Nonvolatile Memories as the Data Storage System for Implantable ECG Recorder

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In this article, we propose a data storage system with the emerging nonvolatile memory technologies used for the implantable electrocardiography (ECG) recorder. The proposed storage system can record the digitalized real-time ECG waveforms continuously inside the implantable device and export the stored data to external reader periodically to obtain a long-term backup. Spin transfer torque random access memory (STT-RAM) and spintronic memristor are selected as the storage elements for their nonvolatility, high density, high reliability, low power consumption, good scalability, and CMOS technology compatibility. The new read and write schemes of STT-RAM and spintronic memristors are presented and optimized to fit the specific application scenario. The tradeoffs among data accuracy, chip area, and read/write energy for the different technologies are thoroughly analyzed and compared. Our simulation results show the configuration with a data sampling rate (e.g., 128 Hz) and a quantization resolution (e.g., 12 bits) can record 18-hour real-time data within $\sim 3.6\text{-mm}^2$ chip area when the data storage is built with single-level cell (SLC) STT-RAMs. Daily energy consumption is 5.46 mJ. Utilizing the multilevel cell (MLC) STT-RAMs or the spintronic memristors as the storage elements can further reduce the chip area and decrease energy dissipation.

Categories and Subject Descriptors: H.3.2 [**Information Systems Applications**]: Information Storage

General Terms: Design

Additional Key Words and Phrases: Spintronic, memristor, STT-RAM, SLC, MLC, ECG, data compression

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1. INTRODUCTION

The past decade has witnessed an extraordinary increase in the development of implantable electronics, which have extensive applications in medical treatments and health care. The examples include the physiological sensors, the cardiac monitoring [Riistama et al. 2007], the pacemakers [Wong et al. 2004], the memory restoration due to brain damage or disease [Berger 2005], etc. With implantation, the amount of disturbance caused by the measurement device to the actual measurand (i.e., the phenomenon to be measured) can be significantly reduced [Takahata et al. 2003]. Furthermore, by collecting the real-time signals, the implantable systems can provide a

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