

HEART RATE MEASUREMENT FROM THE FINGER USING A LOW-COST MICROCONTROLLER

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ABSTRACT

This paper describes the design of a simple, low-cost microcontroller based heart rate measuring device with LCD output. Heart rate of the subject is measured from the finger using optical sensors and the rate is then averaged and displayed on a text based LCD.

I. INTRODUCTION

Heart rate measurement is one of the very important parameters of the human cardiovascular system. The heart rate of a healthy adult [1] at rest is around 72 beats per minute (bpm). Athletes normally have lower heart rates than less active people. Babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm. The heart rate rises gradually during exercises [2] and returns slowly to the rest value after exercise. The rate when the pulse returns to normal is an indication of the fitness of the person. Lower than normal heart rates are usually an indication of a condition known as *bradycardia*, while higher than normal heart rates are known as *tachycardia*.

Heart rate is simply and traditionally measured by placing the thumb over the subject's arterial pulsation, and feeling, timing and counting the pulses usually in a 30 second period. Heart rate (bpm) of the subject is then found by multiplying the obtained number by 2. This method although simple, is not accurate and can give errors when the rate is high. More sophisticated methods to measure the heart rate utilize electronic techniques. Electro-cardiogram (ECG) is [3,4] one of frequently used and accurate methods for measuring the heart rate. ECG is an expensive device and its use for the measurement of the heart rate only is not economical. Low-cost devices in the form of wrist watches [5,6] are also available for the instantaneous measurement of the heart rate. Such devices can give accurate measurements but their cost is usually in excess of several hundred dollars, making them uneconomical. Most hospitals and clinics in the UK use integrated devices designed to measure the heart rate,

blood pressure, and temperature of the subject. Although such devices are useful, their cost is usually high and beyond the reach of individuals.

This paper describes the design of a very low-cost device which measures the heart rate of the subject by clipping sensors on one of the fingers and then displaying the result on a text based LCD. The device has the advantage that it is microcontroller based and thus can be programmed to display various quantities, such as the average, maximum and minimum rates over a period of time and so on. Another advantage of such a design is that it can be expanded and can easily be connected to a recording device or a PC to collect and analyse the data for over a period of time. The building cost of the proposed device is around \$20. One similar basic device from Cosy Communications [7] with no extension capabilities costs around \$100.

II. THE MEASUREMENT DEVICE

Figure 1 shows the block diagram of the proposed device. Basically, the device consists of an infrared transmitter LED and an infrared sensor photo-transistor. The transmitter-sensor pair is clipped on one of the fingers of the subject (see Figure 2). The LED emits infrared light to the finger of the subject. The photo-transistor detects this light beam and measures the change of blood volume through the finger artery. This signal, which is in the form of pulses is then amplified and filtered suitably and is fed to a low-cost microcontroller for analysis and display. The microcontroller counts the number of pulses over a fixed time interval and thus obtains the heart rate of the subject. Several such readings are obtained over a known period of time and the results are averaged to give a more accurate reading of the heart rate. The calculated heart rate is displayed on an LCD in beats-per-minute in the following format:

$$\text{Rate} = nnn \text{ bpm}$$

Where *nnn* is an integer between 1 and 999.

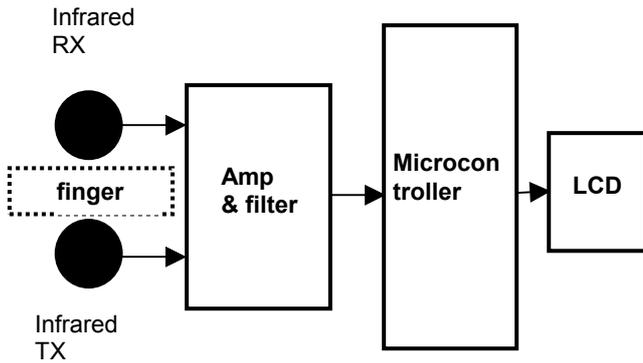


Figure 1. Block diagram of the measuring device



Figure 2. Infrared transmitter and received sensor pair clipped to the finger

The circuit diagram of the measurement device is shown in Figure 3. The circuit basically consists of 2 operational amplifiers, a low-pass filter, a microcontroller, and an LCD. The first amplifier is set for a gain of just over 100, while the gain of the second amplifier is around 560. During the laboratory trials it was found necessary to use a low pass filter in the circuit to filter out any unwanted high frequency noise from nearby equipment. The cut-off frequency of the filter was chosen as 2Hz. Figure 4 shows the frequency and phase responses of the amplifier together with the filter. The output time response of the amplifier and filter circuit is shown in Figure 5 which consists of pulses. An LED, connected to the output of the

operational amplifiers flashes as the pulses are received and amplified by the circuit.

The output of the amplifier and filter circuit was fed to one of the digital inputs of a PIC16F84 type microcontroller [8]. In order to reduce the cost of the circuit the microcontroller is operated from a 4MHz resonator. The microcontroller output ports drive the LCD as shown in Figure 3. The circuit operates when a push-button switch connected to RB1 port of the microcontroller is pressed.

