A wireless ultra-low power system for passive telemetry applications

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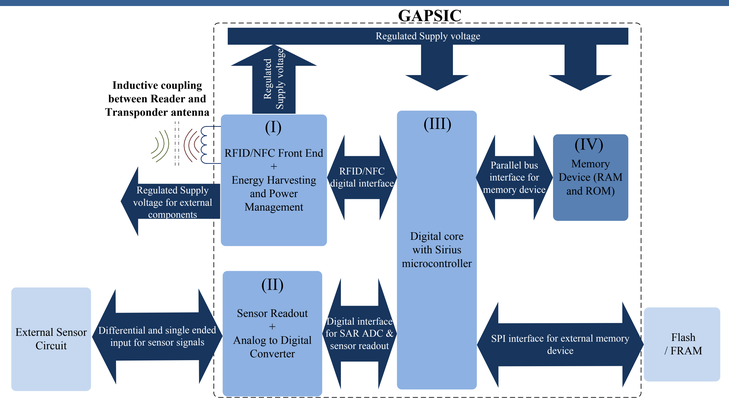
Abstract

The aim of this thesis is to develop ultra-low power sensor systems for various applications by harvesting energy from the electromagnetic field available from a RFID/NFC reader. Wireless sensor networks can generally be used for a very wide range from healthcare, logistics to industrial applications. This work focusses on a system-on-chip (SoC) developed for inductively powered passive sensor systems. The proposed SoC consists of an integrated RFID /NFC (ISO 15693, NFC 5) standard communication interface, analog to digital converter, sensor interface circuit, memory device and integrated microcontroller. The ASIC is fabricated using a 0.18 µm CMOS process with an area of 1.52 mm × 3.24 mm (approximately), consuming power in microwatt range. The proposed SoC is termed as GAPSIC which stands for 'General Application Passive Sensor Integrated Circuit'. It can be programmed depending on the requirement of the application.

Detail system architecture of the SoC



Results and applications

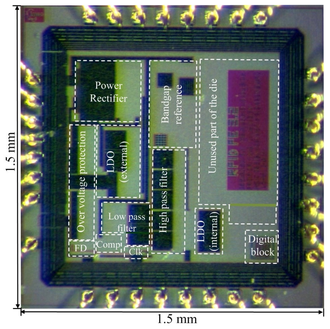


Fig.1 Microphotograph of the RFID/NFC frontend (UMC 180 nm)

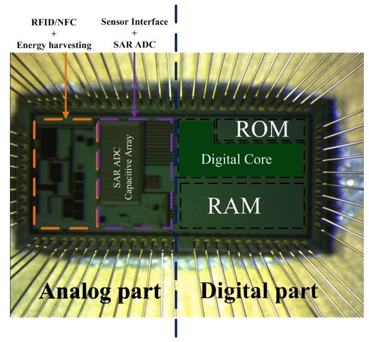
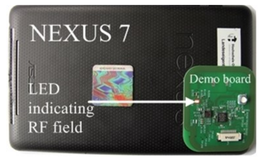
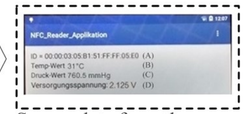


Fig.2 Microphotograph of the SoC – GAPSIC (UMC 180 nm)



Demo board in contact with Nexus 7

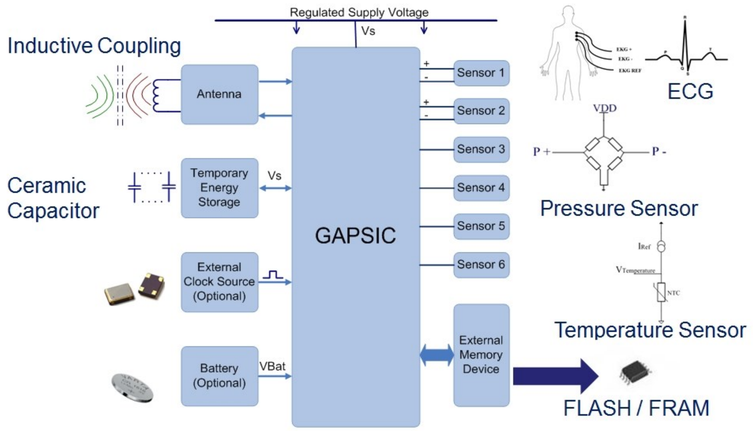
Sensor data readout



Sensor data from the application software

Fig.3 A demonstration board is designed with the stand alone RFID/NFC frontend, commercial microcontroller and temperature and pressure sensors (external). Android based application programe is used to read out the sensor data using NFC capable device (NEXUS 7)

