Electronic circuits & systems (ECS) research group introduction

Prof. David BOL & Prof. Denis Flandre

Research scope of ECS group

Emerging CMOS

MEMS, SOI, Bio, Heterogeneous integration, Noise, Nano-CMOS

Low-power circuits

Crypto, SRAM, CMOS imager, UWB, Ultra-low V_{dd}/leakage, Variability resiliency, MCU, SoC/NoC, Multi-core, Sensor I/F, ML, Neuromorphic, Power management, RF, Harvesting

IoT systems

IoT, Localization, Biomedical, Vision, Smart sensors, AI, Space, Communications

→ Level of abstraction

Professors:

- Prof. David Bol
- Prof. Denis Flandre
- Prof. Jean-Didier Legat
- 10+ researchers

Industrial collaborations:

ST-Micro, IMEC, e-peas, EADS, ACIC, Thales, Cissoid, CEA-Leti, AMS, iStar, Deltatec, Samsung, Honeywell, TowerJazz, intoPix, Siemens, nSilition, Infineon, Synergiam, …

Last 10 years:

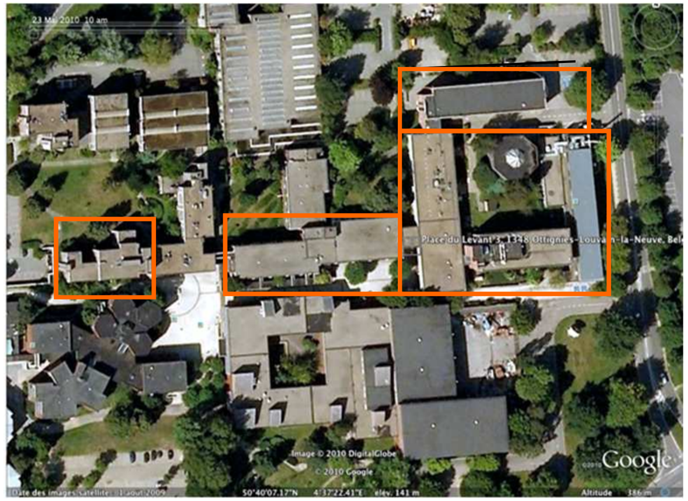
- 5 patents
- 150+ papers
- 3 awards
- 3 spin-off launched
- 10+ PhD graduation

Within UCL ICTEAM institute…

https://uclouvain.be/fr/node/1991

ICTEAM institute

- Three research divisions
  - **Electrical Engineering (ELEN)**
  - Computing Science Engineering (INGI)
  - Mathematical Engineering (INMA)
- About
  - 40+ professors
  - 200+ researchers
  - 20 computer scientists and technicians
  - 150+ publications per year
- WELCOME technology platform
  → measurement facility
- Full access to the WINFAB platform
  → nanofabrication facility



Research directions at ICTEAM

ICTEAM carries both basic and applied world-class research in various domains of Information and Communication Technologies, Electronics and Applied Mathematics.

- Applied Mathematics
- Biomedical Engineering
- Communication Systems and Networks
- Cryptography and Information Security
- Dynamical Systems, Control and Optimization
- **Electronic Circuits and Systems**
- Large Graphs and Networks
- Machine Learning and Artificial Intelligence
- Micro and Nano Process Technologies and Systems
- Microwave Engineering and Applied Electromagnetism
- Signal and Image Processing
- Software Engineering and Programming Systems

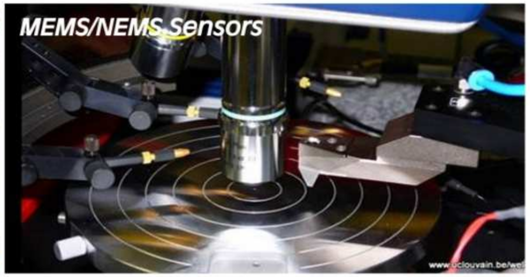
icteam

Institute of Information and Communication Technologies, Electronics and Applied Mathematics

Electronics Circuits and Systems

UCL

Wallonia Electronics & Communications Measurements



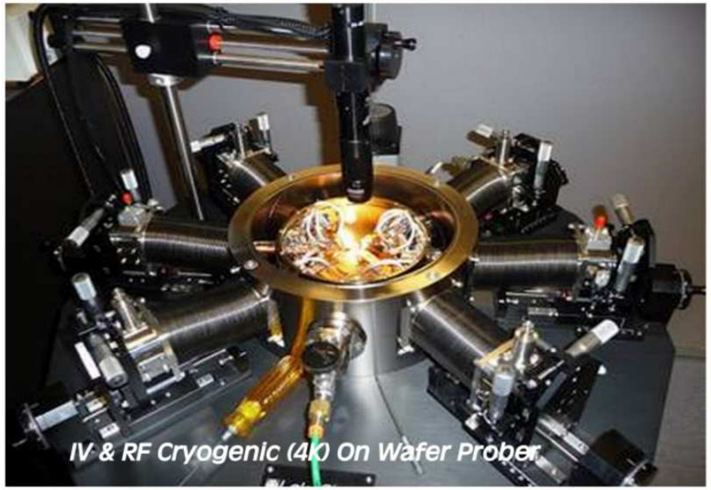
Welcome to multiparametric characterizations

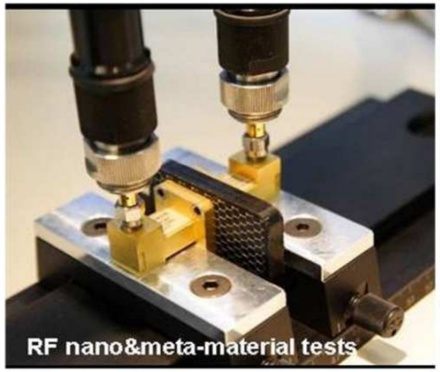
from molecules to signals

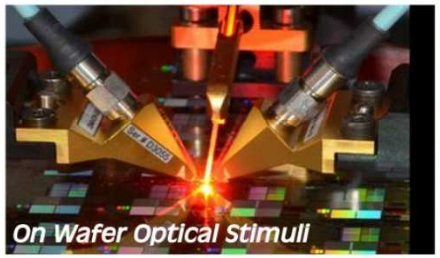
in a 350 m² state-of-the art measuring facility for devices, sensors, circuits and systems

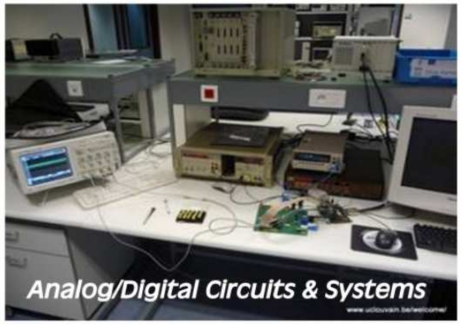
welcome

wallonia electronics and communications measurements









2.13 MEuros equipment over 10 years – over 120 yearly users from 4 corners of the globe
open to research, PhD/Master studies, industry
http://www.uclouvain.be/welcome info-welcome@uclouvain.be

WINFAB : Micro- and nano-fabrication at UCL

winfab
WALLONIA INFRASTRUCTURE NANO FABRICATION

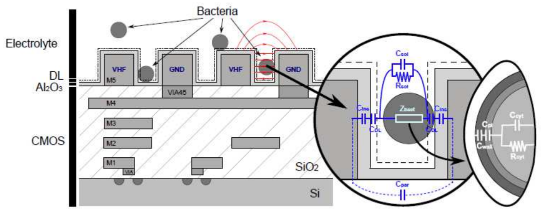
- Cleanroom: **~1000 m²** on two levels
  Critical work areas in ISO5 (stand-by)
  « < 10 particules of 100 nm / feet³ of air »

- Activities : more than **50** state-of-the-art **equipments**,
  ~80 active researchers, more than **20 R&D projects**

Level 1: « Ballroom »

Level 0 : « Support Area »

Process/device research



System research

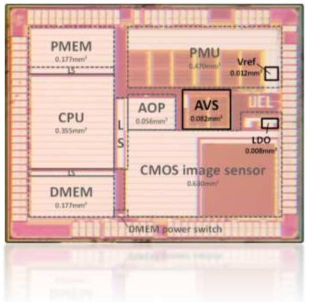
Microfabrication

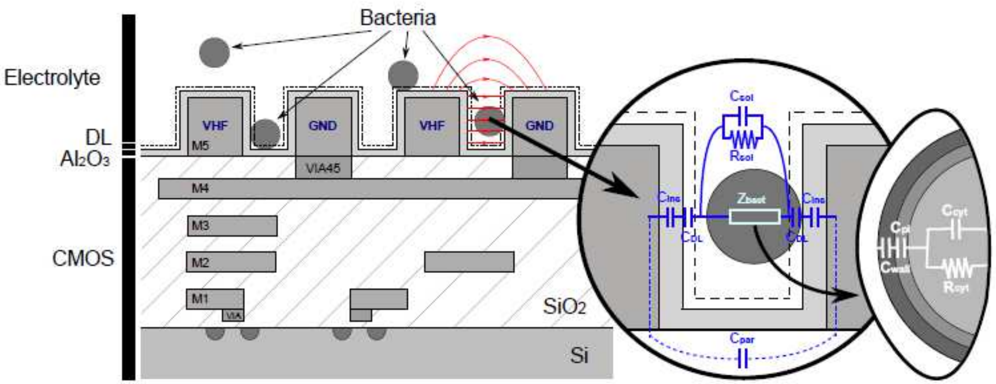
winfab
WALLONIA
INFRASTRUCTURE
NANO
FABRICATION

