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ORIGINAL

Special Study of Earlobe Pulse Oximeter Using MAX30100 for Detecting SpO2 and Heart Beat

Estudio especial del oxímetro de pulso del lóbulo de la oreja con MAX30100 para detectar SpO2 y latidos cardíacos

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Abstract

In this project, we will be using MAX30100 Sensor by applying a breakout-board, integrated with Arduino and an LCD keypad shield that can measure the available oxygen in the blood and measuring the heartbeat, and displays it on an LCD monitor. The concentration of oxygen in the blood which is termed as "SpO2" is measured in percentage and the heartbeat/pulse rate is measured in BPM. The MAX30100 is a Pulse Oximetry and Heart rate sensor device that is designed for the demanding requirements of the other systems. It provides a very small solution size without damaging or destroying any optical or electrical performance. Very few external hardware components are necessary for integration into a device that is comfortable and easily wearable. This hardware is fully configurable through software registers. Also, it eliminates ambient and surrounding light that can interfere with an accurate reading of the values off the monitor. The data are transferred and read through a serial I2C interface to a computer for further processing. One of the advantages of this device is being portable and can be fitted in a person's pocket and connected to the earlobe only via a single wire. The end of this wire connects to a small sensor that attaches to the earlobe. The sensor receives the pulses emitted from the earlobe and transmits it to the Arduino board on the portable part of the device in the person's pocket. Then this board processes the received data from the sensor and by using the previously written program in the board, will transfer the data into the heartbeat signal. Then finally, it shows the data on the attached small LCD monitor of the device and can easily be observed.

Keywords: Pulse Oximetry, MAX30100 Sensor, SpO2, Heart Beat.

Resumen

En este proyecto, vamos a utilizar el sensor MAX30100 mediante la aplicación de una placa base, integrada con Arduino y un escudo de teclado LCD que puede medir el oxígeno disponible en la sangre y la medición de los latidos del corazón, y lo muestra en un monitor LCD. La concentración de oxígeno en la sangre que se denomina "SpO2" se mide en porcentaje y la frecuencia de los latidos del corazón / pulso se mide en BPM. El MAX30100 es un dispositivo de sensor de oximetría de pulso y frecuencia cardíaca que está diseñado para los exigentes requisitos de los demás sistemas. Proporciona un tamaño de solución muy pequeño sin dañar o destruir ningún rendimiento óptico o eléctrico. Son necesarios muy pocos componentes de hardware externos para su integración en un dispositivo cómodo y fácil de llevar. Este hardware es totalmente configurable mediante registros de software. Además, elimina la luz ambiental y circundante que puede interferir en la lectura precisa de los valores del monitor. Los datos se transfieren y leen a través de una interfaz I2C en serie a un ordenador para su posterior procesamiento. Una de las ventajas de este dispositivo es que es portátil y puede colocarse en el bolsillo de una persona y conectarse al lóbulo de la oreja mediante un único cable. El extremo de este cable se conecta a un pequeño sensor que se adhiere al lóbulo de la oreja. El sensor recibe los impulsos emitidos por el lóbulo de la oreja y los transmite a la placa Arduino situada en la parte portátil del dispositivo en el bolsillo de la persona. A continuación, esta placa procesa los datos recibidos del sensor y, utilizando el programa previamente escrito en la placa, transfiere los datos a la señal de los latidos del corazón. Finalmente, muestra los datos en el pequeño monitor LCD del dispositivo y puede ser observado fácilmente.

Palabras clave: Oximetría de pulso, sensor MAX30100, SpO2, latido del corazón.

