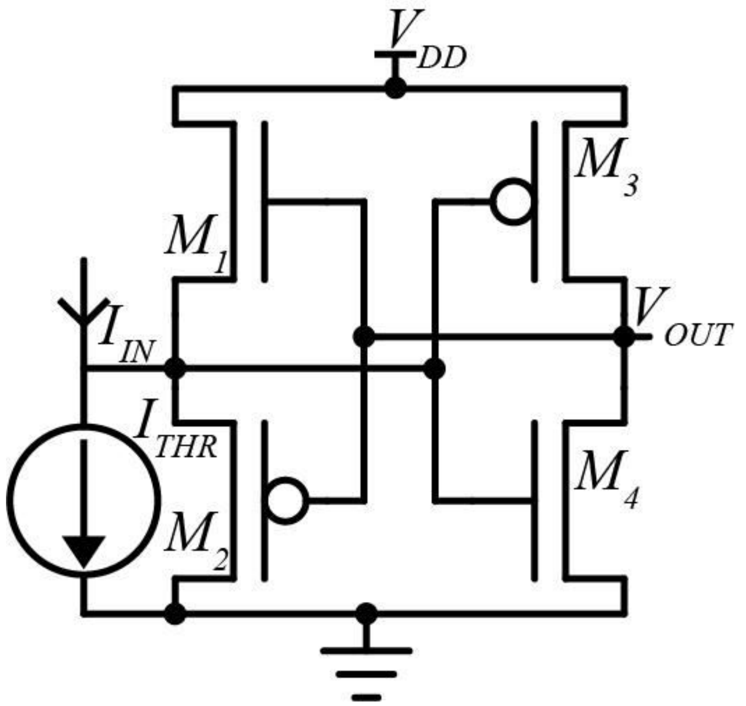


Figure 14. CMOS circuit for Current thresholding circuit

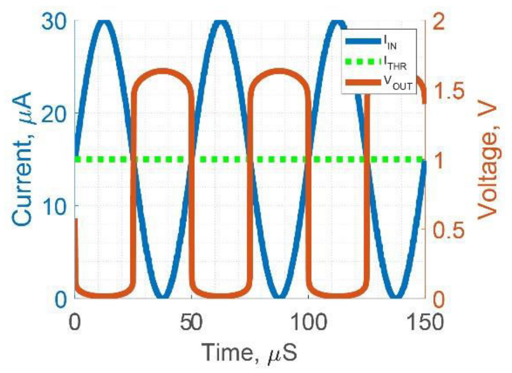


Figure 15. Generated output current

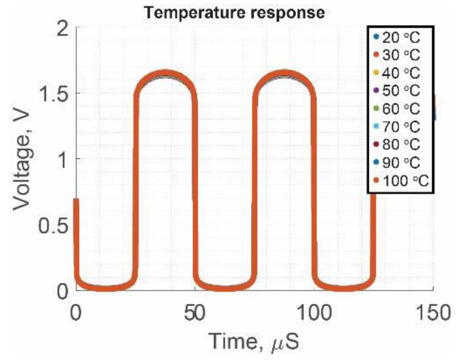


Figure 16. Temperature sensitivity

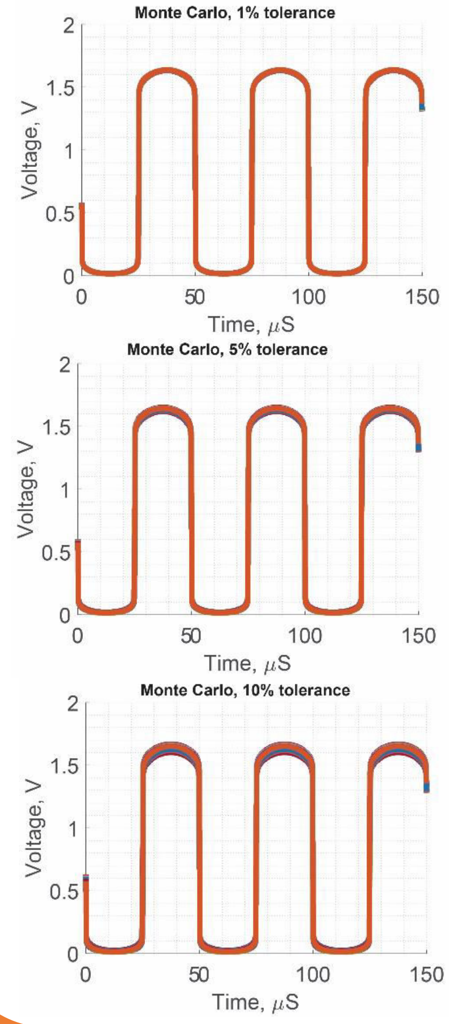


Figure 17. Monte Carlo analysis

Results

Table I. Proposed circuit parameters

Circuits	L_{NMOS}, μm	L_{PMOS}, μm	W_{NMOS}, μm	W_{PMOS}, μm	Area, μm^2	Mean power μW
Pixel CMOS	0.18	1.2	0.36	0.60	97.2 ***	2.6e-4 ***
Crossbar*	0.18	-	0.36	-	64e+4	192
Currents Difference	0.25	0.25	0.40	0.60	648	169.8
Mean Current	0.25 (4.0**)	0.25 (4.0**)	0.40	0.60	103.7	9.39
Threshold	0.25	0.25	0.40	0.60	77.8	32.72
Total for 10×10 array and 50 templates:					32.2 e+6	26.5 e+3

**- for 10×10 array*
***- length of the secondary transistor in a current mirror for the 10×10 pixel array (in order to reduce current sum by approximately 100 times)*
** * *- Only for CMOS components*

SPICE models:
TSMC 0.18 um CMOS model
Biolek memristor model (R_{ON} = 1965 Ω, R_{OFF} = 396750 Ω)

TensorFlow implementation:

1) Extract circuit non-idealities from SPICE simulations
2) Inject them as probabilistic noise into mathematical operations in TensorFlow
3) Train both ideal and non-ideal models with VFC2000-part 1 fingerprint images dataset

Table II. Results of TensorFlow simulations

Number of templates	Average Accuracy, %											
	Ideal	Memristive states					Difference circuit CMOS tolerance			Mean circuit CMOS tolerance		
		2	4	8	16	32	1 %	5 %	10 %	1 %	5 %	10 %
10	49.8	17.5	42.3	45.6	46.0	46.8	44.9	30.9	20.6	38.6	21.3	17.2
20	64.7	18.3	58.3	62.9	65.4	65.4	62.3	34.7	21.0	48.9	22.8	16.1
30	74.3	17.9	72.3	72.9	72.1	76.4	71.9	42.1	20.6	55.6	24.6	15.5
40	82.8	19.8	77.1	81.6	82.5	82.3	80.6	43.3	23.5	61.3	21.1	14.7
50	87.5	21.2	84.8	89.6	88.3	87.7	88.2	45.8	22.4	67.5	20.6	14.2

Future work:

- Increase the scale of the proposed circuit and training dataset
- Design interfacing circuits, compatible with selected CMOS and memristive technologies
- Reduce the circuit sensitivity to process variations
- Test proposed circuit for other biometric modalities