Wireless Power Transfer for Medical Implantable Microsystems

Joint Fourth Year Project

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Wireless Power Transfer has emerged as a suitable technology for powering tiny, sub-millimeter size Medical Implantable Microsystems (MIMs). MIMs can replace the function of organs in the human body, in applications such as nerve stimulators, implantable monitors, endoscopic capsules and more. Wireless Power Transfer (WPT) reduces the need for batteries or bulky receiver coils on the receiver/harvester. Energy harvesting makes use of unconventional sources such as solar, Radio-Frequency (RF), magnetic-resonant, thermal and mechanical energy to power electronic circuits. This year's fourth year project will be co-supervised by Prof. Amaya and Prof. Mason and will be divided into two subprojects all aimed at enabling WPT for MIMS (Refer to Figure 1):

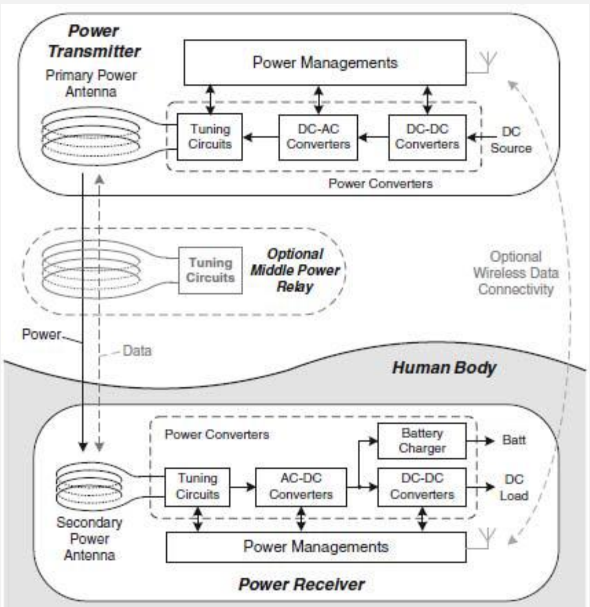

Figure 1 Simplified WPT System

WPT to charge Glucouse Monitoring Systems: This subproject will develop a wireless charging system for the Dexcom G5 glucose monitor. This monitor tracks glucose and shares information in real-time for accurate action and without the need for painful finger pricking [1].

This subproject will ideally support 3 to 4 students with a strong background in ELEC 3105, 3509 and 3909 and who should ideally take ELEC 4505, 4503 and 4706 in their fourth year. The breakout for the proposed work includes:

1. Reverse engineer the G5 transmitter to determine major components and general operation including power consumption in different operating modes.
2. System analysis and simulation using Keysight's SystemView/ADS or Matlab Simulink, to assess the impact of the choice of wireless charging frequency, required Tx and Rx power and efficiency, resonant circuit loss as a function of separation, the use of magnetic relays, adaptive system integration including: required analog/digital components, hardware requirements for self-adaptation (if necessary). Consideration of overall size and cost of solution.
3. HDL and hardware design and implementation of the required hardware and algorithms to drive the wireless power networks. Specifications will be fluid and driven directly from system analysis. A Bluetooth adaptive communication channel may be implemented here if appropriate.

4. Detailed circuit design and implementation of all circuit components in ADS or LT Spice with optimum efficiency at the selected frequency for this project.
5. Construction and testing of a mock G5 transmitter and receiver with wireless charging.