Electrical characterization

welcome
wallonia electronics
and communications
measurements

Circuit research





EMERGING CMOS

Characterization, modeling, & design enablement

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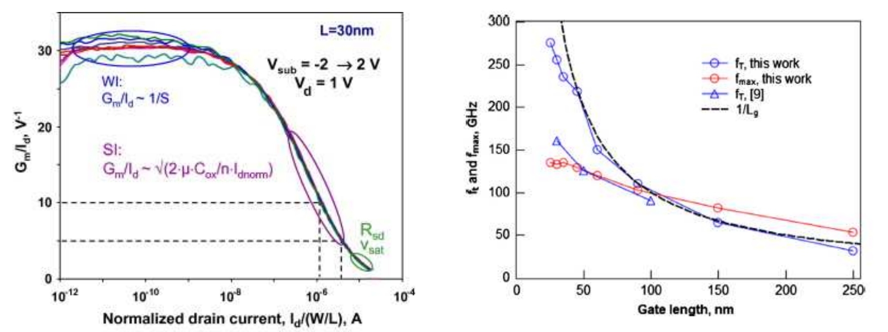
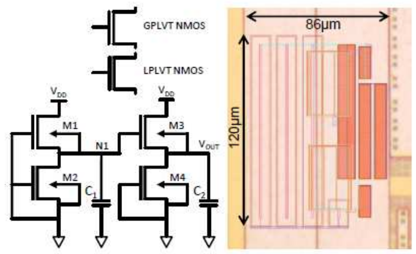
UCL

Characterization and modeling of CMOS technologies

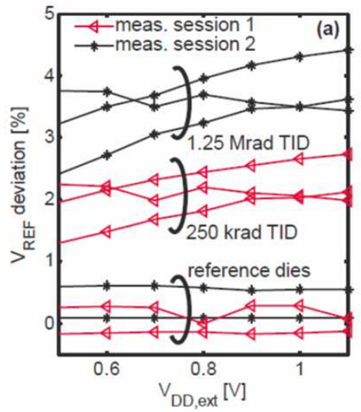
Analog/RF perfs of ultimate MOSFETs *[Arshad, SSE, 2014][Makovejev, SSE, 2015]*



Radiation effects *[de Vos, S3S, 2014]*

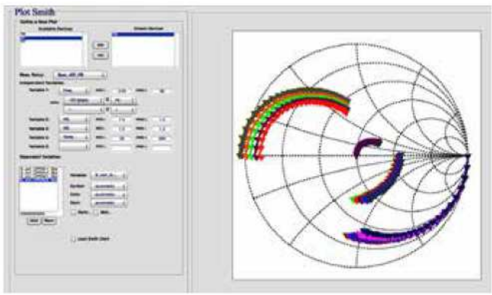


10nW 0.2V ΔV_t voltage reference



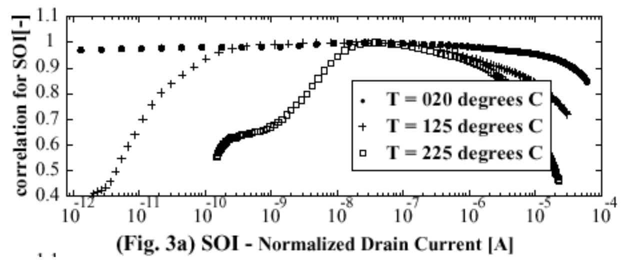
Characterization tools *[incize, 2014]*

incize



Effects of wide temperature range

Correlation coefficient between $\Delta I_d/g_m$ at $V_{gs} = V_{th}$ and $\Delta I_d/g_m$ at other V_{gs}

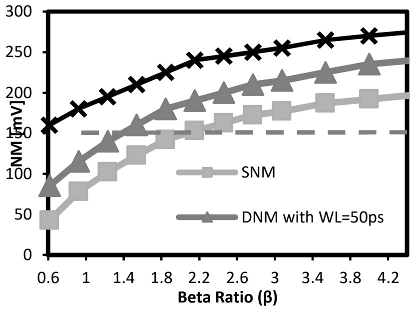


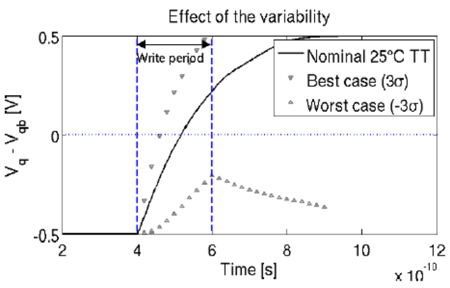
$$\frac{\Delta I_D}{I_D} = -\frac{gm}{I_D}\Delta Vth + f(V_G)\Delta n$$

$$f(V_G) = \frac{1}{\alpha_1 + \left(\frac{V_G}{\alpha_2}\right)^{\alpha_3}}$$

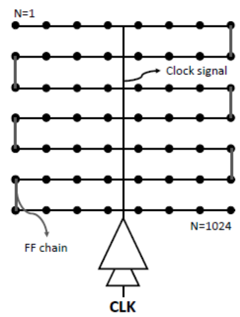
Design enablement

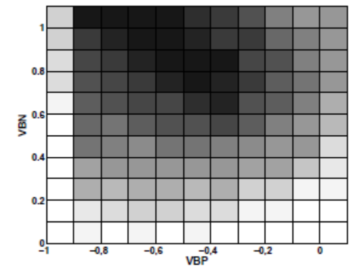
Assessment of embedded memories *[Haine, FETCH, 2015][Elthakeb, ISCAS, 2015]*





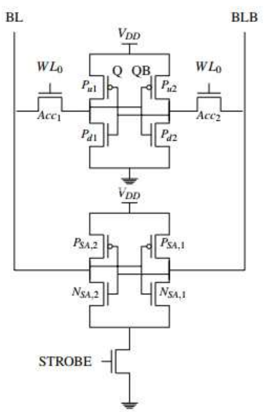
Minimum functional voltage characterization *[Bernard, PATMOS, 2014]*

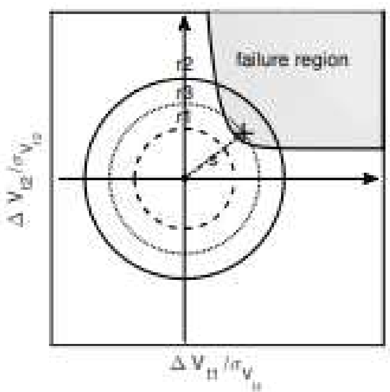




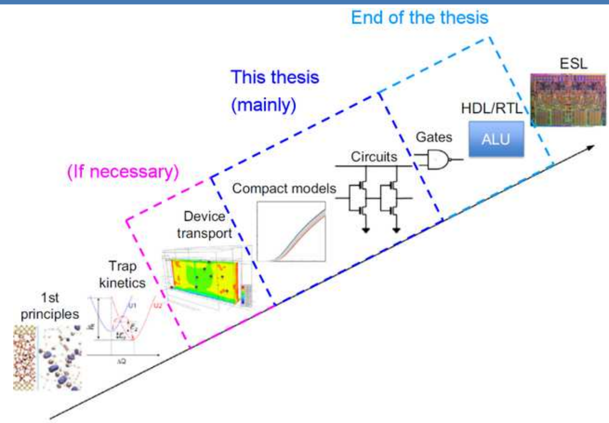
(c) V_{dd} = 0.190V

Fast statistical assessment of high-σ circuit characteristics *[Haine, DATE, 2018]*



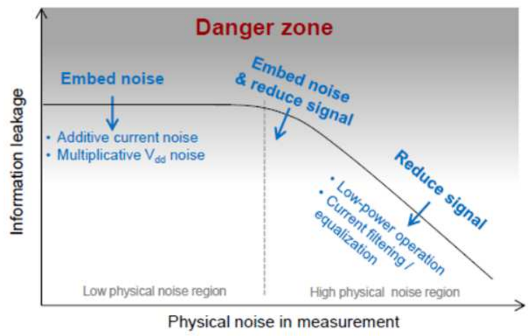


Compact modeling of random telegraph noise *[Van Brandt, MOS-AK, 2017]*

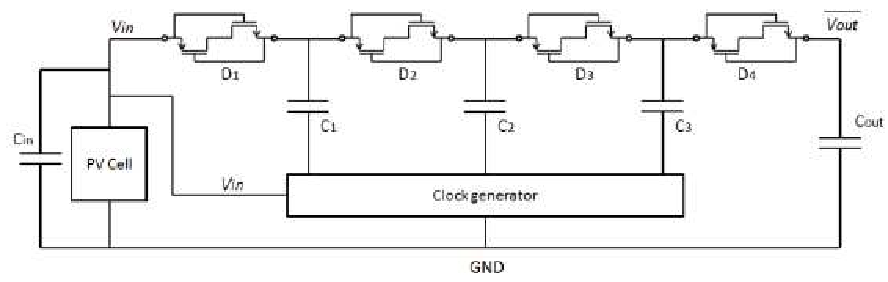


New device/circuit interaction concepts

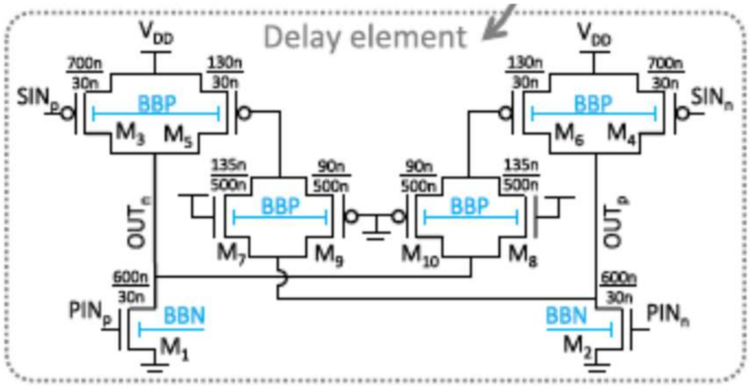
Noise exploitation for secure crypto circuits *[Kamel, SPACE, 2016]*



