# Low-Power RF Energy Harvester Circuit Design for Wearable Medical Applications


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***Abstract*— Electromagnetic based energy harvesting systems are being widely researched with radio frequency (RF) as their energy source. RF energy is preferred due to its availability and characteristics of transferring energy remotely and in all directions. This paper presents a newly design low-power CMOS full-bridge rectifier which works as the receiver of the harvesting system. The proposed rectifier scheme includes two NMOS and two PMOS devices and they are realized in a standard 130nm CMOS process. The work is focused on RF signals of around 900 MHz. To achieve stable energy transmission between the antenna and the proposed AC-DC rectifier, an impedance matching network is designed with values of capacitor and inductor of 550fF and 45nH, respectively. A DC-DC converter with a Maximum Power Point Tracking (MPPT) system is designed for storing energy from the RF signal with minimum current consumption. The peak efficiency of this design is about 5% at 10 dBm. The overall system is very light-weight and requires no external wiring and connection.**


## I. INTRODUCTION

One of the significant technological advancement of low-power CMOS design is the rapid development of implantable and wearable sensor-based electronic systems [1]. The powering of such sensor is becoming a major problem when designing the system as traditional batteries are being used. The usage of such batteries has a high chance of leakage which are hazardous especially used in medical applications [1]. Moreover, as most of these systems are wearable or implantable, the available space needed for powering of the device is very limited and a traditional battery takes up a lot of space [1]. In recent years, energy harvesting systems have been widely studied for a potential solution of powering sensor-based electronics [1]. Various sources of energy can be used as energy harvesters, and an electromagnetic energy source such as radio frequency (RF) can be a suitable option. The RF waveform can be divided into two categories such as radiative energy and non-radiative energy [2]. An example of a non-radiative energy transfer is the magnetically coupled near-field inductive coils [2]. In this case, the two devices must be in close proximity to each other for proper energy transfer. The operating frequency of this method is limited to a few MHz ranges. Alternatively, in the radiative energy transfer system, two devices can be further apart from each other. When considering a system used in medical applications which could be operated remotely, radiative or far-field energy transfer system would be the best choice. The availability of radiative RF energy is quite high as it can be found in the form of wireless internet connections and mobile communications. Since air loss and the energy transfer loss are quite significant in this type of energy transfer system, possible fluctuations in data collection can be present. As a solution, a matching network has been designed for stable input for the AC-DC rectifier which is working as the receiver of the system. Fig. 1 shows a general system architecture of an RF energy harvester where energy is received from the RF transmitter. The matching network system is installed between the antenna and the AC-DC rectifier for matching their impedances. The matched AC signal with adequate voltage from the network then convert into a DC signal through the rectifier and then goes into the DC-DC boost converter acting as the energy storage.

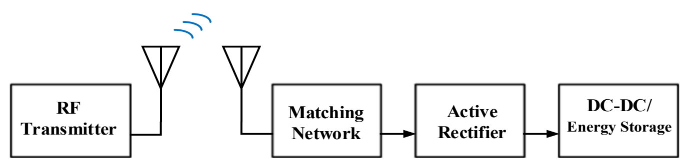


Fig. 1: RF Energy Harvester System Architecture.

## II. OVERVEIW OF THE SYSTEM

AC-DC conversion is required for this system as RF being transmitted and received are in the form of sine wave signals. Conventional AC-DC rectifiers cannot be used in this system as radiative energy transfer has significant amount of air loss and energy loss. To get the required power for the energy storage system, a cross-coupled active rectifier is designed where high-power conversion efficiency (PCE) can be produced with limited available input power range. Careful selection of NMOS and PMOS were done in this proposed structure with optimum sizes.

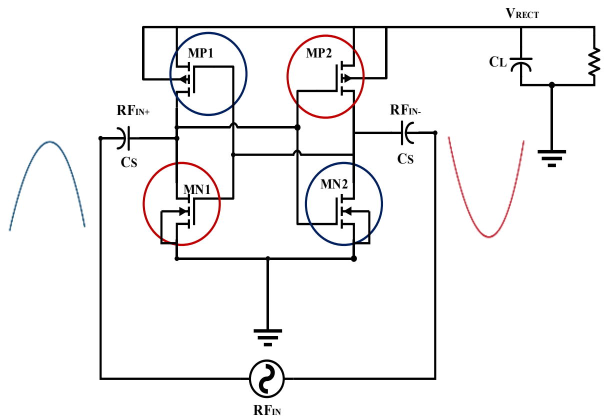

Fig. 2: Operation of the proposed RF Full-Wave Rectifier in each input cycle.

