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SImOS RTD 2009

FNSNF

Instrumented Knee Prosthesis for Force and Kinematics Measurements

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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:

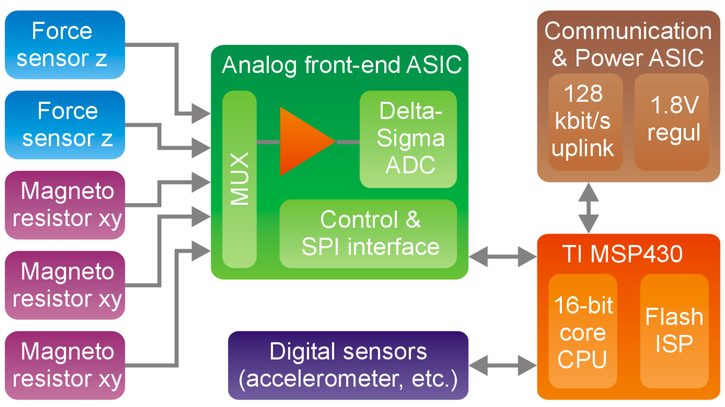
- ❑ improve the precision of the implant positioning
- ❑ quickly detect complications
- ❑ take corrective measures

The goal of SImOS project is to:

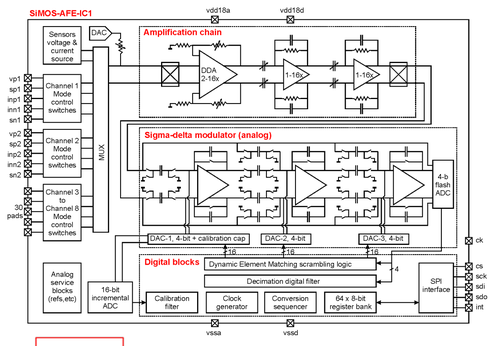
- ❑ Provide useful metrics for the clinicians and prosthesis designers, to correct unbalanced wearing and provide adequate rehabilitation
- ❑ Provide 3D joint angles by fusing with skin mounted sensors, to detect the prosthesis kinematics, thus detecting moving limitations
- ❑Provide micro-motion of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

Electronic System

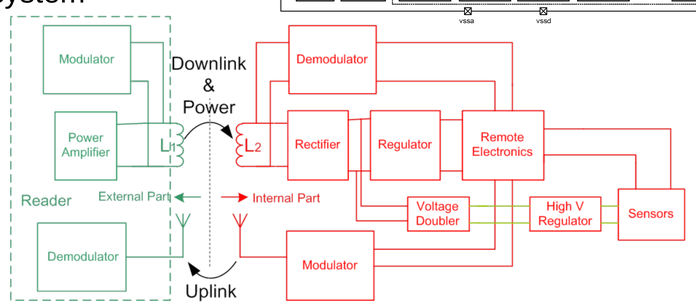
Fully integrated structure based on 2 ASIC and a commercial low-power MCU.
Remote supply & readout of up to 10 analog sensors.



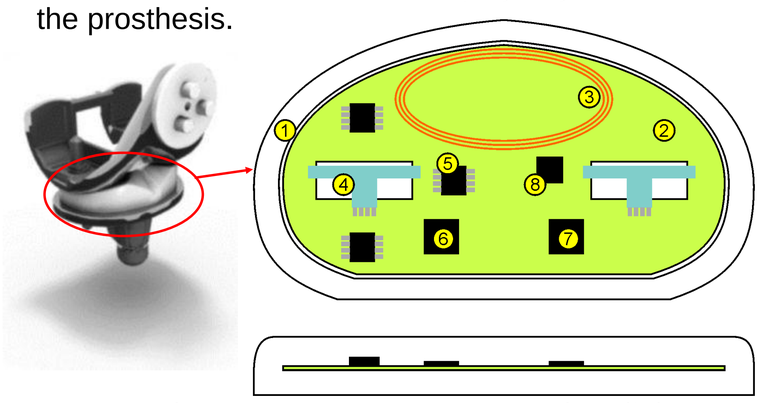
Analog Front-End



Remote powering system



The sensors & readout electronics are implemented on a flex PCB, molded into the polyethylene insert of the prosthesis.

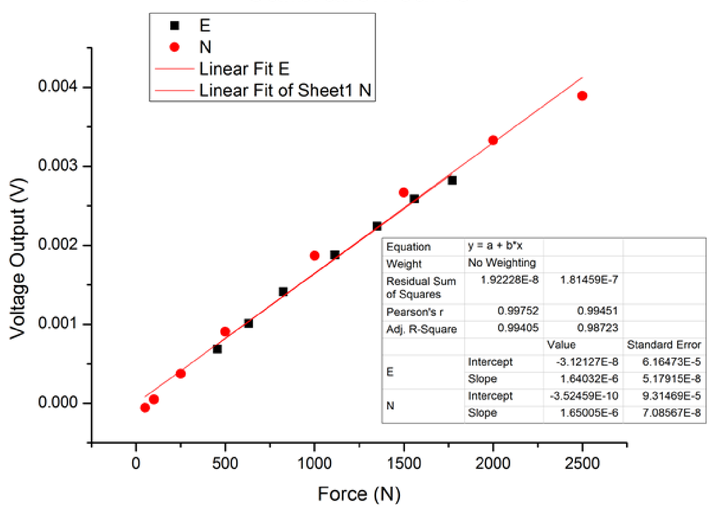


1- PE insert
2- Flex PCB
3- Coil for comm & power
4- Force sensors
5- Magnetoresistors (2D)
6- Analog Front-end ASIC
7- 16-bit MCU, TI MSP430
8- Comm & Power ASIC

Force sensors

In order to measure the total force applied to the prosthesis and the lateral-medial imbalance, strain gauges are designed, fabricated and positioned inside the Polyethylene part.
Resistive sensors are connected in a 6-wires Wheatstone bridge configuration. The bridge resistance is 3.2 kOhms.