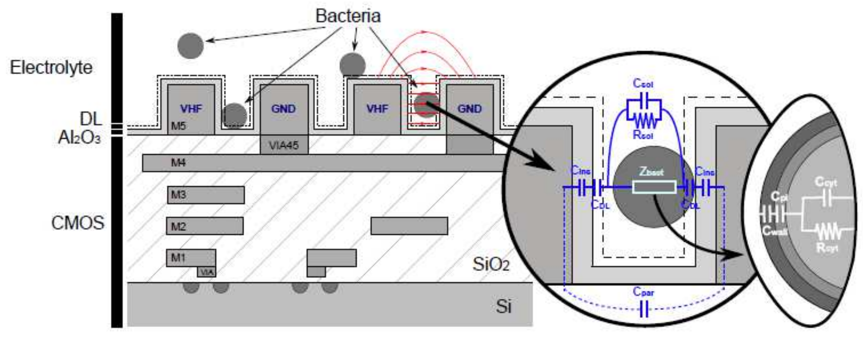
SOI co-integration of PV cell with interface circuit *[Gosset, SOI conf., 2011]*



Back-gate controlled circuits in FD SOI *[de Streel, JSSC, 2017]*



Capacitive bacteria detection onto CMOS *[Couniot, TCAS-II, 2015]*



Data processing & storage

Sensing (transducers)

Power management

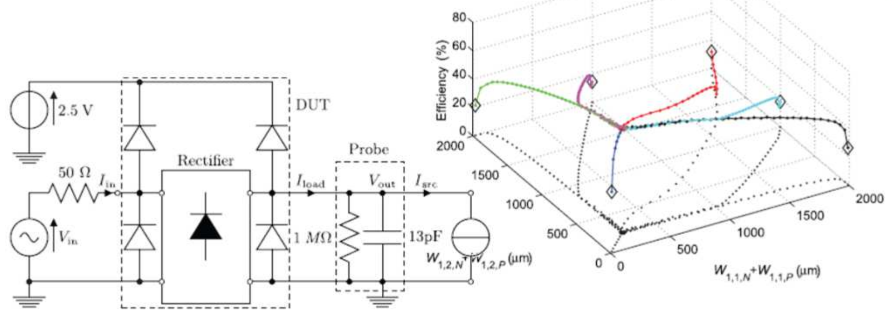
Wireless communications

LOW-POWER CIRCUIT DESIGN

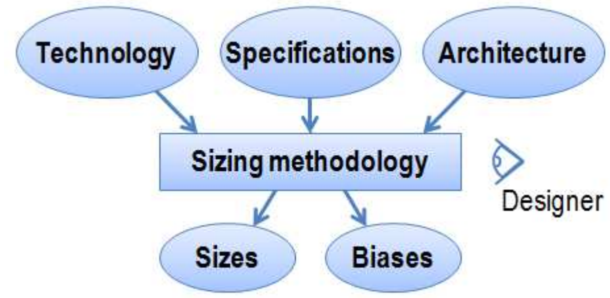
Methodologies and IP blocks in the 4 IC functions

Low-power design methodologies

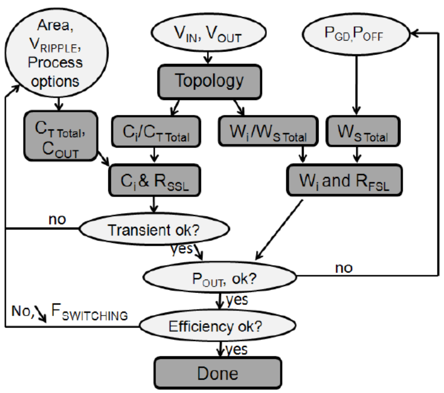
Sizing methodology for AC/DC rectifiers *[Haddad, JSSC, 2016]*



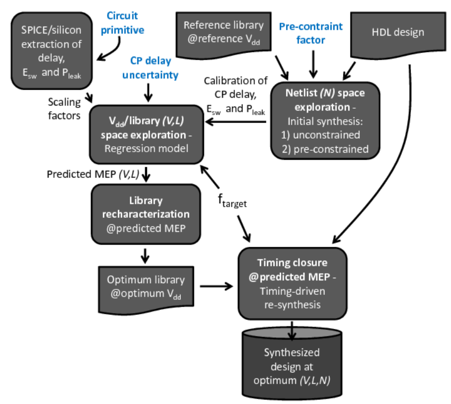
G_m/I_d sizing methodology for analog primitives *[Pollissard, AICSP, 2013]*



Sizing methodology for DC/DC converters *[De Vos, TCAS-I, 2014]*

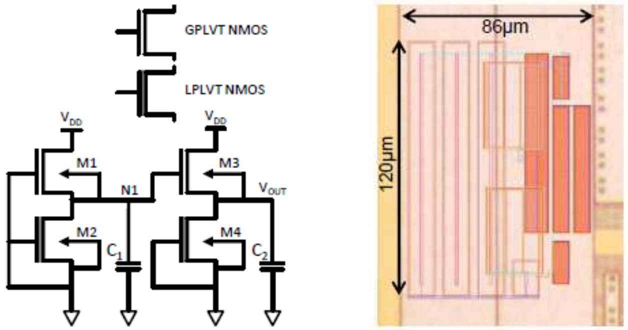


Synthesis flow for ultra-low-voltage logic *[Bol, TCAS-II, 2012]*

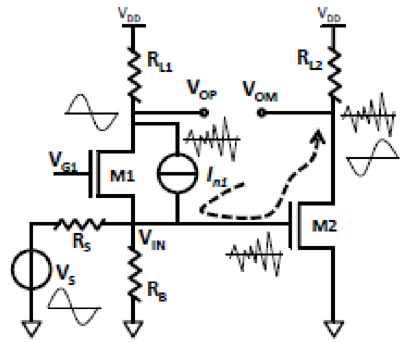


Low-power analog/mixed-signal building blocks

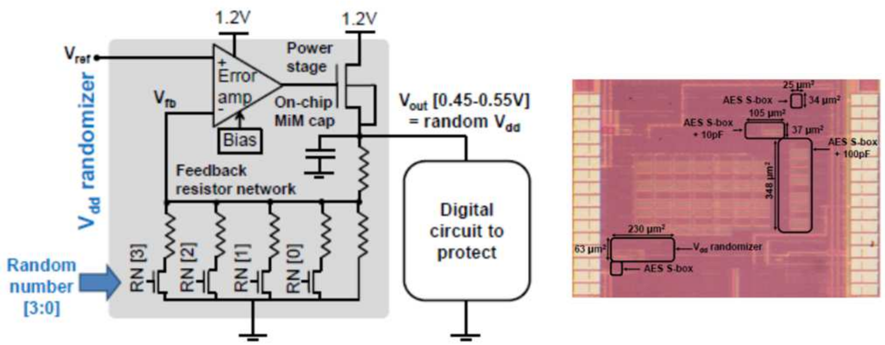
10nW 0.2V voltage reference *[de Streel, S3S, 2015]*



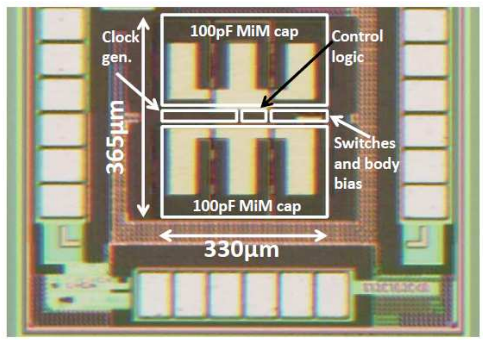
2mW 10GHz wideband low-noise amplifiers *[Gimeno, S3S, 2017]*



