ADI Typical Module in Patient Monitor

Pulse Oximeter Solution

Pulse Oximeter System Theory and Typical Architecture

The pulse oximeter noninvasively measures oxygen levels in the blood. It is measured as a percentage of full saturation level and is expressed as a single number known as the saturated percentage of oxygen, often referred to as SpO2. The measurement is based on the light absorption characteristics of hemoglobin in the blood. Oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hb) have different absorption curves across the visible and near IR spectrum. Hb absorbs more light at red frequencies and less light at infrared (IR) frequencies. HbO2 absorbs less light at red frequencies and more light at IR frequencies. The red and IR LEDs are located as close as possible to each other and transmit light through a single tissue site in the body. The red and IR LEDs are time multiplexed to transmit light, so they do not interfere with each other.

Ambient light is estimated and subtracted from each red and IR signal. A single photodiode that responds to both red and IR light receives light, and a transimpedance amplifier generates a voltage proportional to the received light intensity. The ratio of the red and infrared light received by the photodiode is used to calculate the percentage of oxygen in the blood. Based on the pulsatile nature of blood flow, the pulse rate and strength are also determined and displayed during the measurement cycle.

The pulse oximeter includes transmit path, receive path, display and backlighting, data interface, and audio alarms. The transmit path include red, IR LEDs, and DAC used to drive the LED. The receive path includes photodiode sensor, signal conditioning, analog-to-digital converter, and processor.

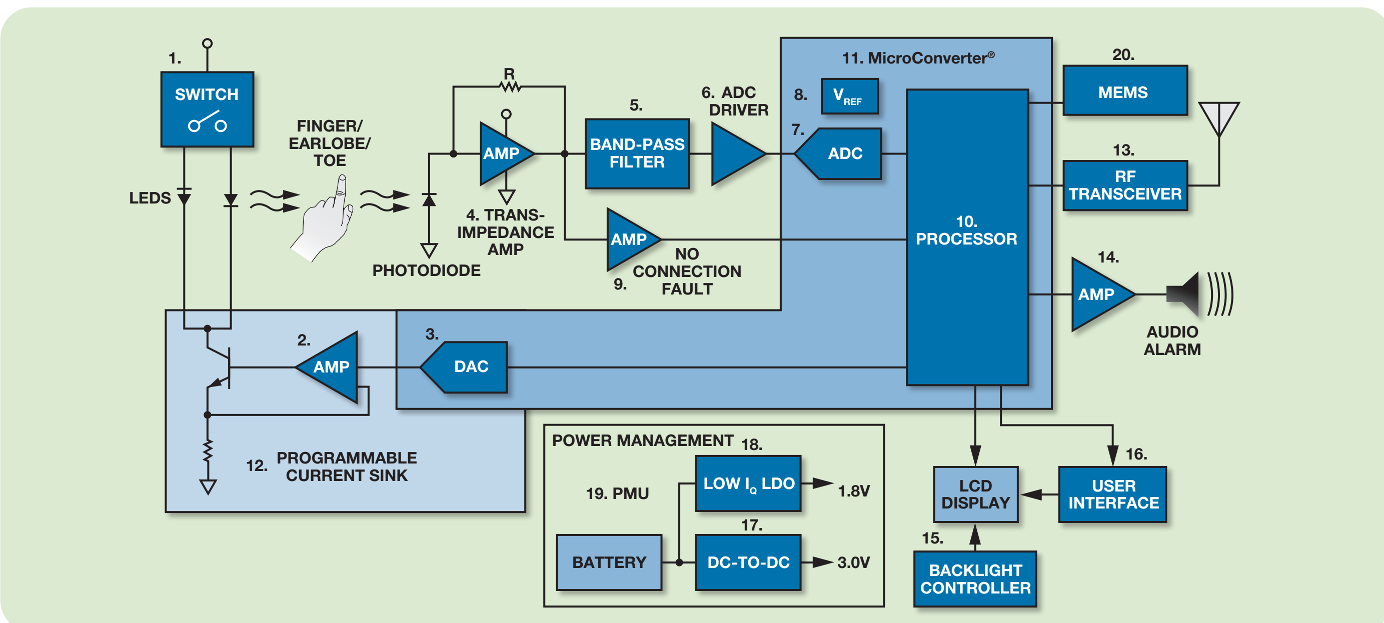
Pulse Oximeter System Design Considerations and Major Challenges

When designing pulse oximeter systems, there are various challenges to overcome, such as low perfusion, motion and skin moisture, stray light interferences, and carboxyhemoglobin and methemoglobin interferences.

