Visvesvaraya Technological University

"Jnana Sangama''Belagavi-590018

Mini Project Synopsis on

"Photoplethysmography with Simple Arduino Setups"

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TABLE OF CONTENTS

Abstract

In this project, Photoplethysmography will focus on detecting blood volume changes in the microvascular bed of tissue. The only method to measure absolute changes in blood volume accurately in the extremities is by using chamber-plethysmography.

A PPG waveform comprises two main components; 'AC' arterial pulsatile changes in blood flow synchronized to heart beat and 'DC' elements attributed to venous blood, tissue, respiration, sympathetic nervous system activity and thermoregulation.

The amount of optical absorption or reflection depends on the amount of blood that is present in the optical path, the PPG signal is responsive to changes in the volume of the blood, rather than the pressure of the blood vessels. In other words, PPG detects the change of blood volume by the photoelectric technique, whether transmissive or reflective, to record the volume of blood in the sensor coverage area to form a PPG signal.

The principles on exciting interdisciplinary photoplethysmography experiments during which we can learn how they can build a software-based system to observe their own heart function.

Photoplethysmography can serve as starting points of exciting and inspiring experiments in education, we can observe our own cardiac function and analyze it in various ways.

Introduction

Photoplethysmography was first explored in the 1930's. PPG is a method for measuring the amount of light that is absorbed or reflected by blood vessels in living tissue.

A PPG sensor can be used in reflection mode (for example on the finger) or in transmission mode (for example on the ear) as shown in Figure 1. Normally, a wavelength in the near infrared is used because there we have the strongest modulation of the signal due to light absorption in the haemoglobin in the blood.

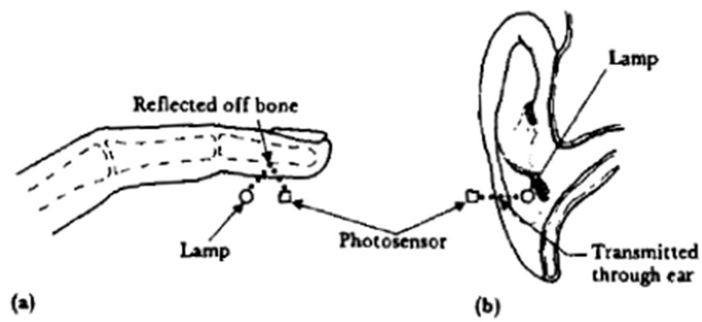

Figure 1. *(a) Light transmitted into the finger pad is reflected off bone and detected by a photo sensor. (b) Light transmitted through the aural pinna is detected by a photo sensor*

The PPG signal is a complex mixture of the blood flow in veins and arteries of the cardiovascular circulatory system. A raw PPG signal generally includes pulsatile and non-pulsatile blood volume.

The pulsatile component of a PPG signal is related to changes in blood volume inside the arteries and is synchronous with the heartbeat, whereas the non-pulsating component is a function of the basic blood volume, respiration, the sympathetic nervous system, and thermoregulation.

PPG technology thus represents a convenient and low-cost technology23 that can be applied to various aspects of cardiovascular monitoring, including the detection of blood oxygen saturation, heart rate, BP, cardiac output, respiration, arterial aging, endothelial function, microvascular blood flow, and autonomic function.

Literature Review

1. **Title:** A photoplethysmography experiment for microcontroller labs
   Author: Z. Gingl
   Publication: Int. J. Elect. Eng. Educ., vol. 49, no. 1, pp. 42–60, 2012
   Description: It focuses on how the hardware price could be reduced and the experiments can be easily ported to other MCU platforms. The experiments in this paper is scalable.
2. **Title:** Analysis of a pulse rate variability measurement using a smartphone camera
   Author: A. Bánhalmi, J. Borbás, M. Fidrich, V. Bilicki, Z. Gingl, and L. Rudas
   Publication: J. Healthcare Eng., vol. 2018, Feb. 2018, Art. no. 4038034
   Description: It focuses on how we can use smartphones to measure our heart rate. No extra cost needed Some of the new technologies are highly efficient, but it focuses mainly on electrocardiogram than photoplethysmography. It also requires high storage and an expensive phone.
3. **Title:** Photoplethysmography sampling frequency: Pilot assessment of how low can we go to analyze pulse rate variability with reliability?
   Author: A. Choi and H. Shin
   Publication: Physiol. Meas., vol. 38, no. 3, pp. 586–600, Mar. 2017.
   Description: Helps with better understanding of how sampling frequency can help in photoplethysmography. And it is potentially reliable but it is inaccurate and doesn't consider all the possibilities.
4. **Title:** Advances in Photoplethysmography Signal Analysis for Biomedical Applications
   Author: Jermana L. Moraes 1 ID , Matheus X. Rocha 1 , Glauber G. Vasconcelos 2 , José E. Vasconcelos Filho, Victor Hugo C. de Albuquerque, Auzuir R. Alexandria
   Publication: Multidisciplinary Digital Publishing Institute
   Description: PPG, a significant expansion in the utilization of this technique as a method of measurement and monitoring the heart rate. This is only possible when interlinking the technique with IoT technologies and artificial intelligence.