V_{dd} randomizer for secure crypto circuits *[Kamel, SPACE, 2016]*

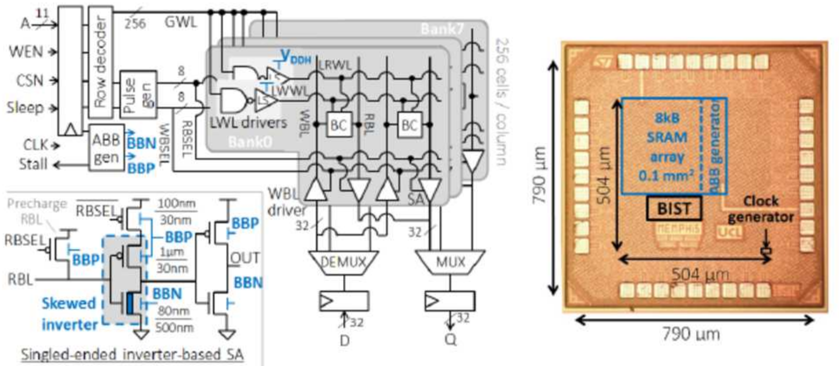


Multi-mode SC DC/DC converters *[De Vos, SubVt, 2012][Clerc, ISSCC, 2015]*

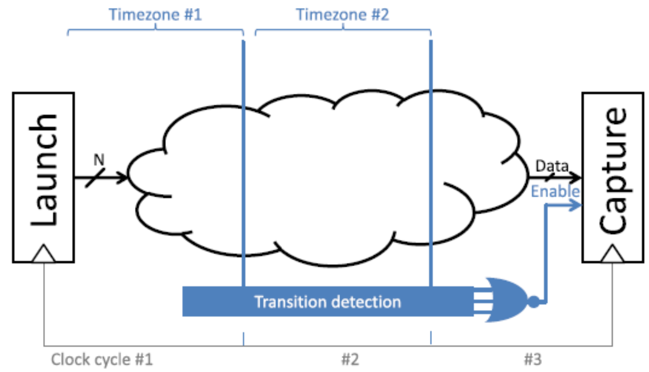


Low-power digital design: architecture and techniques

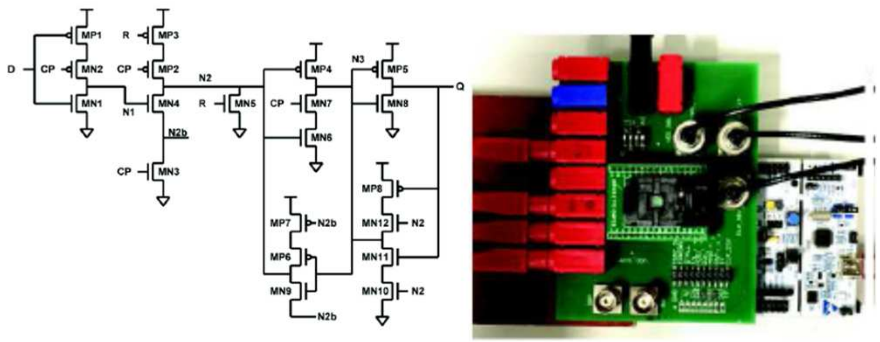
ULP 0.4V 80-MHz SRAM
[Haine, ESSCIRC, 2017]



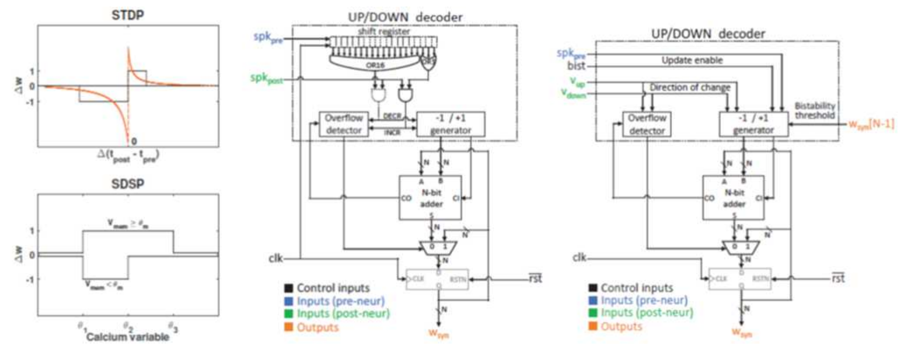
Data-dependent operation speedup technique [Botman, TVLSI, 2014]



0.4V retentive TSPC flip-flops
[Stas, ISCAS, 2017][Stas, TCAS-I, 2017]

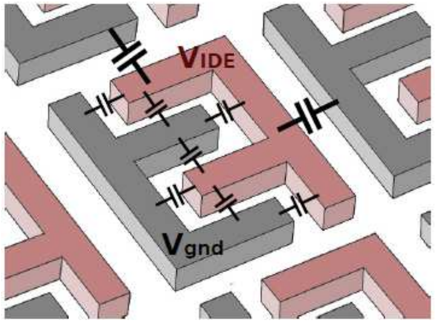


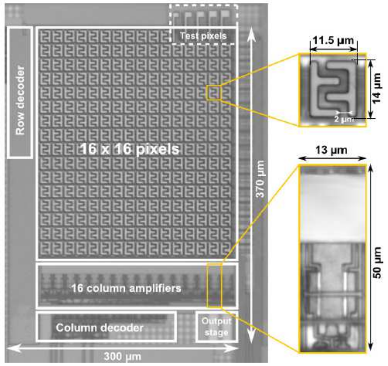
Spiking neural networks with on-line learning *[Frenkel, ISCAS, 2017]*



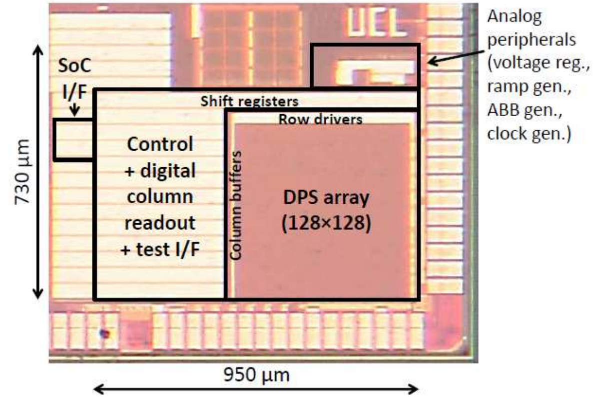
Low-power sensing circuits

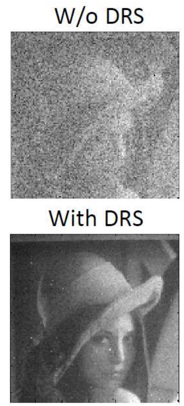
Pixel-based biosensors for single-bacteria detection *[Couniot, TBCAS, 2015]*



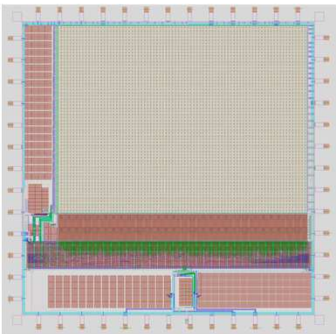


3µW 0.5V CMOS imager [Bol, VLSI, 2014]

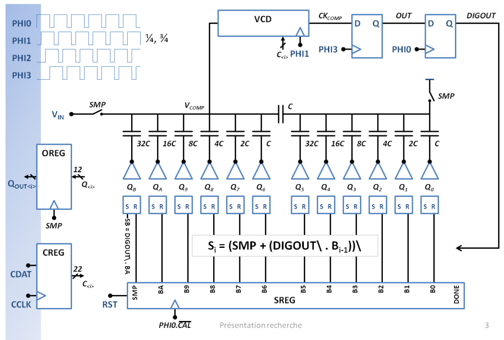


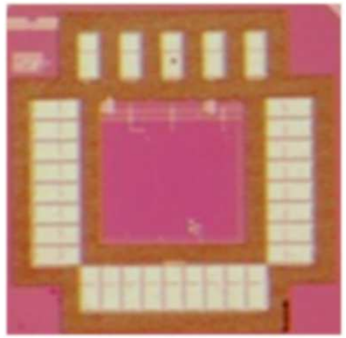


Computational CMOS imagers *[Haine, to appear]*



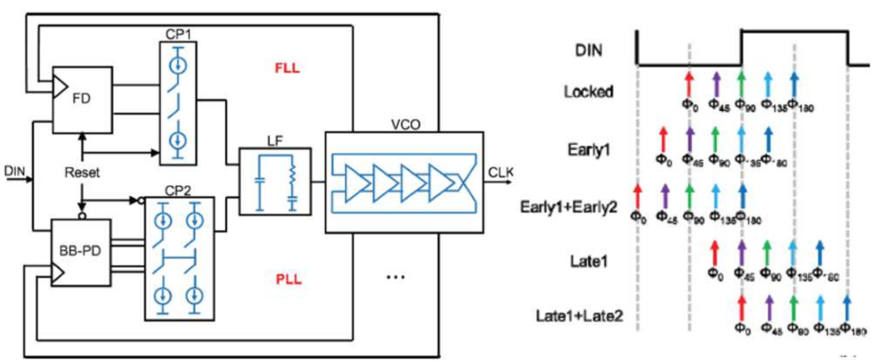
0.5µW time-based ADC *[Pollissard, Ph.D, 2013]*



