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# Merging and Designing Biomedical devices with Telecommunication, for Creating Tele Pulse Oximeter

Monira Omar[1], Mahmoud Omar[2], Farouk Abdallah[3]

**Abstract**— Hypoxia is a critical symptoms of many series chronic disease, it is manifested as lowering the blood oxygen levels. If left unchecked it may lead to life threatening condition. Many devices have been developed over the years to monitor hypoxia. However, most of them lacked portability, security, wireless connection and the ability to communicate with patient's computer and their doctors in case of emergency. This project aim to survey several designs for pulse oximeter and then transforming them into a telemedicine device. The device created was shown to have the same accuracy and precision as any marketed instrument when tested on patients. In addition, it was programed on an e health shield and then Arduino Uno. The created and programed platform could store patient's data and connect to the computer to download the collected data. An extra connectivity wireless module was added to allow internet connection for Mobile health connectivity. Such connection make it possible for data to be sent to doctors and distributed within the hospital using UWB. Thus providing a superior health care.

**Key words: chronic diseases, Hypoxia, pulse oximeter, tel medicine, Mobile health, UWB and Warless communication.**

## 1 Introduction

IN 2012, WHO (World Health Organization ) reported that more than 68% of death word wide was due to chronic diseases[1]. This high percentage could be directly linked to smoking, malnutrition, sanitary under exercised life style, intensive alcoholism, increased pollution and much more. Several diagnostic symptoms could be used to detect and monitor chronic diseases, such as blood sugar for diabetes, heart rate for cardiovascular disease, blood oxygen level for general ischemia [1] . Within recent years several attempts are being developed to allow monitoring of such symptoms effectively, easy and round the clock. An example of this is engineering devices that allow self-testing and diagnoses: as automated devices for measuring blood pressure, portable devices to analyzing blood sugar. These devices allow patients to detect, monitor and if necessarily intervene with their chronic conditions. However, communication between the personalized detection devices and clinicians are fully implemented.

Chronic conditions as obstructive pulmonary disease, chronic mitral stenosis, pulmonary edema, anemia and several heart conditions develop signs of reduced blood oxygen, which is a condition known as hypoxia. Failure to provide adequate oxygen to tissues may result in a series of effects that might be lethal. Traditionally instruments known as bench top oximeter or blood gas analyzer where used to detect blood oxygen levels [2]. However, these instruments where lab based and require patients to travel to clinics, where blood samples are withdrawn and analyzed. Such design is invasive, delay in results, inherent risk of laboratory error especially in developing countries, time and cost consuming due to the frequent need for this analysis. This reasons had led to the need and development of newer, portable, none invasive, instant analysis and cheap device [2][3].

The first discovery to be made that measures the blood Oxygen level without blood sampling was in 1862 [4][5]. Were Von Vierodt invented the first pulse oximeter. He illustrated oxygen levels using transmitted light by wrapping a rubber band around his wrist and since the wrap had to be tight he was also able to measure the heart rate, thus the name pulse oximeter. However, his results were quite biased since the instrument could not detect and differentiate between arterial and venal oxygen [4][6].

In addition, other tissues did also absorb the light. Several attempts were made ever since to design such instrument, but it was not since 1970's where Hewlett−Packard designed a working pulse oximeter that could be attached to the ears and in 1980 the first finger pulse oximeter appeared [2].

Ever since pulse oximeter had become a standard instrument, which can directly detect hypoxia, deficiency of oxygen saturation in the arterial blood. Early detection of hypoxia can reduce the gas poisoning by $CO_2$ or CO, tissue damage, etc. several marketed noninvasive instruments are now available. However, no computer connection, mostly non wireless, lack of communication appendages, inaccurate, cannot be coupled with other sensors for other vital parameters analysis.

Wireless communications is a wide field ranging from mobile phones to internet connections. Such accessory would be an effective means of transmitting patient's data instantly at a very low cost with high degree of security and accuracy. There are several means for short and wide wireless communication techniques [7]. Within a medical field the most important con-


- *Monira Mohamed Omar [1], Department of electronics and communication engendering, University of Arab academy for science technology and Martine Transport, Faculty of engineering (nonira22@gmail.com).*
- *Mahmoud Mohamed Omar[2], Department of Drug delivery and pharmacology, October University for modern Science and Arts faculty of pharmacy (mahmoudomar788@gmil.com).*
- *Farouk Abdula[3] Department of electronics and communication engineering, University of Arab academy for science technology and Martine Transport, Faculty of engineering (farouksalem@yahoo.com)*

