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Interface Circuits for Wirelessly Powered Bio-Medical Sensor Node

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The Main Objective:

To develop wirelessly powered integrated circuit in nano-scaled CMOS technologies which acquires data from various types of sensors. The circuit should also wirelessly communicate with the base station.

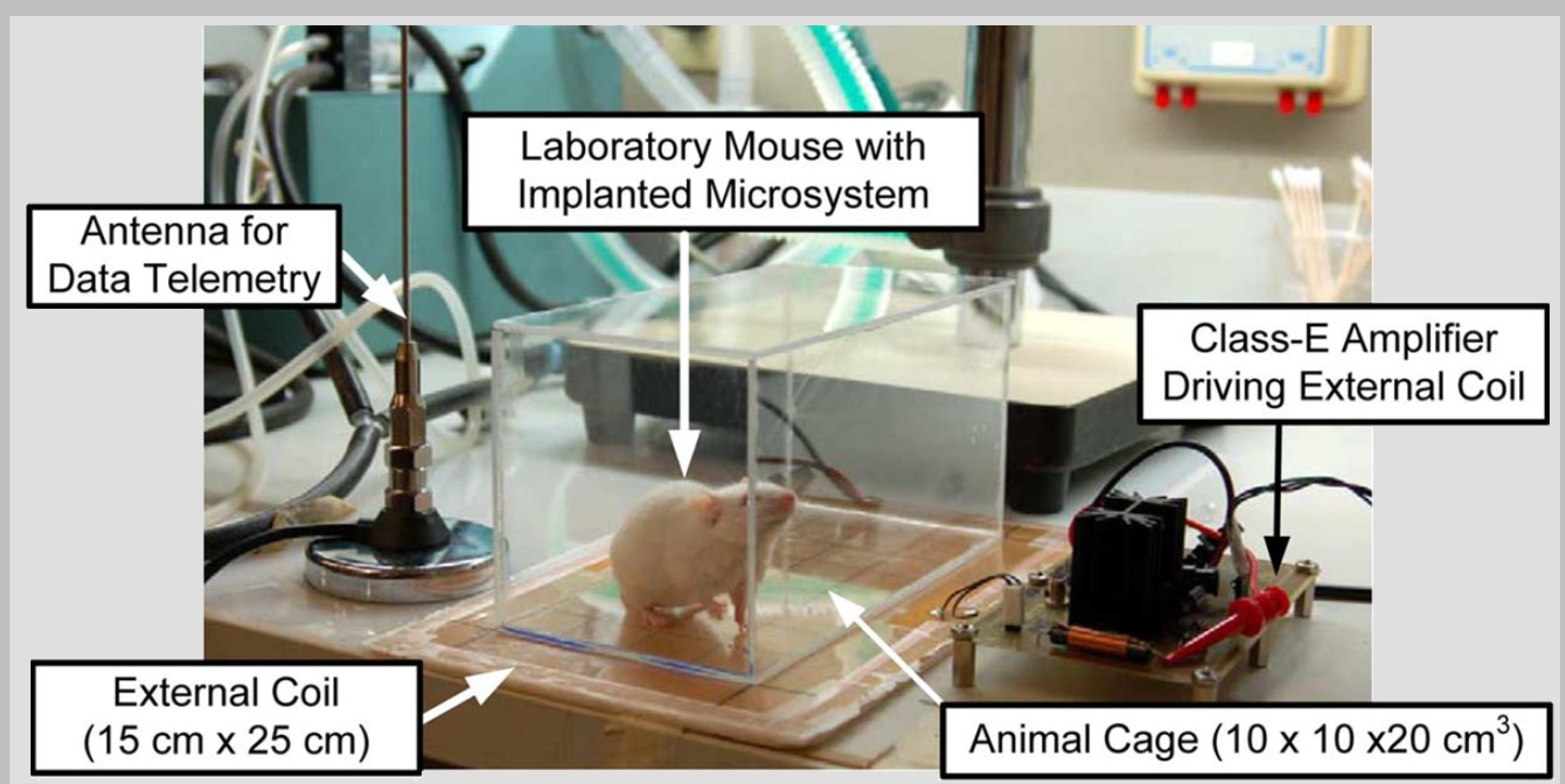
Applications:

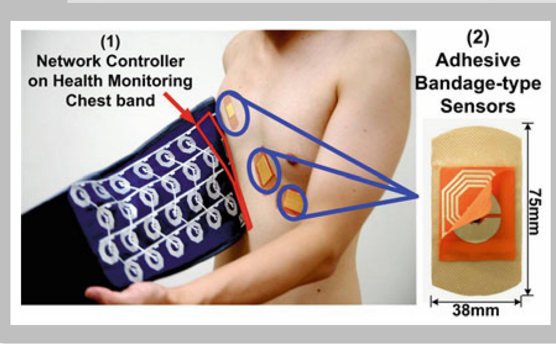
- Sensors monitoring vital signals in humans such as ECG, blood pressure and body temperature.
- Implanted sensors in animals in order to study their physiology or behavior.
- Sensor monitoring environment such as pollution and temperature.
- Security applications like cameras, microphone and gas sensors.