System Overview



System description of the SoC

I. The RFID/NFC frontend along with energy harvesting and energy management block is responsible for communication and meeting the energy need of the entire system
II. Sensor readout circuit consists of an 8 bit programmable gain amplifier (PGA) and a 12 bit charge redistribution type successive approximation (SAR) type analog to digital converter (ADC)
III. The digital core consists of 32 bit microcontroller (developed in house) along with other digital peripheries including JTAG interface
IV. Internal memory includes 16 kB each of RAM (random access memory) and ROM (read only memory)

Highlights of the SoC

- Low power analog blocks driven by regulated 1.21 V power supply which is further level shifted to the system voltage level to reduce the power consumption
- RFID/NFC communication, energy harvesting and power management part is realized as a stand alone chip with a total power consumption of 90 µW
- The entire sensor readout and SAR ADC is kept switched off when not in use
- Internal ROM consists of the BIOS which aids in initial boot up of the system and rest part of the application can be programmed inside the external memory (Flash or FRAM)
- A wide range of sensors can be connected externally to measure temperature, pressure or ECG

Research Objectives

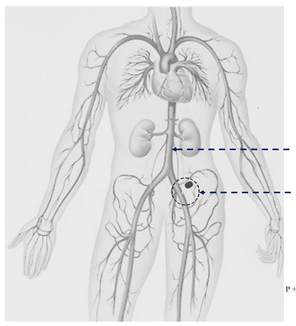
- Low power consuming electronics (microwatt range)
- Passive telemetry system using a commercially available communication protocol
- Fully integrated system, hence small sized electronics

State of the art

- Programmable SoC, which can be configured depending on the application
- Energy harvesting via inductive coupling from the RFID/NFC field
- RFID/NFC (ISO 15693) standard communication interface along with analog to digital converter, sensor interface circuit and a 32-bit microcontroller are key aspects of the design
- Area of application includes industrial sensor systems to biotelemetry

Parameter	Comment
Technology	UMC CMOS 0.18 µm
Size of the chip	1.52 mm × 3.24 mm
Bandgap reference	1.21 V
System clock	6.78 MHz
RFID/NFC Standard	ISO 15693 (NFC V)
ADC	SAR 12 bit resolution (max)

Parameter	Comment
ADC channel	Two differential and four single ended
PGA gain	1 to 100 (8 bit)
Temperature range	-30°C to 85°C
Mode of operation	Passive
Power consumption (analog)	~570 µW (average)
Application area	Biotelemetry, Industrial sensors



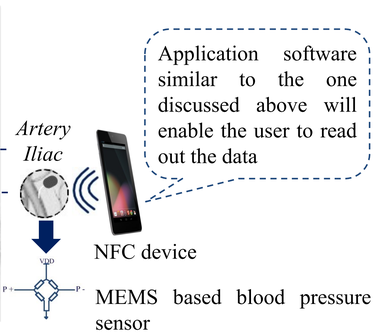


Fig.4 Artist impression of the proposed implant along with the complete system overview for the patients suffering from Peripheral Vascular Disease (PVD)

Selected publications

- M. Bhattacharyya, B. Dusch, D. Jansen, E. Mackensen,"Design, layout and verification of a mixed signal SoC for biomedical applications" – Conference : MPC 2015 – Multi Projekt Chip Gruppe Baden-Württemberg Ulm July 2015, Deutschland ISSN 1868-9221, page 43 – 48
- M. Bhattacharyya, W. Grünwald, B. Dusch, J. Aghassi – Hagmann, D. Jansen, L. Reindl, "A RFID/NFC based programmable SoC for Biomedical applications" – Presented at regular session in ISOCC 2014 conference in Jeju, South Korea, November 2014; IEEE Solid state circuits Seoul chapter award
- M. Bhattacharyya, W. Grünwald, B. Dusch, J. Aghassi – Hagmann, D. Jansen, L. Reindl, "A reconfigurable SOC for ultra low power passive sensor system applications" – Presented at PhD forum in VLSI SOC 2014 conference in Playa del carmen, Mexico, October 2014
- M. Bhattacharyya, T. Volk, A. Kreker, B. Dusch, D. Jansen, "Realization of a RFID Front End IC for ISO 15693 Standard in UMC CMOS 0.18µm Technology" – Conference : MPC 2012 – Multi Projekt Chip Gruppe Baden-Württemberg Aalen July 2012, Deutschland ISSN 1868-9221
- M. Bhattacharyya, T. Volk, D. Jansen, "A passive novel transponder for monitoring leakage in silicone breast implants by using RFID ISO 15693" – Conference : Smart SysTech 2012 - European Conference on Smart Objects, Systems and Technologies 06/12/2012 - 06/13/2012 at Osnabrück, Deutschland
- M. Bhattacharyya, D. Jansen, T. Volk, D. Bau, A. Riske, "A disposable passive temperature sensor with RFID ISO15693 interface" – Conference Location : Sitges, Print ISBN: 978-1-4577-0028-6 INSPEC Accession Number: 12355949 Date of Current Version : 03 November 2011 Issue Date : 15-16 Sept. 2011

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