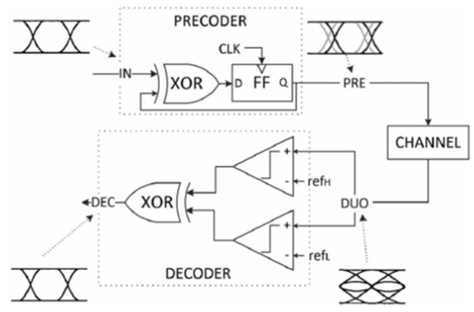


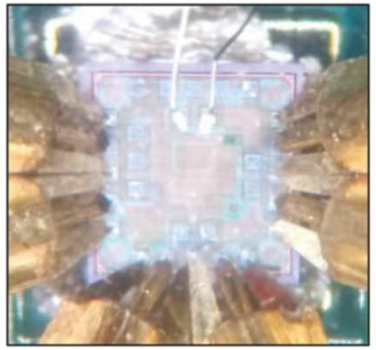
Low-power wireless/wireline communications

Low-power half-rate dual-loop clock recovery *[Gimeno, LASCAS, 2018]*

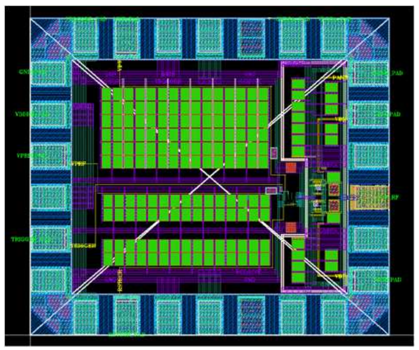


Wireline 10-Gbps duobinary transceiver *[Aguirre, TIE, 2018]*

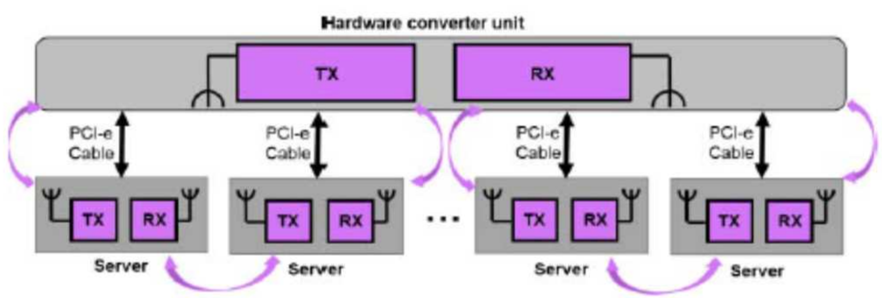




Impulse-radio UWB pulse-shaping emitter *[Schramme, to appear, 2018]*

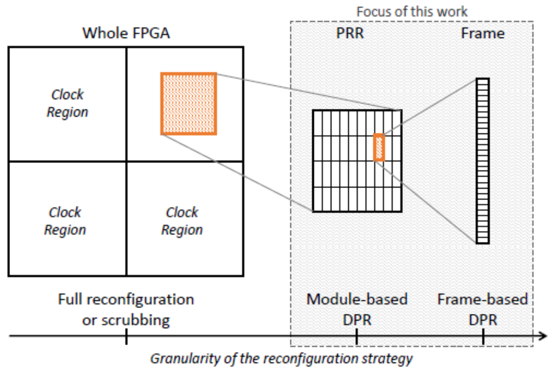


Wireless multi-Gbps transceivers *[Gimeno, TCAS-I , 2018]*

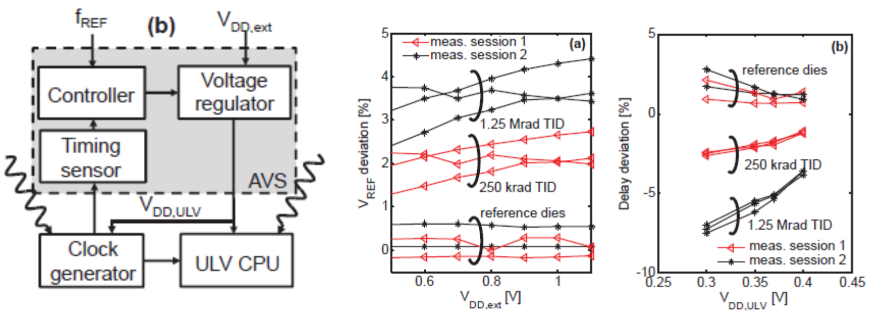


Radiation-hard low-power circuit design

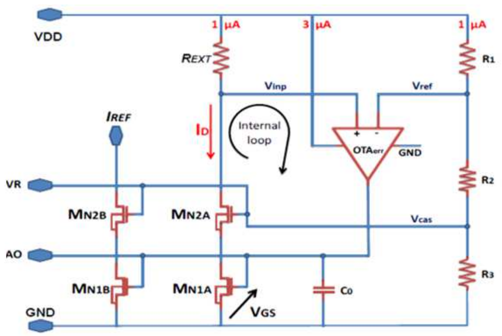
Rad-hard design on FPGA for low-power space applications *[Frenkel, ReSoC, 2015]*



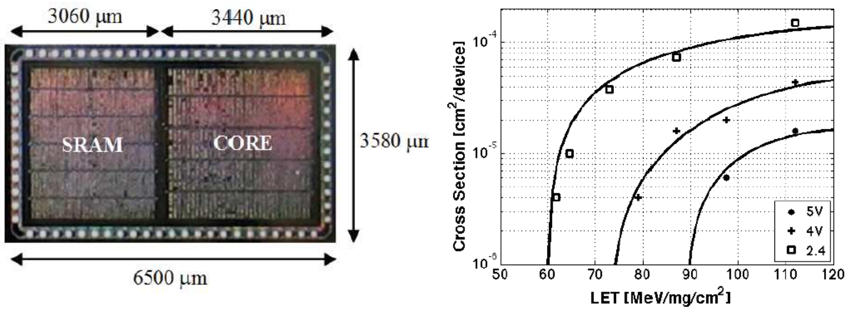
Adaptive circuits compensating total ionizing doze *[De Vos, S3S, 2014]*



PVT-Rad-hard analog circuits *[Boufouss, PhD, 2014]*



PVT-Rad-hard digital circuits *[Manet, RADECS, 2009]*



INTERNET-OF-THINGS SYSTEMS

Smart sensors for sustainable IoT

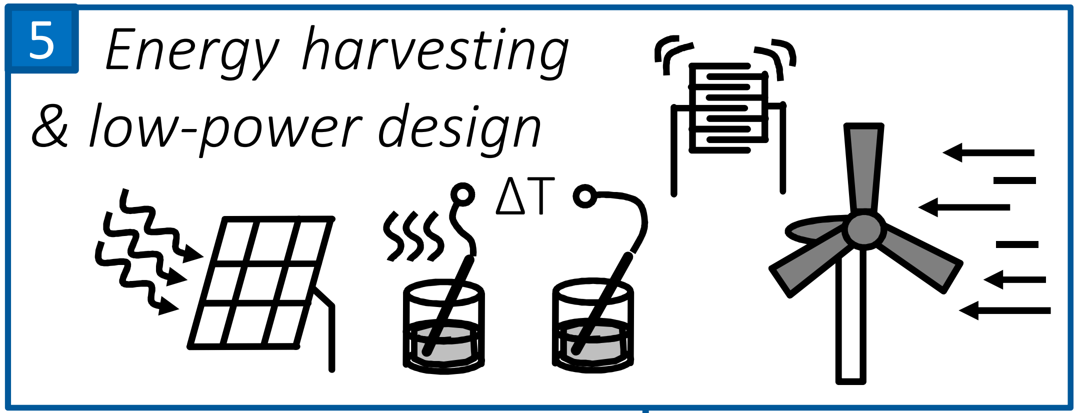
Challenges for a sustainable IoT:

