AC Computing Methodology for RF-Powered IoT Devices

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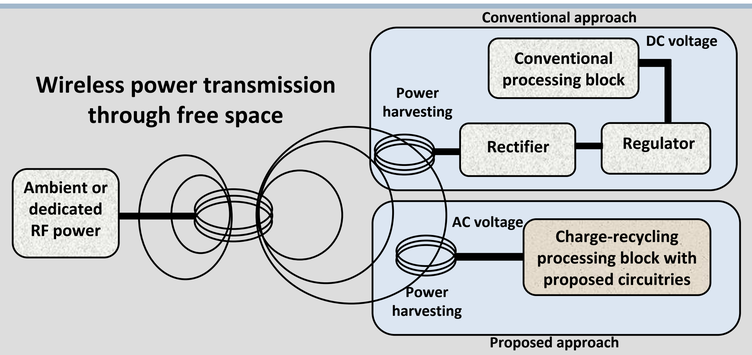
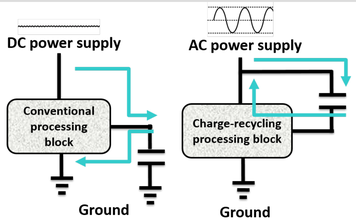


- Energy autonomy is a critical challenge for IoT and WSN based devices
- Ambient and/or dedicated wireless power is a promising energy source
- Leverage AC computing methodology to directly power local processing block
  - More than an order of magnitude increase in energy efficiency
  - Powerful local processing capability
  - Elimination of the power losses due to rectification and regulation
  - Elimination of the strong dependence on battery

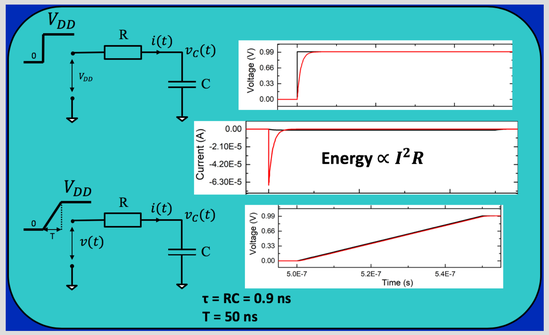
Charge-Recycling Principle



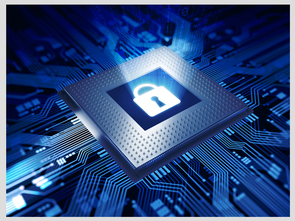
$E_{CMOS} = \alpha \frac{1}{2} CV_{DD}^2$ (a)

$E_{AL} = 2\frac{RC}{T} CV_{DD}^2$ (b)

Adiabatic Switching



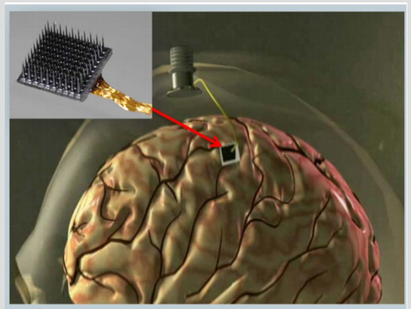
Potential Applications



IoT Security

Structural health monitoring

Source: RFID, by AB&R



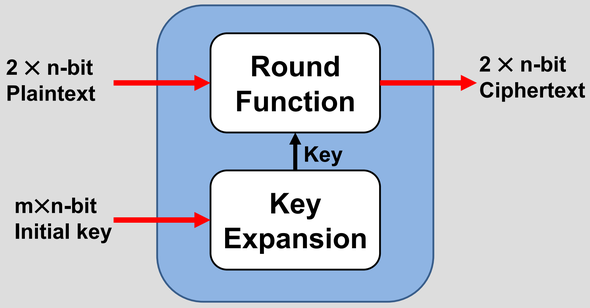
Source: A. V. Nurmikko *et al.*, Proceedings of the IEEE, 2010

