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Wearable Bio-Sensing Series

Application

Cuffless blood pressure monitoring on a wearable device is based on the concept of Pulse Wave Velocity (PWV) which refers to the velocity of the pulse wave across the arteries due to cardiac activity. Blood pressure determines arterial stiffness which in turn affects the PWV. Therefore, changes in blood pressure are reflected as changes in the PWV. Today’s wrist-worn devices support both photoplethysmogram (PPG) and electrocardiogram (ECG) signal acquisitions. Using the relative delay between the ECG and PPG waveforms, a parameter called Pulse Arrival Time (PAT) can be determined which has a correlation to PWV.

In a smartwatch, the PPG signal can be acquired using light-emitting diodes (LEDs) and photodiode (PD) both facing the wrist. The ECG signal can be acquired using a pair of electrodes – one in contact with the left wrist, and the other touched by the finger of the right hand. A third right leg drive (RLD) electrode typically in contact with the wrist, sets the potential relative of the body to the watch ground.

Figure 1 shows synchronized ECG and PPG waveforms. PEP, PTT and PAT refer to pre-ejection period, pulse transit time, and pulse arrival time, respectively.

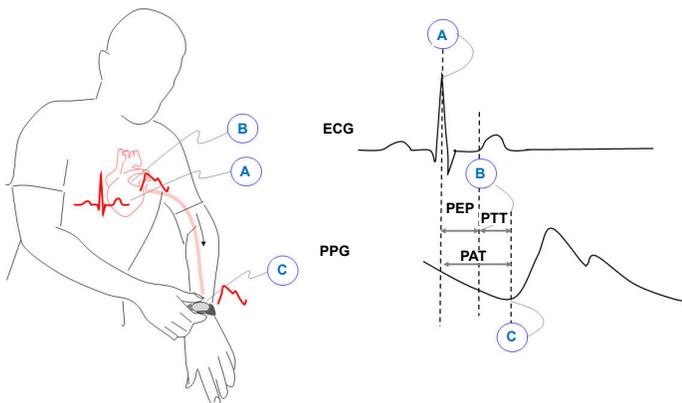


Figure 1. Synchronized ECG and PPG Waveforms

Figure 2 shows the scheme for blood pressure monitoring on a wearable device.

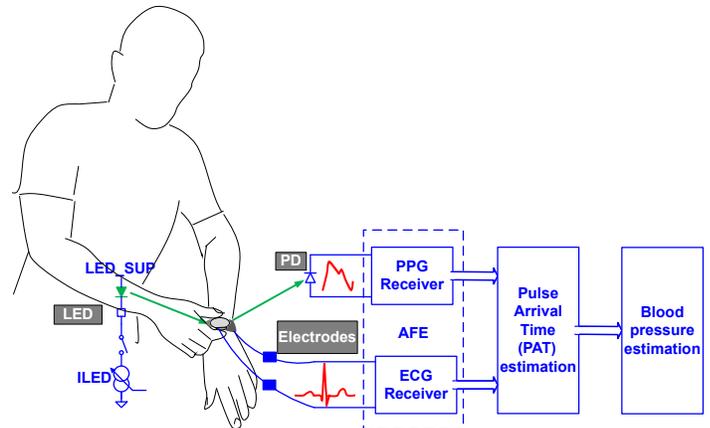


Figure 2. Blood Pressure Monitoring on a Wearable Device

The AFE4950 is an analog front end from Texas Instruments that enables synchronized acquisition of PPG and ECG signals, and is designed for cuffless blood pressure monitoring on a wearable device.

AFE4950 Overview

- **Interface:** SPI™, I²C interfaces: Selectable by pin
- **Package:** 2.6-mm × 2.5-mm DSBGA, 0.4-mm pitch
- **Supplies:** RX: 1.7 V–3.6 V, TX: 3.0-5.5V

AFE4950 Features

- First in, first out (FIFO) with 256-sample depth
- Internal oscillator, external clock options
- Integrated LDO

AFE4950 Differentiation

- PPG signal chain with wide adaptability (LED current, transimpedance amplifier (TIA) gain, offset digital-to-analog converter (DAC) range) for variety of use cases including low perfusion index, high ambient, and motion.
- High-quality ECG signal acquisition from small form-factor electrodes with high-contact impedance – high-input impedance, RLD electrode to improve CMRR
- Flawless timing synchronization between PPG and ECG signal acquisition

Table 1 lists the specifications for a cuffless blood pressure monitoring application.

