Ph.D. Thesis Title

High Precision Biomedical Sensor Readout Circuits Design for Wearable Health Monitoring System

Abstract

With the increasing size of aging population, there has been a rising need to monitor the vital physical parameters of individuals in their daily life. Conventional sensing devices for health monitoring are usually bulky, expensive, and power-hungry, making it cumbersome for daily use. A miniaturized wearable biomedical signal monitoring system can certainly be a game changing technology to enable remote monitoring and diagnosis for personalized home healthcare.

Challenges such as the elevated compatibility of readout circuit with different types of sensors, the low power consumption requirement, high output resolution, and high output stability against environment changes are all popular research topics. In this project, the RC relaxation oscillator is explored as an alternative time domain frontend sensor readout circuit. Three designs have been proposed and fabricated. All designs are compatible with both the capacitive and resistive sensors. The first design achieves high energy efficiency and low phase noise, while the second realizes high output stability against environment changes. The third design combines verified ideas from the previous two, attaining a frontend with all advantages of the previous two designs. Meanwhile, the readout circuit for neuro signal is also researched in this project. The challenge comes from the large noises called artifacts, which are superposed with the neuro signal. The large artifacts cause the frontend to saturate easily, resulting in fail data conversion. A VCO-based Deep Sub Micron (DSM) readout circuit is proposed and fabricated in CMOS 40-nm process. It can operate under large input range of up to 100-mV_{pp} with high output resolution.

Despite of the work done, challenges lying ahead are still exciting. These challenges can be viewed in two ways, the integration of my existing frontends into systems, and the creation for even better readout circuits. Plans to deal with them are constantly being generated and more contributions to the subject matter will certainly be made in the near future.

<u>List of Scientific Publications</u>

1. W. Zhou, W. L. Goh, and Y. Gao, “A 1.6 MHz Swing-Boosted Relaxation Oscillator with ±0.15%/V 23.4 ppm/°C Frequency Inaccuracy using Voltage-to-Delay Feedback,” *2019 IEEE International Symposium on Circuits and Systems (ISCAS)*, Accepted, to be presented in IEEE ISCAS 2019.
2. W. Zhou, W. L. Goh, and Y. Gao, “Biomedical Temperature Sensor System with Relaxation-Oscillator-based Sensor Interface for High Precision Sensing,” *3rd Electron Devices Technology and Manufacturing (EDTM) Conference 2019*, Accepted, to be published in IEEE EDTM 2019 proceedings.
3. W. Zhou, W. L. Goh, J. H. Cheong and Y. Gao, "A 16.6 μW 3.12 MHz RC Relaxation Oscillator with 160.3 dBc/Hz FOM," *2018 IEEE International Symposium on Circuits and Systems (ISCAS)*, Florence, Italy, 2018, pp. 1-5.
4. W. Zhou, W. L. Goh, and Y. Gao, “A 3-MHz 17.3-μW 0.015% Period Jitter Relaxation Oscillator with Energy Efficient Swing Boosting,” *IEEE Transactions on Circuits and Systems II: Express Briefs (TCAS-II)*, Submitted, under review.
5. W. Zhou, W. L. Goh, and Y. Gao, “A 100-mV_{pp} Input Range 10-kHz BW VCO-based DSM Neuro-Recording Interface in 40-nm CMOS,” *2019 32nd IEEE International System-on-Chip Conference (SOCC)*, Submitted, decision pending.
6. W. Zhou, W. L. Goh, and Y. Gao, “A 1.6 MHz Swing Boosted Relaxation Oscillator with Voltage-to-Delay Feedback,” *IEEE Transactions on Circuits and Systems I: Regular Papers (TCAS-I)*, To be submitted by Aug 2019.
7. W. Zhou, Y, Chen, W. L. Goh, and Y. Gao, “A delta-sigma modulator for high dynamic range biomedical sensor interfaces with current re-use Gm-CCO integrator and differential phase quantizer,” to be submitted as a journal paper.