For a first demonstrator we will implement a system which measures the body temperature of mouse in order to study its metabolism to prevent obesity.

Example Applications:

- Implanted circuit to monitor blood pressure of mouse [P. Cong et al., "A Wireless and Batteryless 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].



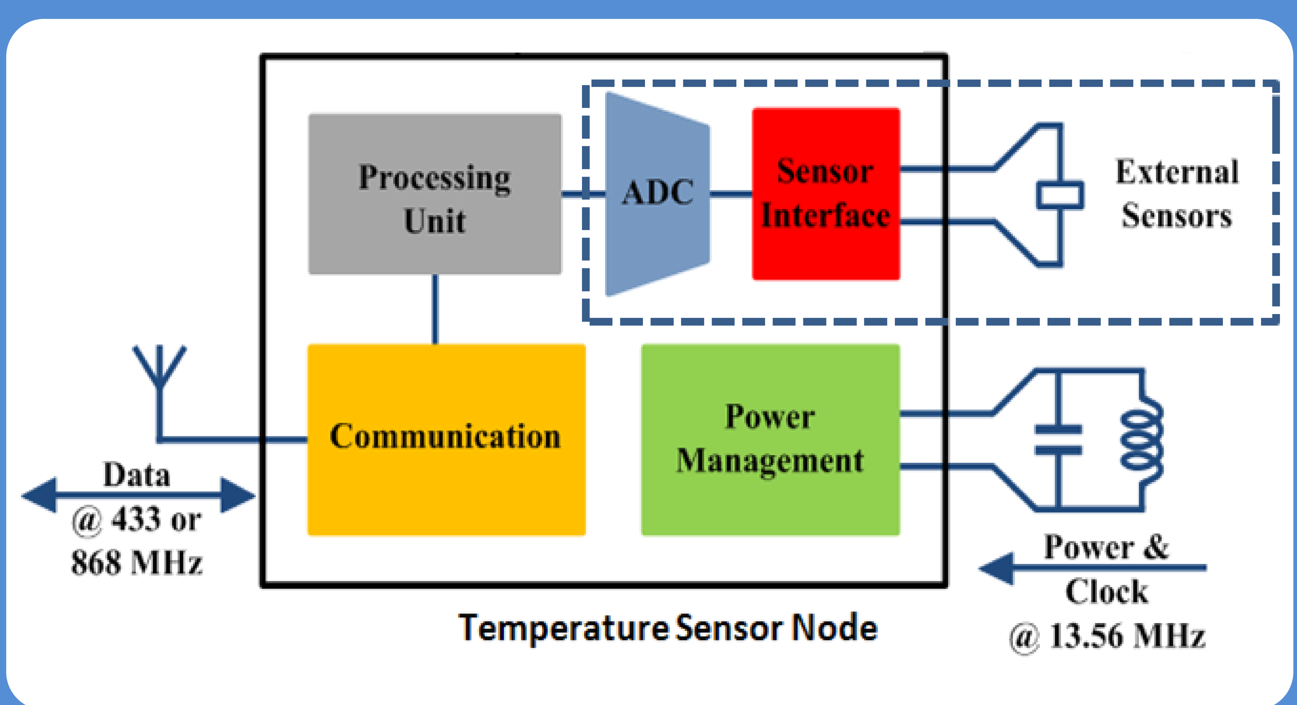


- Batteryless patch sensor for ECG monitoring [J. Yoo et al., "A 5.2 mW Self-Configured Wearable Body Sensor Network Controller and a 12 uW Wirelessly Powered Sensor for a Continuous Health Monitoring System," IEEE Journal of Solid State Circuits, Jan. 2010].

Application:

Specification	
Signal Frequency	<10KHz
Temperature Range	24-48˚C
Resolution	0.05˚C
Power Budget for Interface	100µW

Currently, the project is focusing on a temperature monitoring application for mouse. The main aim of this system is to monitor the temperature change in a particular body tissue inside a mouse without interference on its normal activity. Attaching cables or replacing batteries would lead to inflammation, which can influence the temperature. Therefore, it is necessary to develop a wireless powered sensor node.

