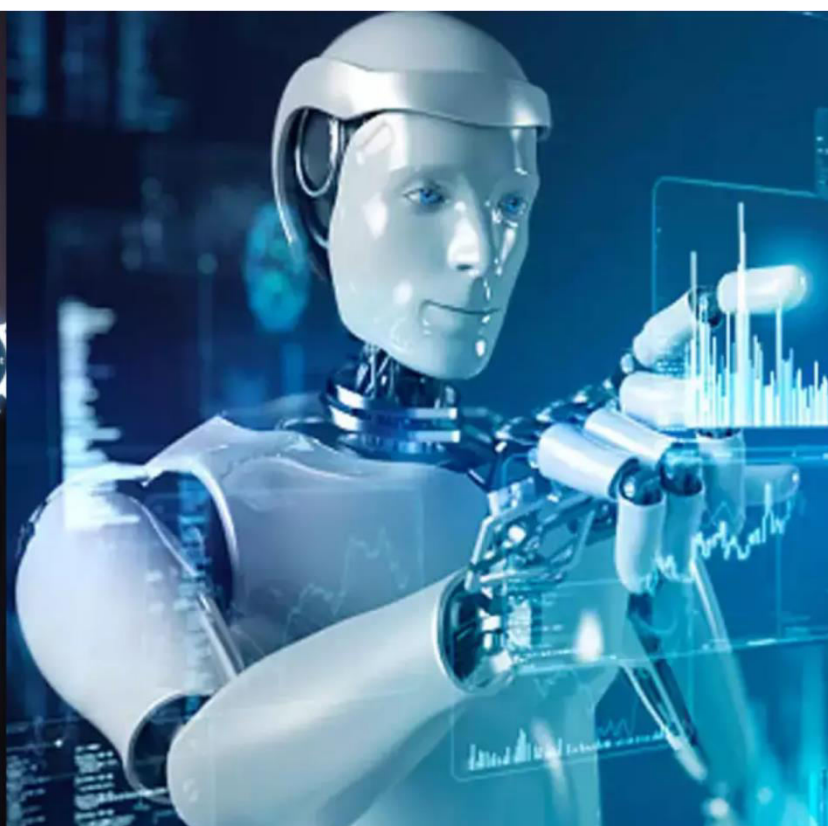




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Design and Fabrication of a Photoplethysmography-based Pulse Rate Sensor

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ABSTRACT: Photoplethysmography (PPG) is a non-invasive optical technique used to measure blood volume changes in microvascular tissue, commonly employed in pulse rate monitoring. This paper presents the design, fabrication, and evaluation of a low-cost, real-time PPG-based pulse rate sensor. The system consists of an optical sensor module, a signal processing unit, and a microcontroller-based display interface. The prototype was tested on human subjects, and the results were compared with commercial pulse oximeters. The developed sensor demonstrated an accuracy of 96.5% with a response time of under 3 seconds, making it a viable alternative for affordable and accessible heart rate monitoring.

KEYWORDS: Photoplethysmography, Pulse Rate Sensor, Optical Sensing, Signal Processing, Biomedical Engineering

I. INTRODUCTION

Cardiovascular health monitoring is crucial in modern medicine, and pulse rate measurement is a fundamental aspect of patient assessment. Traditional methods such as electrocardiography (ECG) and manual pulse checks are accurate but require trained personnel. Photoplethysmography (PPG) offers a cost-effective, non-invasive, and portable solution for real-time pulse rate monitoring.

PPG sensors detect variations in blood volume using infrared (IR) or visible light. These fluctuations correspond to heartbeats, allowing pulse rate estimation. Recent advancements in low-power electronics and signal processing techniques have enabled the development of wearable PPG-based sensors. This paper focuses on the design and fabrication of a PPG-based pulse rate sensor, emphasizing accuracy, affordability, and real-time performance.

II. LITERATURE SURVEY

Wearable PPG technology has been accessible for several decades, but it was not until the early 2010s that it became more widely commercialized and popularized. This phenomenon was largely due to the development of more accurate and reliable PPG sensors, as well as advances in miniaturization and wireless connectivity that made the incorporation of PPG sensors into small, wearable devices practicable. The first commercially available wrist-wearable device with a PPG sensor, the Mio Alpha[1], was released in 2012, followed shortly thereafter by other popular devices, such as the Fitbit Charge HR and the Basis B1 Band. In the smartwatch product line, after the first PPG sensor was introduced in the Samsung Galaxy Gear2 in 2014, the PPG sensor was also installed in the Apple Watch in 2015[2]. Since then, wearable PPG technology has continued to evolve and improve, with many new devices incorporating more advanced sensors and algorithms to monitor a wider range of physiological parameters. Today, wearable PPG technology is broadly used in a variety of applications, including health and fitness monitoring, clinical research, and medical diagnostics. In early 2010[3], as wrist-wearable devices with PPG sensors began to be commercialized, a review of wearable PPG systems was published in the journal Electronics[4]. In the review paper, various wearable form factors, such as rings and earphones, as well as wrist-worn devices, were discussed, and motion noise cancellation methods were carefully reviewed. The functionality of PPG sensors in wrist-wearable devices has evolved significantly over the subsequent years. The earliest function of PPG sensors in wrist wearables was to solely measure the heart rate, which has since become a standard feature in most wrist-wearable devices. More advanced PPG technologies are now being used to monitor various other health metrics. This functionality is still relatively new and requires more rigorous testing and validation, but it has the potential to greatly enhance the capabilities of wrist-wearable devices as health monitoring tools. As the last comprehensive

