PHOTOPLETHYSMOGRAPHY

By s.sindhu ECE IV year
Dr. Sivanthi Aditanar
College of engineering Tiruchendur

ABSTRACT: This paper is about a simple heart rate monitor using 8051 microcontroller. The microcontroller used here is AT89S51.Thedevice senses the heart rate from the fingertip using IR reflection method and displays it on a three digit seven segment display in beats per minute. The circuit has an accuracy of 4 beats per minute and it is very easy to use. In medical terms, the technique used here for sensing heart rate is called Photoplethysmography.
KEYWORDS: Microcontroller, Photoplethysmography, Reflection.

INTRODUCTION: Heart beat is the number of heart beats per unit time typically expressed as beats per minute (bpm). Heart rate can vary as the body's need to absorb oxygen and excrete carbon dioxide changes during exercise or sleep. The measurement of heart rate is used by medical (systole) professionals to assistant in the diagnosis and tracking of medical conditions. It is also used by individuals such as athletes who are interested in monitoring their heart rate to maximum. Photoplethysmography is the process of optically estimating the volumetric measurement of an organ. Respiration detection, pulse oximetry, heart rate monitoring are some of the common applications of Photoplethysmography.
When the heart expands (diastole), the volume of the blood inside the fingertip increases, when the heart contract, the volume of the blood inside the fingertip decreases. The resultant pulsing of blood volume inside the fingertip is directly proportional to the heart rate. Let us have a look at measuring the heart rate from the fingertip by using a microcontroller and a photo diode sensor.

HARDWARE DESIGN: The circuit diagram used is:

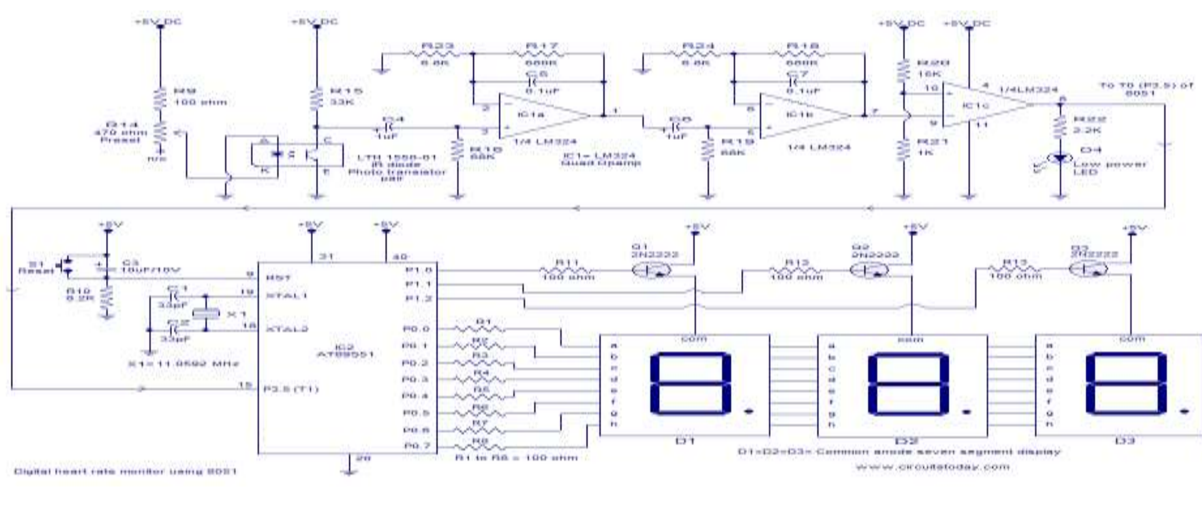

Fig.1. Heart rate monitor

DESCRIPTION: The important components used are described briefly below:

SENSOR: LTH1550-01 photo-interrupter forms the Photoplethysmographic sensor here. It is simply an IR diode and photo transistor pair in single package. The front sides of the IR diode and photo transistor are exposed and the remaining parts are well isolated. When the fingertip is placed over the sensor volumetric pulsing of the blood inside the fingertip due to heart beat varies the intensity of the reflected beam.