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cerns in any wireless technique are: The ability of the technique to co-exist with other radio and medical systems, to provide high level of data security, to make sure that real time patients data is available when required and most important of all is for the technique to be safe and cause no harm to human's body, that is why Ultra wide band (UWB) is a perfect choice for wireless connections inside the hospital. UWB is a short range radio technology that can transmit data extremely quickly over a short range (3.1-10.6 GHz spectrum). At the hospital, UWB is quite superior to wireless local area network (WLAN). It utilizes low energy and short impulses [8][9]. Thus making it an immune to distortion or interference from any other wireless devices as televisions and radios in homes or medical instruments in hospitals or mobile phones. It is also quite safe and have no effect on human health in addition to high data throughput and low cost. Which make it an ideal mean that also connect between medical devices and patient's computer, portable devices and intra hospital devices communication [9].

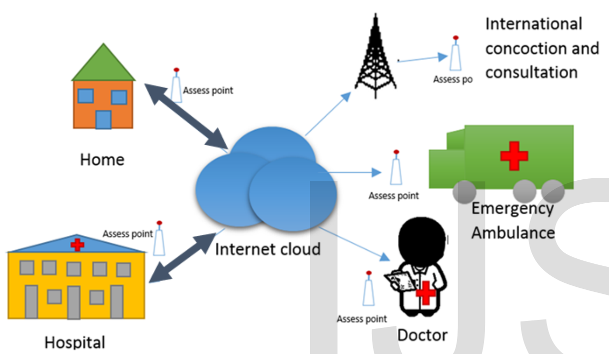


Fig. 1. The telemedicine system connections, In which patients at home or hospital could be directly monitored. Wearable wireless device can send and store data on internet cloud. Such data could be stored and reviewed by doctors, hospital, emergency, or even sent abroad for consultation. All operation can be done instantly

Nevertheless, wide range communication would be also important to allow modern medical devices to communicate from home to national and international clinics. Thus allowing 24 hours health monitoring, diagnosis, distant consultation, and digital cloud data base storage. Mobile network (M health) can enhance health care to patients by transforming a medical devices as a platform for data sharing to patients mobile, analysis data base, patient file, doctors and emergency detection [10][11].

This project aims to merge the medical technology with electronic telecommunication, to form Tele-medicine system. This technology is mostly utilized in monitoring and treatment programs. Wearable health monitoring systems that can be embedded into a tele medical system potentially brings new information technology that is capable to support anticipation and early detection of unusual health condition. This study aims to test and design a several circuits and sensors for their uses in pulse oximeter. The designed wearable pulse oximeter will allow the patient to personally monitor changes in his or her oxygen saturation level and heart rate. In addition, continues monitoring and documentation onto a designed patient's profile will be possible by using either USB cable to connect to computer or wireless communication to connect to the hospital's network connectiom connection. This device will have the advantage of communicating with doctor's clinics and hospital, tracking patient's habits, detecting situation which causes crises and predicting when they will happen. As a result a superior health care system could be designed and implemented for each patients (drug doses, drug time schedule and emergency).

## 2 METRIALS, EXPERIMENTAL DESGINE AND METHODS

### 2.1 Metrials

Red LED (3mm bright, L07R3000F1) was purchased from LED Technology. IR LED (IR emitter 5MM, 940NM -KEL5002A-A) was bought from Knowledge-ON. Photo transistor (3.0MM ROUND, OFT-3301) was purchased from MultiComp. OP AMP( Duel low power SOIC, 8.358, LM358AD ) was bought from Texas Instruments (USA). Microcontroller ATmega644 was purchased from Atmel. Photo transistor OPT101 was purchased Texas Instruments. Arduino Uno was purchased from Arduino (Italy). Nellcor SpO2 sensor was purchased from Nelcor ltd. E-Health shield and Pulse and Oxygen in Blood Sensor was purchased from Purchased from Cooking (Spain) Hacks. Roving RN-XVee module was bought from Roving Networks (USA).

### 2.2 Experimental design

The hardware for deigned pulse oximeter consisted of a mainly light source and a photo detector. As a light beam passes through a finger, it will permeate the skin and is absorbed by the blood passing through capillaries in the finger. The variation in blood volume causes a variation in the light detected by the phototransistor. The source and detector are mounted on either side of the finger to measure changes in transmitted light.

