Application Brief

Measuring Oxygen Saturation (SpO_2) on Wearables

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Wearable Bio-Sensing Series

Application

Oxygen Saturation (SpO_2) has long been considered a vital parameter to be monitored as part of clinical patient care, and has been measured using pulse oximeter devices since the 1970s. Clinical SpO_2 monitoring is most commonly done on the finger, with light-emitting diodes (LEDs) positioned on one side of the finger, and a photodiode (PD) on the other side. Such a method is referred to as transmissive pulse oximetry since the light transmitted by the LED passes through the thickness of the finger. The light is absorbed differently by the different components (skin, blood, tissue, and so forth), finally incident on the PD.

SpO_2 monitoring is also used in wrist-worn wearable devices like smartwatches, serving as a parameter to asses and monitor the user's physical condition during exercise. SpO_2 monitoring on the wrist uses reflectance pulse oximetry, where the LEDs and photodiode both face the wrist, and the light from the LED is reflected by the skin and various layers below the skin, then incident on the photodiode. SpO_2 monitoring on the wrist has also been used to track the quality of sleep and has the potential to detect disorders like sleep apnea. More recently, SpO_2 has emerged as a significant parameter, the lowering of which serves as an early indicator of Covid-induced hypoxia.

AFE4432 Overview

The AFE4432 is a low-power, high-performance analog front end (AFE) from TI which enables accurate SpO_2 monitoring on a wearable device.

- *Interface*: SPI™, I^2C interfaces: Selectable by pin
- *Package*: 1.9-mm × 1.8-mm DSBGA, 0.35-mm pitch
- *Supplies*: *RX*: 1.7 V–1.9 V, *IO*: 3.0 V–5.5 V
- *Features*:
  - First in, first out (FIFO) with 160-sample depth
  - Internal oscillator, external clock options

AFE4432 Differentiation

- Signal chain has wide adaptability (LED current, transimpedance amplifier (TIA) gain, offset digital-to-analog converter (DAC) range) for a variety of use cases including high ambient and motion
- High peak signal-to-noise ratio (SNR) enables excellent SpO_2 accuracy even under the most challenging use cases
- Separate measurement of DC and AC components of photoplethysmography (PPG) signal enables accurate SpO_2 at very low perfusion index

Figure 1 shows the illustration of an SPO_2 monitoring system on a wearable device.

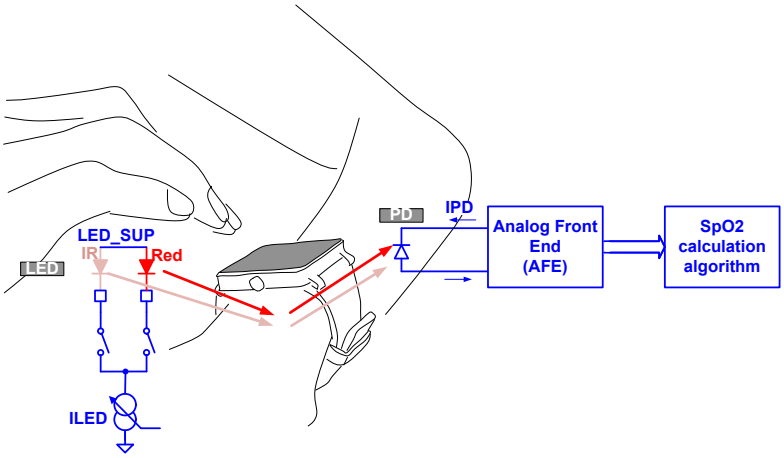

Figure 1. SpO_2 Measurement on a Wearable Device

Figure 2 shows the reference schematic for an SPO_2 system using the AFE4432.

