14.85 µW Analog Front-End for Photoplethysmography Acquisition with 142-dBΩ Gain and 64.2-pArms Noise

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Abstract— This study presents an AFE designed for wearable PPG systems, characterized by low power consumption, high gain, and low noise. Fabricated using a 0.35 µm CMOS process, the AFE achieves a transimpedance gain of 142 dBΩ and an input-referred noise of 64.2 pArms. Key features include a BGL cancellation loop, automatic gain control, and efficient integration to minimize silicon area.

Keywords— analog front-end; low power; photoplethysmography; transimpedance amplifier.

I. INTRODUCTION

PPG signals are critical for applications like SpO2 measurement, cardiovascular disease diagnosis, heart rate, and blood pressure monitoring. The system includes LEDs as transmitters and photodiodes followed by a transimpedance amplifier (TIA) as receivers. The proposed AFE system focuses on the AC component of the PPG signal for blood pressure calculations, aiming for a gain above 140 dBΩ and noise below 100 pArms.

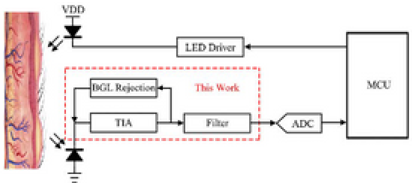

Fig 1. The system diagram of a typical PPG monitoring application.

II. PRINCIPLE OF GENERATION

The principle of generation in this context encompasses several stages, each contributing to the precise capture and enhancement of the PPG signals. Here, we delve into the key components and their roles in the overall system. The Transimpedance Amplifier (TIA) serves as the initial stage in the AFE, converting the current generated by the photodiode in response to light pulses into a voltage signal. This configuration converts the input current (I_PD) into a proportional voltage (V_OUT1), following the relationship V_OUT1 = I_PD * R_f. To achieve low noise performance, the TIA is designed to operate with high transimpedance gain.

The BGL cancellation loop uses an integrator circuit to filter out the low-frequency DC component.This loop comprises an Error Amplifier (EA), a MOSFET (M_ctrl), and a control capacitor (C_EA). The EA compares the output of the TIA to a reference voltage (V_ref) and adjusts the gate voltage of M_ctrl to counteract the DC component.Following the TIA, the Secondary Amplifier (SA) further amplifies the signal. This stage ensures that the amplified PPG signal has sufficient amplitude for accurate processing.The AGC block dynamically adjusts the gain of the SA to accommodate varying signal amplitudes. This is crucial for maintaining a consistent output level despite fluctuations in the input signal strength.he LPF stage filters out high-frequency noise components, ensuring that the output signal is smooth and within the desired frequency band for PPG signals.

III. IMPLEMENTATION

The proposed AFE has four stages, as shown in Fig 2. The first stage (TIA) converts photocurrent from PD (IPD) into a voltage VOUT1 with a high transimpedance gain (122 dBΩ)

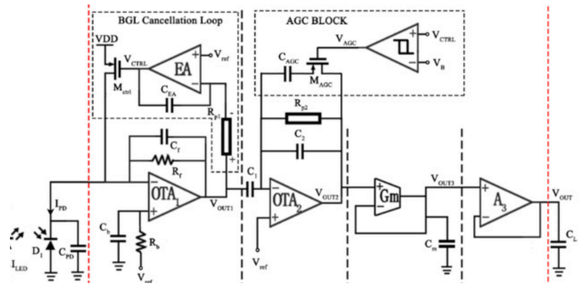

Fig 2. The architecture of the AFE.

A current source or a photodiode model, OTA models from the skywater 130 nm PDK can be used as photodiode. Designing the feedback network using appropriate resistors and capacitors gives high gain and low noise.Include an error amplifier (EA) and a MOSFET. Use capacitors and resistors to form the loop filter.Use the OTA model again for this stage. Design the feedback network to achieve the required gain.Implement the AGC circuit using comparators and control MOSFETs available in the PDK. Design the control loop with appropriate passive components.Use transconductance amplifiers (Gm) and capacitors.Design using an OTA or an operational amplifier model from the PDK.

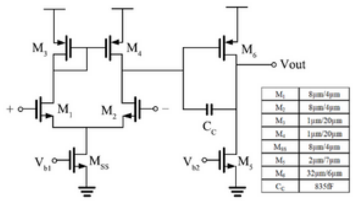

Fig 3. The schematic of OTA

IV. ISSUES & IMPROVEMENTS

The AFE may exhibit higher noise levels than desired, impacting the sensitivity and accuracy of the PPG signal detection. Optimize the design of the transimpedance amplifier (TIA) to reduce input-referred noise. This includes selecting low-noise operational amplifiers and minimizing resistor values in the feedback network to lower thermal noise.

V. CONCLUSION & FUTURE SCOPE

The proposed AFE demonstrates significant improvements in power efficiency, gain, and noise performance for wearable PPG systems. The integration of BGL cancellation and AGC enhances dynamic range and signal fidelity, making it suitable for low-power, high-precision biomedical applications..

REFERENCES

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