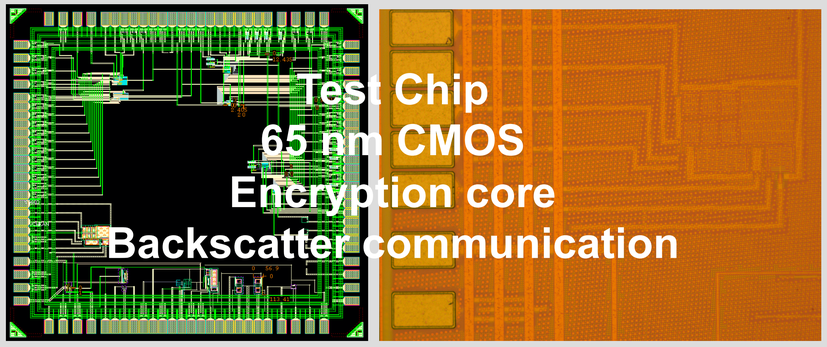
SIMON Cipher

- Bit-serialized SIMON32/64
  - Lightweight cryptographic algorithm
  - 32-bit plaintext input
  - 64-bit initial keys
  - Consists of round function and key expansion

Proposed Architecture

- Primary contributions include
  - Use of adiabatic registers
  - Merging multiplexers and FIFOs to ensure correct synchronization
  - Elimination of the additional flip-flops for appending bits
  - Introduction of balanced transfer paths

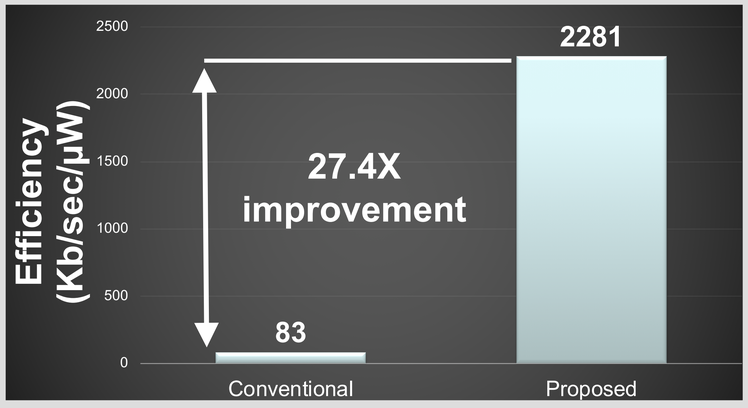




Results

- RF signal amplitude is 1.2 V
- Operation frequency is 13.56 MHz
- 65 nm commercial CMOS technology

Architecture	Conventional	Proposed
Logic	Static Logic	PAL
Average Power (μW)	9.12	0.27
Latency (clock cycles)	576	704
Energy (pJ)	387	14
Throughput (Kbps)	753	616
Efficiency (Kb/sec/μW)	83	2281
Number of Transistors	2966	1242



Current Focus

- Power splitting into AC and DC paths
- Integration of a communication framework (backscatter based)
- Further characterization and testing

Publications

• T. Wan, Y. Karimi, M. Stanacevic, and E. Salman, "AC Computing Methodology for RF-Powered IoT Devices," *IEEE TVLSI*, May 2019

• Y. Huang, T. Wan, E. Salman, and M. Stanacevic, "Signal Shaping at Interface of Wireless Power Harvesting and AC Computational Logic," *IEEE ISCAS*, May 2019

• E. Salman, M. Stanacevic, S. Das, and P. Djuric, "Leveraging RF Power for Intelligent Tag Networks," *ACM/IEEE GLSVLSI*, May 2018

• T. Wan and E. Salman, "Ultra Low Power SIMON Core for Lightweight Encryption," *IEEE ISCAS*, May 2018

• E. Salman, M. Stanacevic, T. Wan, Y. Karimi, "Radio Frequency Energy Harvesting Apparatus and Method for Utilizing the Same," US Patent Pending

• T. Wan, Y. Karimi, M. Stanacevic, and E. Salman, "Perspective Paper – Can AC Computing be an Alternative for Wirelessly Powered Devices," *IEEE Embedded Systems Letters*, 2017

• T. Wan, Y. Karimi, M. Stanacevic, and E. Salman, "Energy Efficient AC Computing Methodology for Wirelessly Powered IoT Devices," *IEEE ISCAS*, 2017

• T. Wan, E. Salman, and M. Stanacevic, "A New Circuit Design Framework for IoT Devices: Charge Recycling with Wireless Power Harvesting," *IEEE ISCAS*, 2016

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