nano-tera.ch
swiss scientific initiative in health / security / environment systems

SImOS RTD 2009

FNSNF

# Instrumented prosthesis for knee implant monitoring

*M. Simoncini, A. Arami, O. Atasoy, D. Forchelet, S. Ali*

Ecole Polytechnique Fédérale de Lausanne (EPFL)

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

## Motivation

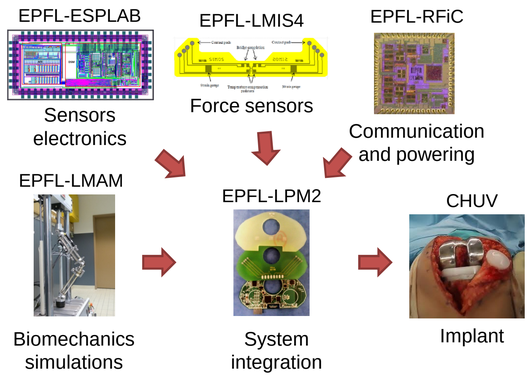
The expected lifetime of a knee prosthesis is around 15 years, less for young people. A prosthesis failure requires a revision surgery, which is more complex and traumatic than the first replacement. An instrumented prosthesis could help in order to:

- ❑ Improve the precision of the implant positioning
- ❑ Quickly detect complications
- ❑ Take corrective measures

The goal of SImOS project is to:

- ❑ Provide useful metrics for the clinicians and prosthesis designers, to correct unbalanced wearing and provide adequate rehabilitation
- ❑ Provide 3D joint angles by fusing with skin mounted sensors, to detect the prosthesis kinematics, thus detecting moving limitations
- ❑ Provide micro-motion of the prosthesis relative to the bone, to estimate loosening using vibrating plate-form

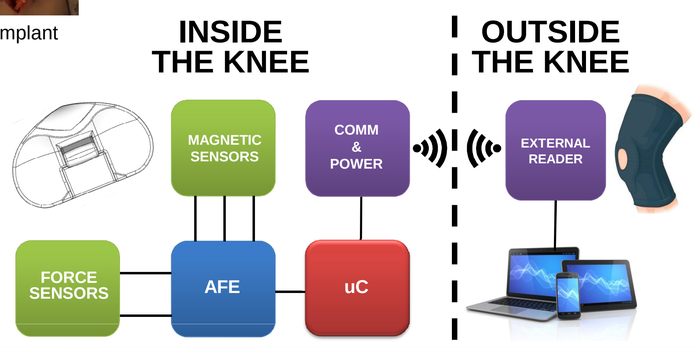
## System overview




- ❑ The SImOS consortium encompasses a pool of experts in different domains, working together to provide the medical doctors with an instrumented knee prosthesis

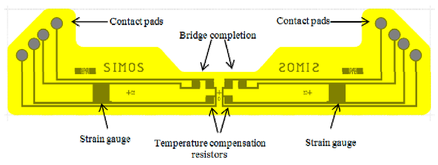
SImOS sub-systems:

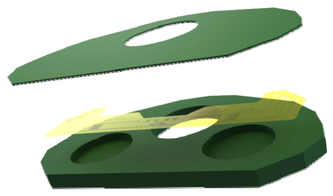
- ❑ Sensors
- ❑ Sensors electronics
- ❑ Microcontroller
- ❑ Communication and powering



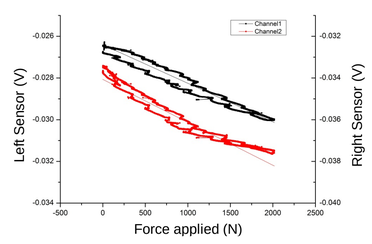

## Force sensors

- ❑ Thin film strain gauge sensor fabricated in cleanroom facilities
- ❑ Sensor assembled to thin PCB deflecting, upon force application, over cavities in another PCB



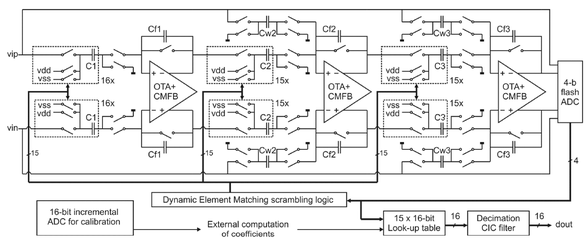



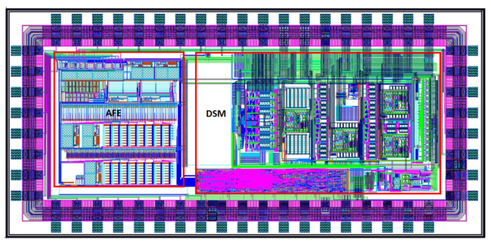
- ❑ The structure consisting of PCBs and sensor is assembled in the polymer insert
- ❑ The sensor output exhibits good proportionality to force, good stability and fast response