Methodology/Planning of Work

The principle of photoplethysmography is very simple: the blood volume variations, example: in the finger caused by heart activity are monitored by light absorption or reflection, as shown below. We use infrared LED to emit light into a finger or earlobe and to observe the transmitted or reflected light by a phototransistor.

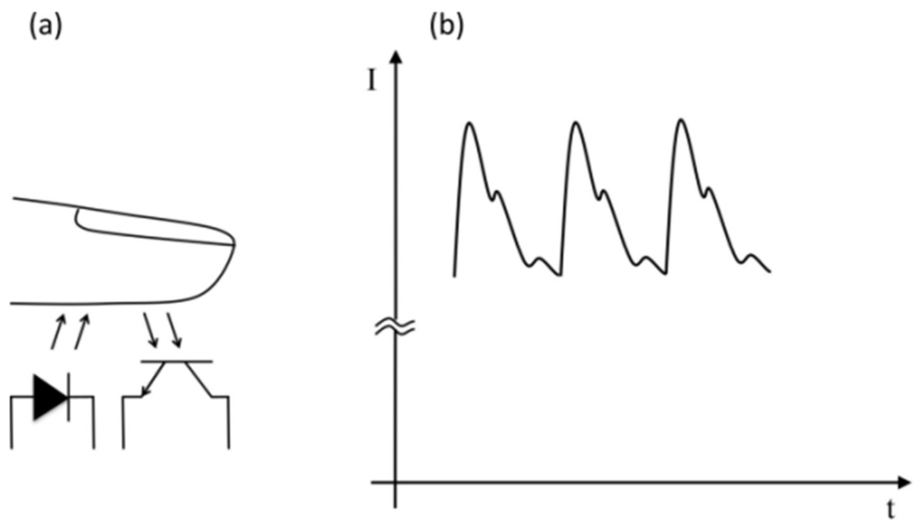

Figure 2: ***Principle of reflective photoplethysmography. The fingertip is simply placed over the LED and phototransistor pair (a). The output signal of the phototransistor circuit has a small AC component in addition to a large DC value (b)***

Another common solution to measure heart activity is to use the stethoscope. It can be considered as a mechanical amplifier to detect sound and using a microphone as a sensor the heart sounds can be digitized.

The aim is to build a signal conditioning circuit to transform the signals of the sensors to a voltage that fits in the range of the ADC of the Arduino board. The most commonly used range is from 0V to the supply voltage, nominally 5V.

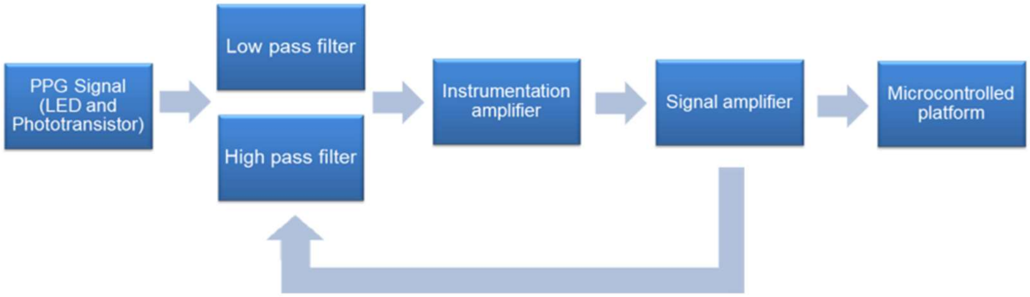

Figure 3: Block Diagram of Photoplethysmography

Low-pass and high-pass filters can be implemented to reduce computational cost.