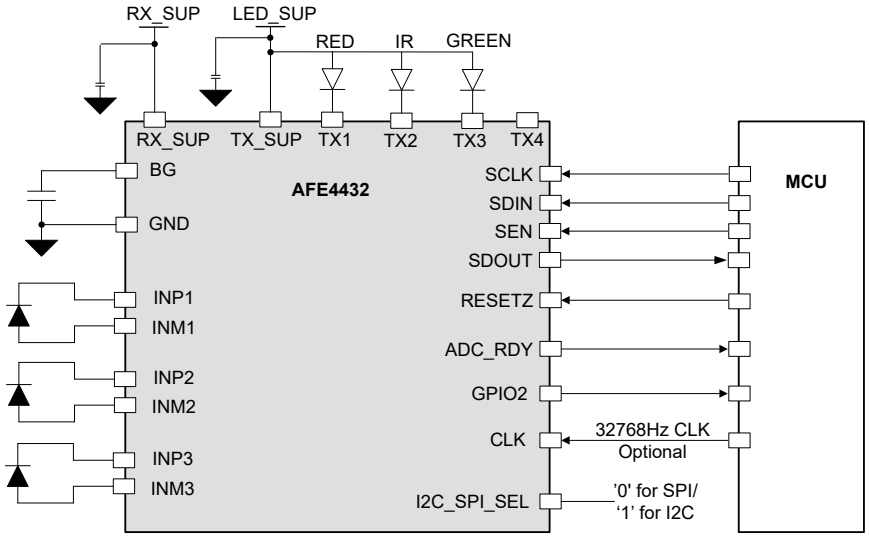

Figure 2. Reference Schematic for an SPO_2 System Using AFE4432

Table 1 lists the key specifications for an SPO_2 measurement system.

Table 1. Specifications for SpO_2 Measurement on Wearables

System Specifications	AFE4432	Comments
Multi-sensor support for SpO_2, heart rate monitoring	4 LEDs, 3 photodiodes (PDs)	A typical SpO_2 system can use a green LED in addition to red and infrared (IR) LEDs. The red and IR wavelengths share the same PD, whereas the green wavelength can use a different PD.
Sampling rate	1 Hz–1 kHz	A typical SpO_2 application can use a sampling rate of a few 100s of Hz
Peak SNR	115 dB over 10-Hz bandwidth	Important consideration to achieve good accuracy in low perfusion cases
Ambient rejection	> 70 dB up to 160 Hz	Good ambient rejection helps remove the spurious tones caused by ambient light from sources such as indoor lighting.

Figure 3 shows the PPG signal chain in AFE4432 and the interface to external LEDs and PDs.

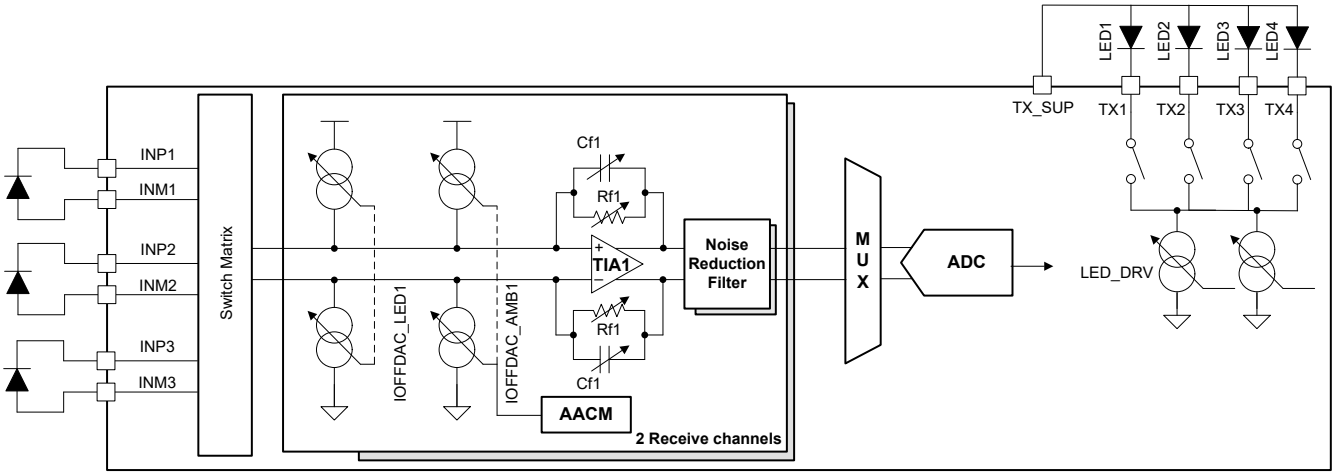

Figure 3. PPG Signal Chain in AFE4432

The LED driver drives up to 4 LEDs with programmable current. Each receiver can interface to up to 3 PDs and comprises a TIA, input DC offset cancellation DACs (for ambient, LED light), and a noise reduction filter with programmable bandwidth. Both receivers share a common analog-to-digital converter (ADC). SpO_2 monitoring on wearables is also supported on several other AFEs from Texas Instruments. Recent products include the AFE4950, AFE4960P, and AFE4500.

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