Table 1. Specifications for Cuffless Blood Pressure Monitoring on Wearables

System Specifications	AFE4950	Comments
Multi-sensor PPG support	8 LEDs, 4 PDs	Combining signals from multiple PDs and LEDs improves accuracy and helps mitigate motion artifacts.
Number of ECG Electrodes	3	Two electrodes for ECG signal acquisition, and a third electrode to drive RLD
PPG signal acquisition – peak signal-to-noise ratio (SNR)	110 dB	Enables high-accuracy PPG monitoring even in low perfusion cases
ECG signal acquisition - Noise	0.7 μV_{RMS}	In a 0.5-Hz to 150-Hz band

Figure 3 shows the reference schematic for a cuffless blood pressure monitoring system using AFE4950.

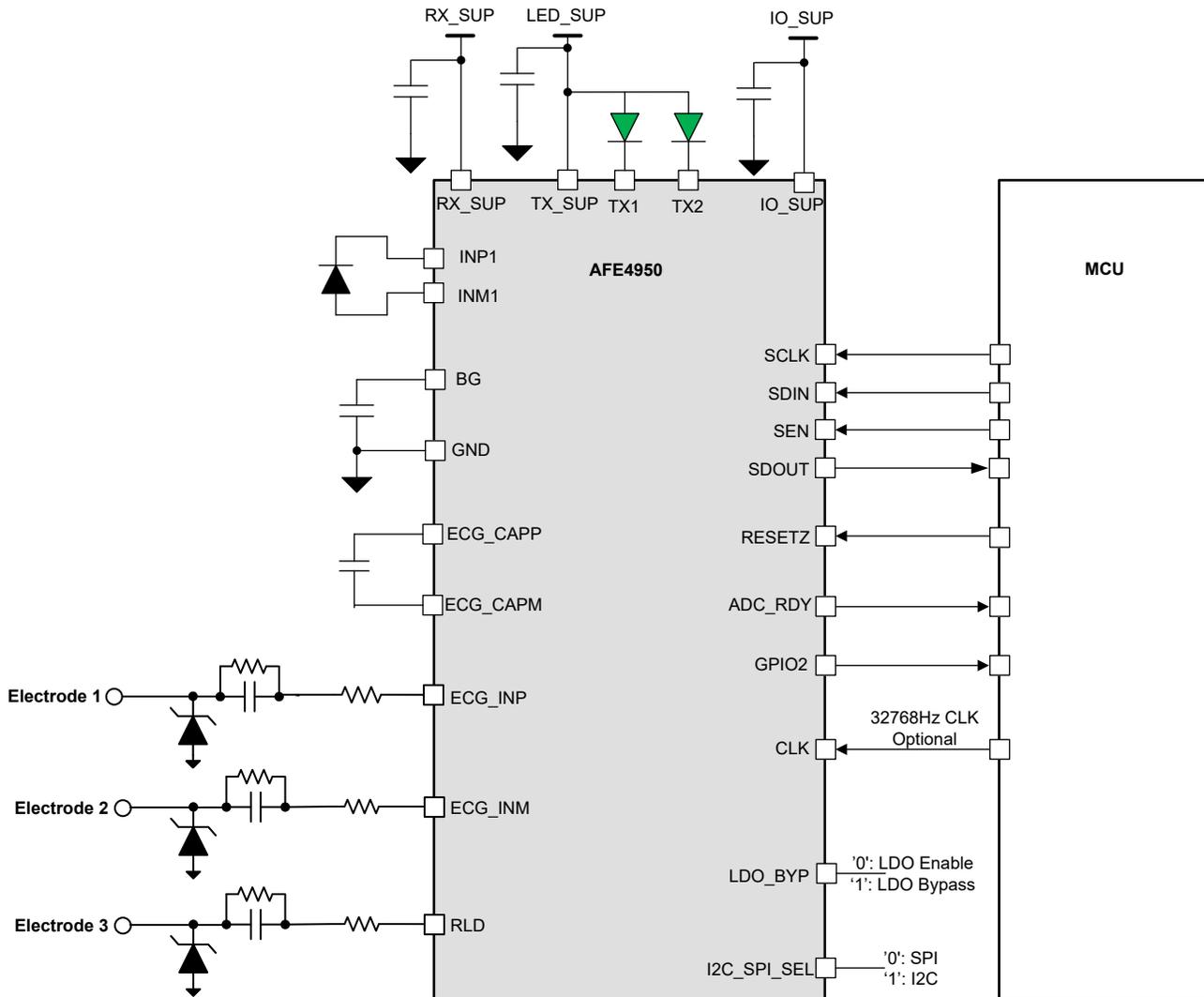


Figure 3. Reference Schematic for a Blood Pressure Monitoring System Using AFE4950

Figure 4 shows the AFE4950 signal chain. The output of the PPG and ECG front ends are converted by the same analog-to-digital converter (ADC) in different time slots, resulting in a flawlessly-synchronized signal acquisition of PPG and ECG.