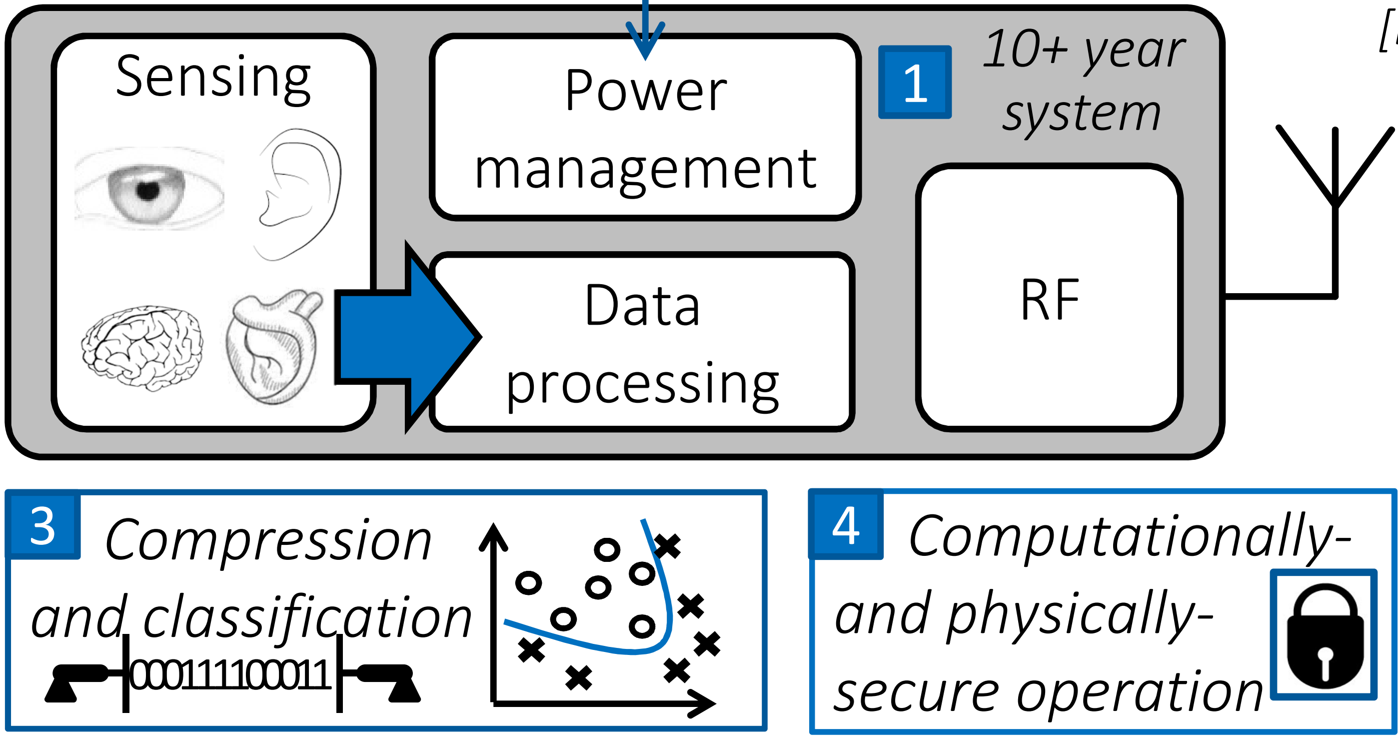
1 Deployment:
carbon footprint & natural resource pressure, ecotoxitiy

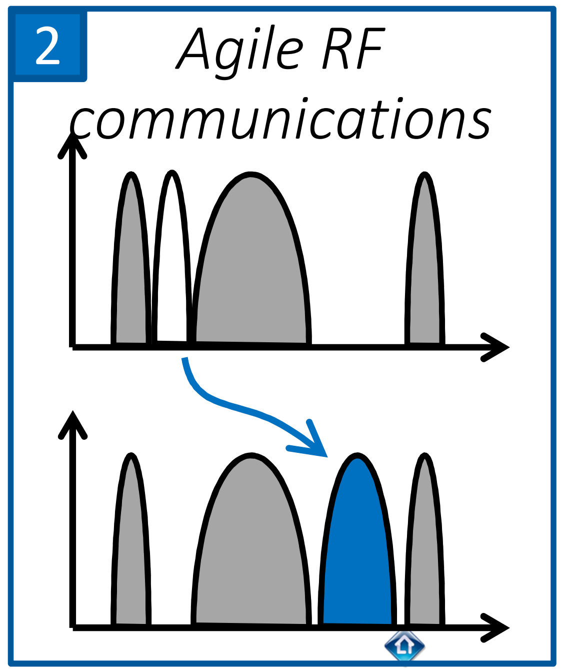
2 Operation: spectrum congestion
3 data deluge
4 security flaws

5 Maintenance:
battery replacement

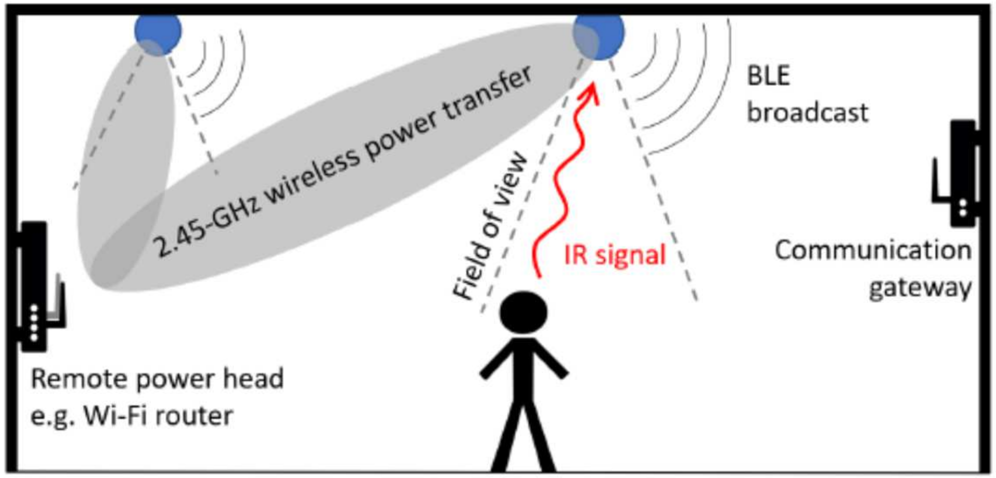
[D. Bol et al., IEEE S3S, 2015]