Introduction

One of the usual and regular care procedures for continuous analysis of the saturation of blood oxygen in patients is to measure the heart rate and oxygen saturation (SpO2). Since the invention of pulse oximetry by Takuo Aoyagi in the early 1970s, its use has expanded beyond perioperative care into neonatal, pediatric, and adult intensive care units (ICUs). Pulse oximetry is the most important advances in respiratory monitoring, since its readings are used clinically as an indirect estimation of arterial oxygen saturation (SaO2)[1]. Using pulse oximetry is highly effective in accelerating the weaning from mechanical ventilation and intubation. It also reduces the frequency of bleeding needed for analysis of arterial blood gases (ABG). Because pulse oximetry could be a proper alternative for the patients who just need checking for oxygen saturation[2]. Easy usage, speed, and high accuracy in the detection of hypoxia and also continuous monitoring of patients are other features of pulse oximetry[5]. This device detects the amount of oxyhemoglobin and deoxygenated hemoglobin in arterial blood and heartbeat and shows them as Oxyhemoglobin saturation (SpO2) and heartbeat (BPM)[6], which is an indirect estimation of arterial oxygen saturation (SaO2)[7]. The typical amount of SpO2 in healthy individuals is 97% to 99%. However, in more critically ill patients, the amount of pulse oximetry error is recorded as 7.2%[9]. Many factors can affect the accuracy of the device including: physiological, environmental, technology failures, and human errors[11]. In different experiments, sensors were placed frequently on the sole, palm, ear lobe, or toes in addition to the finger. Finger pulse oximetry sensors are often used to obtain functional oxygen saturation (SpO2) and heartbeats. But these sensors may perform inadequately if the digit is badly perfused or there is excessive hand movement[13]. However, earlobe pulse oximetry system does not encounter these difficulties. A pulse oximeter with a probe can be used on the ear lobe. Ear lobe sensors require a pulse oximeter. The handheld pulse oximeter with an ear sensor can measure oxygen saturation and heart rate from the ear lobe. This device can also use a tabletop oximeter instead of a handheld one. Ear clip sensors are most effectively used when a patient has weak blood circulation in the fingers.

In this paper, the MAX30100 sensor has been used. This sensor is a commercial and precise sensor for the determination of the availability of oxygen in the blood and measuring the rate of the heartbeat. This sensor, according to the I2C protocol, is connected to the microcontroller. Then it finds the heartbeat rate and the value for the percentage of oxygen in the blood.

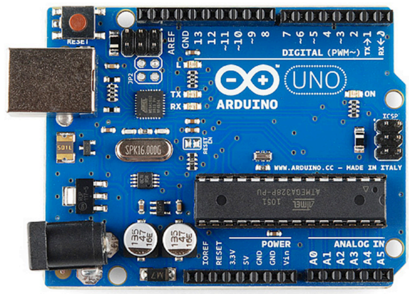
Materials and methods materials

1. Hardware:

1.1. Arduino Uno Board

This board is a microcontroller based on ATmega328. This board contains 14 incoming and outgoing digital pins, six incoming analog pins, one 16 megahertz Ceramic Resonator, one USB port, one power jack (for power inlet), one ICSP header, one reset button, and some other small chips. The required voltage for the Arduino Uno board can be supplied through either the USB connection or an external power supply; such as a battery or an AC/DC adaptor.(**Figure 1**)

Figure 1: Arduino Uno Board



1.2. MAX30100 Sensor

MAX30100 is integrated pulse oximetry and a sensor device for monitoring the heart-rate. This sensor integrates two LEDs (IR and Red lights), a photodetector (Red light), one optimized optics, and one low-noise analog signal processing. All these parts are used for detecting pulse oximetry and heart-rate signals. It can also be easily configured through software registers. Also, the digital output data is stored in a 16-deep FIFO which is within the device.

It has an I2C digital interface for communication with a host microcontroller. The pulse oximetry subsystem in MAX30100 consists of several parts including ambient light cancellation (ALC), 16-bit sigma-delta ADC, and a proprietary discrete-time filter. It has an ultra-low-power operation that consumes a little power and makes it ideal for battery-operated systems. MAX30100 operates by using a supply power in the range of 1.8 to 3.3V. It is practical to use in wearable devices, fitness assistant devices, medical monitoring devices, etc. (**Figure 2**)

Figure 2: MAX30100 Sensor

1.3. Module Pins

In design of the module circuit, there are 14 main pins for the sensor which seven of the pins are chosen to be connected to the microcontroller at the final connection as illustrated in **table I.**

Table I: Pin Description.