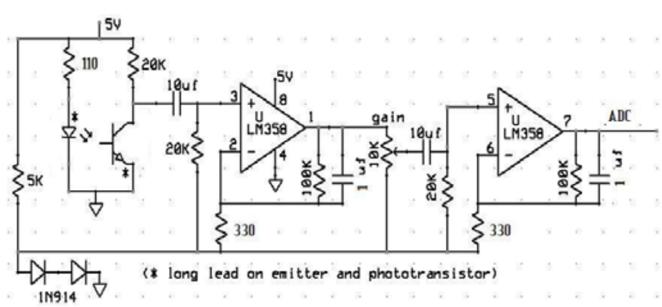


Fig. 2. The deign 1 hardware schematic The above circuit is repeated twice, once for the IR LED and another for the RED LED , each on a separate board. Both circuit boards are connected to the micro controller (AT mega 644) board. Atmega644 is an 8 bit microcontroller and has been used in the project. Atmega644 has 10 bit ADC which is used for sampling and digitizing the input analog signal. Hardware also includes the interfacing of the Atmega644 to the LCD displa

### Design 1

A detailed explained schematic diagram is shown below in Figure (2). Briefly infrared LED (940 NM) and red LED (66s0 NM) where mounted each in a separate circuit broad with its own photo detector (PHOTOTRANSISTOR 3.0MM ROUND, MULTICOMP) in front of them. The ratio of light absorptions from the two LEDs will give us a Sp02 reading. For increasing the accuracy and signal strength of Analog to Digital convertors. To do this, a LM358 package of dual operation amplifiers was used to band-pass and amplify the signal.

### Design 2

This circuit design is similar to that of design 1, except for the photo detector used is OPT101 and both IR LED and RED LED are on the same circuit board.

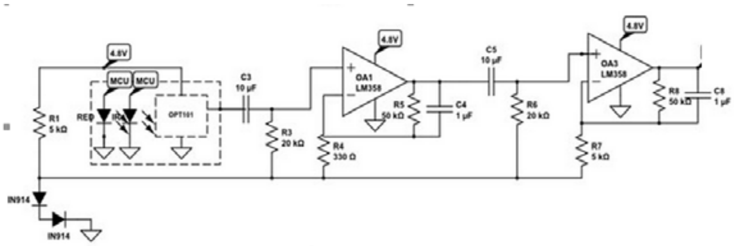


Fig. 3. The Design of pulse oximeter with two LEDs on the same circuit board.

### Design 3

This design is similar to the previous design (design 2), but we have replaced the red LED, infrared LED and the photo detector with the Nellcorc SpO2 sensor. Figure shows the schematic of the NellcorSpO2 sensor. From the Nellcor sensor we will connect pins 2 and 3 to replace the red and infrared and we will use pins 6 and 9 to replace the photo detector as shown in figure.

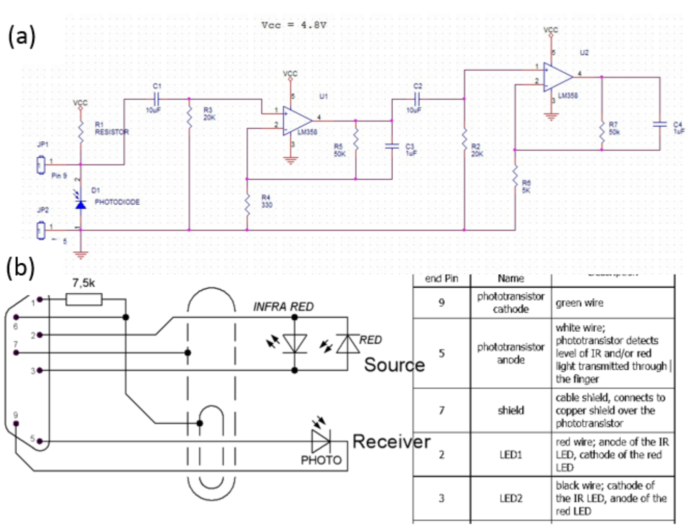


Fig. 4. (a) the schematic diagram of design3. (b) The schematic diagram of Nellcor sensor [17].

### Design 4

In this design, we connected the Digital I/O connectors, the general purpose pins and analog input connector of the e-Health sensor platform to the digital pins, power pins and analog pins respectively on the Arduino. After that, we placed the Pulse and Oxygen in Blood Sensor (SPO2) into pulse oximetry connector found on the e-Health sensor platform.

