

Multi-parameter Health Monitor with Alarm System based on Machine Learning Techniques

Shengxin Jin¹, Shizhe Yang², Haoze Guan³, Shengkai Xu⁴, Yilin Shen⁵

¹The State University of New York at Stony Brook, Stony Brook, New York, 11790, United States;

²Case Western Reserve University, Cleveland, Ohio, 44106, United States;

³Beijing University of Technology, Beijing 100124, China;

⁴Pennsylvania State University, University Park, State college, Pennsylvania, 16802, United states;

⁵University of Pennsylvania, Philadelphia, PA, 19104, United States.

Abstract

This article aims to realize a wearable multi-parameter health monitoring system that integrates heart rate detection, blood oxygen saturation measurement, non-invasive blood pressure measurement, and blood glucose measurement. Then extract and calculate various health parameters to maintain real-time health warnings. First, this article extracts some basic health parameters, including blood sugar, blood pressure, blood oxygen, and heart rate. Then, using the detection methods of each parameter to complete the design of the entire monitor system. Finally, machine learning is applied to design a health parameter monitoring system. With the development of modern health science, the focus of medical treatment is gradually changing to prevention and early diagnosis of illnesses. Early detection of diseases usually leads to effective and targeted treatment. So far, prevention is mainly through medical tests. However, people in fast-paced life can hardly go to hospitals with testing equipment and have a continuous observation of their health condition. The wearable health parameter testing devices can conveniently solve this problem. Testers can simply put on the system and complete sampling and acquisition of health sign parameters without the complicated testing process or paying the expensive testing fees.

Keywords

Multi-parameter; Non-invasive Health Monitoring; Machine Learning; Wearable Detector.

1. Introduction

In recent years, great progress has been made in wearable health parameter detection, with the emergence of different health sign parameters monitoring.

Joao Martinho [1] designed a remotely operable physiological monitoring device, a prototype of which accomplished the measurement and acquisition of three physiological indicators: ECG, blood oxygen, and blood pressure, and sent the waveforms to a remote back-end server via Wi-Fi Internet, allowing remote control without patient intervention.

Keri J. Heilman [2] developed and designed the "LifeShirt" wearable physiological parameter monitoring system, which is a lightweight cotton undershirt with a biosensing sensor embedded in it to monitor respiratory status. The device uses a conventional Ag/AgCl electrode, a single-channel ECG signal to calculate heart rate information, a three-dimensional

accelerometer to detect body posture and physical activity, and continuous heart rate measurements to monitor heart rate variability.

2. Wearable health parameter

Heart rate, arterial oxygen saturation, blood pressure and other vital signs are an important way to identify cardiovascular diseases such as heart disease and hypertension and are of great importance in the field of clinical medicine, community medicine and home health monitoring. Heart rate is the most direct symbol of human heart health. Before going to the hospital, for people at high risk of cardiovascular disease, long-term continuous observation of heart rate can establish the first line of defense for prevention.

Arterial oxygen saturation is a vital indicator that maps the oxygen content of human arterial blood tissue. It is usually defined as the amount of oxygenated hemoglobin in arterial blood tissue as a percentage of the total hemoglobin content [3]. Oxygen is one of the substances necessary for the body to sustain life and is a prerequisite for life activities. Human tissue cells need to carry out metabolism is based on the oxygen component extracted from the blood. Oxygen in the air enters the blood through the body's respiratory movement. Oxygen is transported to all tissues and organs of the body through the blood flow caused by heart contraction. Insufficient blood oxygen will definitely cause all tissues and organs of the body to fail to work normally, therefore, whether sufficient oxygen can be dissolved in the arterial blood is essential to maintain life. Therefore, timely detection of the adequacy of oxygen content in arterial blood tissues is an important parameter for judging whether the human respiratory system, cardiopulmonary function and circulatory system are dysfunctional or the oxygen changes in the surrounding environment [4]. Noninvasive oxygen measurement is mainly based on the photoelectric method, which measures oxygen saturation by the property that oxyhemoglobin and other hemoglobin have different absorbance rates in different light regions. Blood pressure (BP) is also one of the important vital signs of human health, which can map the functional state of the human heart and vascular blood circulation system and is an important evidence for clinical identification of diseases, examination of medical effects and prognostic projection.