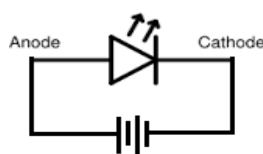
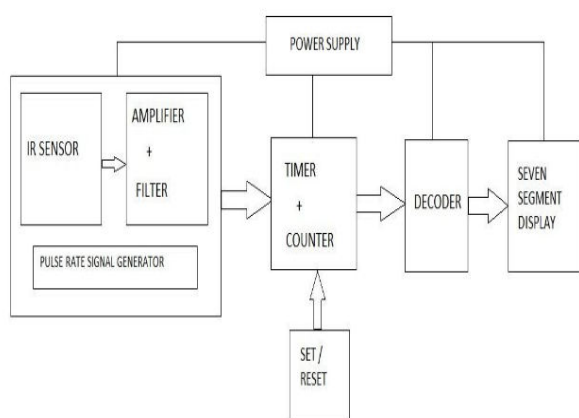
review of wearable PPG technology was published a decade ago, this article aims to review the latest research developments that have enabled various health monitoring functions through PPG sensors.

The work in this paper is divided in two stages. 1) Sensing with the help of Photodiode as the basic sensor to sense the pulse beats from the fingertip artery 2) feeding the pulse signals from heart beat is fed to a counter through a timer circuit.3) Finally the counter on receiving signal counts the pulses and gives output digitally.

III. METHODOLOGY

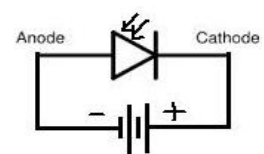
Photoplethysmography (PPG) is a simple and low- cost optical technique. The PPG waveform comprises a pulsatile physiological waveform attributed to cardiac synchronous changes in the blood volume with each heartbeat, and is superimposed on a slowly varying baseline with various lower frequency components attributed to respiration, sympathetic nervous system actively and thermoregulation. In PPG methods, the interaction of light with biological tissue is an important factor and it includes the optical processes of scattering, absorption, reflection and transmission which further depends on blood volume change, blood vessel wall movement and also on wavelength of light. As the main constituent of tissue is water, the absorption spectra of water allow red or near infrared light to pass through tissues more easily enabling blood flow measurements. Modern PPG sensors often utilize low-cost semiconductor technology with LED and matched photo detector devices working at the red and/or near infrared wavelengths. LEDs convert electrical energy into light energy and have a narrow single bandwidth (typically 50 nm). They are compact, have a very long operating life (>105h), operate over a wide temperature range with small shifts in the peak-emitted wavelength, and are mechanically robust and reliable.

The choice of photo detector is also important. Its spectral characteristics are chosen to match that of the light source. A photo detector converts light energy into an electrical current. Carefully chosen filtering circuitry is also needed to remove the unwanted higher frequency noise such as electrical pick up from (50 Hz) mains electricity frequency interference. There are two main PPG operation configurations: transmission ('trans- illumination') mode operation where the tissue sample (e.g. fingertip) is placed between the source and detector, and reflection mode operation where the LED and detector are placed side by side. Clearly, transmission mode PPG impose more restrictions that the reflection mode PPG on the body locations available for study. The PPG probe should be held securely in place to minimize probe- tissue movement technology. For example, artifact can arise from ambient light interference or any source of minimal vibration



Bias circuit

IR TRANSMITTER



Bias circuit

IRRECEIVER IR



Transmitter LED (white), IR Receiver LED (black)

[Block diagram of the pulse rate detector]

Circuit Component

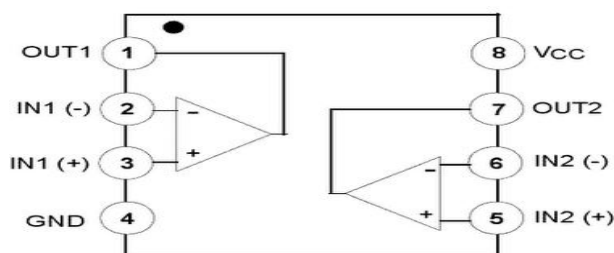
Infrared sensor and receiver:

The characteristics of IR rays produced secondary wavelets when it collides with any obstacles in its path. When any obstacle interferes in the path, the IR rays get cut and it produces secondary wavelets which transmit further to fall on a photo detector with a different intensity. Infrared photo receiver is a two terminal PN junction device. Figure is presented in previous page.

