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PlaCiTUS RTD 2010

FNSNF

Remotely Powered Implantable Chip for Sensing Bio-medical Signals

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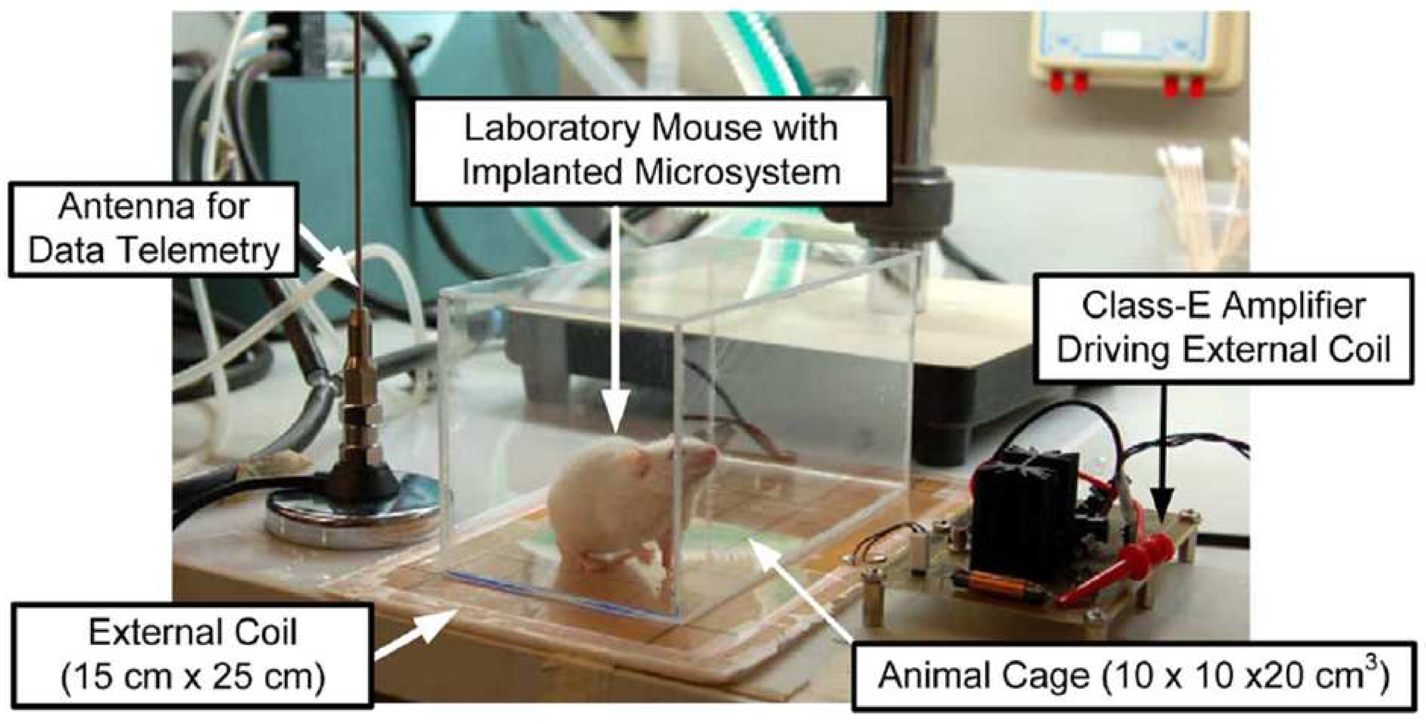
Goal

Obesity is a major threat to the global public health and causes many other abnormalities like diabetes and cardiovascular problems. Studying the metabolism of laboratory mice leads to new strategies for treating obesity in humans.
In the frame work of the PlaCiTUS project, this research aims to develop remotely powered integrated circuits (ICs). The implantable circuits are targeted to record temperature of laboratory mice locally to monitor energy absorption and dissipation.