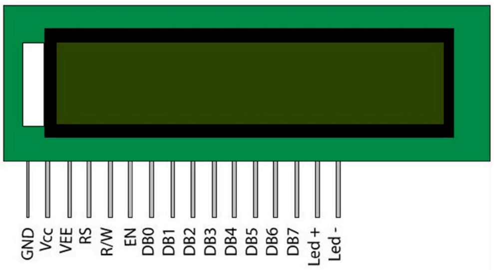
VIN	Modules' power source (3.3 volts)
SCL	I2C Clock Input
SDA	I2C Clock Data, Bidirectional
INT	Active-Low Interrupt
IR-DRV	IR LED Cathode and LED Driver Connection Point
R-DRV	Red LED Cathode and LED Driver Connection Point
GND	Analog Ground

*1.4. LCD Monitor with 2*16 Characters*

An LCD (Liquid Crystal Display) monitor is an electronic display module having a wide range of applications. A 16x2 LCD is a basic module and is widely used in various devices and circuits. A 16x2 LCD has two lines on it and sixteen characters can be displayed on each line.

Specifications of each one of the 16 Pins are described as **figure 3**.

Figure 3: LCD Monitor with 16*2 Pins



Pin no. 1 (GND): This pin is related to the power supply of the LCD and must be coupled to the negative supply or the GND pin on the Arduino Uno board.

Pin no. 2 (VCC): This pin is related to the power supply of the LCD and should be coupled to the positive supply or the 5-volt pin on the Arduino Uno board.

Pin no. 3 (VEE): This pin is related to the contrast adjustment of the LCD monitor. The adjustment is such that as the voltage of the power supply gets closer to the value of 5.0 volts, the color shown on the monitor is dimmer; on the contrary, as the voltage gets close to the value of zero volts, the color will appear brighter. In addition, a potentiometer with a capacity of 10 k Ω will be used for the interval of 0 to 5 volts for all circuits used in projects.

Pin no. 4 (RS): This pin is related to the registers and locators for reading or writing on the LCD driver chips.

Pin no. 5 (R/W): This pin will help the user to choose reading a value from LCD or to write on it. When the value on this pin is designated to zero, then the LCD is ready to receive the data, and whenever the value is set to one, then the user can read the values from the LCD monitor.

Pin no. 6 (EN): On some occasions, the LCD monitor may be set to be active or non-active.
Whenever the value of this pin is designated to zero, the LCD monitor turns off and when the value is set to one, the monitor will turn on and remains available for usage.

Pin no. 7 to 14 (D0-D7): At occasions when we want the monitor to display certain data, these eight pins will be used in the 4 bit or 8-bit format. In this project, a 4-bit format is used.

Pin no. 15 (backlight VCC): This pin is related to the positive polarity of the LED lamp which is the background light of the LCD monitor. It must be connected to the 5-volt pin on the Arduino Uno board.

Pin no. 16 (backlight GND): This pin is related to the negative polarity of the LED lamp which is the background light of the LCD monitor. This pin must be connected to the power supply or the GND pin on the Arduino Uno board.

1.5. Three resistors with 1 K ohm Capacity

Three resistors with 1k ohm capacity are connected and integrated with a parallel to divide voltage network. And it is designed to provide a specific amount of resistance in the circuit.

2. Software

The MAX30100 Launcher Program is written and run at the beginning stages and is specially written for Arduino Uno. Then, the special codes for displaying the heartbeat on the monitor is written and run.