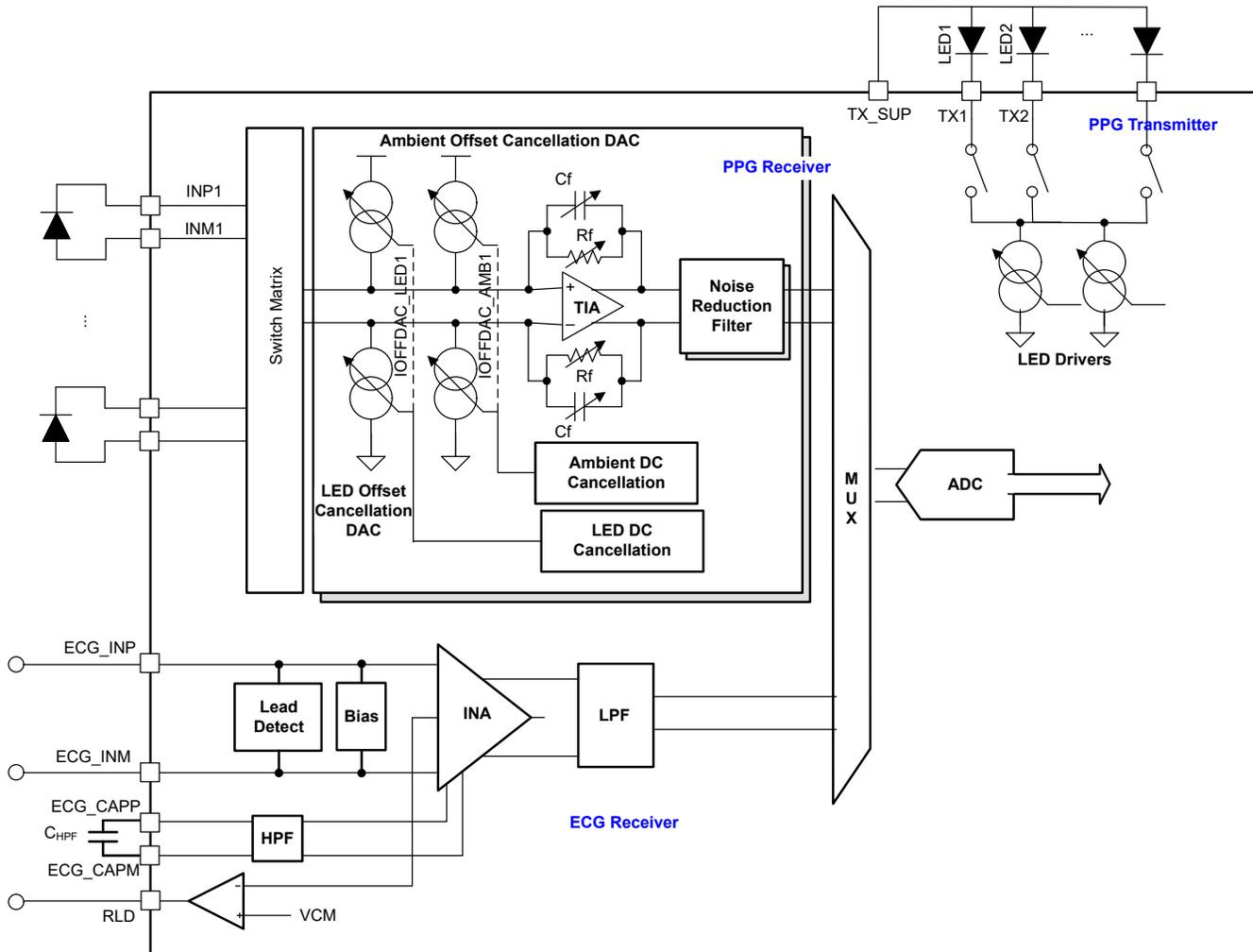


Figure 4. AFE4950 Signal Chain

Other analog front ends from Texas Instruments that support blood pressure monitoring on wearable devices include the AFE4960, AFE4960P, and AFE4500.

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