Wireless Heart Rate and Oxygen Saturation Monitor

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Wireless Heart Rate and Oxygen Saturation Monitor

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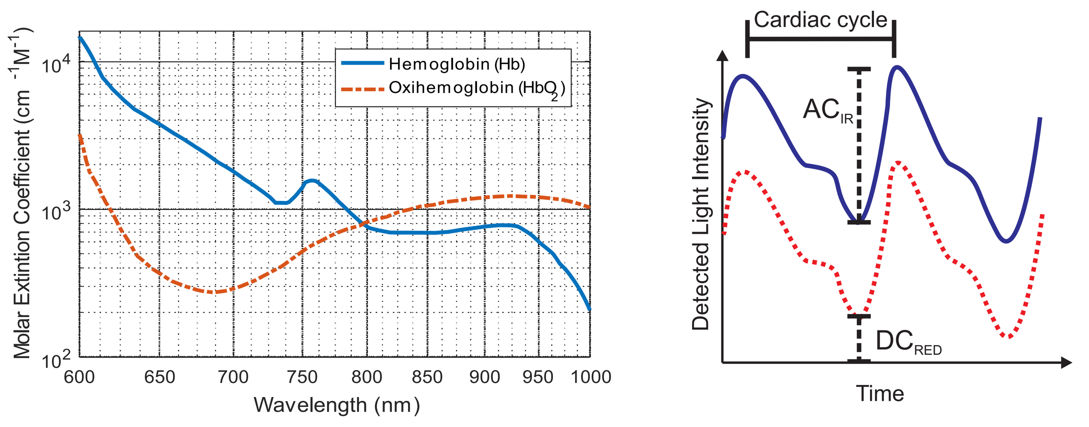
Abstract. In this paper a wireless microcontroller based heart rate and oxygen saturation monitor, known as pulse oximeter, is described. Pulse oximetry is a non-invasive method which uses the signal of two light sources at dierent wavelength and a photodetector to capture the amount of light that is transmitted through a tissue. The signal captured, named photoplethysmogram signal (PPG), is used to determine Oxygen Saturation (SpO2) and Heart Rate (HR). The system presented has the peculiarity that it is connected to a wireless local network though Wi-Fi technology; the information is transmitted in real time to a webpage for remote monitoring. The measurements obtained in finger measurements are compared with a commercial pulse oximeter using the Bland-Altman method. The obtained results present reliable measurements of SpO2 and HR.

INTRODUCTION

- Vital signs monitors are devices that continuously detect and show physiological parameters of a patient.
- Continuous monitoring of these parameters helps physicians to make medical evaluations, enhance treatment, improve diagnostics and take decisions in benefit of the patients [1].
- In medical emergency situations, such as in a road traffic accident, a natural disaster, earthquakes, search and rescue situations, a first response instrument is used.
- Some patients require continuous observation of their vital signs in spite of not being hospitalized.
- For these reasons is highly desirable to transmit the information to a trained physician in a controlled facility to perform life decisions.

METHODS

- Pulse oximetry is a non-invasive method that measures oxygen saturation and heart rate of a person.
- A pulse oximeter consists of two sources of light at different wavelength, typically red and infrared LEDs, and a photodiode, that measures the intensity of the transmitted and/or reflected light from the tissue is used, also called the photoplethysmogram signal (PPG) [2].
- The ratio of oxygen-rich hemoglobin, named oxyhemoglobin, to the total concentration of hemoglobin, determines the oxygen saturation.
- A pulse oximeter relies in the differential absorption properties of the hemoglobin (*Hb*) and oxyhemoglobin (*HbO_2*), at different wavelengths, and the DC and AC components of the PPG signal. As seen in Figure 1.



a) Absorption Spectra b) PPG signals

FIGURE 1. Absorption spectra and PPG signals

Implementation

- In order to perform remote measurements of heart rate and oxygen saturation we assemble a pulse oximeter and wireless communication unit in a single device
- A reusable pulse oximetry sensor is used to capture the PPG signal.
- The integrated circuit (IC) AFE4490 from Texas Instruments converts the current from the photodiode to numerical information, controls the on/off sequencing along with the light intensity of the LEDs.
- The signal processing is computed in a TM4C123GH6PM 32-bit microcontroller from Texas Instruments. PPG signals are digitally filtered and then processed.
- Digital singnal processing alorithms computate the HR, SPO2 values.
- A Wireless microcontroller manages the webpage and the user interface.