2.1. Heart rate sensor

There are lots of ways to measure the heart rate. Right now, the most precise one is using the Electrocardiography, which is ECG. However, the much easier one is to use heart rate sensor. It has different size and shape, which is allowed to measure the heart rate instantly.

Due to the size of ECG is too large that is impossible to insert it on the wearable sensor, there is a new technology that can be used on it, which is PPG-Photoplethysmography.

Photoplethysmography (PPG), is a simple technology of optical. The measurement process is just at the skin surface, which is a low cost and non-invasive method. Blood in the skin under the action of the heartbeat changes, when the heart contractions, the peripheral blood volume is the maximum, the light absorption is the maximum, the detected light intensity is the minimum. Vice versa, during diastole, light intensity was highest. The intensity of the light received by the optical receiver shows the pulsating change, then converting the signal into an electrical signal to obtain the heart rate. That is how most of the wearable heart rate sensor work right now.

[5] A heart rate monitor consists of an electronic circuit that monitors the heart rate by clamping it on a fingertip. It does this by shining light on or through the finger and measuring the amount of light reflected or absorbed. As the blood is pumped through your finger, it goes up and down. To serve as an optical heartbeat detector, a combination of infrared LEDs and phototransistors is used. The LED shoots light into or through the finger and reflects or transmits light detected

by a phototransistor that acts as a variable current source, conducting different amounts of current depending on the light received. The voltage varies as it wishes and is obtained from the collector of a phototransistor. The small signal obtained is used as input to the subsequent circuit and provides the output signal as a heartbeat detector or monitor. For obtaining the output which is relevant, we need to make the signal to be passed through the multiple circuits. The output signal of the preamplifier: heartbeat measurement setting is decoupled through a series capacitor and amplified using a negative feedback resistor (R_4). Low pass filter: RC filter eliminates high frequency (noise). The voltage follower buffers: the output of the low-pass filter and reproduces its voltage with a low impedance output. Inverting amplifier with low pass filter: amplifies voltage signal and reduces high frequency (noise).

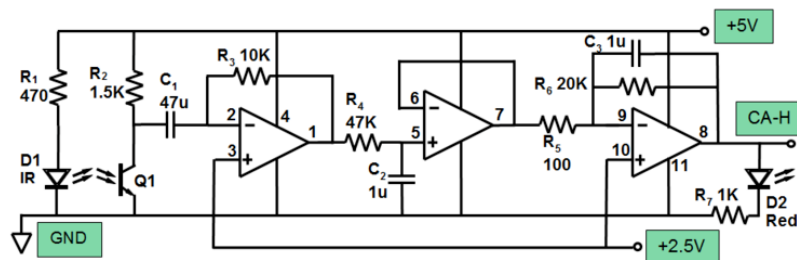


Figure 1. Sample circuit [5]

Also due to the difference of the heart rate between static state and movement state. We planned to add a flip-flop on the input of the circuit. Using one circuit to measure two statement but restore the data in two different databases. $Q(t)$ mean the static state and $Q(t)$ prime mean the movement state. That can make the data easily be analyzed by two different statement.

2.2. Breathing sensor

The breathing sensor will play an important role under the control and will follow up some disease which is relevant to breathing, such like Chronic obstructive pulmonary disease, sleeping apnea, asthma and so on. The device could trigger alarm functions for drug, or even contact a general practitioner for an appointment, or call emergency services.

[6] Wearable sensor for breathing monitoring have various types pf electronic sensor, they can be inserted into clothes, attached to belts, or even fixed on the skin and etc. There are many ways to make wearable devices and some of them are described separately by the type of primary sensor in the following sections. They are Pressure sensor, Acoustic sensor, Humidity sensor, Oximetry sensor, Acceleration sensor and Resistive sensor.

