An Integrated Microsystem for Environmental Sensing Powered by Energy Scavenging

By
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Research Goal

Demonstrate a 1mm³ microsystem that is able to run on energy scavenging alone and provides the functions of sensing, data readout, and local storage.
Create implantable micro-devices to help people cope with conditions like Parkinson's disease, deafness, paralysis, blindness, and epilepsy.

Motivations:
- Biomedical Implants
  Create implantable micro-devices to help people cope with conditions like Parkinson's disease, deafness, paralysis, blindness, and epilepsy.
- Environmental Sensors
- Homeland Security
Miniature low-cost intelligent system

- gather information from their environment
- interpret the data received
- communicate with a host system over a bi-directional wireless link.
Capacitive Pressure sensor → Read out circuitry → A/D converter → RAM

Control

Power

Power generation from external RF source

Block Diagram
Approach and Methodology

Using capacitive devices, sensing can be accomplished with virtually no expenditure of energy. However, the energy required for sensor readout is less clear. The use of oscillators and integrators for reading out capacitive sensors can be done with very little energy.

The tradeoffs between these two approaches and the interplay between accuracy, calibration, size, power, aperture time, and other parameters will be studied.
Oscillators for reading out capacitive sensors can be done with very little energy, and data conversion can be accomplished with counting and logic; however, considerable time is required for data capture when high accuracy is desired. For a 100kHz oscillator, 12b resolution requires an aperture time of 40msec.

As an alternative, a switched-capacitor integrator can provide 12b resolution in less than 20µsec but with higher power levels and the need for a subsequent data converter.
Results and Accomplishments
Oscillator Circuit Performance Comparison

- Simulating different Oscillator topologies using Multisim and comparing the performance of each in terms of power, size and accuracy.

- Oscillator Topologies
  - Schmidt Trigger
  - Hartley
  - Coplit
  - Multistable
Integrator Performance Comparison

- Simulating and analyzing various Integrator circuits using Multisim and comparing the performance of each in terms of power, size and accuracy.

- Integrator topologies
  - Simple Integrator
  - Programmable Integrator
Over 31 Undergraduate and Graduate Students have been Involved in the Research

Anderson, Rochelle
Arceneaux, Terry
Babb, Henry
Baffour-Awuah, Habibah
Brewer, Craig
Cox, James
Crawford, Chris
Dixon, Jon-Paul
Douglas, Robert
Fotouh, Mohamed
Godoy, Xavier
Green, Khawonda

Hunter, Shirnette
Jackson, Erick
Johnson, Corey
McKnight, Pamela
McQuiller, David
Michelin, Ian
Oliver, Anthony
Onwamere, Onyeka
Preston Perry
Ray, DeAundre
Robey, Marc
Seymour, James
Singletary, Clayce
Wolfe, Clarence

Graduate students
Golston, Marcus
Kher, Supriya
Lindor, Felicia
Ribeiro, Miguel
Robinson, Crystal
Tate, Richard
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Dr. P. Obiomon/ Crystal Robinson

• Goal: to develop the blocks for an intra-ocular sensor could track eye pressure (for the study of glaucoma) and could be readout occasionally by RF powering the implant over a passive telemetry link

• Recent Progress:
  - Analysis of capacitive sensors
  - Analysis of readout circuitry
    - Oscillator vs Integrator designs
    - Comparison of ADC technology
    - Designed a frequency counter

• Contributions:
  - Define trade offs and limits of each block in the intra-ocular sensor
Undergraduate Project: Build a sensing device using commercial parts

![Diagram](attachment:diagram.png)
Undergraduate Project: Interfacing with Ultra-Low Power Commercial Processor

**Goal:** Allow processor to interface readout circuitry.

**Progress:** Currently have the capability of programming the new commercial ultra-low power ATMEL processor.

Figure 1: Commercial processor programmed to communicate with readout circuitry

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- Capacitive Pressure sensor
- Readout Circuitry
- A/D converter
- Memory
- Commercial Processor
- Power
- Readout Circuitry
- Power generation from external RF source
Future Work

Work with CECSTR to develop a passive-telemetry interface and transmit sensor information to an external system.
Academic Partnerships

**Dr. Kensall D. Wise**, Director of WIMS Engineering Research Center, University of Michigan, Ann Arbor

**Dr. C. Akujuobi**
Director of Center of Excellence for Communication Systems Technology Research (CECSTR)
Industrial Partnerships

Mr. A. Holland, Senior Manager of Research & Development, Alcatel USA, Prairie View Alumni

Alcatel USA is a global telecommunication company. Currently, Alcatel is the number one provider of telecommunication equipment in the world. Mr. Holland has over 30 years of experience in RF design, research and development. He is the manager of a systems development group for the Wireless Telecommunication Division in North America. The group is responsible for modem development, software development and system architecture design. He has taught several electrical engineering courses at the University of Texas at Arlington.

Dr. P. Jackson, Boeing, Seattle, Washington, Prairie View Alumni

Boeing is the world's leading aerospace company and the largest manufacturer of commercial jetliners and military aircraft. Dr. Jackson received the Modern Day Technology Leader Award, for shaping the future of engineering, science and technology. He locates new technologies and applies them to real-world engineering concepts for Phantom Works, the company's advanced research and development unit, in Bellevue, Washington.