Photoplethysmography Technique to Measure Heart Rate Count

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Abstract-*The Measurement of heart beat of a human being using stethoscope is a general way. With the implementation of this project, we are able to measure the heart rate accurately and efficiently using Photoplethysmography technique. This device uses a sensor which can easily detect the heart rate and accurate digital readings are given at the display unit. The sensor module and two stage amplifier circuit used, amplifies the weak signal and provides output. It is also very helpful in measuring irregular heartbeat, easy to use and can be accessed by common man without any external assistance.*

Keywords*-*oximeter, plethysmograph, pulsatile tissue, ECG;,sensor;

I. INTRODUCTION

Heart rate measurement indicates the soundness of the human cardiovascular system. This project demonstrates a technique to measure the heart rate by sensing the change in blood volume in a finger artery while the heart is pumping the blood. It consists of an infrared LED that transmits an IR signal through the fingertip of the subject, a part of which is reflected by the blood cells. The reflected signal is detected by a photo diode sensor. The changing blood volume with heartbeat results in a train of pulses at the output of the photo diode, the magnitude of which is too small to be detected directly by a counter circuit. Therefore, a two-stage high gain, active low pass filter is designed using two Operational Amplifiers (OpAmps) to filter and amplify the signal to appropriate voltage level so that the pulses can be counted by a counter module. The heart rate is displayed on a 3 digit seven segment display.

The use of **TCRT5000** simplifies the build process of the sensor part of the project as both the infrared light emitter diode and the detector are arranged side by side in a leaded package, thus blocking the surrounding ambient light, which could otherwise affect the sensor performance and its output is a digital pulse which is synchronous with the heart beat. The output pulse is fed to a digital counter module retrieving the heart rate in beats per minute (BPM).

II. PROBLEM STATEMENT

The ECG will be integrated with medical technology platform which uses a system to record and displays patient data. Problem with focus on development of a portable ECG with pulse oximeter for detection of rapid changes in the electrical activity. The problem is there is no known feasible method of noninvasively monitoring CO2 with O2 using spectroscopy to effectively monitor the overall respiratory health of patients. Oximeter must be durable, inexpensive and deliver data to a system as an analog signal. Pulse oximeter is a device that measures oxygen saturation level of a patient's blood.

III. RELATED WORK

Oximeter is measurement of transmitted light through a translucent measuring site to determine a patent's oxygen status noninvasively. In 1934 one investigator reported measuring oxygen saturation in blood flowing through closed vessels in animals. In 1939 German researchers reported use of an "ear oxygen meter" that used red and infrared light to compensate for changes in tissue thickness, blood content and other variables. Between 1940 and 1942 a British researcher, Millikan, used two wavelength of light to produce a practical, lightweight aviation ear oximeter for which he coined the word "oximeter". The system went through many modifications during 1940's and 1950's and this system was mainly used in physiology, aviation and experimental studies. In 1964 a San Francisco surgeon developed a self-calibrating, 8-wavelength oximeter that was marked by Hewlett Packard in the 1970's.This system was used in clinical environments but was very large. In later 1970's, the Box Corporation in Colorado made significant advances in pulse oximeter, 2-wavelength measurements. They first introduced the use of Light Emitting Diodes(LED's) for red and infrared light source. In 1980's along with Nellcor and Novametrix, continued to make significant advances in size reduction, cost and development of multiple site probes. Today there are many manufacturers of pulse oximeter where they use simple method of measuring oxihemoglobin saturation by two wavelength of light in the red and infrared range.

IV. PROPOSED METHOD

The proposed method consist of three modules

1: sensor module
2: signal conditioning unit
3: digital display unit

The proposed method is based on the principle of photoplethysmography(PPG) which is a non-invasive method of measuring the variation in blood volume in tissues using a light source and a detector. Since the change in blood volume is synchronous to the heart beat, this technique can be used to calculate the heart rate. Transmittance and reflectance are two basic types of photoplethysmography. For the transmittance PPG, a light source is emitted in to the tissue and a light detector is placed in the opposite side of the tissue to measure the resultant light. Because of the limited penetration depth of the light through organ tissue, the transmittance PPG is applicable to a restricted body part, such as the finger or the ear lobe. However, in the reflectance PPG, the light source and the light detector are both placed on the same side of a body part. The light is emitted into the tissue and the reflected light is measured by the detector. As the light doesn't have to penetrate the body, the reflectance PPG can be applied to any part of human body. In either case, the detected light reflected from or transmitted through the body part will fluctuate according to the pulsatile blood flow caused by the beating of the heart.

