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NEW CIRCUIT DESIGN TO MEASURE PHOTOPLETHYSMOGRAPHY

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Abstract

Throughout this paper, we emphasize design; photoplethysmograph hardware design. We propose to build and test a photoplethysmograph. This device will be used to determine heart rate using a volume measurement. This is done by using low levels of infrared sensors to detect small changes in blood content in the micro-circulation of the skin that occur with each heart beat . An LED is used to transmit light into the skin. The infrared is reflected by the iron content of the blood in the skin and tissues. The transmitted light through the blood and tissue is detected by a receiver. This information is processed and amplified to provide blood flow data. The photoplethysmograph gives a good technique to the physician to get the suitable diagnosis to his patient according to the output data that he gets from this device.
Keywords : as photoplethysmograph (PPG), Pulse Rate.

Introduction

Photoelectric plethysmography, also known as photo-plethysmography (PPG); is a noninvasive method to detect cardiovascular pulse wave that propagates through the body using a light source and a detector. Compared to the other types of plethysmograph, PPG is easy to set up, simple to use and low in cost.

The photoplethysmograph is a tool that uses an emitter-receiver pair to determine blood flow. A light emitting diode is used to transmit light through the skin. The receiver picks up the transmitted signal, which is then analyzed with signal processing techniques. The pulse wave is produced by the changes in blood volume in the arteries and capillaries. The light transmitted through the tissue can be highly scattered or absorbed depending on the tissue. The detector, which is positioned on the surface of the skin, can detect the transmission or the reflection in other situation of waves from various depths and from highly absorbing or weakly absorbing tissues. The output is proportional to blood flow.

Optoelectronic components

Optoelectronic components increasingly used in modern electronics. The main fields of application are in medical application (photoplethysmograph and pulse oximeter), light barriers for production control and safety devices; light control and regulating equipment like twilight switches, fire detectors and facilities for optical heat supervision; scanning punched cards and perforated tapes; positioning of machine tools for measuring length, angle and position of optical apparatus and ignition processes; for signal transmission at electrically separated input and output; and conversion of light into electrical energy. Depending upon the application, either photovoltaic cells or photodiodes can be used. Photodiodes are preferred where ever amplifiers with high input impedance are required. Phototransistors are predominantly used in connection with transistor circuits or to drive integrated circuits.

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1. Phototransistors

Phototransistors shown in Figure 1.1 are solid state light detectors that possess internal gain. This makes them much more sensitive than photodiodes of comparably sized area. The current-voltage characteristics of the phototransistor are similar to NPN signal transistors; with the major exception that incident light replaces current base drive. The phototransistor offers the following general characteristics and features:

- Low cost visible and near-IR photodetection.
- Available with gains from 100 to over 100,000.
- Moderately fast response times.
- Usable with almost any visible or near infrared light source such as LEDs, neon, fluorescent, incandescent bulbs, laser, flame sources, sunlight, etc.....

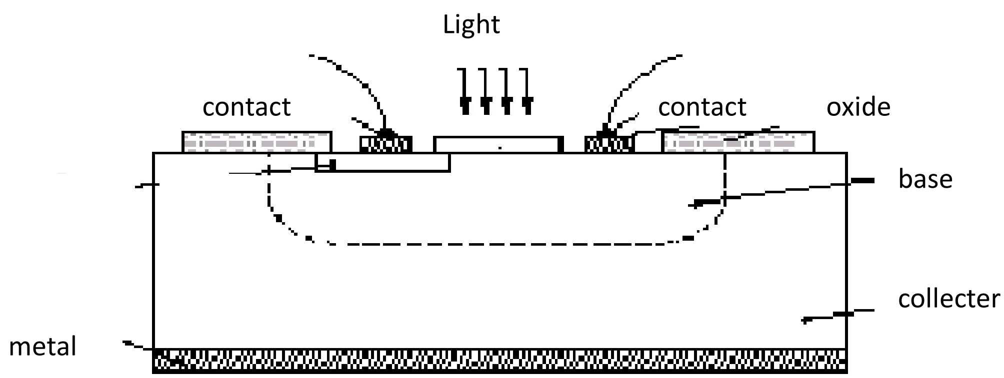

Figure 1.1 phototransistor

2. Infra-Red Light Emitting Diodes (IRLED's)

IRLED's shown in Figure 2.1 are solid state light sources which emit light in the near-IR part of the spectrum. Because they emit at wavelengths which provide a close match to the peak spectral response of silicon photodetectors both GaAs and GaAlAs LEDs are often used with phototransistors.