- Low perfusion (small signal levels). Photodiode measurements require signal conditioning with wide dynamic range and low noise gain to capture the pulse event. High quality, lower noise LED drive circuits with high resolution DAC and high precision analog front end circuits with high resolution ADC are required for the transmit and receive path.
- Motion and skin moisture. Motion causes artifacts that can be overcome by software algorithm, or accelerometers such as the ADXL345 can be used to detect and overcome it.
- Stray light interferences. The photodiode is used to responded to both red and IR light, and it is easy to be interfered with by ambient light. So the algorithm used to filter out the interested signal for red and IR is very important, which means the signal processing is more complex. In this case, DSP with higher signal processing power is required.
- Carboxyhemoglobin and methemoglobin. Carbon monoxide (CO) attaches easily to hemoglobin, which makes the blood more similar to red HbO2. The measurement results in a falsely high SpO2 value. The iron in the heme group is in an abnormal state and cannot carry oxygen (Fe+3 instead of Fe+2), resulting as reduced hemoglobin, making the SpO2 reading falsely low. Using more wavelengths can improve accuracy, but it needs higher performance digital processing—DSP. Processing timing is critical.

Pulse Oximeter Functional Block Diagrams

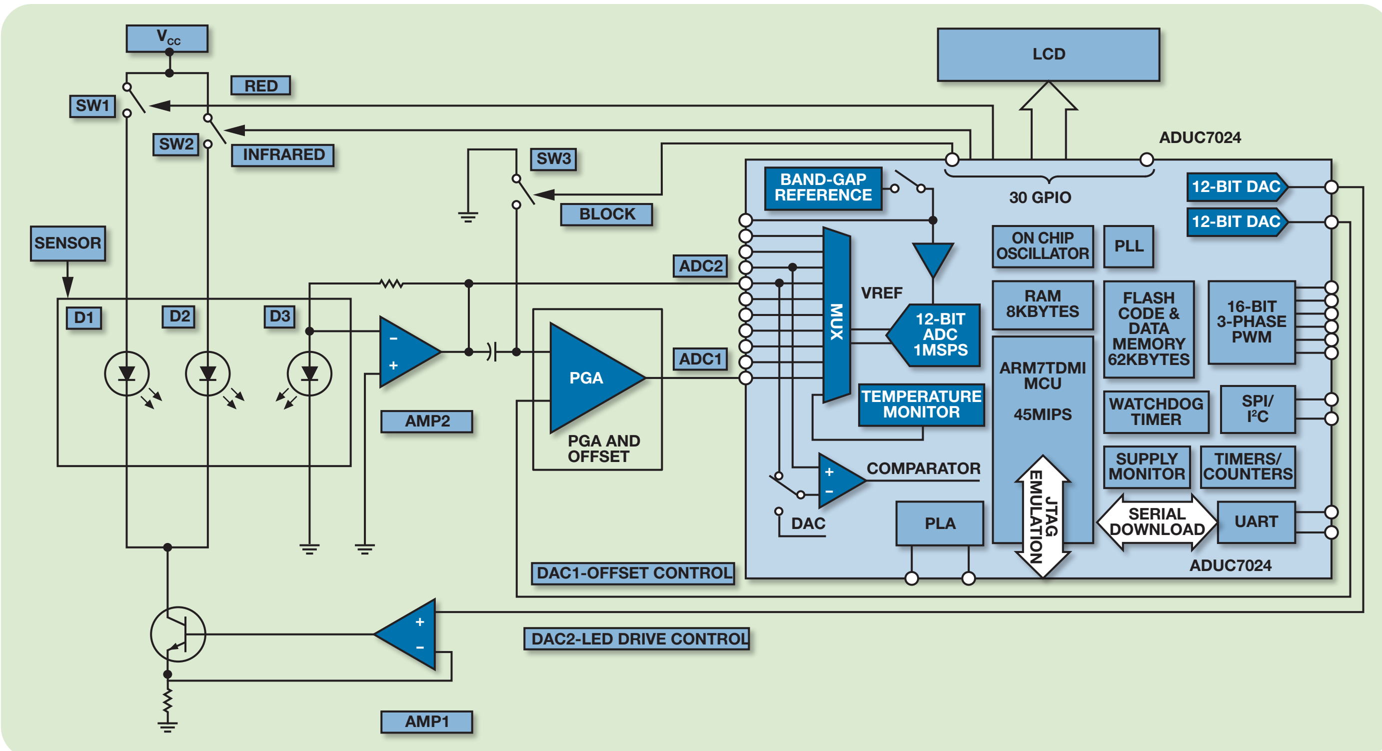
ADI offers a comprehensive portfolio of high performance linear, mixed-signal, MEMS, and digital signal processing technologies for pulse oximeter designs. Our data converters, amplifiers, microcontrollers, digital signal processors, RF transceiver, and power management products are backed by leading design tools, applications support, and systems expertise.