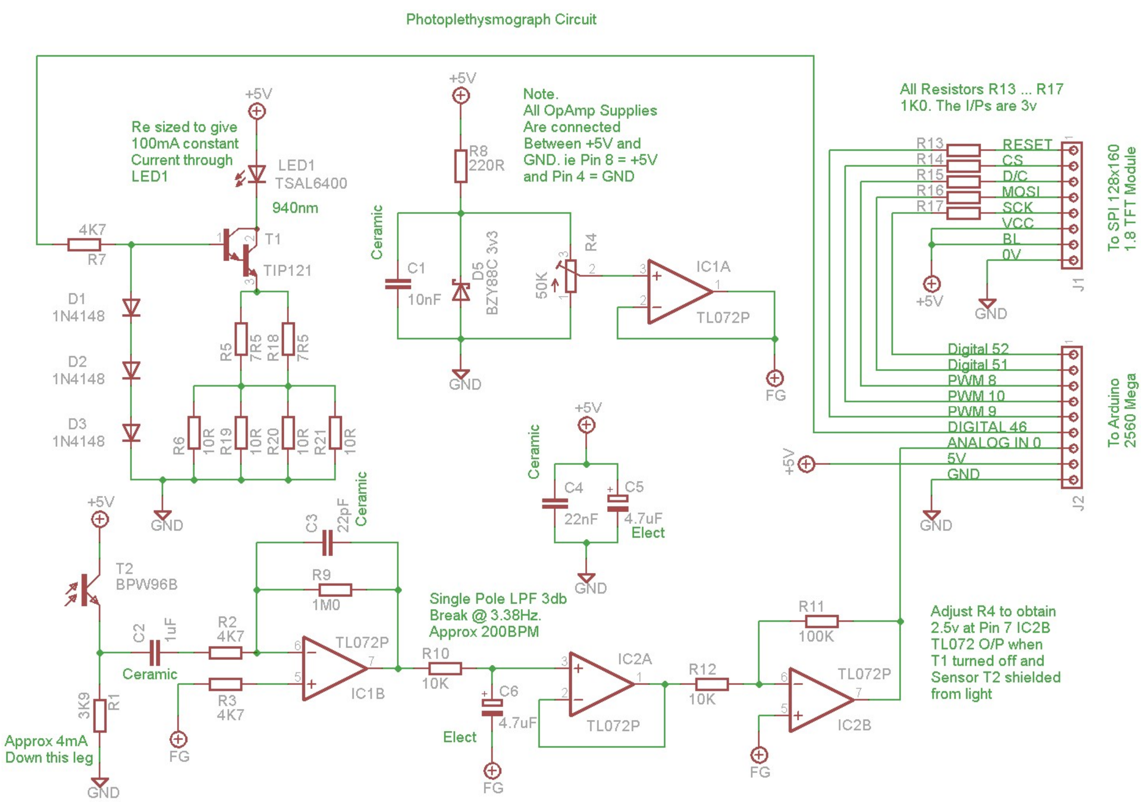

Figure 4: ***Circuit diagram of PPG***

Components Required

a) Arduino Mega 2560

b) The Sensor

c) 1.8 SPI 128x160 TFT Module.

d) TL072 FET OpAmps

e) T121 NPN Darlington Transistor

f) 1N4148 diodes

g) BZY88C 3v3 Zener diode

h) BPW96B Phototransistor

i) TSAL6400 940nm IR 5mm Led

j) Ceramic 1uF capacitor

k) 4.7uF Electrolytic capacitors

l) 22pF Ceramic capacitor

m) 22nF Ceramic capacitor

n) 10nF Ceramic capacitor

o) 50K 10 turn potentiometer

p) 4K7 resistors

q) 10R resistors

r) 7R5 resistors

s) 1M0 resistor

t) 3K9 resistor

u) 1K,10K,100K resistors

v) 220R resistors

Expected Results/Outcomes

The benefits of the PPG approach compared to ECG are greater than the drawbacks, bearing in mind that it is a simpler technique and there is not the necessity of attaching electrodes to the patient's chest.

The extensive utilization of this technique is related to its simplicity, convenience, easiness of connection with IoT technologies, and for it being a non-invasive approach.

Better understanding of PPG. Less expensive than the current methods. Higher accuracy and efficiency.

Conclusion

The increasing demand for the PPG-based wearable devices also provides an interesting direction for continuous ambulatory measurement of blood volume. Arduino development environment are enough to measure, display and study photoplethysmography signals. All parts, methods and basic principles are made as transparent and clear as possible.

Bibliography/References

[1] Z. Gingl, ‘‘A photoplethysmography experiment for microcontroller labs,’’ Int. J. Elect. Eng. Educ., vol. 49, no. 1, pp. 42–60, 2012

[2] A. Bánhalmi, J. Borbás, M. Fidrich, V. Bilicki, Z. Gingl, and L. Rudas, ‘‘Analysis of a pulse rate variability measurement using a smartphone camera,’’ J. Healthcare Eng., vol. 2018, Feb. 2018, Art. no. 4038034

[3] A. Choi and H. Shin, ‘‘Photoplethysmography sampling frequency: Pilot assessment of how low can we go to analyze pulse rate variability with reliability?’’ Physiol. Meas., vol. 38, no. 3, pp. 586–600, Mar. 2017.

[4] “Advances in Photoplethysmography Signal Analysis for Biomedical Applications”, Jermana L. Moraes, Matheus X. Rocha, Glauber G. Vasconcelos, José E. Vasconcelos Filho, Victor Hugo C. de Albuquerque Auzuir R. Alexandria