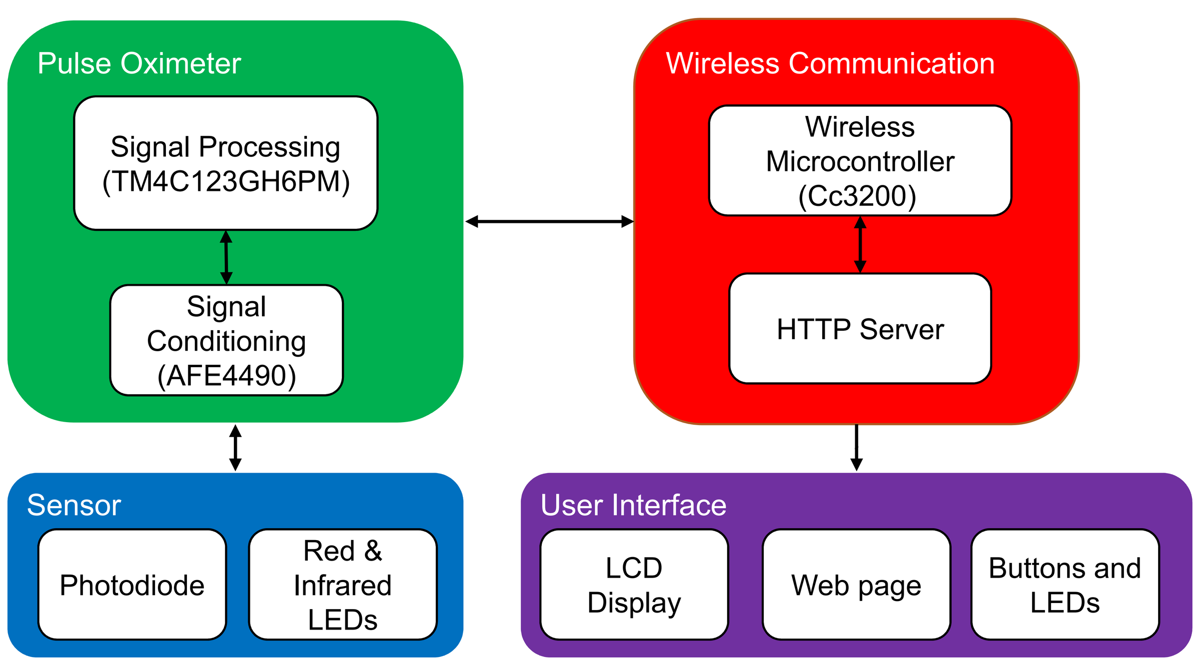


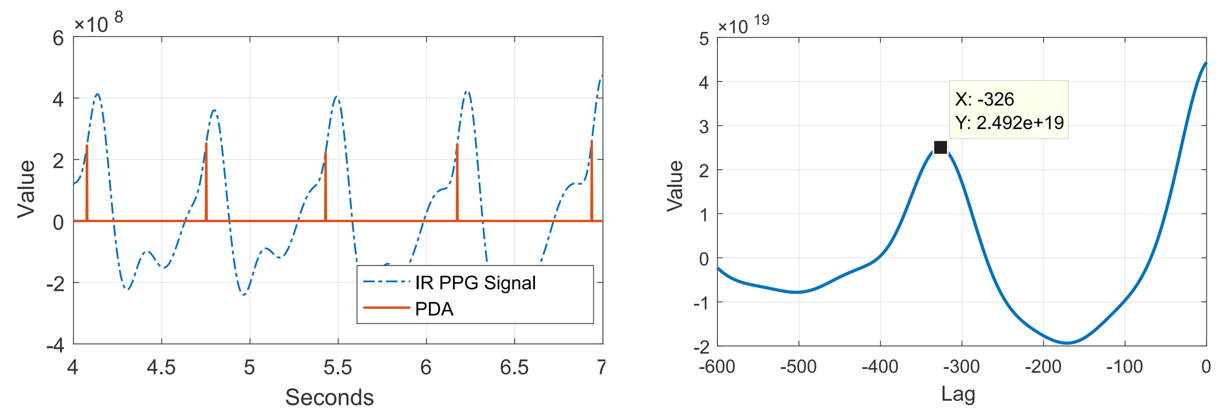
FIGURE 2. Block diagram of the monitor

Pulse Oximeter

Heart Rate Detection

Two Methods Implemented

1. **Peak detection algorithm (PDA)**:
   - Uses a combination of threshold detection and zero crossing.
   - Between the pulses a counter acquire their period and consequently the heart rate.
2. **Autocorrelation function (ACF)**:
   - The microcontroller stores a window of 1.4 seconds of the PPG signal,
   - The autocorrelation function is calculated
   - The location of the first harmonic indicates the time between peaks and therefore the heart rate.



a) Peak Detection Algorithm (PDA) b) Autocorrelation Function (ACF)

FIGURE 3. Heart rate detection methods

Oxygen Saturation Calculation

- The employed method reduces the mathematical complexity of the measurement by turning on and measuring alternately the light sources [4].
- The next equation is called the ratio of ratios (R) and gives an approximate ratio of the SpO2 by calculating the AC and DC components of the red and infrared PPG signals.

$$R = \frac{AC_{Red} / DC_{Red}}{AC_{IR} / DC_{IR}} \qquad (1)$$

- Oxygen saturation is lineally proportional to R[5]. As seen in equation 2.
- The compensation coefficients *a* and *b* are calibrated performing a lineal interpolation using the least squares method (LS).

$$SpO_2 = a + bR \qquad (2)$$

- The quality of the final measurement depends on the quantity of the calibration samples [6].
- Samples from a healthy patient were taken from a commercial pulse oximeter (MD300C2 from ChoiceMMed).
- The normal SpO2 range of a healthy patient is within the range of 95 to 99%. Precision out of this range cannot be guaranteed.

Wireless Communication

- The system works in two modes.

1. **Station mode (STA):**
   - The device is connected to an existing wireless network.
2. **Access point mode (AP):**
   - The device creates its personal ad-hoc wireless network.