This is the schematic of the sensor which we use to be designed. There are four stage in this scheme.

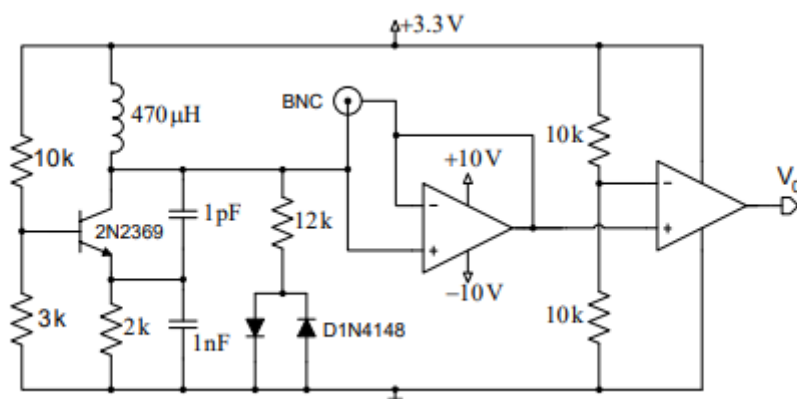


Figure 2. Schematic of the sensor [6]

The first stage is to use an oscillator to achieve a high quality factor. We need a good frequency, by optimizing the transistor and a low collector-base junction capacitance. The second stage is a network which is formed a resistive and a two ground-derived diodes which need to be antiparallel. We need to couple into an oscillator in order to improve the performance. The third stage is to set a reduction shield to reduce the affection from the circuit, electrode and parasitic capacitance. The reduction will be set a- part, which need to operate the output of the voltage. The final stage is formed by an additional operational amplifier. The operational amplifier here is the same as a comparator, which is to provide square wave under the constant voltage. The signal will apply the microcontroller to obtain the operating frequency of the oscillator. In order to make such oscillator-based capacitive sensing system to be worked successfully. We need to make it to capture a better respiratory rate. The resolution of it is an optimized design of oscillator and the correct design and size of electrode.

2.3. Blood sugar and Blood pressure

2.3.1. Primitive circuit layouts

To perform accurate pressure sensing, the circuit must be able to detect small signal change during when it's outputting analog signals. For instance, the circuit shown below:

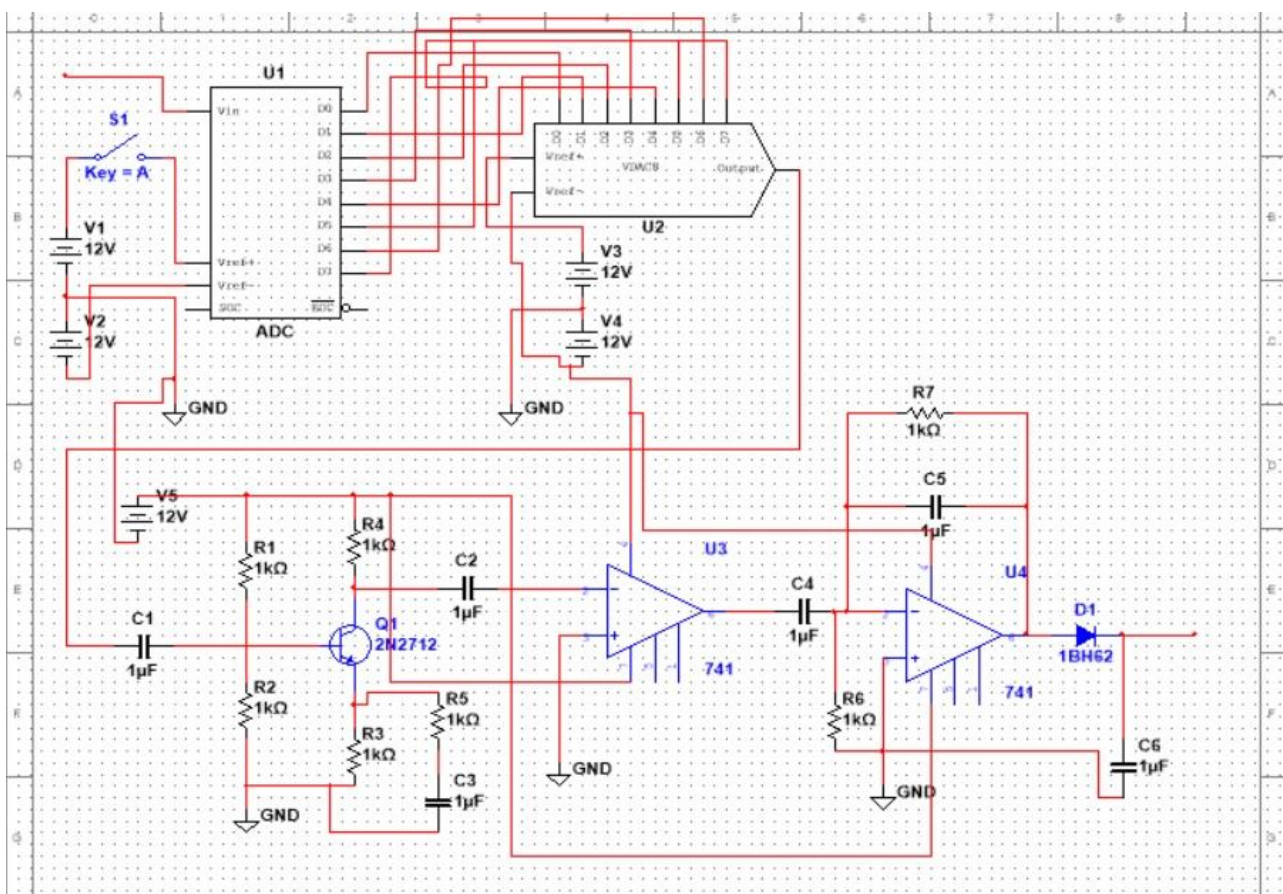


Figure 3. Small signal detectable circuit

First we need to connect the input end to the analog to digital converter (ADC). The purpose of this procedure is because we want to ensure that people is not in motion, as the blood pressure will be different under different body conditions. When the switch is cut off, the whole ADC is cut off as Vref is not receiving voltage reference. From ADC to digital to analog converter (DAC), the output ends gives ac small signal to the first stage of transistor that is utilized to control the gain of the amplifying stage and also limiting the current flowing through the circuit. Since the

signal is in AC, it's better to have a filter stage before and after the transistor. After capacitor connected to the collector of the transistor, the output end will be connected to an amplifier buffer, which is used to eliminate possible noise from the ac signal. The third stage is another band filter stage connected with an amplifier, while it can also provide gain to the stage. After the filter stage, it's a half-rectifier, or a peak detector. It's used to transform ac signal to dc, in order for the future analysis, possibly going into another ADC for the computer to process the signal to determine the current status of the monitored personnel.

2.3.2. Examples

From Fassebender [7], the pressure sensor should be implantable, which means that the circuit design should take into the maximum operating voltage and current into account. Non-invasive device means that it cannot output voltage or current that will damage the human body.