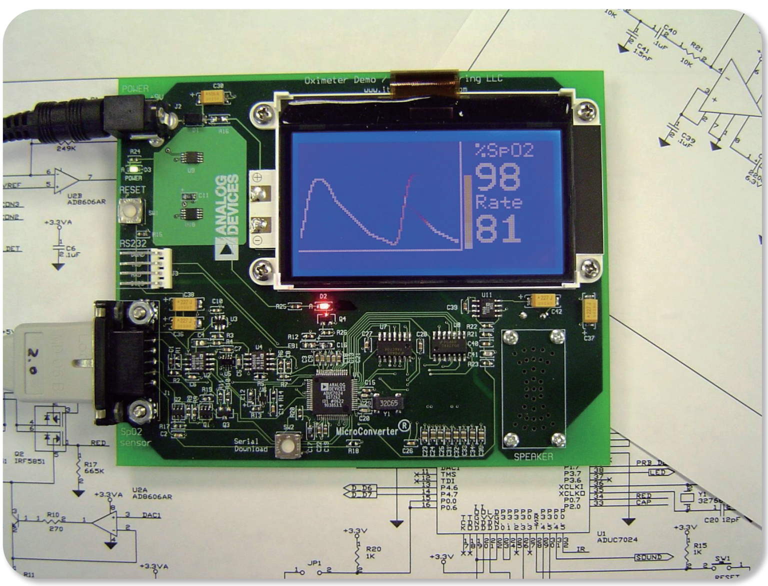
1. Switch	2. Buffer Amp	3. DAC	4. Transimpedance Amp	5. Band-Pass Filter	6. ADC Driver	7. ADC	8. Voltage Reference	9. No Connection Fault Amp	10. Processor
ADG819 ADG820 ADG823 ADG779	AD8663 AD8605 AD8606 AD817	AD5541 AD5542 AD5160	AD8065 ADA4817 ADA4004 AD8606	ADA4898-1 AD8606 AD8610 ADA4051	ADA4841-1 ADA4932-1 ADA4505 AD8606	AD7685 AD7942 AD7980 AD7683	ADR29x ADR36X ADR42X ADR43X	AD8605 AD8601 AD8613 AD8541	ADSP-BF51x ADSP-BF52x ADSP-BF592
11. Microconverter	**12. Current Sinking DAC**	**13. RF Transceiver**	**14. Audio Power Amp**	**15. Backlight Controller**	**16. User Interface**	**17. DC-to-DC**	**18. LDO**	**19. PMU**	**20. MEMS**
ADUC702x	AD5398	ADF7020 ADF7021 ADF7025	SSM2211	ADP5501 ADP5520 ADP8860 ADM8843	AD7147 AD7148	ADP1612 ADP2108 ADP3050 ADP2503	ADP170 ADP171 ADP121 ADP1720	ADP2140 ADP5023 ADP5043	ADXL345 ADXL346

Note: The signal chains above are representative of pulse oximeter design. The technical requirements of the blocks vary, but the products listed in the table are representative of ADI's solutions that meet some of those requirements.