Operational amplifier:

The operation amplifier (OPAMP) manufacture with integrated circuit technology contains transistors, diodes, resistors and capacitors can perform such importance functions as isolation, inversion, addition, subtraction, multiplication and division. The operational amplifier has two types of connections: 1) Inverting 2) Non- inverting.

Here we used IC LM 358 is a dual operational amplifier.



Features:

1. Internally frequency compensated for unity gain.
2. Large DC voltage gain: 100 dB
3. Wide power supply range: 3v- 32 v includes ground
4. Input common mode voltage range – 1.5 V DC
5. Large output voltage swing: 0 v DC to Vcc
6. Power drain suitable for battery Pin operation.

(Configuration of LM 358 a dual Op-amp)

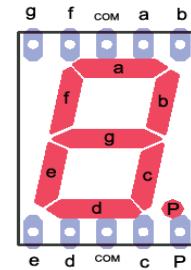
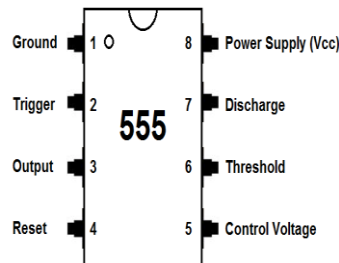
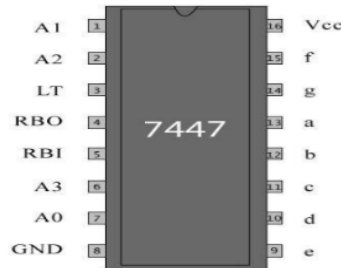
Counter:

In electronics, counters can be implemented quite easily using register-type circuits such as the flip-flop, and a wide variety of classifications exist: 1. Asynchronous (ripple) counter- changing state bits are used as clocks to subsequent state flip-flops 2. Synchronous counter – all state bits change under control of a single clock 3. Decade counter – counts through ten states per stage 4. Up/Down counter – counts both up and down, under command of a control input 5. Ring counter- formed by a shift register with feedback connection in a ring 6. Johnson counter – a twisted ring counter 7. Cascaded counter 8. Modulus counter.

IC 74LS47 Display driver: 74LS47 is a BCD to 7-segment decoder/driver IC. It accepts a binary coded decimal as input and converts it into a pattern to drive a seven-segment for displaying digits 0 to 9. 74LS47 IC accepts four lines of BCD input data and generates their complements internally.

555 Timers: Supply voltage (Vcc): 4.5 to 15 V, Supply current (Vcc = +5v): 3 to 6 mA Output current (maximum): 200 mA, Maximum power dissipation: 600 mW . Operating temperature: 0 to 70 degree C. It has 3 Monostable, Astable and Bistable.

Digital Display: It is a one type of display device which can show the output in digital form. Each segment has LEDs or incandescent filaments within it that emits light when current passes through it. “a,b,c,d,e,f,g” are the naming of each segment as shown in figure. Seven segment displays are available in two configurations: Common Cathode, Common Anode.



IV. EXPERIMENTAL RESULTS

Case study 1:

SL.NO.	Pulse Rate when person under rest (bpm)	Pulse Rate when person have done some work (bpm)
1.	77	102
2.	75	98
3.	69	89

Case Study 2:

SL.NO.	Pulse Rate when person under rest (bpm)	Pulse Rate when person have done some work (bpm)
1.	75	76
2.	77	79
3.	68	68

V. BENEFITS AND FUTURE SCOPE

Benefits: The pulse rate detector designed is cost effective. This device if made to use commercially can be popular in this competitive market. It is very light weight and portable to be bought and utilized by any person other than doctors or hospitals. This circuit design becomes much simpler and less complicate to fabricate.

Scope of future works: The pulse rate monitor designed counts the pulse from a pulse signal generator and the counted value is displayed digitally. If the fingertip is not steadily placed, then minor movement of the finger can vary the output Also, another important reason that varies the output is interference of ambient light picked up by IR transmitter receiver pair. The readings that were obtained from different persons were taken for 60 seconds. In future it is supposed that this device can be modified by a circuit that should be taken less time.

VI. CONCLUSION

Depending on the benefits and future scopes of this project further statements are made like Pulse rate detection is a very primary factor in determining a person's health. Various invasive and non-invasive techniques have been utilized

in determining pulse rate. Photoplethysmography is a non-invasive method that is incorporated in designing this pulse rate detector. The fabricated pulse rate detector has an optical sensing unit that transmits its electrical output to a digital display unit. The pulse rate detector is of low cost so it can be thought of to be made commercial in future. The design and fabrication of this device involves an extensive study on the application of instrumentation in biomedical science. As biomedical science is developing, hence this work can prove to be a benefit in this field. In the occasion of cost, it has low cost and long durability. Further improvements in signal processing and sensor integration could enhance its performance, paving the way for widespread healthcare applications, especially in resource-limited settings.

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