- Once the device is connected to a client, (PC, tablet, cellphone), the data is sent to the webpage.

Web Page

- The web page, displays: heart rate and oxygen saturation values, pulse detection and finger detection indicators, a real time PPG graphic and a line graph for the heart rate and the oxygen saturation.

FIGURE 4. Wireless vital signs monitor web page.

RESULTS AND DISCUSSION

- The proposed system was compared with the commercial pulse oximeter MD300C2 usign the Bland-Altman method.
- Results can be observed in Table 1.
- Hear Rate results are similar to documented works [7].
- Oxygen saturation precision is not guaranteed for values lower than 95%, because of the limitations of the calibration process.
- Wireless communication was tested during 12 hours without losing the connection.
- The web page user interface shows to be easy to use and data were successfully updated during remote monitoring.

TABLE 1. HR and SpO2 results

	A-B	Standard Deviation	Mean Deviation	Limits of Agreement
HR	PDA-MD300C2	2.2826 bpm	0.545 bpm	-4.3 to 4.6 bpm
	ACF-MD300C2	2.2608 bpm	1.3928 bpm	-3 to 5.8 bpm
SpO2	Device-MD300C2	0.782%	0.018%	-1.5 to 1.4%

FIGURE 5. Wireless vital signs monitor.

CONCLUSIONS

- In this paper we have successfully designed and developed a wireless heart rate and oxygen saturation monitor using low cost microcontrollers.
- Obtained oxygen saturation measurements gave similar values than the reference pulse oximeter with a difference lower than 2%.
- Heart rate estimations using the proposed PDA and the ACF proved to be accurate measurements.
- Adding wireless technology to a heart rate and oxygen saturation monitor, allows patients to be constantly monitored, reduce considerably time responses, discover health tendencies, detect diseases in its early state and help first response assistants to perform the correct decisions with the help of a remote specialist.

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