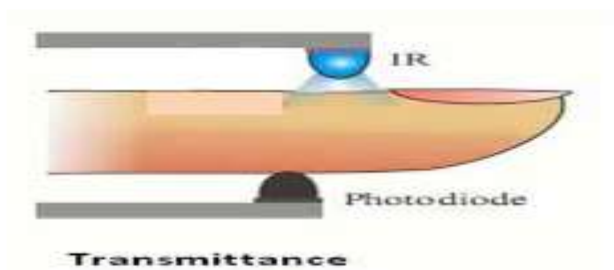

Fig.2. Illustration of fingertip sensor

AT89S51 MICROCONTROLLER: AT89S51 is a low power high performance CMOS 8-bit microcontroller with 4K bytes of in-system programmable flash memory. The device is produced using Atmel's high density non-volatile memory technology and is compatible with the industry standard 80C51 instruction set and pin out. The on-chip flash allows the program to be in reprogrammed in-system or by a conventional non-volatile memory programmer.

LM324: The M324 is the low cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply application. The quad amplifier can operate at low voltage as 3.0 V and high as 32V.

The common mode input range includes negative supply, thereby eliminating the necessity external biasing components in many applications. The output voltage range also includes the negative supply voltage. It is internally compensated and a highly flexible and cost effective solutions for many embedded control applications.

SEVEN SEGMENT DISPLAY: A seven segment display is a simply eight grouping of LED's some including a decimal point. Each segment is labeled (a) to (g). It is available in two forms:

*common anode

*Common diode

A seven segment display is used to display the decimal numbers 0-9 and some alpha characters. The resistor value determines the amount of current that is flowing through the LED in the SSD. This is why they are sometimes called current limiting resistors.

Figure:3 display

WORKING: When more light falls on the photo transistor, its collector current increases and so its collector voltage decreases. When less light falls on the photo transistor, its collector current decreases and so its collector voltage increases. This variation in the collector voltage will be proportional to the heart rate. This Voltage variation is also feeble and additional signal conditioning stages are necessary to convert it into a microcontroller recognizable form.

The next part of the circuit consists of a two active low pass filters using LM324. The two low pass filter form a very critical part of the circuit as any noise or false signal passing to the microcontroller stage will produce disastrous result. The output of the filter stage will be a voltage level fluctuating between 0 and 0.35volts and this fluctuation is converted into a 0 to 5V swing using the comparator based on third opamp(IC1c). The reference voltage of the comparator is set to 0.3V. Whenever the output voltage of the filter stage goes above 0.3V, the output of the comparator goes to zero and when the output voltage of the filter stage goes below 0.3V, the output of the comparator goes to positive saturation. The result will be a neat pulse fluctuating between 0 and 5V at a rate equal to the heart rate. This pulse is fed to the AT89S51 for counting.

SOFTWARE DESIGN: For the counting purposes both the timers of 8051 (timer 0 and timer 1) are used. Timer 1 is configured as an 8bit auto reload counter for registering the number of incoming zero going pulses and timer 0 is configured as a 16bit timer which generates the necessary one second time span for the timer 1 to count. For counting the number of beats timer 0 and timer 1 are used. Timer 1 is set as an 8-bit auto reload counter for counting the number of pulses (indicating the heart beat) and timer 0 is set as a 16-bit timer which generates a 6553Us delay. When looped 230 times it will produce a 15 sec time span (230*6553Us=15S) for the timer 1 to count. The number of counts obtained in 15seconds is multiplied by 4 to obtain the heart rate in beats per minute. The timer 0 which generates the span is configured in Mode 1. So the maximum it can count is 2^16 and it is 65536. In 8051 the crystal frequency divided by 12 using an internal frequency divider network before applying it as a clock for the timer that means the timer will increment by one for every 1/12th of the crystal frequency. For 8051 based system clocked by a 12MHz crystal, the time taken for one timer increment will be 1Us (i.e. 1/12MHz). So the maximum time delay that can be obtained one session of the time will be 6553Us.

CONCLUSION: In this paper, the design and development of a low cost heart rate monitor device has been presented. The device is ergonomic, portable, durable and cost effective. This device is efficient and easy to use. Tests have shown agreement with actual heartbeat rates. This device could be used in clinical and non-clinical environments. It can also be readily used by individual user. It has a high future scope.

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