The Arduino uno will then send the patient's data to the computer through USB 2 serial cable, the type communication used is serial communication. Patient's data can be viewed on the LCD screen found on the Pulse and Oxygen in Blood Sensor (SPO2) or displayed on the computer screen.

## 2.3 Methods

### *In vivo* comparative test

Experimental application of the designed instrument carried out on humans. Each analysis was done with both the designed and a standard marketed version of the pulse oximeter. Three age groups were selected (teen ager, young adults and geriatrics). For each age group 7 healthy male and 7 healthy females were chosen. Each test subject was tested for its SPO2 and heart rate at resting state, for each test subject the analysis was repeated 3 times with each instrument. Statistical investigation and level of significant between results was then analyzed**.**

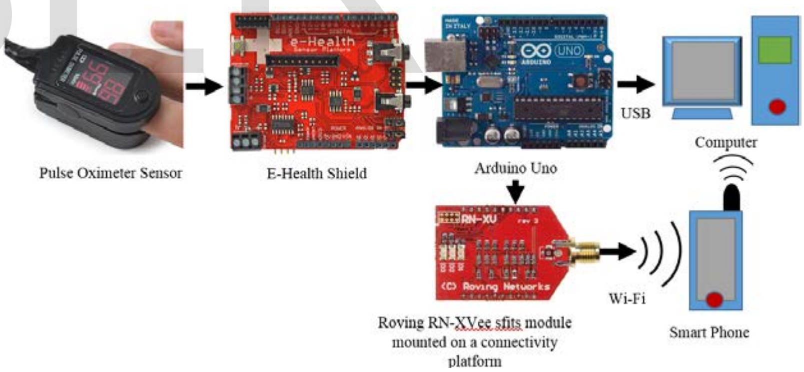


Fig. 5. The proposed telecommunication device. The pulse oximeter is connected to an E-Health shield. The E-health shield was then combined with an Arduino Uno. The created platform could be directly connected to a computer by a USB cable. Alternatively a Roving RN-XVee module could be connected to the Arduino Uno by the means of a connectivity platform. With this appendage wireless Wi-Fi connection to a router or smart phone (doctors, patients or emergency) is possible.

### Software used

Microsoft Excel 2013, was used for graph plotting. Statistical analysis was done with Graph Pad QuickCalcs (California, USA). For hardware computer communication Arduino 1.6.3 (Italy).

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## 3 Results and Discussion

With design 1, phototransistor 3.0MM round could not detect and manage the algorism of two LEDs at same time. For this reason the design was modified were three circuit boards where made. Two identical boards, each contain different LEDs (IR, RED) in order to reduce the interference between two LEDS, while the third circuit board had Atmega 644 microcontroller. However, such design had high cost, since most components were bought twice. In addition the design was more complex, with many wiring thus did not meet our aim in designing a warble compact pulse oximeter with additional appendages for communication was used. Upon testing it on humans it was inaccurate compared to the marketed device, especially in humans who showed more keratinized skin and bigger fingers. It was then concluded that the phototransistor 3.0MM round could not be used.


Fig. 6. (a) The comparative bar chart diagram of SP02 between marketed and designed device in several age sex groups. Where STM (standard device on ten age males), DTM (designed device on ten age males), STF (standard device on ten age females), DTF (designed device on ten age females), SYAM (standard device on young adults males), DYAM (designed device on young adults males), SYAF (standard device on young adults females), DYAF (designed device on young adults females), SGM (standard device on geriatric males), DGM (designed device on geriatric males), SGF (standard device on geriatric females) and DGF (designed device on geriatric females). (b) The comparative bar chart diagram of Heart rate between marketed and designed device in several age sex groups. Standard device Designed devices. At P=95%

Design 2 utilized the same circuits as design 1, but IR and RED LEDs were mounted on the same boards. The photo detector was changed to OPT101 as shown in figure 3. OPT101 could manage the two LEDs at same time and thus one circuit board was used. However, there was a notable noise and inaccuracy still during testing and the finger probe designs made it hard for bigger finger to be analyzed.

In the following design 3, the IR, RED LEDs and the photo detector was replaced by a Nellcor SPO2 sensor, to avoid the previous design disadvantages and could accommodate various skin types and finger sizes. The new design is shown in figure 4. Nevertheless, the circuit amplifier and microcontroller where quite compatible with the sensor. Which led to unclear output signal with high noise level. As a result no accurate result could be obtained.