SpO2 Demonstration System Block Diagram



SpO2 Demonstration System



Introduction of Main Products for Pulse Oximeter

Part Number	Description	Benefits
ADC		
AD7980	16-bit, 1 MSPS, 1.5 LSB (24 ppm); PulSAR® differential ADC; pin for pin compatible with 18-bit version, AD7982, AD7986 (2 MSPS)	High speed, high accuracy; pin for pin compatible series can be flexibly selected
AD7685	16-bit; maximum 2 LSB INL; 250 kSPS PulSAR differential ADC; pin for pin compatible with 18-bit version: AD7691	Higher resolution, lower INL for high accuracy sampling system
Amplifiers		
AD8605	Low noise: 8 nV/√Hz, low input bias currents: 1 pA maximum, low offset voltage: 65 μV maximum, high open-loop gain: 1000 V/mV	Low noise, low bias current, low offset, and high gain improve system performance
AD8065	Low noise: 7 nV/√Hz (f = 10 kHz) and 0.6 fA/√Hz (f = 10 kHz), FET input, 1 pA input bias current; voltage range from 5 V to 24 V	Low noise, low bias current, high input impedance provide high performance for current to voltage conversion
ADA4841	Low wideband noise : 2.1 nV/√Hz and 1.4 pA/√Hz; low 1/F noise: 7 nV/√Hz @ 10 Hz and 13 pA/√Hz @ 10 Hz; rail-to-rail output	Suitable for ADC driver with up to 10 pF of capacitive load drive capability; low noise for small signal conditioning
DAC		
AD5541/ AD5542	Full 16-bit performance, 1 LSB INL accuracy, 1.5 MSPS update rate, 1 μs settling time; unbuffered output capable of driving 60 kΩ loads	Low noise performance low power consumption suitable for high performance and portable application
AD5398	10-bit DAC with 120 mA output current sink capability, 31 kSPS update rate, 250 μs settling time	Big current sink capability; integrated current sense resistor; easy for SpO2 transmit application
Processor		
ADuC7xxx	Precision analog microcontrollers; 12-bit analog I/O; ARM7TDMI MCU; 40 MIPS MCU speed	SoC, higher integration with signal besides MCU benefits to small size applications; larger memory for data storage
ADSP-BF592	Low cost entry point into the blackfin portfolio of processors; with a 400 MHz core clock speed and a peripheral set	High data processing capability and flexible peripheral interface, and low cost to reduce BOM cost
ADSP-BF51x	Highly integrated system-on-a-chip solutions for the next generation of embedded network connected applications; with a 400 MHz core clock speed and a peripheral set	Low cost, low power, general-purpose parts with enhanced internet and consumer connectivity
ADSP-BF52x	Provides good scalability 600 MHz odd numbered and 400 MHz even number product; with rich set of peripherals and connectivity options	Low power processors that balance the combination of high performance, power efficiency, system integration to enable highly optimized designs
Analog Switch		
ADG820	0.25 Ω max on-resistance flatness, low on resistance 0.8 Ω max at 125°C, 200 mA current carrying capability	Lowest on resistance guarantees the signal integration and quality
Voltage Reference		
ADR43x	Ultralow noise, voltage references with current sink and source; 0.15% accuracy and 10 ppm/°C for a grade	Current sink and source; simple driver circuits; low drift and high accuracy benefit ADC sampling performance
MEMS accelerometer		
ADXL345/ ADXL346	Small, thin, ultralow power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16 *g*; output is formatted as 16-bit	Well suited for mobile device applications, such as SpO2 motion detection; low power modes can reduce power consumption
Capacitance to Digital Converter		
AD7147	Integrated CDC with on-chip environmental calibration; 13 inputs channeled through a switch matrix to a 16-bit, 250 kHz sigma-delta ADC	High integration for implementing buttons, scroll bars, and wheels; sensor needs one PCB layer for ultrathin systems
Audio Power Amplifiers		
SSM2211	1.5 W output, highly stable phase margin: >80 degrees, low distortion: 0.2% THD + N @ 1 W output, wide bandwidth: 4 MHz	Low distortion audio power for audio application; continues to operate down to 1.75 V suitable for battery applications
Backlight Driver		
ADP5520	Backlight driver with I/O expander, efficient asynchronous boost converter for driving up to 6 white LEDs	Capable of controlling the slider backlight intensity, on/off timing, dimming resulting in valuable battery power saving
RF/IF ICs		
ADF702x	High performance ISM and licensed band transceivers	Allows device to operate in the presence of strong interferers with high sensitivity; low power consumption
Power Management		
ADP2503	600 mA, 2.5 MHz buck-boost dc-to-dc converter; 38 μA typical quiescent current	Less external components and small inductor for circuit design, suitable for portable applications
ADP121	5.5 V input, 150 mA, low quiescent current, CMOS LDO	Low I_Q for high accuracy; easy to use
ADP2140	5.5 V input, 3 MHz, 600 mA, low quiescent current buck with 300 mA LDO regulator	Integrated with switch regulator and LDO, easy to use

Circuits From The Lab™ Reference Circuits for Pulse Oximeter

Refernce circuits are subsystem-level building blocks that have been engineered and tested for quick and easy system integration.

- *High Precision, Low Power, Low Cost Pulse Oximeter Infrared and Red Current Sinks Using the ADA4505-2 10 µA Zero Input Crossover Distortion Op Amp, ADR1581 Precision Shunt Voltage Reference, and ADG1636 Dual SPDT Switches* (CN0125)—*www.analog.com/CN0125*

Design Tools

ADIsimOpAmp: Amplifier Parametric Evaluation Tool
www.analog.com/ADIsimOPAmp

To view additional pulse oximeter resources, tools, and product information, please visit:
www.analog.com/healthcare/pulse-oximetry

To obtain a sample, please visit:
www.analog.com/sample

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