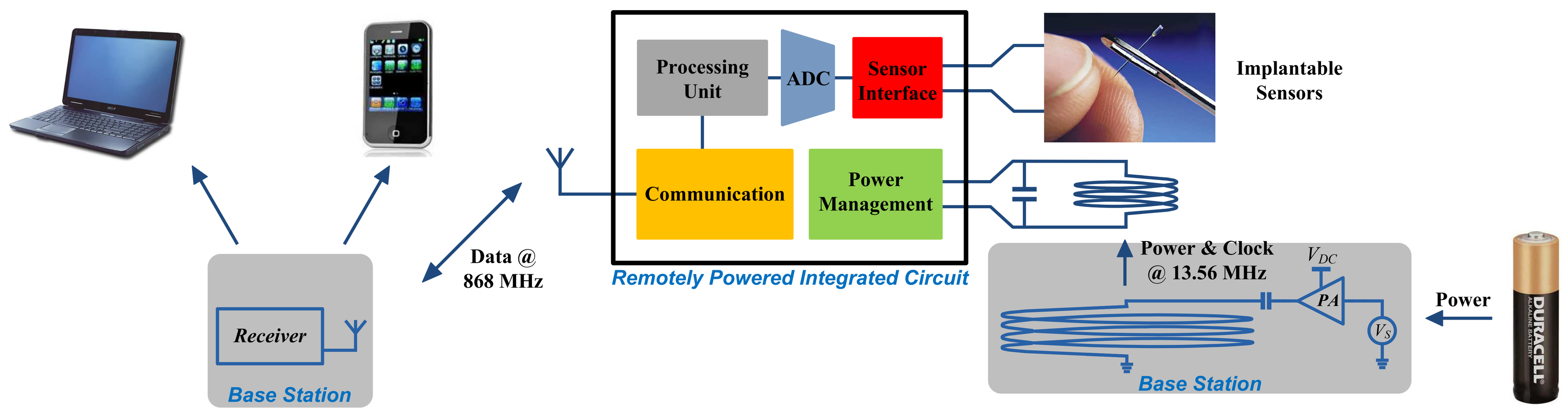
Example System

Blood Pressure Monitoring System



P. Cong et al., "A Wireless and Battery less 10-Bit Implantable Blood Pressure Sensing Microsystem With Adaptive RF Powering for Real-Time Laboratory Mice Monitoring," IEEE Journal of Solid State Circuits, Dec. 2009.

Building Blocks

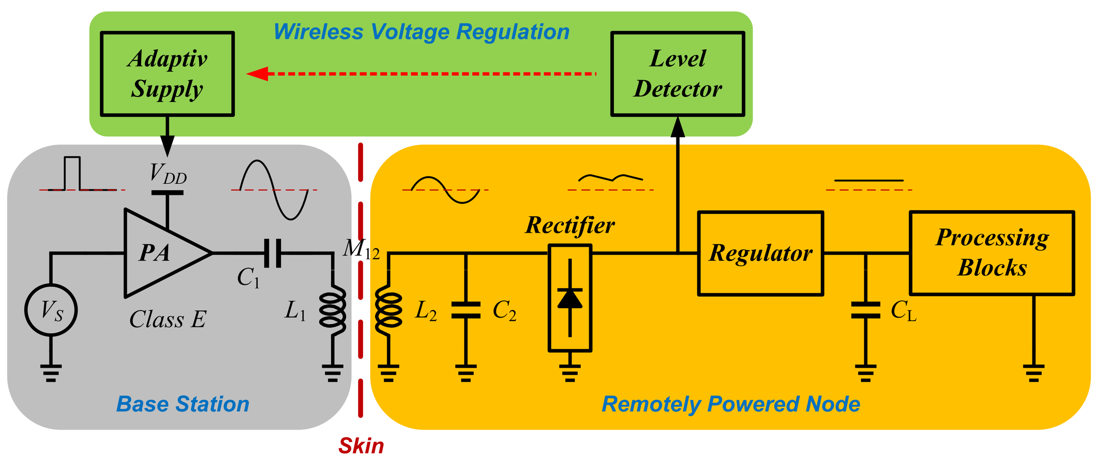


The Main Challenges:

- *Implementing the internal circuits of the sensor node with low power consumption.*
- *Increasing the efficiency of wireless power transmission.*

Remote Powering

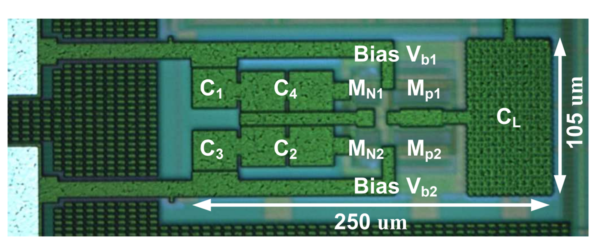
Main Blocks for Wireless Power Transfer:

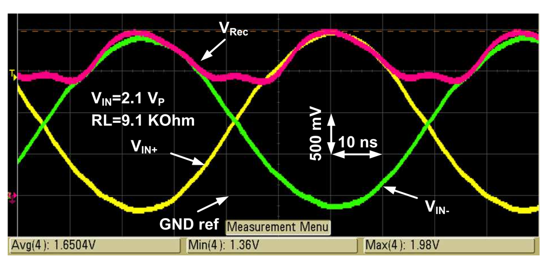


Total Link Efficiency: $\eta_T = \eta_{PA} \times \eta_{Coupling} \times \eta_{Rectifier} \times \eta_{Regulator}$

Functions of Different Blocks:
PA is converting the DC power from the battery to AC power for coupling.
L1 & L2 are coupling energy from base station to remotely powered side.
Rectifier is converting coupled AC voltage to DC voltage.
Regulator is stabilizing the voltage for processing blocks.
Wireless Voltage Regulation can be used to compensate the variation of the coupling between the inductors.

Performance of the Fabricated Rectifier:





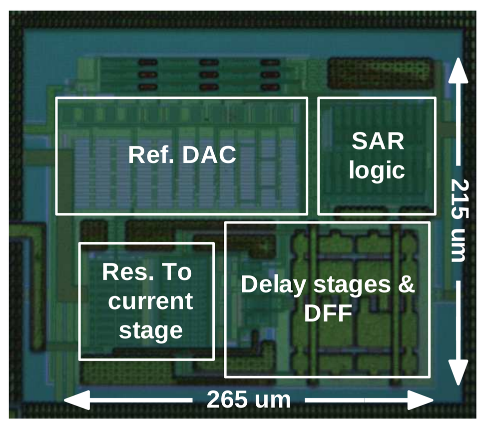
Rectifier Measurement	
Technology	0.18 um
Frequency	13.56 MHz
Output Power	300 uW
Output Voltage	1.65 V
Peak Input Voltage	2.1 V
PCE (Simulated)	85 %

M. A. Ghanad and C. Dehollain, "A passive cmos rectifier with leakage current control for medical implants," in IEEE Int. Conf. on Electronics, Circuits and Systems (ICECS), Dec. 2012.

Sensor Readout

To implement ultra low power sensor readout, time-domain signal processing is employed to amplify and resolve the sensor response.
Significant power savings is achieved by omitting the power hungry low noise Front End Amplifier (FEA) conventionally used in standard sensor readout circuits.

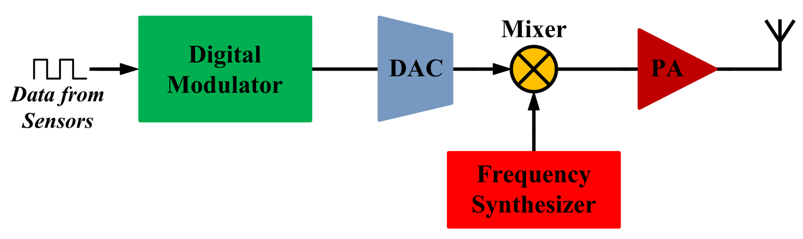
Performance of the Fabricated Sensor Readout:



Sensor Readout	Measurement
Technology	0.18 um
Sensor Type	Thermistor
ADC Type	SAR
Supply Voltage	1.5 V
Power	15 (uW)
Sampling Rate	5.5 (kS/s)
ENOB	7.6
FoM	14 (pJ/c-s)

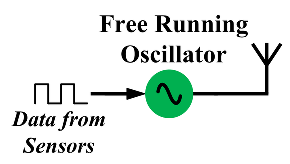
Low Power Communication

Standard Transmitter:



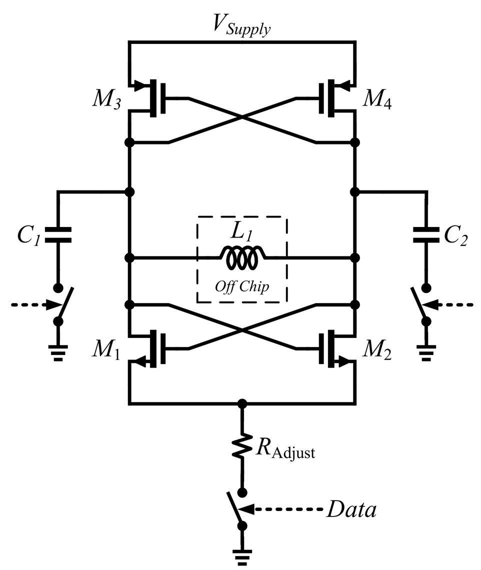
Standards transmitters are suitable for high data rates and require power hungry blocks like frequency synthesizers and power amplifiers.

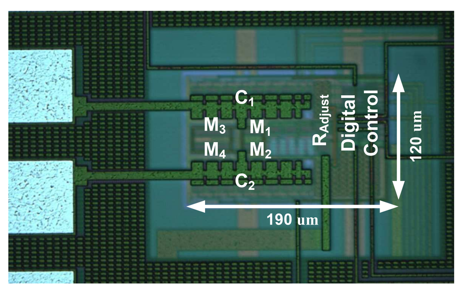
Low Power Transmitter:



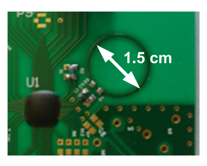
Low data rate of biomedical signals and short communication range make it possible to use low precision transmitter by directly modulating the free running oscillator.

Performance of the Fabricated Transmitter:





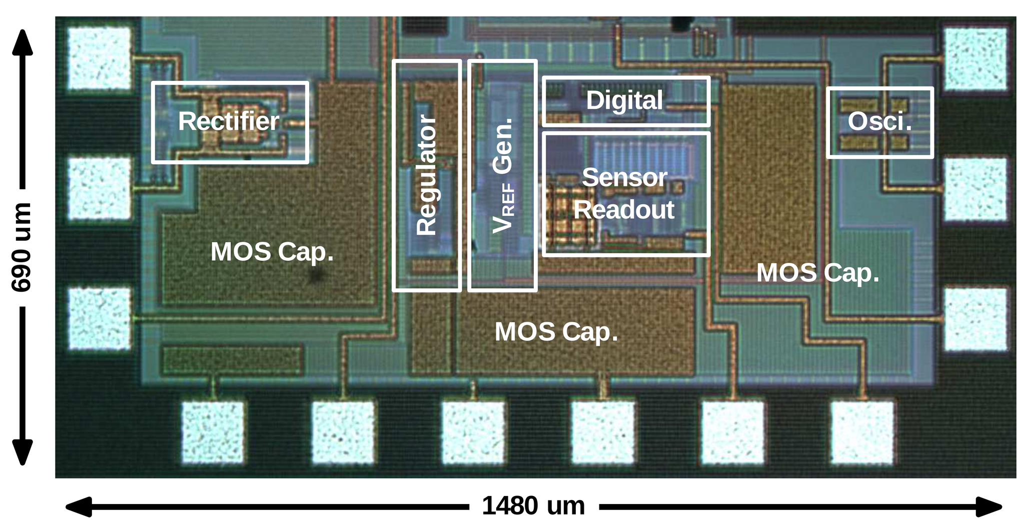
External Inductor as Transmitter Antenna



Oscillator Performance	
Technology	0.18 um
External Inductor	27 nH
Frequency	700 – 802 MHz (5 Bit)
Supply Voltage	1 V
Supply Current	65 – 176 uA (4 Bit)

Implantable Chip

Performance of the Fabricated Implantable Chip:



Implantable Chip Measurement	
Technology	0.18 um
Sensor type	Thermistor
Power	53 (uW)
V_{REC} Min.	1.5 (V)
Tran. Data Rate	1.7 (Mbps)
Sampling Rate	21 (kS/s)
Accuracy	±0.09 C°

Contributions

Several improvements are proposed over already existing platforms:

- *New Semi-active rectifier topology for loads ranging from few micro Watts to few mili Watts.*
- *Time-domain signal processing to implement low power sensor readout.*
- *Increasing communication efficiency by using amplitude modulation schemes.*
- *Intelligent power management techniques to optimally use the harvested energy at the implanted side.*