In Fig. 2, it shows the operation of the proposed RF rectifier in each cycle. The blue circles represent the positive cycle known as the discharging phase and the red circle shows the negative cycle or the charging phase. Next, the antenna in the receiver side of the system works as a transducer converting electromagnetic energy into electrical energy. Because of the conduction loss and the internal loss of the antenna, a matching network is placed in between the antenna and the rectifier as shown in Fig. 3.

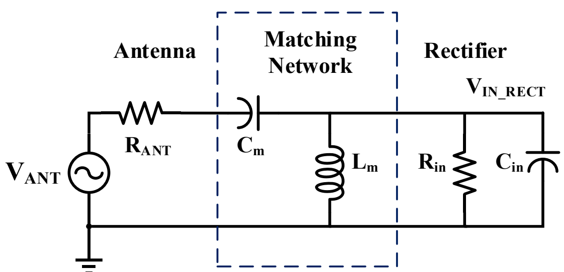


Fig. 3: The Matching Network used in the proposed system

$$V_{ANT} = 2\sqrt{2R_{ANT}P_{ANT}} \qquad (1)$$

The available voltage from an antenna can be calculated from equation (1) where $R_{ANT}$ and $P_{ANT}$ is the resistance and power of the antenna, respectively [2], [3]. The capacitance of the matching network, $C_m$ and inductance, $L_m$ are 550 fF and 45 nH, respectively. The next step of the process is designing a DC-DC boost converter for a stable output voltage. To transfer maximum available power from the cross-connected rectifier to the DC-DC boost converter, impedances from both sides of the devices should be matched. Fig. 4 showcases the design of an MPPT system where the input impedance from the converter and the output impedance from the rectifier are being matched.

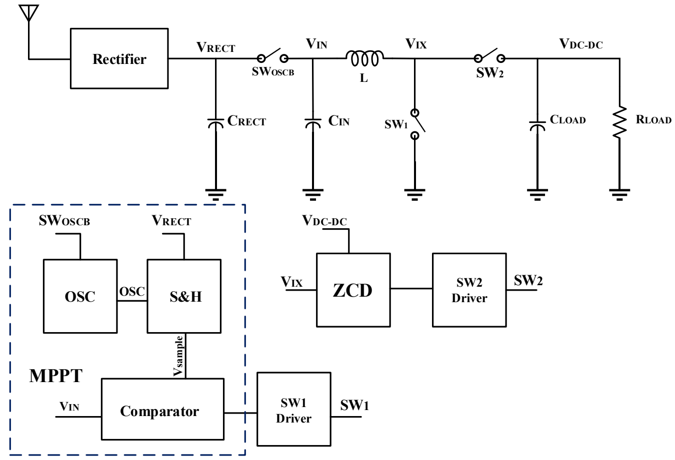

Fig. 4: The proposed architecture used in the DC-DC Boost Converter.

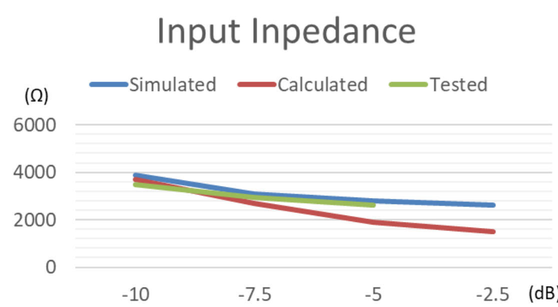


Fig. 5: The overall input impedance of the proposed DC-DC Boost Converter.

The proposed DC-DC system can achieve a maximum power from an RF rectifier with the minimum size (253µmx230µm) of MPPT.

## III. Conclusion

In this paper a RF energy harvester has been presented with cross connected AC-DC rectifier and DC-DC Boost converter. The design of the matching network transfers stable data and the proposed MPPT design connected to the DC-DC converter requires less area and does not need to be calibrated whenever the system is re-booted.

## References


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