Design 4 e-health pulse and oxygen sensor was used. It showed a clear signal with low noise level for both heart rate and oxygen saturation. Three age groups were selected to test the proposed design 4 and compare it with a marketed device. Results showed that average SPO2 and heart rate was within the normal values for both designs, 4 and the marketed device.

Results were consistent for each age and sex group and the relative standard deviation was below 10% in all experiment. For the same age group comparison was made between both devices. No significant difference at p=95%, suggesting the design 4 had the same accuracy and precision as the marketed device as shown in Figure (6)

Design 4 was then chose to be connected with e-health shield and then Arduino for further computer connection. E-Health Sensor Shield V2.0 allows Arduino and Raspberry Pi users to connect there biometric and medical devices The e-health acts as plat form for connecting several sensors as: pulse, oxygen in blood (SPO2), airflow (breathing), body temperature, electrocardiogram (ECG), glucometer, galvanic skin response (GSR - sweating), blood pressure (sphygmomanometer), patient position (accelerometer) and muscle/electromyography sensor (EMG). In this design the e- health shield act as a connector for combining the design 4 and the connectivity plate form,

Arduino Uno was chose as the connectivity platform due to several reasons. Initially Raspberry Pi needs an additional bridge circuit for operation which will make the design more bulky, expensive and complicated [12].

Arduino Uno is a simple platform with a resettable polyfuse that allows it's user to easily communicate with the computer, and other platforms**.** It has the advantage that it could work without the need of an external power supply if connected to the computer via the USB. In addition it allows the pulse oximeter attached to the e-Health shield to work with no batteries if connected to the computer. Thus saving the cost of batteries every now and then [12].

Arduino Uno was then connected to the e-shield and special programing was done to make it work compatible with the pulse oximeter. The information gathered with the connected Arduino – pulse oximeter can be used to monitor real time the state of a patient or to get sensitive data in order to be subsequently analyzed. Biometric information gathered can be wirelessly sent using any of the 6 connectivity options available: Wi-Fi, 3G, GPRS, Bluetooth, 802.15.4 and ZigBee depending on the application [7][13].

If real time image diagnosis is needed a camera can be attached with a 3G module to the Arduino platform, in order to send photos and videos of the patient to a medical diagnosis center. Data can be sent to the Cloud in order to perform permanent storage or visualized in real time by sending the data directly to a laptop or Smartphone. IPhone and Android applications have been designed in order to easily see the patient's information. The e-Health sensor platform application can be easily downloaded from Apple store in case iPhone is used, or from Google play store in case an Android device is used. The patient can now easily send his data by forwarding it to his/ her doctor through mobile health system, which is known as m-Health [11][14][13].

Security and Privacy is one of the most important factors of any applications. For this reason the platform includes several security levels. To share medical data with the cloud, perform real-time diagnosis and send data to the mobile. Many communications modules can be used to send data over several wireless transmission protocols by adding the communication shield to the Arduino Uno platform. Several communication shield can be used as XBEE 802.15.4 RF module or Wi-Fi Module Roving RN-XVee. The XBEE module has a transmission distances of only 30m indoors (line of sight) and 100 m outdoor. While Roving RN-XVee connects wirlessly to a router allowing it to incert itself in hopital's ultra wide Band network and the main internet. With this module low power and low cost wireless communication applications, such as wireless sensor networks [15][16].

The Wi-Fi Module Roving RN-XVee fits in the XBee socket on the desgined communication Shield and allows connection of the Arduino shield to a Wi-Fi network, now a telemedicine network could be connected and the aim of the project could be achieved[15][7].

## 4 CONCLUSION

Telemedicine is the utilization of communication techniques to overcome problems with patient monitoring. Such as distance, time, frequency of sampling and patient incorporation. This project has shown to overcome such barriers. The designed device was able to measure $SP0_2$ and heart rate, with the same accuracy and precision as marketed devices that are unable to communicate. In addition, the designed instrument was able to store several patients reading using the added microcontroller. Nevertheless the device was able to connect to the computer by USB cable and wirelessly through the internet. Thus the device can store patient's data, upload and record it to the computer. The device can also utilize the internet appendage to directly send the data of each measurement to doctors, clinics or hospital, for any necessarily measures to be taken. Thus making the project device more superior in terms of telemedicine than marketed device.

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