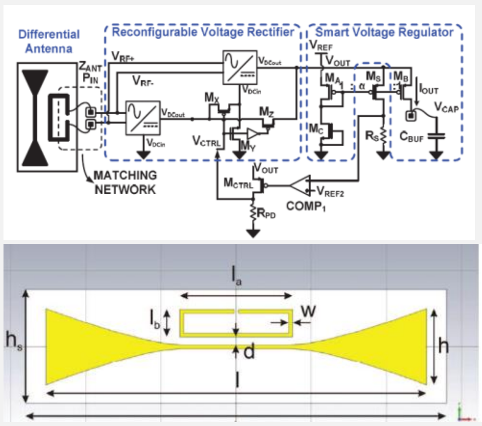

Figure 2 Integrated Adaptive Power Harvester

Fully Integrated 900 MHz Power Harvesters: A second subproject will focus on integrated, miniaturized, adaptive RF power harvesters operating in the 900 MHz ISM band (Figure 2). RF harvesters are widely used in applications where a wired power line is not available including: remote sensing and telemetry, asset tracking, personal identification, enhanced security of remote locations and, as outlined in this project, medical implants [2]–[4]. In many applications the power associated with communication signals is unpredictable and relatively small and required electromagnetic fields can be generated ad hoc. Note that all students involved in this activity, will be required to take ELEC 4609. This thrust will attempt to demonstrate functional RF Wireless Power Transmission through the human body to power up fully-integrated RF power harvester implemented using Carleton's in-house Silicon-On-Insulator (SOI) process. This subproject will ideally support 3 to 4 students with a strong background in ELEC 3509, 3908 and 3909 and who should ideally take ELEC 4505 and 4503 in their fourth year. Semiconductor design and modeling of SOI devices will make use of MINIMOS and Cadence Analog Artist/Virtuoso simulators to extract models and simulate all circuits. Passive circuit design will make use of EM solvers such as Keysight's Momentum, Ansys HFSS or Sonnet while active circuit/system design will make use of commercial software such as Keysight's SystemView/ADS or Matlab Simulink. The breakout for the proposed work includes:

6. Assessment of available models of integrated semiconductor devices in Carleton's in-house SOI process. Tasks will include examining available fabricated devices and/or measured data and comparison to simulated MINIMOS models, SPICE level 3 transistor model verification using the Cadence Design Environment using both Analog Artist and Virtuoso.
7. System analysis of the requirements for medical implants and simulation of all required blocks including required ad hoc power source, custom differential antenna, differential RF-DC converter, smart voltage regulator and the external capacitor C_{BUFFER} used for energy storage. In addition, this task will define all external control logic requirements. Emphasis will be placed on optimizing system efficiency while considering practical implementation using Carleton's in-house SOI process.
8. Design and layout implementation of a differential antenna in a printed substrate and operating at 900 MHz including on-chip/off-chip sections, matching circuitry to optimize power transfer between antenna and integrated rectangular loop in the power harvester.
9. Detailed circuit design and layout implementation of differential RF-DC converter to include low power sensitivity and wide dynamic range.
10. Detailed circuit design and implementation of a smart voltage regulator to keep output voltage constant using supplied reference levels while not degrading system efficiency.

11. Final layout design completed in time for fabrication in late February 2017. Designs will be fabricated and tested at Carleton
12. Develop a test plan including system design as well as required high frequency structures for the individual characterization of building blocks.

List of References

[1] Dexcom, “Dexcom G5 Mobile Bluetooth CGM for Diabetics.” [Online]. Available: https://www.youtube.com/watch?v=4JjsOL81wdA. [Accessed: 26-Jul-2017].

[2] S. Scorcioni *et al.*, “An Integrated RF Energy Harvester for UHF Wireless Powering Applications,” *IEEE Wirel. Power Transf.*, pp. 0–3, 2013.

[3] A. Bertacchini, L. Larcher, M. Maini, and L. Vincetti, “Reconfigurable RF Energy Harvester with Customized Differential PCB Antenna,” *J. Low Power Electron. Appl.*, vol. ISSN 2079-, pp. 257–273, 2015.

[4] P. Broutas, H. Contopanagos, E. D. Kyriakis-bitzaros, D. Tsoukalas, and S. Chatzandroulis, “Sensors and Actuators A : Physical A low power RF harvester for a smart passive sensor tag with integrated antenna,” *Sensors Actuators A. Phys.*, vol. 176, pp. 34–45, 2012.