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Enabling a Battery-Less Sensor Node Using Dedicated Radio Frequency Energy Harvesting for Complete Off-Grid Applications

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Received: 4 August 2020; Accepted: 5 October 2020; Published: 16 October 2020

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Abstract: The large-scale deployment of sensor nodes in difficult-to-reach locations makes powering of sensor nodes via batteries impractical. Besides, battery-powered WSNs require the periodic replacement of batteries. Wireless, battery-less sensor nodes represent a less maintenance-intensive, more environmentally friendly and compact alternative to battery powered sensor nodes. Moreover, such nodes are powered through wireless energy harvesting. In this research, we propose a novel battery-less wireless sensor node which is powered by a dedicated 4 W EIRP 920 MHz radio frequency (RF) energy device. The system is designed to provide complete off-grid Internet of Things (IoT) applications. To this end we have designed a power base station which derives its power from solar PV panels to radiate the RF energy used to power the sensor node. We use a PIC32MX220F32 microcontroller to implement a CC-CV battery charging algorithm to control the step-down DC-DC converter which charges lithium-ion batteries that power the RF transmitter and amplifier, respectively. A 12 element Yagi antenna was designed and optimized using the FEKO electromagnetic software. We design a step-up converter to step the voltage output from a single stage fully cross-coupled RF-DC converter circuit up to 3.3 V. Finally, we use the power requirements of the sensor node to size the storage capacity of the capacitor of the energy harvesting circuit. The results obtained from the experiments performed showed that enough RF energy was harvested over a distance of 15 m to allow the sensor node complete one sense-transmit operation for a duration of 156 min. The Yagi antenna achieved a gain of 12.62 dBi and a return loss of −14.11 dB at 920 MHz, while the battery was correctly charged according to the CC-CV algorithm through the control of the DC-DC converter.

Keywords: battery-less sensor nodes; RF harvesting; off-grid; wireless sensor networks; wireless power transfer

1. Introduction

In creating a smarter, more connected world, wireless sensor networks (WSNs) are becoming more widespread. The proliferation of the Internet of Things (IoT) has had a positive impact on a broad range of applications, including agriculture, medicine, and supply chain optimization [1]. The large scale and sometimes remote placement of sensor nodes makes the powering of such sensor nodes with wires or batteries impractical [2]. Improvements in communication technologies have made low power energy harvesting methods a viable solution of wireless power transfer to sensor nodes [3]. The increasing