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Research paper

Challenges Faced in Extracting Raw SpO2 Sensor Data

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Abstract

This paper presents the challenges faced in the primitive development of the hardware to acquire the raw SpO2 signals. The issues faced during the selection of the sensor, the integration of the sensor circuitry and incorporation of the sensor circuitry with the microcontroller are presented in the paper.

Keywords: *I2C , IR-Sensor, MAX 30100, MicroController.*

1. Introduction

Since the research is based on improving the SpO2 signal by removing the motion artefact, we were faced with a challenge of how to acquire the signal. Immediate solution was to gather data from the local hospitals. A formal visit was done to a few local hospitals (Names not mentioned on request). It was learned that most of medical practitioners in those hospitals used commercially available pulseoxymeters. Few of the most commonly found pulseoxymeter was MD300C20 from Omron®,.Masimo etcThis pulseoximeter is very well designed with good accuracy, but it cannot be utilized for our research work with the reason being, it only can display the SpO2 values; it does not have the option of storing data. An insight was given from the medical practitioners that they record SpO2 values manually in regular intervals. Furthermore there was no sane way to acquire raw IR and Red led DC/AC values, which were very much vital for our research work from those modules. [1]
The pursual for another pulseoxymeter led us to CMS60C from Contec®. The CMS60C had an advantage of projecting the data through the USB interface, hence data can be stored in a text format or ported to an excel sheet for further investigation. But the problem here was CMS60C yielded the values of SpO2 in percentage which is pretty much futile to our research, the reason being our research focuses on the betterment of the SpO2 values by removing a few factors which require unprocessed IR and Red LED values.
There are other modules also available commercially like the iHealth wireless pulseoxymeter which send the data wirelessly over Bluetooth. However they all lack the capability to yield raw data required for our research.
Further investigation led to “physionet”. According to the site proprietors,”PhysioBank is a large and growing archive of well-characterized digital recordings of physiologic signals and related data for use by the biomedical research community. Physio Bank currently includes databases of multi-parameter cardiopulmonary, neural, and other biomedical signals from healthy subjects and patients with a variety of conditions with major public health implications, including sudden cardiac death, congestive heart failure, epilepsy, gait disorders, sleep apnea, and aging.”[1]But contrary to that there was no data found relevant to the research. [2]
This motivated to build a sensor unit of our own. Through an extensive research it was found that a SpO2 sensor consists of the following components,

- An IR sensor LED
- A Red LED
- A Low Noise Amplifier
- An ADC unit.

The simple block Diagram of a SpO2 sensor circuit is as shown in figure 1.

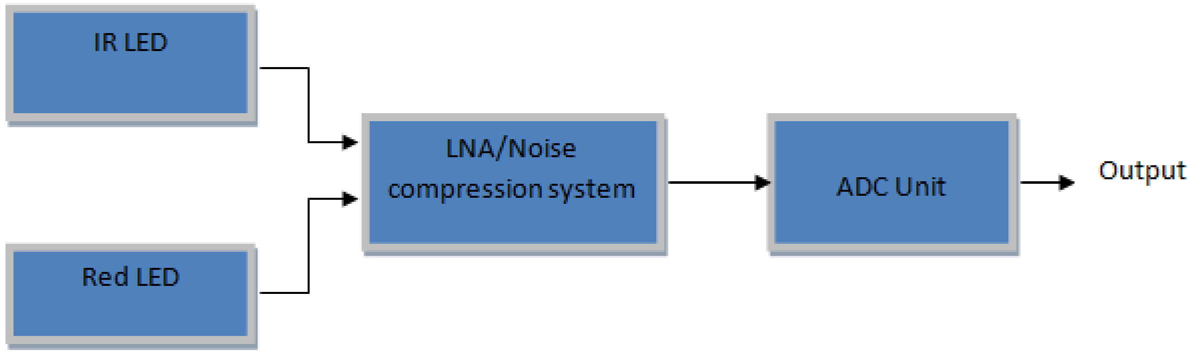

Fig. 1: A simple block diagram that depicts the architecture of a SpO2 sensor

It consists of a block containing the LEDs, an ADC system and a signal processing and correction system. To accomplish the task an ADC system with 8-bit resolution is needed at the least, however a 10-bit ADC would prove to be more efficient. The sampling frequency should be more than 60 but less than 150 samples per seconds. Because sampling frequency more than 150 will result in oversampling which will eventually end-up in erroneous readings. The control unit controls the sequence at which the LEDs should be powered. The output of this system is given to a microcontroller where the data is processed.[3]