III. THE SOFTWARE

The software was developed using the popular PROTON+ Basic compiler developed and distributed by Crownhill Associates [9]. The operation of the software is described below as a *Program Description Language* (PDL):

BEGIN

```

Initialize program variables
Configure input-output ports
Display message "READY"
Wait until switch is pressed
Sum = 0
DO 3 times
    Get count in 10 seconds
    Count = 6 * Count
    Sum = Sum + Count

```

ENDDO

```

Calculate the average, Rate = Sum / 3
Display the average on the LCD

```

END

If the number of pulse counts in time T is n , then the heart rate per minute is given by N , where,

$$N = 60n/T \quad (1)$$

If the duration of a measurement is 10 seconds, then the heart rate is calculated as:

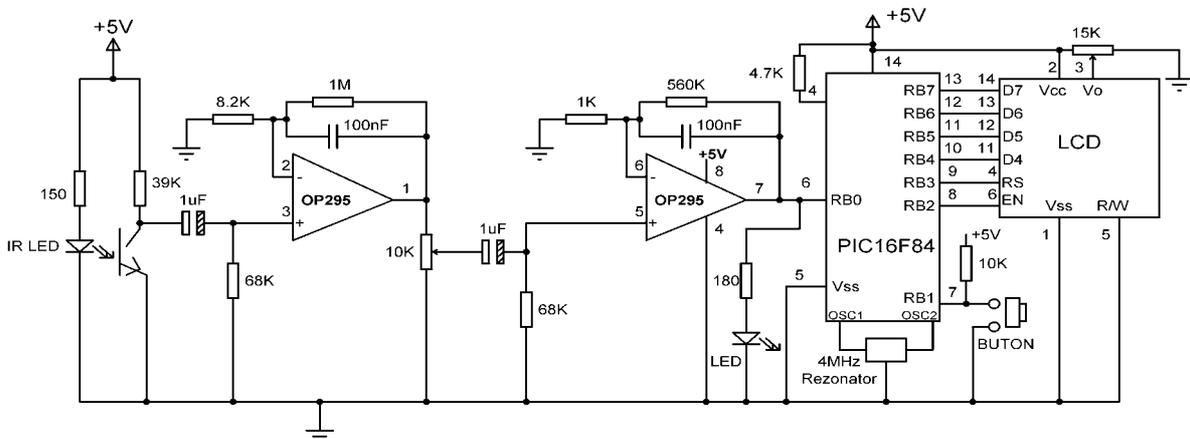


Figure 3. Circuit diagram of the device

$$N = 6n \quad (2)$$

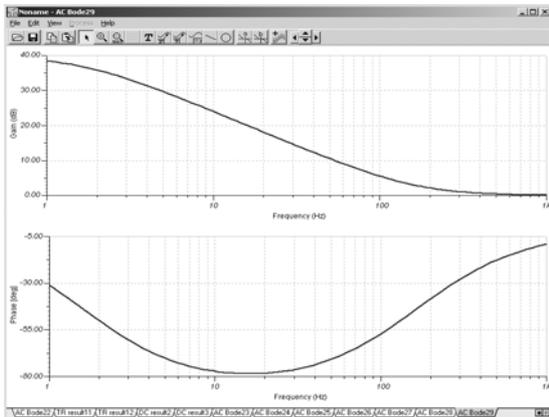


Figure 4. Frequency and phase responses of the amplifier and filter circuit (obtained by connecting a PC based oscilloscope to the circuit)



Figure 5. Output response of the amplifier and filter circuit (obtained by connecting a PC based oscilloscope to the circuit)

Figure 6 gives the program listing of the microcontroller. At the beginning of the program various variables used in the program are declared and PORT B pins RB2 – RB7 are configured as outputs. RB1 is configured as an input port. The program waits until the button is pressed. Then, the heart rate is read 3 times and the average is calculated and displayed on the LCD in the following format:

Heart = nn /min

```
*****
** File:          HEART.BAS
** Date:         23/10/2006
** Version:      1.0

** In this project a PIC16F84 type microcontroller is
** used and an infrared sensor is connected to pin
```

** RB0. Also, a button is connected to pin RB1 of
** the microcontroller.

** The average heart rate is measured and
** displayed on a LCD

Device = 16F84

Symbol SVIC = PORTB.1

Dim Counter As Byte

Dim Heart As Word

Dim J As Byte

TRISB = %00000011

DelayMS 1000

Print "READY..."

,

' Wait until BUTTON pressed

,

While SVIC = 1

Wend

Cls

Heart = 0

For J = 1 To 3

Print "CALCULATING ",Dec J

Counter = Counter PORTB.0,10000

Counter = 6 * Counter

Heart = Heart + Counter

Cls

Next

Heart = Heart / 3

Cls

Print "Heart = ",Dec Heart," /min"

End

Figure 6. Microcontroller program listing

IV. CONCLUSION

The design of a low-cost microcontroller based device for measuring the heart pulse rate has been described. The device has the advantage that it can be used by non-professional people at home to measure the heart rate easily and safely.

The device can be improved in certain areas as listed below:

- A graphical LCD can be used to display a graph of the change of heart rate over time

- Sound can be added to the device so that a sound is output each time a pulse is received.
- The maximum and minimum heart rates over a period of time can be displayed.
- Serial output can be attached to the device so that the heart rates can be sent to a PC for further online or offline analysis.
- Warning or abnormalities (such as very high or very low heart rates) can be displayed on the LCD or indicated by an LED or a buzzer.

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