Wireless Power Transfer to Biomedical Implants for Patient Monitoring

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***Abstract*—**A real-time active matching circuit (MC) for wireless power transfer applications, especially for biomedical systems. One prototype of low-cost real-time automatic MC, utilizing a variable circuit topology, including discrete passives and p-i-n diodes, has been implemented and the principle has been verified by measurements. One genetic algorithm was introduced to optimize the design over a wide range of impedances to match. As a result of preliminary operation verification tests, the proposed real-time MC system results in improving the transfer coefficient. Similar performance improvement results were observed in additional tests under misaligned conditions, as well as for nonsymmetrical Tx–Rx coil configurations further verifying the potential applicability of the proposed system to practical biomedical devices.

***Keywords*—**Biomedical Implants; Bridge Rectifier; IC Voltage Regulators; Patient Monitoring; Wireless Power Transfer.

***Abbreviations*—**Internet Of Things (IOT); Low-Rate Wireless Personal Area Networks (LR-WPANs); Matching Circuit (MC); Unmanned Aerial Vehicles (UAVs); Wireless Energy Transfer (WET); Wireless Power Transfer (WPT).

I. Introduction

WIRELESS POWER TRANSFER (WPT) technology is one of the most highly demanded technologies to realize truly cableless/batteryless mobile devices and wirelessly connected electronics, which are required for practical implementation of Internet Of Things (IOT) topologies, and good potentially alleviate the typical issues of the short cruising range until next recharging, as well as the in continuous of wired charging of electrical vehicles [Kim, 1; Shin, 2; Imura et al., 3]. In addition to this application, the medical field is one of the most important application areas of the technologies. For hygienic purposes, the unique capability of HF waves and microwaves to transfer power to sealed devices in a contactless/cableless way is a magic. Furthermore, WPT could have a significant impact in health and biomonitoring applications, virtually eliminating the need for painful and infection prone surgical procedures, which are currently necessary for periodical battery replacement, by wirelessly charging in –vivo implanted electronics. Generally, there are three types of electromagnetic (EM) wireless power transmission systems: far-field radio waves, inductive power transfer and capacitive power transfer and each method as its pros and cons [Shoki, 4; Dai & Ludois, 5]. The resonant coupling, especially the magnetic resonant coupling method, which belongs to the inductive power transfer techniques.

II. Existing Systems

Wire connections between electronic products already are accustomed to everyone. Wire connections could sometimes, become trouble and inconveniences. Existing technologies can be classified into two categories: electromagnetic (EM) radiation and magnetic resonant coupling [Kurs et al., 6]. Higher loss in the measurement results is assumed to be associated with greater radiation loss because of the fabrication error.

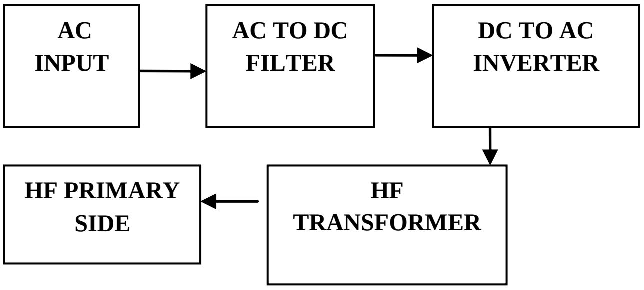

Figure 1: Transmitter

III. PROPOSED SYSTEM

Wireless Energy Transfer (WET) unique capability of HF waves and microwaves to transfer power to sealed devices in a contactless/cable less way is a major advantage. Efficiency is very high due to transfer power without a manmade conductor connected between power source.