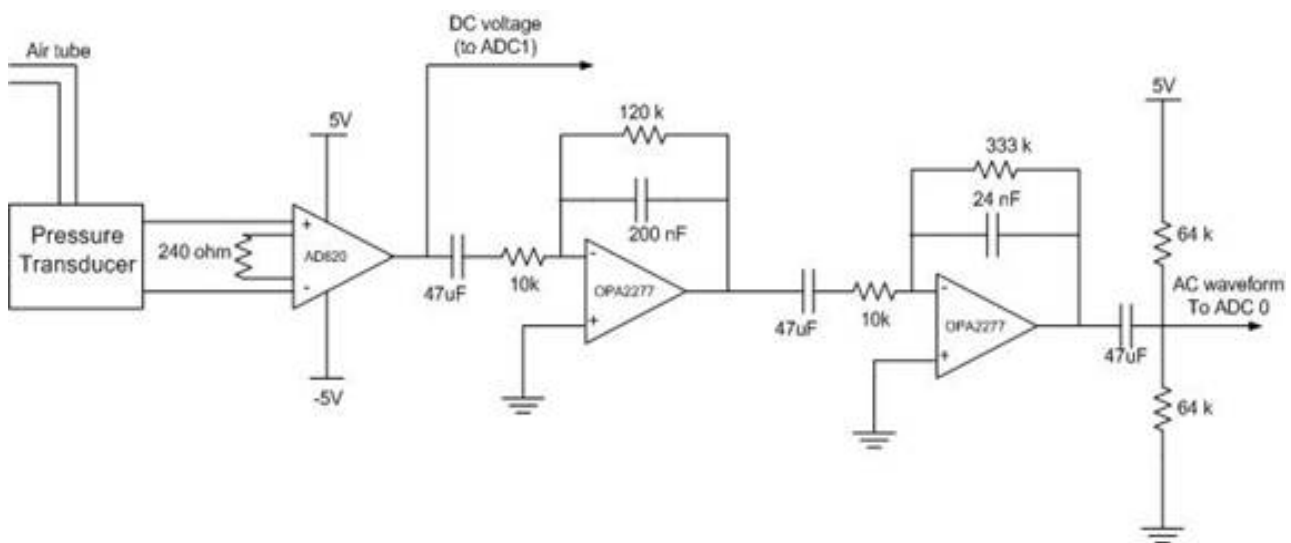


Figure 4. Schematics of Analog Circuit [8]

As shown in the figure above, researchers from Cornell University has a similar layout of the pressure sensor circuit. It also requires ADC stage and amplifier-filter stage. The output end will provide the waveform to the computer to process.

When using pressure sensor, if the sensor is highly conductive [9], such as the ultra-thin gold sensor with nano-wires [10], we need to consider if the conductivity will bring problems such as the extra noise caused by the conductivity and the filtering might not be good enough to filter out unwanted noise.

When speaking of sweat sensor, it's also about conductivity. When the conductivity changes, it's critical for the designed circuit to detect the change caused by the conductivity sensor. Since the gradient of the change might be small [11], it will bring challenge to analyze the signals.

3. Data and evaluation

In order to investigate the precision and reliability of our prototype, we hired 10 volunteers to participate in our measurements. We kept recording data from each of the persons at the same time of the day and lasted 10 days to get the average value.

Some of them playing sports and the others are quiet so that we can get various results from the measurements.

We set a control group to check if our prototype works as expected. Unsurprisingly, two groups of data kept equal.