Figure 2.1 The Light emitting diode

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3. Finding the Frequency from the Wavelength of Light

The frequency of light is related to the wavelength of light in a very simple way. The spectrometer can be used to examine the light from the LED, and to estimate the peak wavelength of the light emitted by the LED. But we prefer to have the frequency of the peak intensity of the light emitted by the LED. The wavelength is related to the frequency of light by [Serway, 1996]:

$$f = \frac{c}{\lambda}$$

Where c is the speed of light (3 x 10^8 m/s) and λ is the wavelength of light read from the spectrometer (in units of nanometers or 10^{-9} meters). Suppose you observed the infra red LED through the spectrometer, and found that the LED emits a range in colors with maximum intensity corresponding to a wavelength as read from the spectrometer of λ= 940 nm or 940 x 10^{-9} m .The corresponding frequency at which the infra red LED emits most of its light is $f = \frac{3 * 10^{8}}{940 * 10^{-9}}$ =319 THz, and for red Led λ=680 nm the frequency is 440 THz. The unit for one cycle of a wave each second (cycle per second) is a Hertz (Hz).

4. Band-Pass Filter circuits

Band-pass fliter (rejects high and low frequencies, passing only signal around some intermediate frequency).

The simplest band-pass filter can be made by combining the first order low pass and high pass filters shown in Figure 2.5.

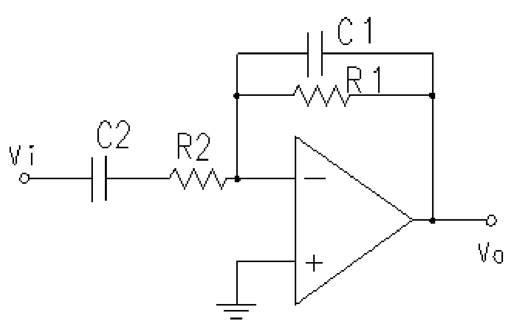

Figure 2.3 The band pass filter

Hardware Design

The hardware design details include the electrical specifications of the transmitter (IRLED), the receiver (Phototransistor), the amplifiers, and the filters. The equations that were used in the design procedure will be shown with its detail calculations. By using these equations, the values of the used resistors and capacitors can be calculated, taking in consideration the maximum allowed current passing through the

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transmitter and receiver to satisfy the safety conditions of these devices, and not to damage them. It also includes the calculations of the cut off frequencies of the filters.

The desired signal that the circuit is designed to pick up, has the following specification:

1. Very low amplitude.
2. Frequency content ranges between 0.33 to 24Hz.
3. Has an AC and DC component.

So the designed circuit must have the following stages to satisfy those specifications.
Figure 3.1 shows these stages.

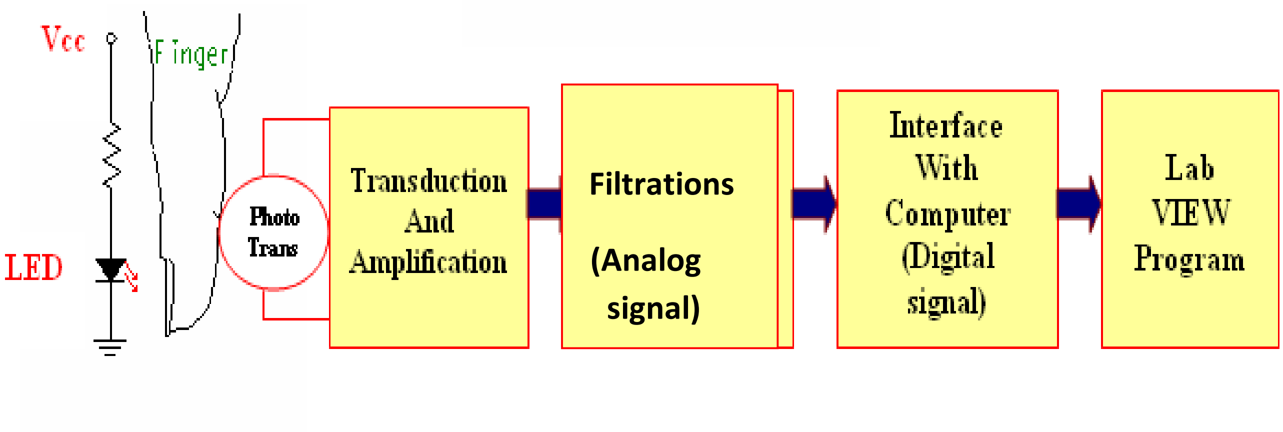

Figure 3.1 stages of designed circuit

Sensor stage calculations

1- Transmitter calculation

The used IRLED has a maximum allowable current of 20 mA, and forward voltage of 1.6 V. the used voltage source is 15V DC. So a protection resistance is needed to limit the current pass through and voltage applied on the transmitter.

