Preface

With recent developments in electronics and progress on micro/nano/biotechnologies, implantable biosystems have become more common. These systems help to improve the quality of health care. The measurement results can be obtained more precisely from the tissue thanks to the biosensors placed inside the body. Moreover, the patient can be monitored continuously for a long-term duration. All these benefits of the implantable systems help to diagnose the patient accurately, follow the progression of the treatment, or develop new therapy strategies for the patient.

The laboratory animals, especially rodents, are commonly used in many medical research projects due to their small size and reconfigurable DNA sequence. These animals are also essential in developing new drugs and medications. The drugs create side effects and toxic effects in the body. Therefore, the drugs should be tested on small animals before using them on humans. In this scope, an implantable biosensor system is necessary to monitor the vital signals of the animal continuously for a long-term duration. In addition, the animal should be in a stressless and natural environment to obtain reliable measurement results from the animal. Accordingly, the animal should be in a conventional living space and move freely to reduce stress.

This study proposes a batteryless remote-powered implantable microsystem for the freely moving small animal. Firstly, many different studies of the implantable systems for small animals have been investigated, and the current problems are pointed out. Accordingly, the objectives of this study have been defined. A prototype of an implantable system is realized, and the performances of the system are verified. The size and weight of the system should be minimized as much as possible for the comfort of the small animal. The volume and weight of the proposed microsystem are $12 \times 12 \times 2.3\,\text{mm}^3$ and 1.05 g, respectively. The overall implantable system is capable of remote powering and data communication. The power is transferred wirelessly by an optimized remote-powering link with more than 21 % of power transfer efficiency over a 30 mm distance. The link is driven by an efficient class E power amplifier at 13.56 MHz.

The implantable remote-powering electronics consist of AC-to-DC conversion & supply voltage generation and power management blocks. The induced AC voltage is converted to a DC voltage by a passive full-wave rectifier. The rectifier performs with 80 % of power efficiency for a 2 mW load condition. A high-speed voltage regulator follows the rectifier to generate clean and stable 1.8 V supply voltage. The voltage regulator has more than 60 dB of power supply rejection ratio at DC and in the frequency band of interest. The power management unit enables or disables the biosensors and communication blocks according to the available power level of the implantable system. The received power by the implantable system changes according to the movements of the animal. Moreover, the load of the rectifier also changes by the number of active biosensors and communication blocks. The power at the implantable system may not be sufficient to perform the functions; hence, the transferred power level should adapt to the demand of the implantable system. Therefore, the power feedback loop helps to keep the power level of the implantable system at a certain level by adapting the transferred power dynamically.

Data communication is another important challenge to overcome. There are different scenarios for uplink and downlink communication. One solution is to transmit the data by using the same channel with remote powering. However, a free moving animal in the living space can easily change the amplitude of the remote-powering signal. Accordingly, a suitable modulation method should be chosen to distinguish between data transmission and animal movement. Moreover, data communication using the remote-powering channel reduces the performance of the remote powering. In order to solve this issue, a low-power transmitter is implemented to operate over another channel at 869 MHz. The received signal is measured as −61 dBm at 40 cm away from the transmitter. In addition, a custom-designed receiver is realized with −85 dBm input sensitivity. The data rate of uplink communication can increase up to 1.5 Mb/s. For downlink communication, a PPM demodulator is designed to receive the commands at 13.56 MHz which are sent by using a remote-powering link. Therefore, the data rate is chosen as 5 kb/s to make sure the remote-powering performance is not degraded.

Finally, the power needs to be delivered to the implantable system in the whole living space. Therefore, the wireless power transfer should cover the whole bottom of the living space. An intelligent remote-powering (IRPower) system is proposed to track the animal in the living space and deliver the power to the implantable system efficiently. In addition, the IRPower system allows the continuous monitoring and the animal movement recording.

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