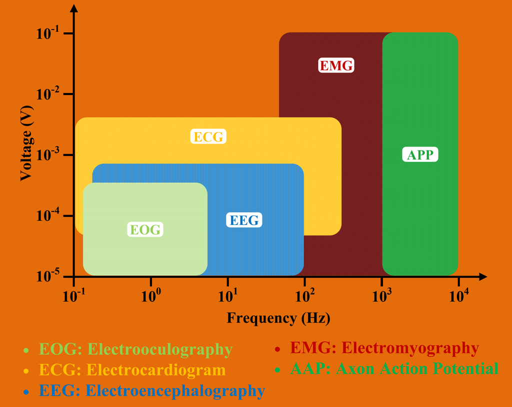


The system is composed by two main parts, the interface blocks for sensors, and RF circuits for power and data transmission. The sensor node is implanted inside the mouse. A coil is placed under the cage, generating an electro-magnetic field, through which the implant absorbs power. At the same time, an antenna is placed near the cage, receiving the signal transmitted back from the implant. In our system, the power signal is at 13.56MHz and the communication signal is at 868MHz. Total available power for the interfacing circuits is 100µW.

Publication:
Xiao Liu and Catherine Dehollain, "A Non-Linear Model for Micropower Rectifiers in UHF-Band RFIDs," 17th IEEE International Conference on Electronics, Circuits, and Systems, pp.1057-1060, Dec.2010

Sensor Interface:

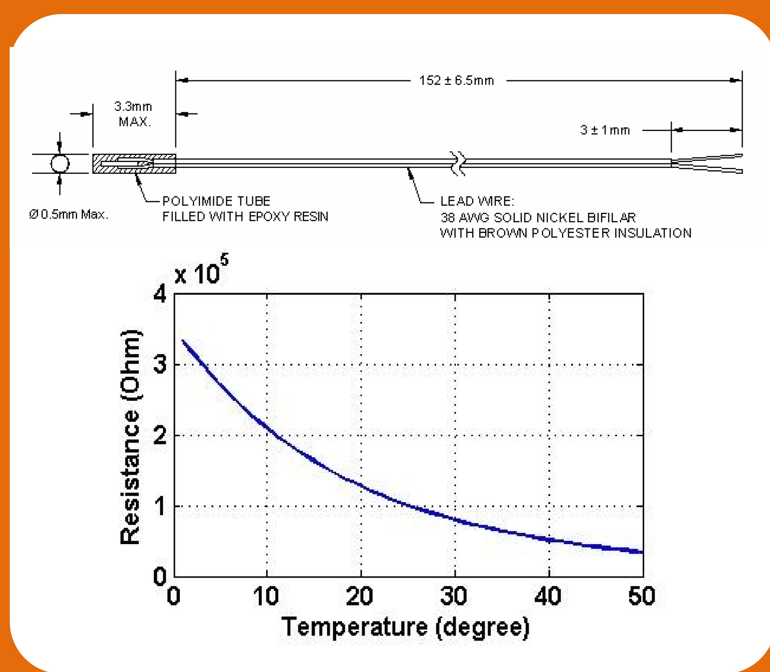
For medical implants, the sensor interface converts the various physiological signals into digital codes for further processing. For example, the bandwidth and magnitude of bio-electric signals are shown on the right, which are in the order of uV to mV and the frequencies span from DC to a few kHz. The sensor interfaces are composed by the pre-filter/amplifier, analog-digital convertor (ADC) and calibration circuits if necessary.

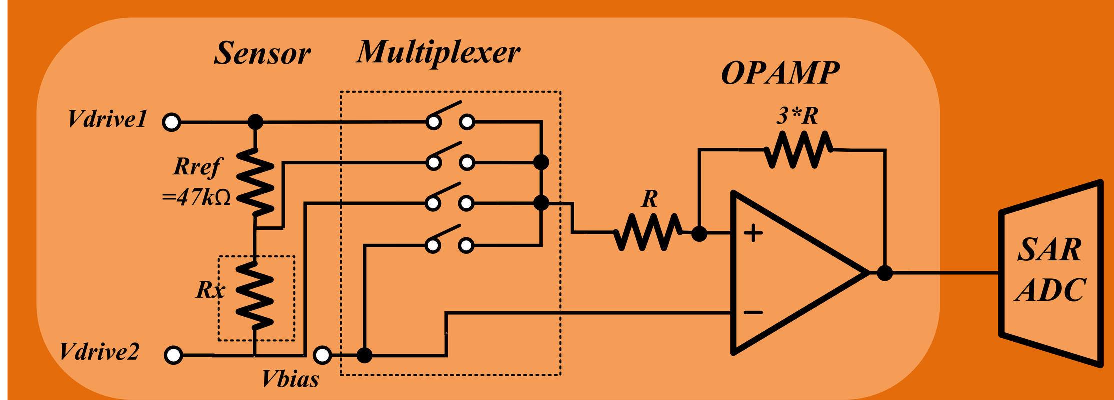


Considering for different medical applications, the sensor node must be compatible with a variety of sensors, each of which corresponds to particular specifications. As a result, design margins are left in critical parameters, such as the maximum sampling rate and the resolution. An SAR ADC is used in this interface, because its power consumption is directly proportional to various sampling frequency..