This resistor is calculated using the equation: **R=V/I**

$= 15 / 20*10^{-3} = 750\ \Omega$

2. Receiver calculation

The used phototransistor has a voltage V_{CEO} of 30V, and the power source has a maximum value of 15V. So any resistance can be used, but the value of the resistance affects the strength of the signal. So the value of the resistor is selected experimentally, which is 100KΩ.

3. Block DC signal component

The output of the sensor consists of two components; AC which refers to absorption due to pulsatile arterial blood, which is the smaller component of the signal, and DC component which refers to the absorption of nonpulsatile arterial blood.

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Since the required signal is the AC component which reflect the change in blood volume and the DC component causes saturation to the electronic component especially the amplifiers. So, we must deal with the AC component and block the DC component. A capacitor with value 33µF with resistor of 1.6 MΩ is used to block the DC component of the pulsatile signal level. Figure 3.2 shows the capacitor that serves to block the dc level. The time constant (τ) is

$$\tau = R * C \qquad (3.2)$$

Also, a switch is used to restore the trace if too much motion artifact is introduced into the circuit.

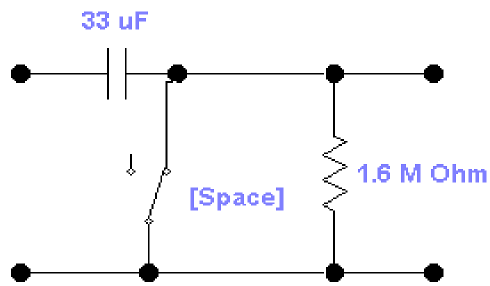

Figure 3.2 Capacitor to block dc noise

4. Amplifier stage calculations

Since the signal magnitude is very low, so we need multi stage amplifiers that have a gain around 3000. In the first amplification stage an inverting amplifier was used with a gain of 100, and according to the equation

$$A = V_{out} / V_{in} = (- R_f/R_{in})$$

So the resistor R_{f1} = 99KΩ and the resistor R_{in1} = 1KΩ satisfy this gain as shown in Figure 3.3. This amplifier is also used as a low pass filter that rejects all frequencies above 48 Hz when a capacitor of 33nF is connected in parallel with 99KΩ according to equation

$f_c = 1 / (2*\pi*R_f*C_f) =$ 48.7 Hz

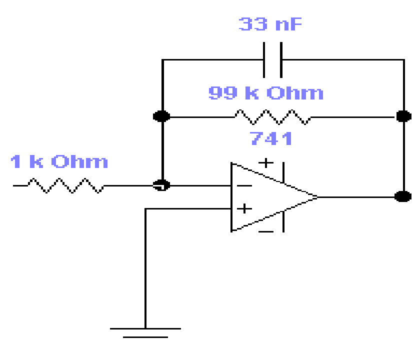

Figure 3.3 The inverting amplifier with a low pass filter

The second stage amplifier has a variable gain that depends on the value of potentiometer. The amplifier has a minimum gain of 17 and maximum gain of 122. the amplifier is also used as a low pass filter as shown in Figure 3.4 that rejects all frequencies above 48 Hz when a capacitor of 3.3nF is connected in parallel with 1MΩ according to equation

$$f_c = 1 / (2*\pi*R_f*C_f) = 48.2 \text{ Hz}$$

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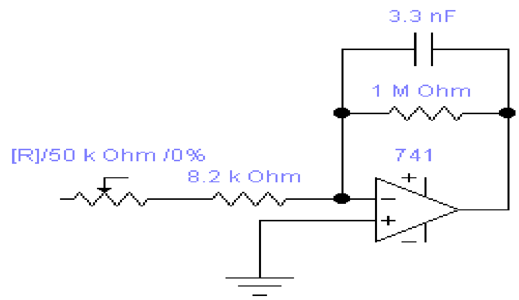
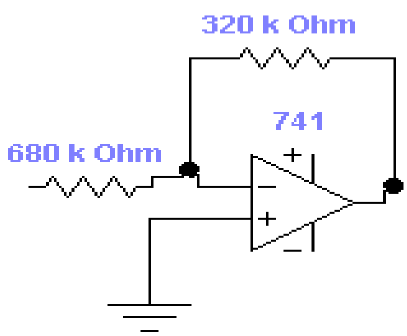


Figure 3.4 The inverting amplifier acts as a low pass filter

The next stage in this circuit design is at added the low and high pass filter then the trapped filter or Notch filter, as shown in figure 3.5

The final all stages of circuit design as shown in Figure 3.5.