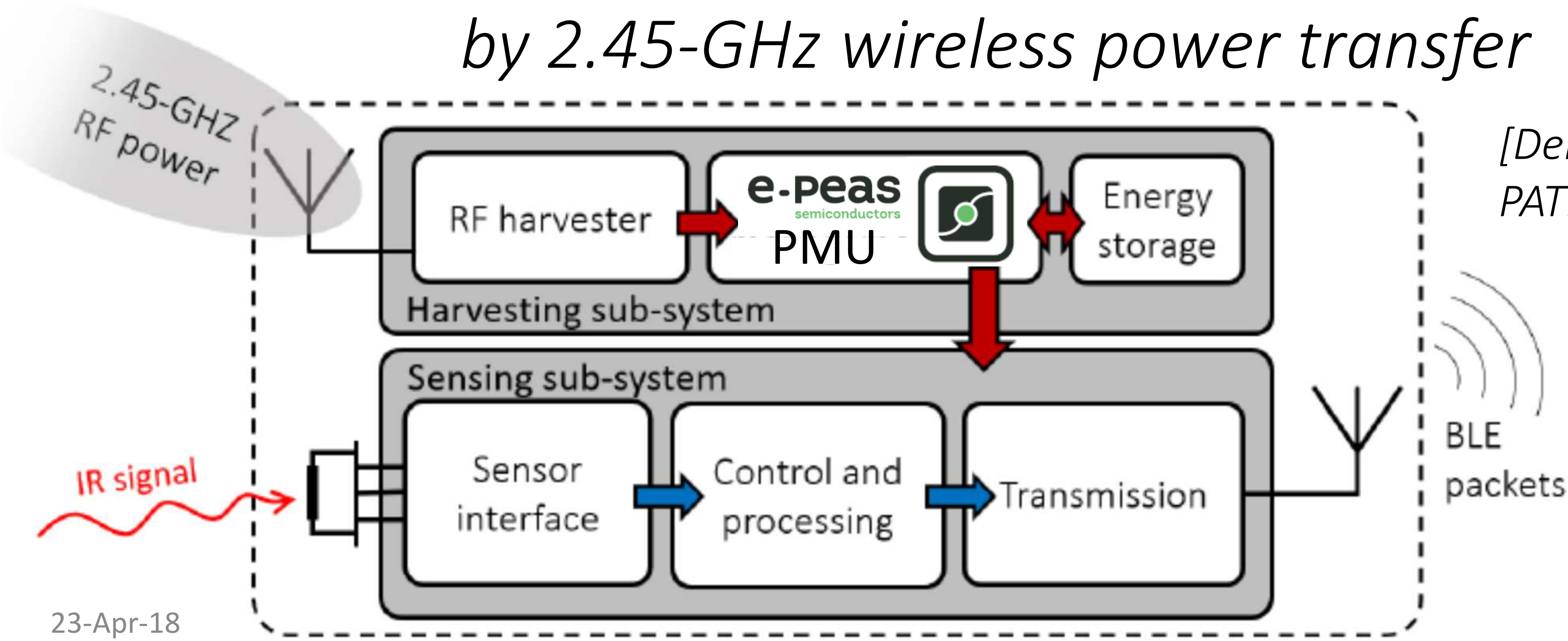




IoT smart sensor example: room occupancy detection

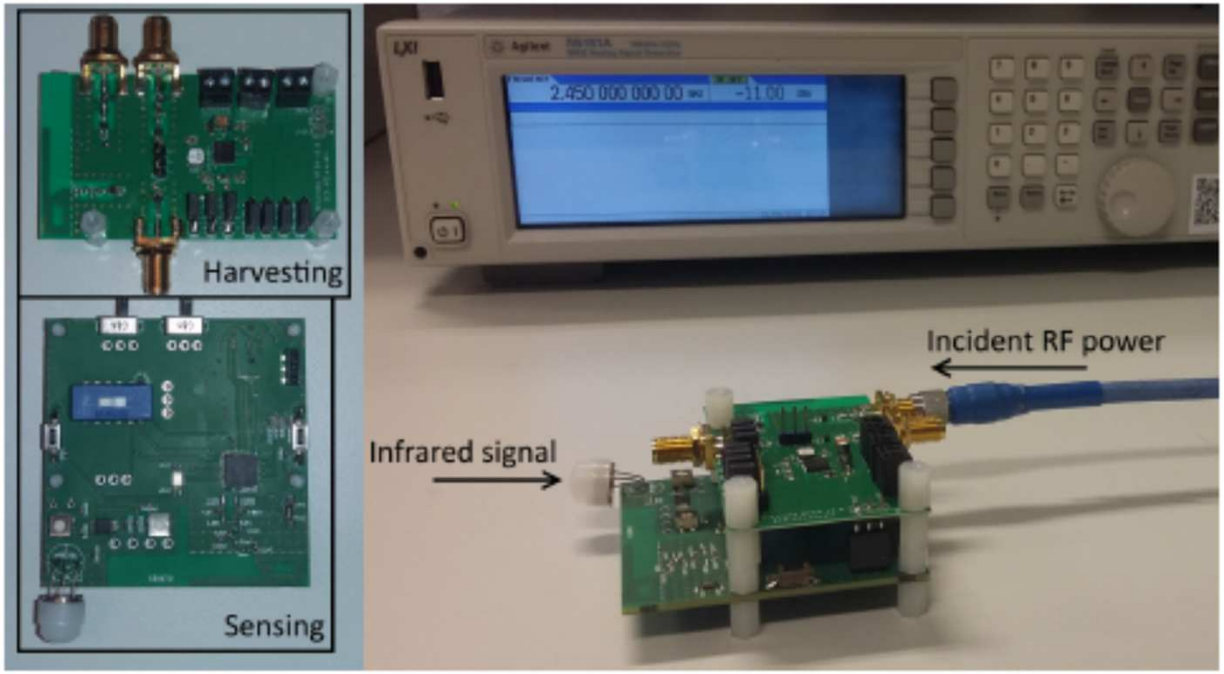


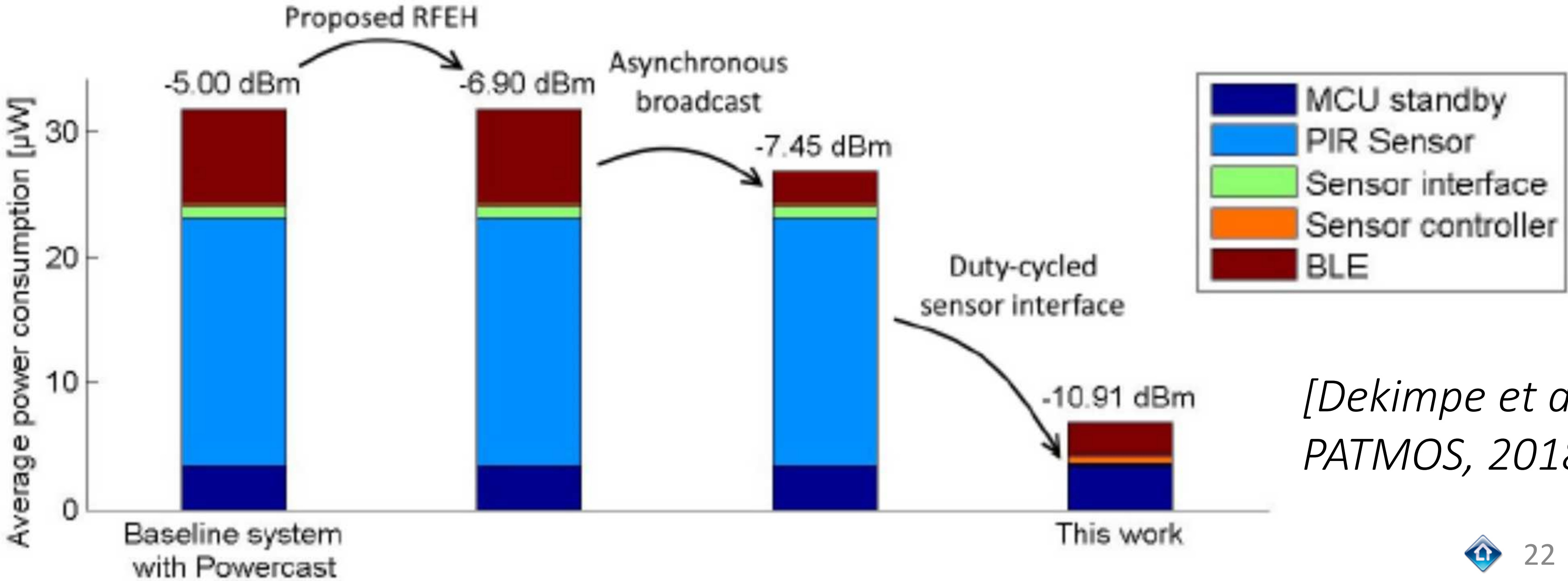
A battery-less BLE motion detector supplied by 2.45-GHz wireless power transfer



[Dekimpe et al., PATMOS, 2018]

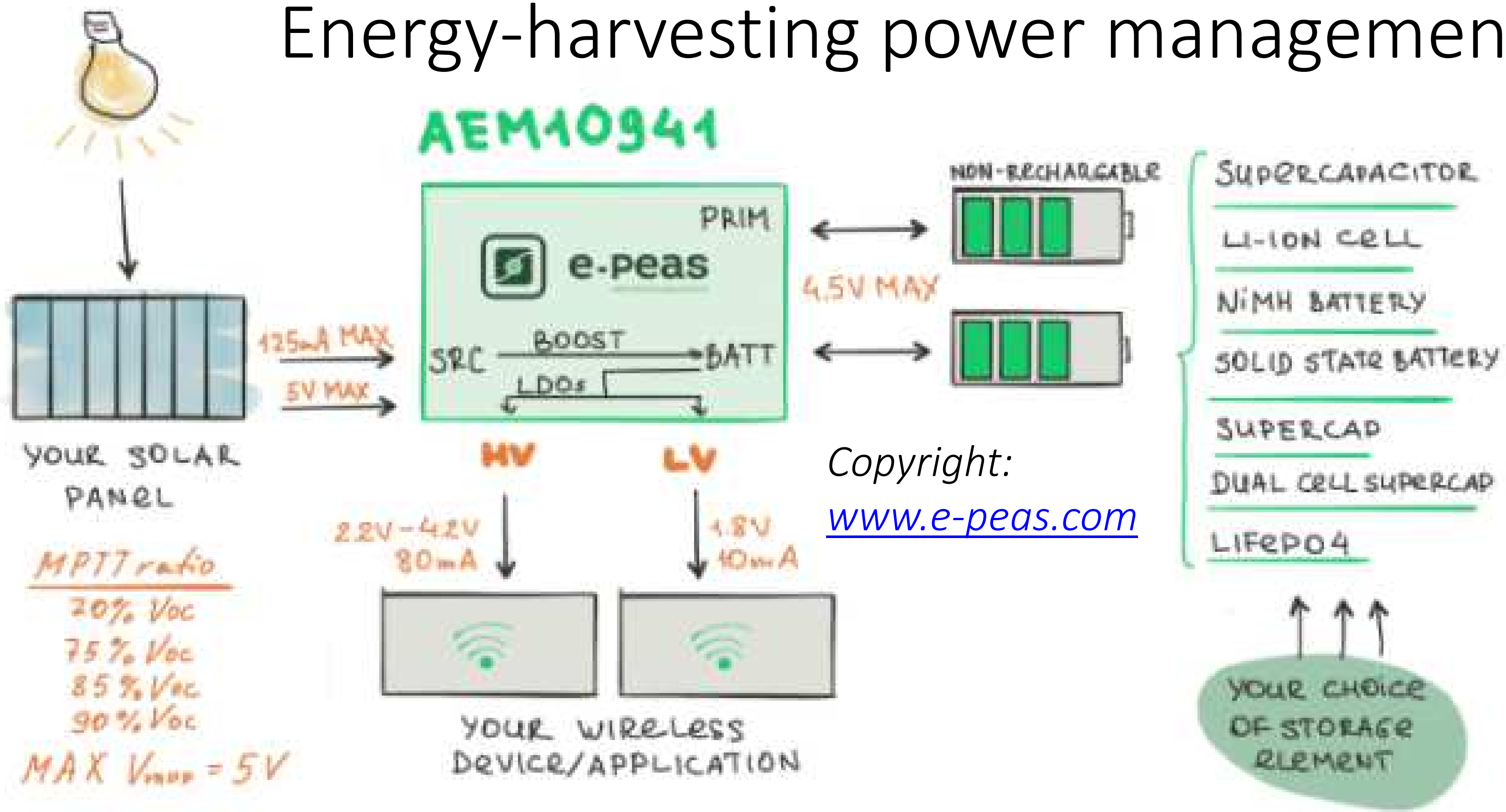
Battery-less BLE motion detector supplied by 2.45-GHz WPT



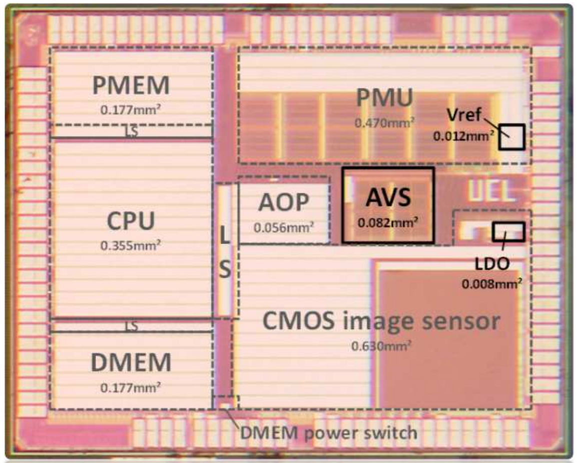


[Dekimpe et al., PATMOS, 2018]