The 100K6MCD1 thermistor probe from Measurement Specialties Company is used as temperature sensor for its high sensitivity and relatively small volume.

Parameters	Value
Resistance@+25˚C (kΩ)	100
Response time in liquids (ms)	200
Dissipation constant in still air (mW/˚C)	0.3
Resistive Response (Ω/0.05˚C)	200

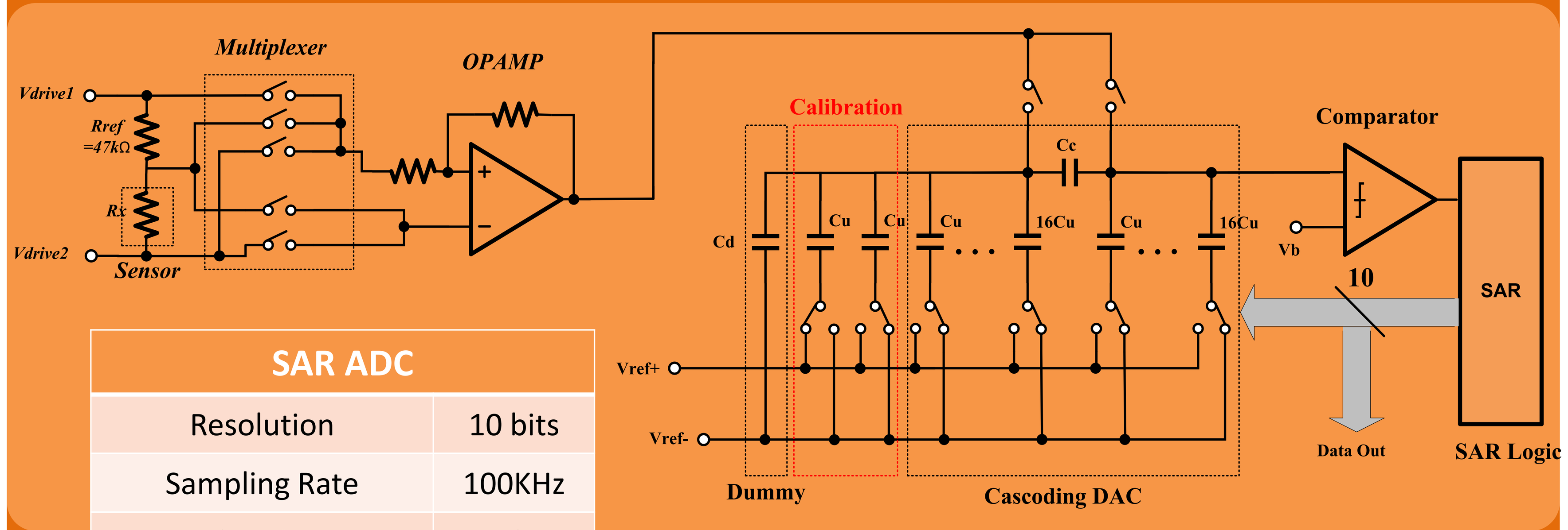




Pre-Amplifier	
DC Gain	57dB
Phase Margin	85˚
Bandwidth	6MHz
Power consumption	28uW

A four-wire measurement topology is used [5], where a multiplexer switches the input signal between the sensor output and reference voltage. The input could also be set to short-circuit to measure the offset voltage of interface circuits.
The sensor is connected to reference resistance R_{ref}, which is chosen as 48kΩ, to generate voltage signal and suppress sensor non-linearity. In order to reduce the power-consumption, voltage between V_{bias1} and V_{bias2} equals to 900mV, which leads to 5.4µW power at 24C˚. A pre-amplifier is used to match the signal to ADC dynamic range.

Analog-Digital Convertor:



SAR ADC	
Resolution	10 bits
Sampling Rate	100KHz
Simulated ENOB	9.2 bits
Power consumption	15uW

A 10bit SAR ADC is used to convert the signal into digital codes which is transferred through communication blocks. In order to suppress comparator noises, binary-scaled compensation is used. And the DAC structure is optimized to adapt the compensation method with minimum DAC sizes, and provides redundant capacitances which could be used to compensate DAC non-linearity due to parasitics. The ADC consumes 15µW power at 100KHz sampling rate. Simulation results shows 9.2bits ENOB.

Publication:
Xiao Liu and Catherine Dehollain, " A Low-Power Sensor Interface Circuit for Remotely Powered Implants," accepted by 9th Conference on Ph. D. Research in Microelectronics and Electronics 2013.