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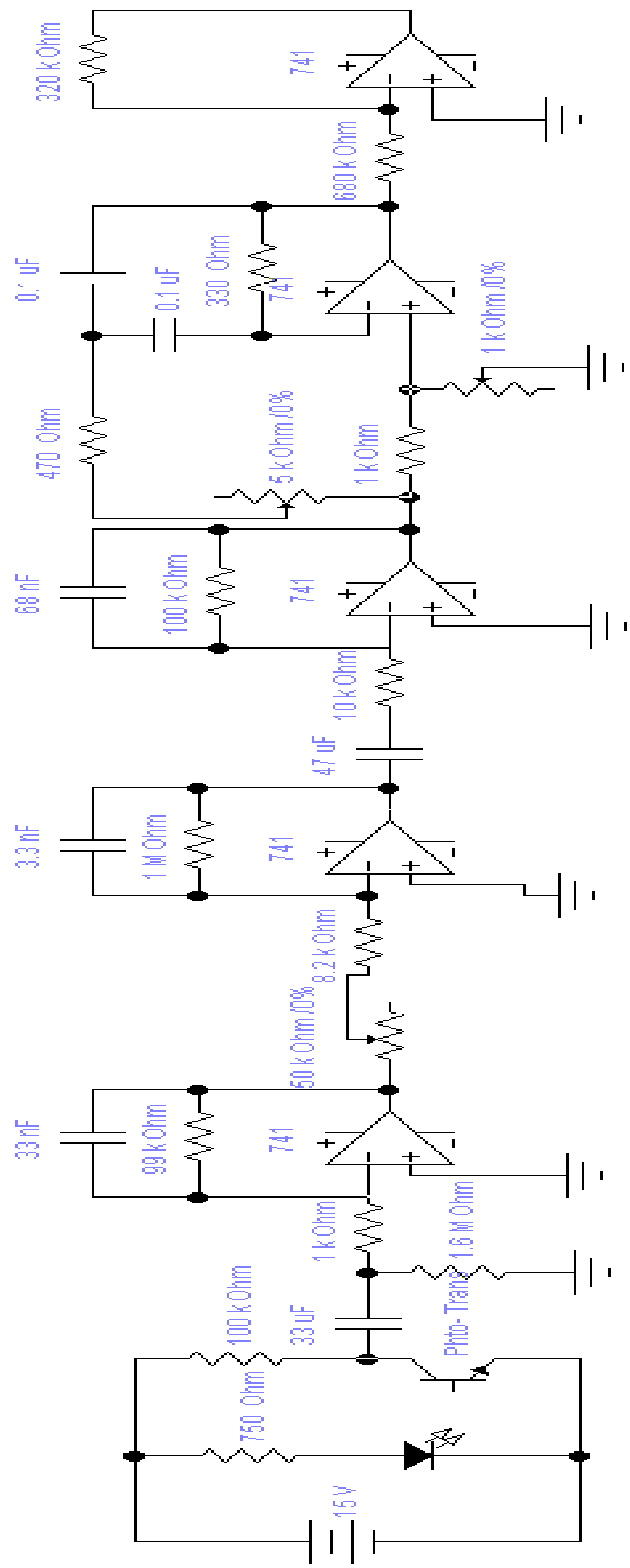

Figure 3.5 complete hardware circuit design with infra red transmitter receiver pair

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Results and Recommendations

The output signal of the hard ware design as shown in Fig 4.1 by using LABVEW software by the computer

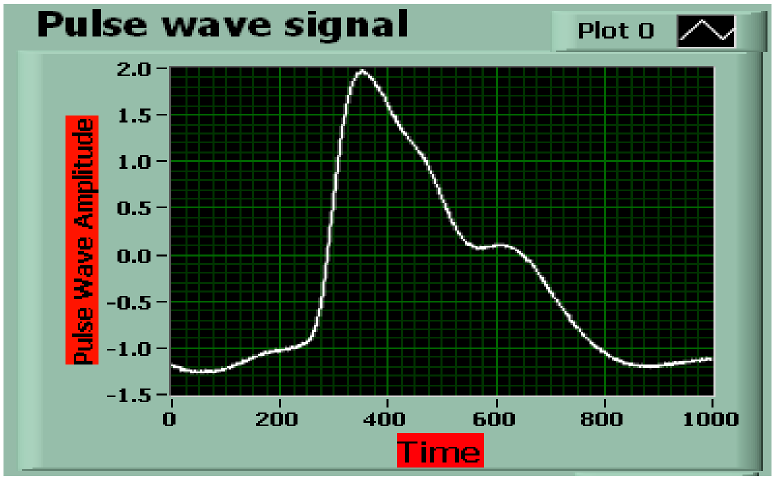

Figure 4.1 pulse wave signal

Recommendations

The recommendations of this project are as follow:

1. Making the hardware in a printed board will make it applicable to be portable.
2. developed program to measure all parameter by using LabView system.
3. Take many measurement sample from many people and compare it withother pulse oximeter device to calculate the accuracy and precision.
4. The hard ware can be developed to act as a pulse oximeter to measure the oxygen saturation in blood SPO_2.
5. Building the pulse oximeter simulator to calibrate the device.

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