A Fully Integrated Analog Differentiator for Derivative of Photoplethysmographic Signal Processing

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***Abstract*— A fully integrated analog differentiator is designed to process derivatives of photoplethysmographic (PPG) signals which provide much critical information on physiological system. In order to satisfy the requirement of ultra-low frequencies application, an ultra large time constant integrator in the feedback loop is obtained by adopting the current steering technique. The simulation results demonstrate that the derivative of analogue signal at very low frequencies can be processed over frequency range from 10^{-2} to 10^{3} Hz.**

I. Introduction

It has been reported that the information extracted from the second derivative of PPG is correlated with age and other risk factors for atherosclerosis [1]. Therefore, the objective of this study is to develop a signal acquisition circuit which can be used for obtaining the degree of change (i.e., the time derivative) of PPG signal. In order to meet the requirements of miniaturization, it is an appropriate choice to integrate signal conditioners and processing units into a whole circuit. Based on this, we present a novel on-chip analog differentiator circuit towards the processing derivative of PPG signal.

II. Circuit Concept and Design

The schematic of the proposed differentiator is demonstrated in Figure 1. In the path of feedback signal control, the amplifier A2, passive elements C1 and R1, and transistors NM1 and NM2 constitute an ultra large time-constant integrator. Acting as the current-steering transistors [2], transistors NM1 and NM2 control the current I_{D1} flows across the capacitor C1. The time constant R1·C1/α (α is given by $\alpha=I_{D1}/I_{D2}$ ($\alpha<1$)) of integrator is tuned by varying transistors NM1 and NM2 gate voltages. The relationship between input and output of the differentiator is given by

$$V_{out} = \frac{R2}{R0}\frac{R1C1}{\alpha}\frac{dV_{in}}{dt} \qquad (1)$$

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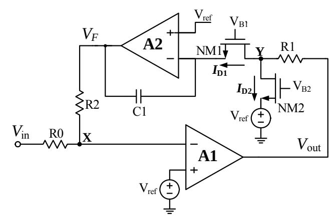

Figure 1. Schematic of the proposed analog differentiator circuit

III. Simulation Results

The proposed differentiator was implemented in 0.18-μm CMOS process with a supply voltage of 1.8 V. In order to validate the functionality of the proposed differentiator, the proposed circuit was simulated with a triangular waveform voltage as input voltage, as shown in Figure 2. The simulated results demonstrate that the triangular waveform voltage of input signal was converted into the rectangular waveform voltage of output signal. The amplitude-frequency response was also simulated and clearly indicated that the proposed differentiator is working well for the frequency range from 10^{-2} to 10^{3} Hz.

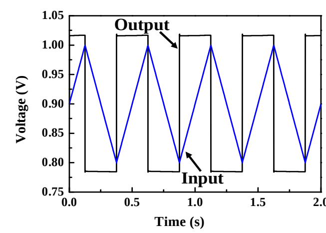

Figure 2. Input and output simulation waveforms of proposed differentiator

IV. Summary

A fully integrated analog differentiator at very low frequencies is proposed. The simulated results demonstrate that it can work well over the frequency range from 10^{-2} to 10^{3} Hz and consumes 243 μW at 1.8 V. This proposed differentiator can be used to process derivative of PPG signal at very low frequencies.

References

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