Title:

Wireless Power Transfer: From Fundamentals to Applications

Abstract:

This tutorial aims at familiarizing the audience with the fundamentals, design, optimization, and some of the latest developments in key building blocks of the rapidly growing Wireless Power Transfer (WPT) mechanism in a wide range of applications from mm-sized implantable medical devices (IMD) with power consumption in the micro-watt range to electric vehicles (EV) with power consumption in the tens to hundreds of kilo-watt range. Being developed and presented by experts, who have conducted cutting-edge research in this field, a unique feature of this tutorial is looking at the above mentioned topics all the way from the theoretical foundation to design and optimization procedures and specific priorities in target applications, providing the audience with a full coverage of the ins and outs of WPT technology. The tutorial will cover the entire power flow from the energy source, RF power amplifier, and driver circuitry on the transmitter (Tx) side to geometrical design and optimization of the two or more coils that constitute the inductive link, to the matching, AC-DC conversion, and power management blocks on the receiver (Rx) side. Safe and robust system design considerations in response to non-idealities and various types of disturbances to the WPT circuits, such as misalignments, load variations, heat dissipation, safety issues, and interference will be discussed, while looking at both open-loop and closed-loop system behaviors. **This tutorial is based on the new book: "Inductive Links for Wireless Power Transfer: Fundamental concepts for designing high-efficiency WPT links" by the speakers to appear in 2021 (Publisher: Springer).**

Keywords:

Wireless power transmission, Implantable microelectronic devices (IMD), electric vehicles, power transfer efficiency, near-field, adaptive matching, AC-DC conversion, power amplifier, electromagnetic interference, specific absorption rate (SAR) limits

Motivation and Focus:

Wireless Power Transfer, which is the focus of this tutorial, is important to the LASCAS community because it directly utilizes the fundamentals of circuit design at all levels, while itself is often a key part of a larger system, such as IMDs. WPT is an essential part of a large majority of IMDs, such as cochlear implants and retinal prostheses, without which these applications would not be possible. At the same time, popularity of WPT is soaring in a rapidly growing number of other applications from wirelessly rechargeable watches and smartphones to home appliances, drones, underwater robots, and EVs because of the convenience in cord-cutting, being environmentally friendly by eliminating or reducing the use of primary batteries and their toxic materials, and robustness against wear and tear. On the other hand, certain CAS techniques should be utilized to keep the power transfer efficiency above a certain level, and limit the temperature rise and potential interference with other nearby equipment.

Target Audience, Pre-requisite Knowledge, and Learning Objectives

This tutorial is targeted at researchers, engineers, and graduate students from both academia and industry who have strong knowledge of circuit and system design, and familiar with fundamental concepts of electromagnetics, power electronics, and/or bioengineering, but would like to learn more specifically about the fundamentals, design, optimization, and applications of key circuit blocks used in rapidly advancing field of WPT with its growing applications in various fields, demanding a wide range of power levels from μW to kW, along with their specific requirements.

Contents of the Tutorial

1st part:

- Introduction to WPT

- Near-field vs. far-field WPT
- Near-field, inductive WPT fundamentals
- Optimization of the two, three, and four-coil links
- Closed-loop control
- Coil design and modeling
- WPT safety and EMC issues
- Overview of circuits for WPT (Tx and Rx)
- Application of WPT in IMDs, RFIDs, EV
- Conclusion

2nd part:

Extended coverage of circuits for WPT and application examples
Hands-on simulations of inductive WPT links

Speakers Bios

Dr. Pablo Pérez-Nicoli received the degree in electrical engineering in 2013 and the Ph.D. degree in 2018 from the Universidad de la República, Montevideo, Uruguay. In 2012, he joined the Electrical Engineering Department, Universidad de la República, where he is currently a Research Assistant. His current research interests include wireless power transmission and ultra low-power analog integrated circuits design.

Prof. Fernando Silveira received the degree in electrical engineering from the Universidad de la República, Montevideo, Uruguay, in 1990, and the M.Sc. and Ph.D. degrees in microelectronics from the Universitè catholique de Louvain, Louvain-la-Neuve, Belgium, in 1995 and 2002, respectively. He is currently a Professor with the Electrical Engineering Department, Universidad de la República. His current research interests include the design of ultra low-power analog and RF integrated circuits and systems, in particular with biomedical application. In this field, he has coauthored one book and many technical papers. He has had multiple industrial activities including leading the design of an application specified integrated circuit for implantable pacemakers and designing analog circuit modules for implantable devices for various companies worldwide.

Dr Maysam Ghovanloo received the B.S. degree in electrical engineering from the University of Tehran in 1994, and the M.S. degree in biomedical engineering from the Amirkabir University of Technology, Tehran, Iran in 1997. He also received the M.S. and Ph.D. degrees in electrical engineering from the University of Michigan, Ann Arbor, in 2003 and 2004, respectively. From 2004 to 2007 Dr. Ghovanloo was an Assistant Professor in the Department of ECE at the North Carolina State University, Raleigh, NC. From 2007 to 2019 was with the Georgia Institute of Technology School of Electrical and Computer Engineering. In 2012 he started Bionic Sciences Inc. to develop advanced medical devices, where he serves as the CTO. He has authored or coauthored more than 250 peer-reviewed conference and journal publications on implantable microelectronic devices, integrated circuits and microsystems for medical applications, and modern assistive/rehabilitation technologies. He also holds 10 issued patents.