Abstract

Wireless power transfer (WPT) technology is gaining its popularity in recent years, which is largely motivated by extensive research work. It is attractive as the power and data transmission can be done through the magnetic field between two coils without the usage of power wires. It offers the convenience of charging or operating a device without having to plug-in. For example, electronic devices such as cell phones, smart watches and electric vehicles could be charged without utilizing power cord as in the conventional way. WPT technology is advantageous to various applications with different specifications and constraints. Besides wireless charging, it contributes greatly to RFID and medical fields as well, such as wireless capsule endoscopy for early detection screening, biomedical implants like cochlear implants, RFID animal tag for prevention of infectious disease, etc. The emerging WPT technology has become an appealing approach in industrial applications and it is expected to continually grow in near future.

In this research, the focus is on the power management integrated circuits (PMIC) design of the wireless power receiver in an inductively WPT system. Several designs are proposed to improve the performance of the receiver for the applications in the range of 1mW-100mW of output power and operate in an ISM band of 125 kHz, such as for RFID animal tag or biomedical implants. In a wireless power receiver, a rectifier and a voltage regulator are crucial blocks for AC-DC conversion and DC-DC regulation respectively. Hence, an unbalanced biasing comparator design is proposed to enhance the power efficiency of the rectifier block. A buck regulator with a proposed energy-efficient pulse frequency modulation (PFM) controller is implemented as well. Measurement results show that the rectifier achieves a peak efficiency of 85.92% while the buck regulator achieves a peak efficiency of 91%.

However, the two-stage design restricts the overall power efficiency of the receiver. In order to improve the power efficiency, a one-stage AC-DC regulator is proposed by introducing a dual-mode concept. As a result, the power losses incurred has been reduced from two-stage to one-stage, improving the power efficiency substantially. Fabricated in 0.18μm CMOS process, the measured peak efficiency is 93.48% in an output power range of 2mW-80mW.

To maximize the circuits' performances of embedded applications, more than one supply voltage is often required in a system. Hence, a new architecture which is able to rectify and regulate multiple outputs concurrently in a single-stage is developed. In addition, a multi-mode controller is also proposed to control the multiple switches of the structure efficiently. As a proof of concept, a prototype has been validated for the tri-mode dual-output design. Nonetheless, the concept is applicable and extendable to N outputs. The measured peak power efficiency of the tri-mode dual-output design is 91.68% in an output power range of 3.8mW to 114mW.

Lastly, a single-stage voltage doubler regulator is proposed. The previous designs operate with a criterion that the input voltage has to be greater than output voltage. To solve the limitation, a voltage doubler structure is utilized. By embedding the regulation function in the voltage doubler structure, the voltage rectification and regulation can be achieved at an output voltage that is twice of the input voltage amplitude.

Publication List

Journals:

1. **Qiong Wei Low**, Mi Zhou, Liter Siek, “A Single-Stage Direct-Conversion AC-DC Converter for Inductively Powered Application,” submitted to IEEE Transactions on Very Large Scale Integration (VLSI) Systems. – under revision
2. Mi Zhou, Zhuochao Sun, **Qiong Wei Low**, Liter Siek, “Fast transient response DC-DC converter with start-up in-rush current control,” IET Electronics Letter 2016.

Conferences:

1. **Qiong Wei Low**, Liter Siek, Mi Zhou, “A high efficiency rectifier for inductively power transfer application,” IEEE International Conference on Very Large Scale Integration (VLSI-SoC), Oct 2015.
2. **Qiong Wei Low**, Mi Zhou, Liter Siek, “Performance analysis on active rectifier structures for inductively powered application,” International Symposium on Integrated Circuits (ISIC) 2016.
3. Mi Zhou, **Qiong Wei Low**, Liter Siek, “A high efficiency synchronous buck converter with adaptive dead-time control,” International Symposium on Integrated Circuits (ISIC) 2016.