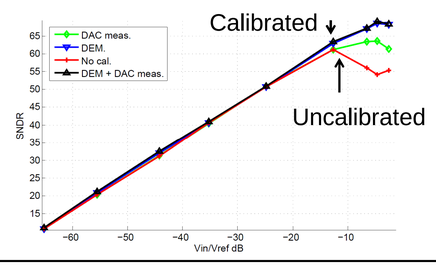

## Analog Front-end

- ❑ Analog front-end and ΣΔ modulator



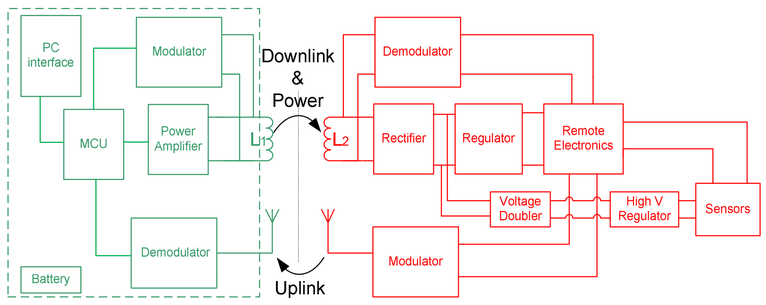




ΔΣ ADC with mismatch correction capability.
Programmable gain AFE.
8x channel digitization capability.



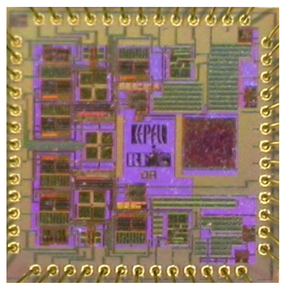

| Parameter | Specification achieved |
|---|---|
| Technology | 0.18 µm CMOS |
| Area | 1400 µm x 960 µm |
| Bandwidth | 32 kHz |
| Sampling frequency | 2 MHz |

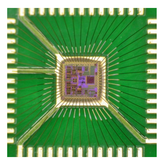
## Communication and powering




- ❑ Meets the high power consumption requirements (~20mW)
- ❑ Application specific antenna and remote powering blocks for high remote powering efficiency
- ❑ Two frequency bands (13.56 MHz & 27 MHz) design for flexible remote powering
- ❑ High data rate (up to 200 kbits/sec)
- ❑ Air core coil as the remote powering antenna
- ❑ Small implanted area with the storage capacitor

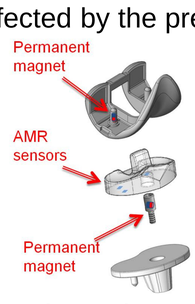
The external controller v1



## Kinematics measurements

- ❑ The traditional measurement of the 3D knee kinematics, based on skin-mounted sensors, is affected by the presence of soft tissues

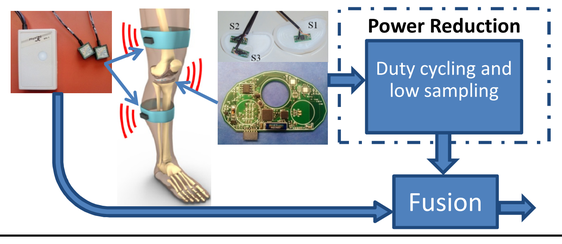



- ❑ A new approach, based on internal Anisotropic Magnetic Sensors (AMR), has been designed

| Validation set. | Mean error (º) | STD error (º) | $R^2$ |
|---|---|---|---|
| IE estimation | 0.0±0.2 | 0.9±0.0 | 0.97±0.01 |
| FE estimation | 0.9±0.8 | 2.7±0.7 | 0.99±0.00 |

Comparison with measurements made with infrared Vicon Cameras (gold standard)

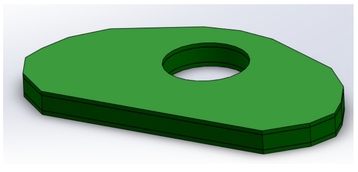
- ❑ As an alternative to reduce power consumption on internal sensors, the internal sensors data are fused with externally worn inertial measurement units data

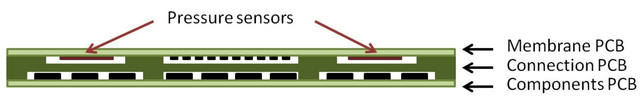


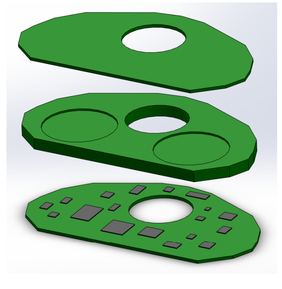

| Validation set. | Mean error (º) | STD error (º) | $R^2$ |
|---|---|---|---|
| IE estimation | 0.0±0.1 | 0.8±0.1 | 0.88±0.06 |
| FE estimation | 0.6±0.6 | 3.2±1.1 | 0.96±0.04 |

## Packaging

- ❑ A bio-compatible, waterproof capsule containing all the SImOS system, will be fabricated to be embedded inside the polyethylene insert





- ❑ It will be based on a sandwich structure, with the force sensors in the upper PCB, the magnetic sensors and the rest of the electronics in the lower PCB