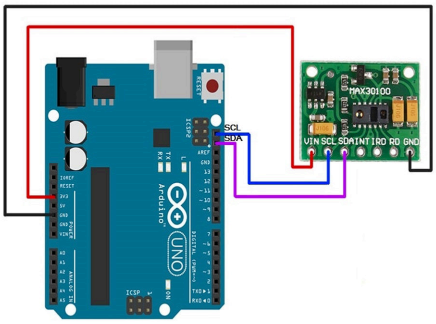
Method of Work

A small clamp-like device is placed on the earlobe and will be connected to the device only via a single wire. The wire is connected to a small sensor attached to the earlobe. The sensor receives the pulses emitted from the earlobe via the wire and transmits them to the Arduino board on the device. Then the board will process the received data from the sensor and transfers the data into the heartbeat signal by using the previously written program in the board. And finally, the board will show the result on a small LCD monitor which is also attached to the device that is fitted in the patient's pocket.

Connection to Arduino

The board is easily connected to the computer via the USB port and necessary programs can be written and transferred to the board. This board may be powered by an AC/DC adaptor or a battery through the related jack. The power source pin of the sensor will be connected to the 3.3-volt source of the Arduino board, and similarly, I2C data and clock are connected to A4 and A5 analog, INT pin to D2, and GND is connected to the ground port on the Arduino board. When all the connections are made correctly, the LED light on the sensor module should turn on. (**Figure 4**)

Figure 4: Arduino connection to MAX30100



Conclusion

Pulse oximeters have been developed and widely used since the 1930s. The designs and products have evolved from large sizes to small ones. Devices that are large, heavy, expensive, and available only for military and sleep laboratories[20] have changed into ones that are cheap and small (ear-lobe usage, fingertip compatible[3].

The accuracy of pulse oximetry is reduced in patients with conditions like severe and rapid oxygen desaturation, low blood pressure, body temperature, and reduced blood perfusion conditions. While the earlobe pulse oximetry has more accurate and reliable performance regarding these changes[16]. Haynes (2007) claimed that the earlobe probe can be considered as the proper method of finger type pulse oximetry. He said “in finger probe, the body movement is limited and the risk of reduced tissue perfusion is increased”[18]. Thus, considering the results of our study, the earlobe probe can be used as the proper and reliable method for examining the oxygen saturation regarding the importance of continuous monitoring and maintaining hemodynamic stability in patients under heart surgery[17].

The MAX30100 is a complete pulse oximetry and heart rate sensor system solution that has been designed for the demanding requirements of wearable devices. The MAX30100 provides a very small total solution size without sacrificing optical or electrical performance. In order to integrate this device into a wearable oximeter, minimal external hardware components would be necessary to accomplish it.

The MAX30100 is fully configurable through software registers, and the digital output data stored in a 16-deep pins within the device. The pins allow the MAX30100 to be connected to a microcontroller or microprocessor on a shared bus, even though the data is not being read continuously from the device’s registers.

The MAX30100 transmits data on SDA in sync with the master-generated SCL pulses. The master section acknowledges receipt of each byte of data. The SDA section operates as both an input and an open-drain output.

A pull-up resistor, typically with the size of 1kΩ, is required on SDA. SCL operates only as an input. A pull-up resistor, typically with the size greater than 1kΩ, however, is required on SCL. This is the case when there are multiple masters on the bus, or if the single master has an open-drain SCL output.

As was mentioned in this paper, the designer has chosen to use Arduino Uno for communication with the MAX30100 module. And besides, it uses the 2*16-character LCD monitor to show the data. In this way, a comfortable and portable device was fitted into the system. Since the sensor used in this project is a very delicate and sensible segment, the measurement of a patient’s heartbeat will be done with more accuracy as compared to other methods of measurements. For the future improvement of this project, the second part of this sensor (the part which was not used in the project), which measures the percentage of oxygen in the blood, can be arranged to measure the amount of oxygen both before and after various exercises. One of the advantages of this device is its usage for people who have no hands and the measurement of heartbeat and rate of breathing through hands are not possible.

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Interests conflict

The researchers declare that they have no conflict of interest.

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