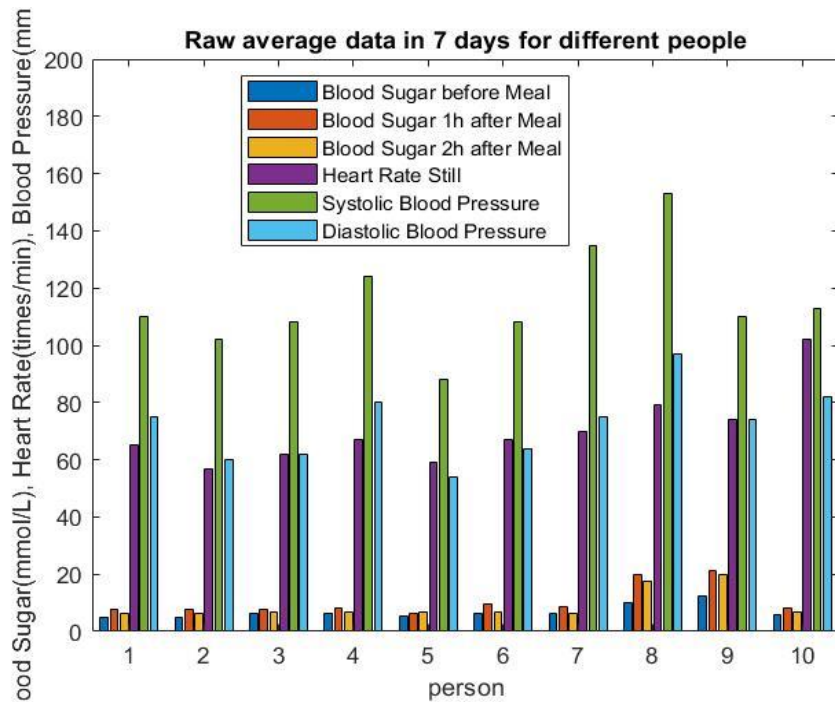


Figure 5. Raw average data in 7 days for different people

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BS_List = [5.1,4.9,6.1,6.4,5.4,6.2,6.1,10.2,12.2,5.7];
BS1h_List = [7.9,7.6,7.9,8.2,6.3,9.7,8.8,19.9,21.3,8.4];
BS2h_List = [6.4,6.4,6.6,7,6.6,6.9,6.5,17.7,19.8,6.7];
HR_List_m0 = [65,57,62,67,59,67,70,79,74,102];
HR_List_m1 = [188,167,153,177,169,177,192,198,183,189];
BPH_List = [110,102,108,124,88,108,135,153,110,113];
BPL_List = [75,60,62,80,54,64,75,97,74,82];

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Figure 6. Raw average data in 7 days for different people(2)

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>> simulation
person 1: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Normal
person 2: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Normal
person 3: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Normal
person 4: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Elevated
person 5: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Hypotension
person 6: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Normal
person 7: BloodSugar: Normal, HeartRate: Normal, BloodPressure: Normal
person 8: BloodSugar: Medium, HeartRate: Normal, BloodPressure: Hypertension Stage2
person 9: BloodSugar: Severe, HeartRate: Normal, BloodPressure: Normal
person 10: BloodSugar: Normal, HeartRate: Too High, BloodPressure: Normal

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Figure 7. Raw average data in 7 days for different people(3)

The precision of the blood pressure is 3mmhg and the blood sugar is 0.1mmol/L.

The range of the blood pressure is 0-280mmhg and the blood sugar is 0-33.3mmol/L.

We have the the expected normal blood pressure intervals: less than 120mmhg systolic and less than 80mmhg diastolic. Standard elevated pressure: 120mmhg to 129mmhg systolic and less than 80 diastolic. Stage 1 hypertension: 130 to 139mmhg systolic or 80 to 89mmhg

diastolic. Stage 2 hypertension: 140 to 180mmhg or 90 to 120 mmhg. Hypertensive crisis higher than 180mmhg systolic or higher than 120mmhg diastolic. [12]

Blood sugar has many different standards to define “normal” in many situations. In order to make our prototype easier for most of the unprofessional users to understand, we only took the most generalized standard to evaluate the recorded data. Normal blood sugar before meal is expected to be 3.9-6.1(mmol/L). Normal blood sugar after meal 1 hour is expected to be 6.7-9.4(mmol/L). Normal blood sugar after meal 2 hour is expected to less or equal to 7.8(mmol/L). [13]

Normal resting heart rate for adults ranges from 60 to 100 beats per minute. Higher are set to be “Too high”[14]

4. Conclusion

We did some preliminary works at the beginning to be familiar with basic ideas of wearable health devices and related applications with examples which is helpful for licensed doctor to diagnosis. Then we focused on blood pressure, blood sugar and heart rate to be our main three measurable index. Throughout literature review and primitive circuit design, we have gained basic understandings of how the circuit should perform in order to process signals received from the output. Signal processing plays a major role in the prototype and should be considered as priority in future design. Furthermore, integrate several circuits into one might significantly decrease the size of the wearable health device, but it might also increase the possibility of damaging the integrity of the whole system. Therefore, in order to minimize the possibility of damaging, in future experiments, we should design the project in a bottom-up structure to ensure that the system is intact and functional. Then we actually used our prototype to measure and evaluate data to see if it works properly. With a control group to compare with, the data from the prototype gives a satisfying results in an acceptable uncertainties.

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