2. Problems Faced During Designing the Sensor

Choosing the LEDs with the correct wavelength was the first challenge. The red LED was supposed to be maintained at 660nm and the IR led should emit a wavelength of 940nm. Most of the LEDs don't have a generic standard wavelength. The LED ergonomics also mattered because this application requires an LED with smaller build and a nominally high intensity. Designing the ADC was a major issue faced when designing the system. The resolution of the ADC denotes its accuracy, 10- bit ADC will is very much required for a system shown above. [3]
Next issue was in the circuitry bring-up of the control unit. As mentioned earlier, one of the LEDs either red or IR should be turned on for the first cycle, the other LED should be turned on for the next cycle and both the LEDs need to turn off for the next cycle for about 30 times per second. Maintaining this was an issue, because this is a synchronized task as this perceived light's intensity should be captured by the photodetector circuit. This task needs an on-board microcontroller to be embedded on the sensor system. The need for an on-board microcontroller system arises from the following facts. [4]
The LEDs should maintain a uniform blink cycle.The received intensity from the photoreceptor should be sent to an ADC unit the ADC output should be interpreted by a microcontroller.Lack of availability in the local market, because most of the sensors manufactured do not attract the local audience hence shipping them through online portals is the only option. Online portals are great for day to day products but products like these take a period of 15 to 30 business days to reach us.[5]
As mentioned earlier, sensors are susceptible to damage so it is always advisable to buy more than one unit of the sensor and its associated circuitry systems. This adds up to the cost of the research.
Sensors thus shipped sometimes do not work as per the specifications present on the datasheet. May be the fact that they are sensitive to the ambient temperature or they were damaged due to Electro-Static Distortion.
Talking about price, PCB manufacturing of single unit prototypes is not cost effective and furthermore the design should be revised several times and the lead times are high.Probes for SpO2 sensors are not readily available in the market. If an attempt was made to create a sensor probe from scratch its current handling and current leaking characteristics can be unpredictable due to parasitic capacitance. The parasitic capacitance causes the current to leak to the ground.
Sensor's sensitivity with respect to skin plays vital role in acquiring the signals. High sensitivity may result in picking up noise; a less sensitive senor will make it harder to acquire the signals because it has to be placed in the body where the skin is thinnest.
Hardware design is pretty tricky because most of the time the sensor picks up noise due to high sensitivity.
Tackling the leakage currents is very challenging due to the usage of wires and bread board. When a circuit is built on a bread board the contact between the leads of the components and the bread board itself generates some stray capacitance these capacitances along with DC currents lead to the leakage of currents which lead to Inter Symbol Interference.
The board bring-up presents a lot of unpredictable issues including Inter Signal Interference and Low Signal to Noise Ratio.

3. Moving on to other Readily Available Sensors in the Market

These challenges forced to move on to other readily available sensors. Initial Board bring up was done using ADC based SpO2 Sensor from SunRom. This sensor is based on Ti's MSP430 series of devices. The sensor was interfaced with 8051 based microcontroller. The problem with 8051's architecture is that it doesn't have an on–chip ADC unit, so an external ADC unit had to be used had to be. PIC based microcontroller served as a better option. But PIC microcontrollers are very power sensitive which makes them vulnerable to current leakages. Driver development for PIC based microcontrollers is very challenging.

MAX30100 as the final choice

MAX 30100 was chosen as the most suitable sensor for the task for the following reasons,
MAX30100 is a sensor developed by maxim integrated which is highly accurate in measuring the SpO2 signals. It was recently made available in the market. It is designed to produce its output through I2C protocol. As opposed to an amateur-made sensor the MAX30100 has embedded the IR and red LEDs on a single chip. [6]

The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photo detector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart rate meter

It has following advantages over the previous designs.

- Highly efficient ergonomic design.
- Occupies very less space.
- Can be SMD mounted.
- Works over a varied range of voltage (1.8 to 3.3v).
- Highly accurate.
- Miniature model built at the size of 5.6mm x 2.8mm x 1.2mm.
- Can be used for low power applications.

The ADC has a varied range of sampling rates which can be configured from 50 to 1000 samples per second.Since the sensor is compact, it can be implemented as a wearable system, so the samples can be acquired at different conditions like walking, running etc.

4. Conclusion

However designing the Application Peripheral Interface was a major issue in this sensor. As mentioned earlier MAX30100 works on serial peripheral protocol called I2C, acquiring data from the sensor is quite grueling. Furthermore the data has to be processed to get the AC/DC values. Since the I2C protocol drives data on an open-drain configuration, it can only drive either a low voltage or a high-impedance. So, care has to be taken to add a suitable pull-up resistor.

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