The following picture shows a basic reflectance PPG probe to extract the pulse signal from the fingertip. A subject's finger is illuminated by an infrared light-emitting diode. More or less light is absorbed, depending on the tissue blood volume. Consequently, the reflected light intensity varies with the pulsing of the blood with heart beat. A plot for this variation against time is referred to be a photoplethysmographic or PPG signal.

V. CIRCUIT DIAGRAM

A. Sensor module:

The sensor used in this project is **TCRT1000**, which is a reflective optical sensor with both the infrared light emitter and phototransistor placed side by side and are enclosed inside a leaded package so that there is minimum effect of surrounding visible light. The circuit diagram below shows the external biasing circuit for the **TCRT1000** sensor. Pulling the **Enable** pin high will turn the IR emitter LED on and activate the sensor. A fingertip placed over the sensor will act as a reflector of the incident light. The amount of light reflected back from the fingertip is monitored by the phototransistor.

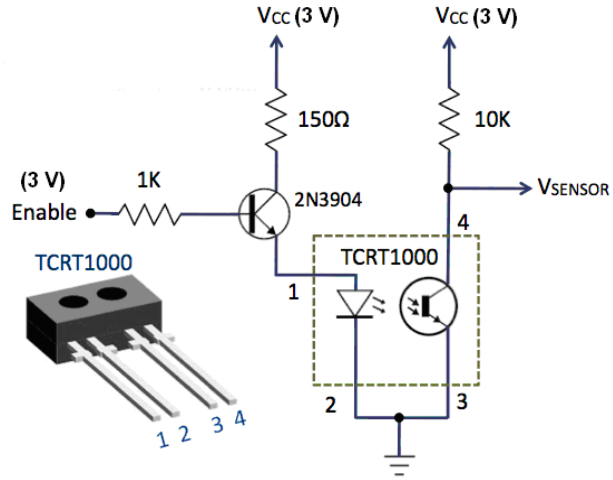

Figure1: TCRT1000 used for sensing pulse from fingertip

The output (V_{SENSOR}) from the sensor is a periodic physiological waveform attributed to small variations in the reflected IR light which is caused by the pulsatile tissue blood volume inside the finger. The waveform is, therefore, synchronous with the heart beat.

B. Signal conditioning unit:

The following circuit diagram describes the first stage of the signal conditioning which will suppress the large DC component and boost the weak pulsatile AC component, which carries the required information.

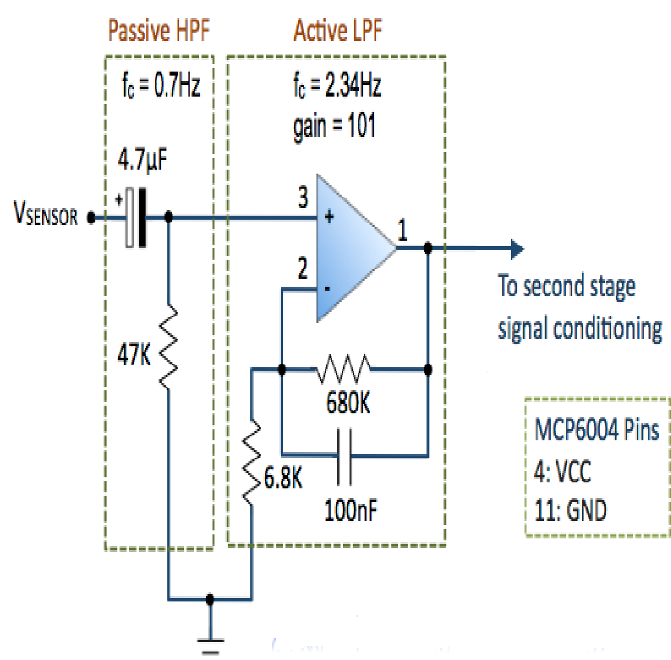

Figure2. First stage of signal conditioning

In the circuit shown above, the sensor output is first passed through a RC high-pass filter (HPF) to get rid of the DC component. The cut-off frequency of the HPF is set to 0.7 Hz. Next stage is an active low-pass filter (LPF) that is made of an Op-Amp circuit. The gain and the cut-off frequency of the LPF are set to 101 and 2.34 Hz, respectively. Thus the combination of the HPF and LPF helps to remove unwanted DC signal and high frequency noise including 60 Hz (50 Hz in some countries) mains interference, while amplifying the low amplitude pulse signal (AC component) 101 times.