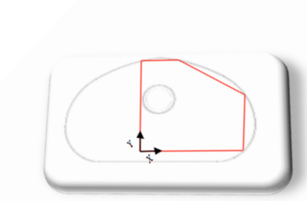
Calibration curve



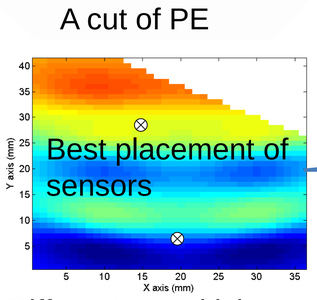
Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	1.92228E-8	1.81459E-7	
Pearson's r	0.99752	0.99451	
Adj. R-Square	0.99405	0.98723	
		Value	Standard Error
E	Intercept	-3.12127E-8	6.16473E-5
	Slope	1.64032E-6	5.17915E-8
N	Intercept	-3.52459E-10	9.31469E-5
	Slope	1.65005E-6	7.08567E-8

Kinematics measurements

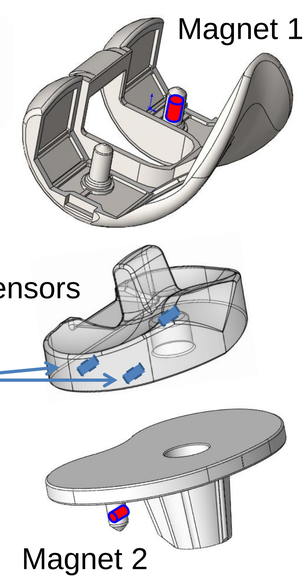
Kinematics measurements are made using two magnets and 3 magnetic sensors.
The sensors placement is based on simulation and validated towards Motion-Capture

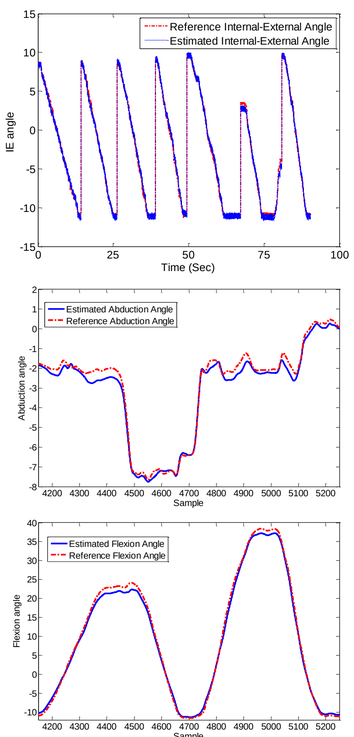


A cut of PE

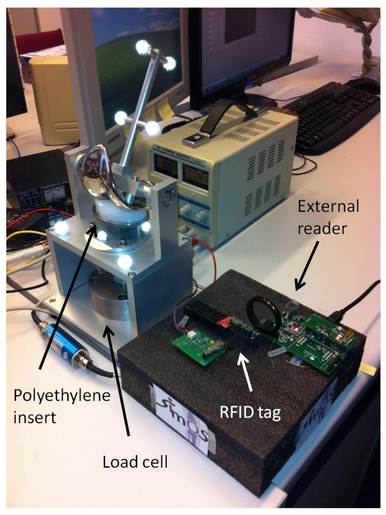


Different sensitivity regions for Flexion-Extension

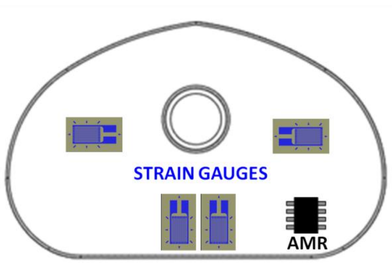


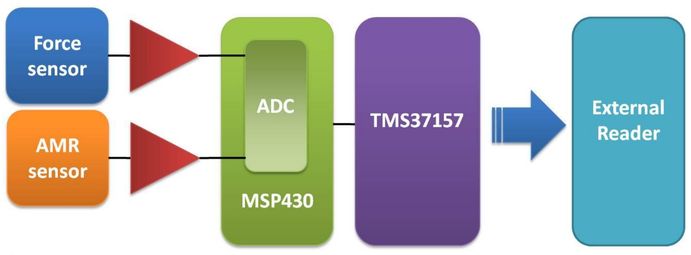


Experimental Setup



Simultaneous acquisition of a force sensor and two channels of a 2D analog magneto-resistors (AMR), implanted inside the polyethylene insert.





Signals acquired from the sensors during multiple antero-posterior rotations, performed with a manual mechanical simulator.