Energy-harvesting power management



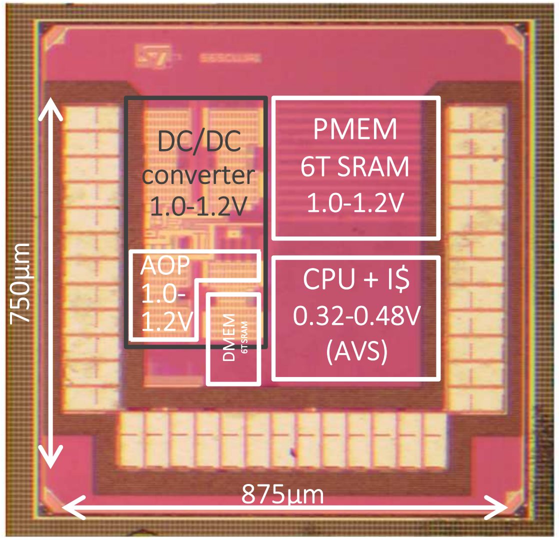
- 9 years active research lead to the creation of e-peas company in 2014
- e-peas' AEM product line offers power management units (PMICs) for solar, thermal, vibration and RF energy harvesting
- Best-in class efficiency and minimum input power



CHIP EXAMPLES

*From MCUs to **mixed-signal** SoCs*

SleepWalker 65nm microcontroller SoC



- Low system CO_2 footprint
  - ✓ low die area
  - ✓ few off-chip components
- Energy-harvesting operation
  - ✓ low active energy
  - ✓ adaptive voltage scaling 0.32-0.48V
- Compatibility with commercial components
  - ✓ MSP430 instruction set, same memory capacity and peripherals
  - ✓ 25MHz speed robust under industrial conditions

MSP430	**This work** *[Bol, JSSC, 2013]*	**MIT (best research)** *[Kwong, JSSC, 2009]*	**TI (best commercial)** *[Zwerg, ISSCC, 2011]*
Speed [MHz]	**25 @0.4V**	0.3 @0.5V	24 @1.5V
Energy [µW/MHz]	**7**	27.3	164
CO_2 footprint [kg/1000 units]	**14**	47	83

3-mm² solar-powered video analysis SoC

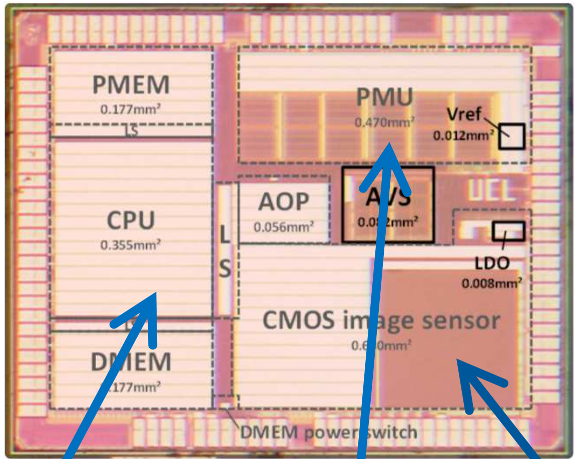
SunPixer 65nm SoC

Micro solar cells

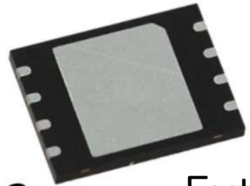
power

Supercapacitor

energy



Pictures, video, features, events

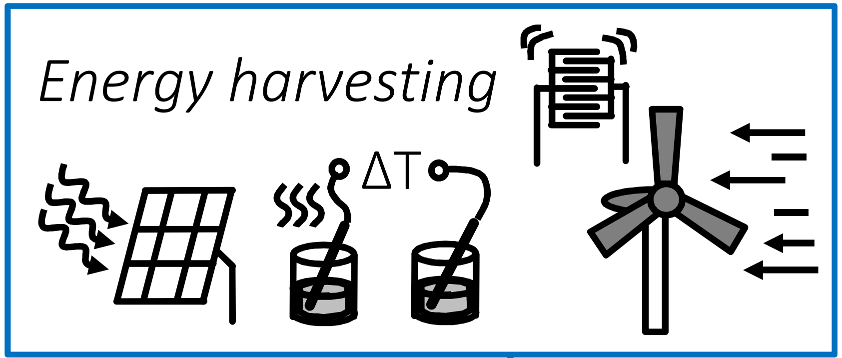


External radio

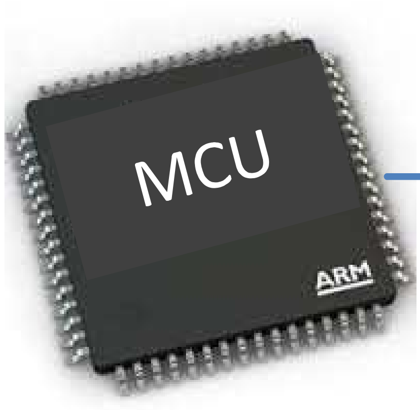
Compression, calibration, image enhancement

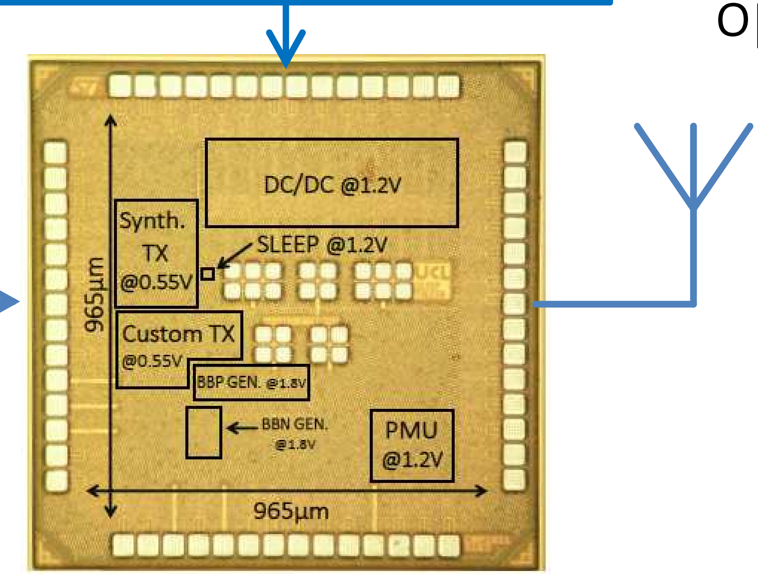
50MHz / 0.37V SIMD microcontroller	Inductor-less harvesting power management unit	0.5V CMOS image sensor
[F. Botman et al, IEEE ISCAS, 2014]	*[D. Bol et al, ESSCIRC, 2015]*	*[N. Couniot et al, IEEE JSSC, 2015]*

700-µW IEEE 802.15.4a RF transmitter SoC



100x less power than Decawave DW1001 enables energy-harvesting operation

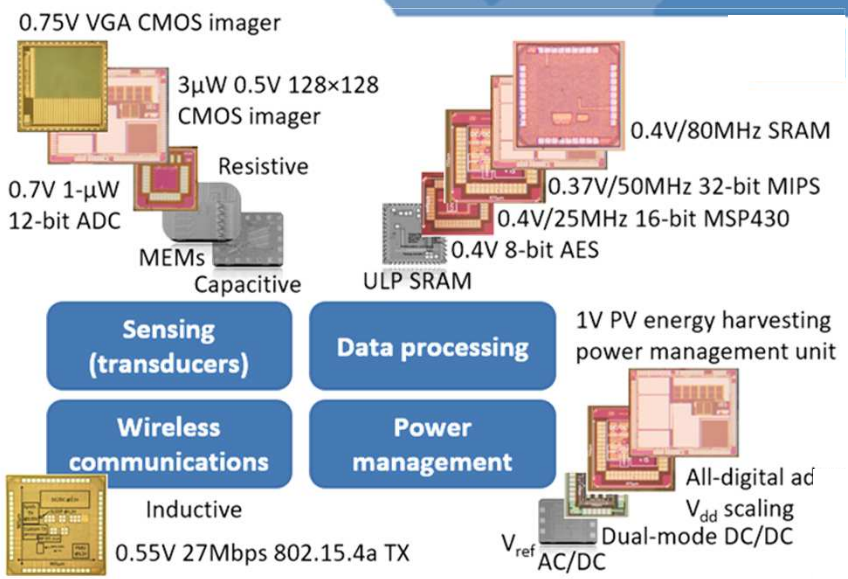




27 Mbps @10-30m

SleepTalker 28nm FDSOI SoC

[G. de Streel et al, IEEE Symp. VLSI, 2016] [G. de Streel et al, IEEE JSSC, 2017]



- Cutting-edge research @ UCL-ECS
from process to circuits to systems
- Tens of working silicon chips
from building IP blocks to full SoCs
in 1µm, 0.18-0.13µm, 65nm, 28nm CMOS
Strong added value @system/application levels *when off-the-shelf components limit the specs/performances*