The output from the first signal conditioning stage goes to a similar HPF/LPF combination for further filtering and amplification (shown below). So, the total voltage gain achieved from the two cascaded stages is **101*101 = 10201**. The two stages of filtering and amplification converts the input PPG signals to near TTL pulses and they are synchronous with the heart beat. The frequency (f) of these pulses is related to the heart rate (BPM) as

Beats per minute (BPM) = 60*f

An LED connected to the output of the second stage of signal conditioning will blink when a heart beat is detected. The final stage of the instrumentation constitutes a simple non-inverting buffer to lower the output impedance.

The operational amplifiers used in the instrumentation circuit described above are from the MCP6004 IC, which has got four general purpose Op-Amps offering rail-to-rail input and output over the 1.8 to 6V operating range. The picture below shows an assembled Easy Pulse board designed using the above circuit. Instead of fixing on the board, the TCRT1000 sensor can also be wired to the board through header pins and jumpers. This way you have more flexibility in using the sensor. You can hold the sensor between two fingers or you can face it down on the skin on your palm, and so on. The board operates from 3-5.5V and therefore, it can be used with both 3.3V and 5.0V microcontroller families.

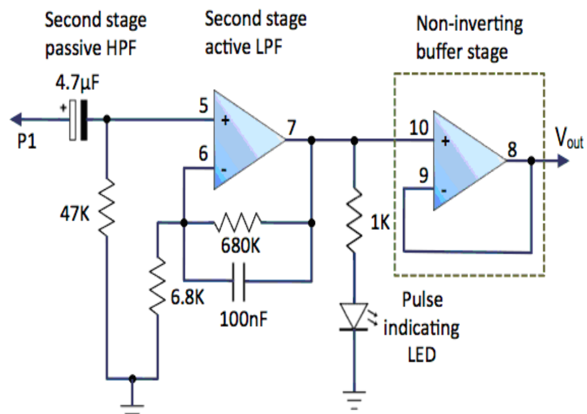

Figure3: Second stage of signal conditioning

C. Digital display unit:

4026 decode counter and 7-segment display driver
The count advances as the clock input becomes high (on the rising-edge). The outputs a-g go high to light the appropriate segments of a common-cathode 7-segment display as the count advances. The maximum output current is about 1mA with a 4.5V supply and 4mA with a 9V supply. This is sufficient to directly drive many 7-segment LED displays. The table below shows the segment sequence in detail.

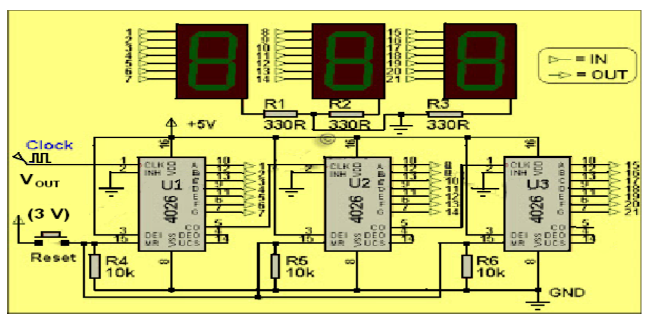

Figure 4: 3-digit 7-segment display circuit using IC 4026.

The reset input should be low (0V) for normal operation (counting 0-9). When high it resets the count to zero. The disable clock input should be low (0V) for normal operation. When high it disables counting so that clock pulses are ignored and the count is kept constant. The enabledisplay input should be high (+Vs) for normal operation. When low it makes outputs a-g low, giving a blank display. Theenable out follows this input but with a brief delay. The ÷10 output (h in table) is high for counts 0-4 and low for 5-9, so it provides an output at $^{1}/_{10}$ of the clock frequency. It can be used to drive the clock input of another 4026 to provide multi-digit counting. The not 2 output is high unless the count is 2 when it goes low.

VI. ADVANTAGES AND DISADVANTAGES

Advantage is Pulse oximetry measures a patient's arterial saturation of oxygen (SaO2) in seconds. Oximeters have only one button and as long as the probe is placed properly, virtually anyone can use it.

Disadvantage is it does not detect whether or not enough blood is actually moving through the tissues in states of low perfusion, such as shock, hypothermia. A comprehensive 1999 review of pulse oximeters published in "Critical Care" noted that, on average, oximeters are accurate within 2 percent for oxygen saturations of 90 percent or more.

VII. APPLICATIONS

It may take minutes to detect an esophageal intubation in a well-pre-oxygenated patient. When de-saturation occurs the pulse oximeter detects it quickly and accurately.

VIII. CONCLUSION

In the present situation everyone goes to doctor to check their heart rate. To reduce the manual efforts and human errors, we need to have some kind of automatic device to measure the heart rate without the need of external aid.

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