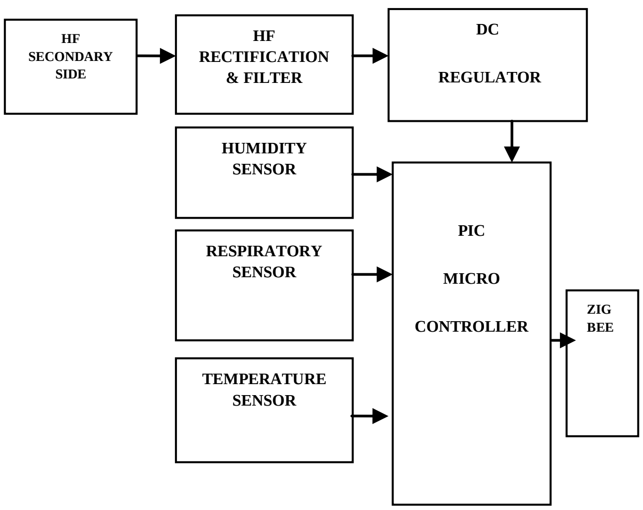

Figure 2: Receiver Node 1

IV. POWER SUPPLY UNIT

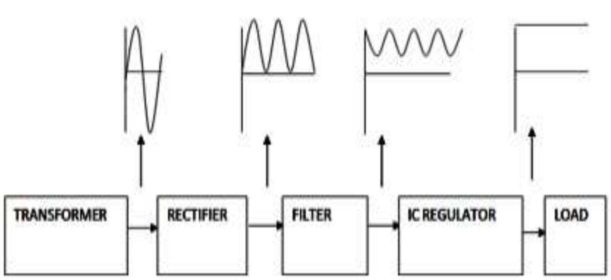

Figure 3: Block Diagram of Power Supply

4.1. Transformer

The potential transformer will step down the power supply voltage (0-230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op–amp. The advantages of using precision rectifier are it will give peak voltage output as DC, rest of the circuits will give only RMS output.

4.2. Bridge Rectifier

When four diodes are connected as shown in figure, the circuit is called as bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners.

Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. the positive potential at point A will forward bias D3 and reverse bias D4.

The negative potential at point B will forward bias D1 and reverse D2. At this time D3 and D1 are forward biased and will allow current flow to pass through them; D4 and D2 are reverse biased and will block current flow.

The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point B. this path is indicated by the solid arrows. Waveforms (1) and (2) can be observed across D1 and D3.

One-half cycle later the polarity across the secondary of the transformer reverse, forward biasing D2 and D4 and reverse biasing D1 and D3. Current flow will now be from point A through D4, up through RL, through D2, through the secondary of T1, and back to point A. This path is indicated by the broken arrows. Waveforms (3) and (4) can be observed across D2 and D4. The current flow through RL is always in the same direction. In flowing through RL this current develops a voltage corresponding to that shown waveform (5). Since current flows through the load (RL) during both half cycles of the applied voltage, this bridge rectifier is a full-wave rectifier.

4.3. IC Voltage Regulators

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustably set voltage. The regulators can be selected for operation with load currents from hundreds of milli amperes to tens of amperes, corresponding to power ratings from milli watts to tens of watts. A fixed three-terminal voltage regulator has an unregulated dc input voltage, Vi, applied to one input terminal, a regulated dc output voltage, Vo, from a second terminal, with the third terminal connected to ground. The series 78 regulators provide fixed positive regulated voltages from 5 to 24 volts. Similarly, the series 79 regulators provide fixed negative regulated voltages from 5 to 24 volts.

V. FEATURES & DESCRIPTION OF REGULATORS

- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

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VI. Operation Test of the Automated Real –Time Matching System

6.1. Performance Characterization of Automated Real-Time Matching System

In order to test the performance of the developed automated real-time matching system, the received power at different separation distances was measured by utilizing a real-time spectrum analyzer, RSA3408A from Textronix Inc., with and without a MC and the Tx coil is adjusted to be 0dBm in both cases with and without a MC, respectively. The received power with respect to the coil center to center separation distance with and without an automated matching system. It can be easily concluded that the received power increases by utilizing the MC for separation distances in the range from 10-16cm with a maximum received power improvement of 3.2dB.

VII. ZigBee

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs), such as wireless light switches with lamps, electrical meters with in-home-displays, consumer electronics equipment via short-range radio. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking.

ZigBee is a low-cost, low-power, wireless mesh networking standard. First, the low cost allows the technology to be widely deployed in wireless control and monitoring applications. Second, the low power-usage allows longer life with smaller batteries. Third, the mesh networking provides high reliability and more extensive range.

VIII. Conclusion

In this study, the feasibility of the real-time active MC for bio-medical WPT application is discussed [Bito et al., 7]. First, open helical type coil, which have a self-resonance frequency of 13.56 MHz, were designed utilizing an EM simulator and characterized through measurement. Based on the measured S-parameter of the coils, a variable MC unit was designed utilizing the GA [Imura et al., 8]. The proto type of low-cost real-time automatic MC was also designed and analyzed to quantitatively reveal the limitations of real-time automatic matching system. Finally, the real-time matching system was implemented and verified through the measurement. Eventually, the proposed real-time automatic MC system achieved the maximum of 3.2-dB transfer coefficient improvement in the range of 10-16-cm coil separation distance automatically in about 64ms.Additional operation verification test conducted for misaligned coil topologies and for nonsymmetrical Tx-Rx WPT system featured similar improvement results with the preliminary well-aligned same-size Tx and Rx configuration. For example, charging of skin implanted devices, electrical vehicles, and unmanned aerial vehicles (UAVs). Possibly, the system can be applied to powering of deep tissue implanted devices utilizing optimally designed coils.

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