Journal of Theoretical and Applied Information Technology
30th April 2014. Vol. 62 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A MICROCONTROLLER-BASED AUTOMATIC HEART RATE COUNTING SYSTEM FROM FINGERTIP

[1]MAMUN, A. L., [2]AHMED, N., [3]ALQAHTANI, M., [3]ALTWIJRI, O., [2]RAHMAN, M., [4,*]AHAMED, N.U., [5]RAHMAN, S.A.M.M., [2]AHMAD, R.B., [4]SUNDARAJ, K.

[1] Electronics Division, Atomic Energy Centre, Dhaka-1000, Bangladesh
[2] School of Computer and Communication Engineering, Universiti Malaysia Perlis, Malaysia
[3] Biomedical Technology Department, College of Applied Medical Sciences, King Saud University, Kingdom of Saudi Arabia
[4] AI-Rehab Research Group, Universiti Malaysia Perlis, Kampus Pauh Putra, Arau-02600, Perlis, Malaysia
[5] College of Computer Science and Information System, Najran Univeristy, Kingdom of Saudi Arabia
Email:[4,*] nizam1557@gmail.com

ABSTRACT

This article describes the design process of a low cost and portable microcontroller based heart-rate counting system for monitoring heart condition that can be implemented with off-the-shelf components. The raw heart-rate signals were collected from finger using IR TX-RX (Infrared Transmitter and Receiver pair) module which was amplified in order to convert them to an observable scale. The inherent noise signal was then eliminated using a low pass filter. These signals were counted by a microcontroller module (ATmega8L) and displayed on the LCD panel. An algorithm has been developed which was programmed into the microcontroller to run the proposed heart rate counting system. The results obtained using the developed device when compared to those obtained from the manual test involving counting of heart rate was found satisfactory. The proposed system is applicable for family, hospital, clinic, community medical treatment, sports healthcare and other medical purposes. Also, fit for the adults and the pediatrics. However, presented method in the developed system needs further investigation and need more functionality, which may be useful to consider advance in future research.

Keywords: *Heart Rate, Microcontroller, Finger-Trip, Sensor.*

1. INTRODUCTION

Currently there is a growing research interest in measuring the heart rate from the body, because it is one of the important parameters of the human cardiovascular system [1]. This countable rates from the heart is the number of heartbeats per unit of time which is typically expressed as beats per minute (bpm)[2]. The rate of the bpm varied on subject-to-subject, like age, physical condition and activities. For example, the average heart rate of a healthy adult at rest is around 72 bpm [3]. On the other hand, infants and babies have a much higher heart rate than older individuals which is above 120 bpm [4].

However, to understand and to count the exact bpm from different subjects, it is necessary to develop an easy to use, portable and low cost heart rate monitoring system. Because, the measurement of heart rate is used by medical professionals to assist in the diagnosis and tracking of medical conditions. It is also used by individuals, such as athletes (during prolonged exercise), who are interested to view their heart rate to acquire maximum efficiency [5]. There are many ways to count or measure the heart rate from the human body where the rhythmical throbbing of arteries produced by the accepted contractions of the heart (pulse-felt). For example, palpated at the wrist or in the neck, from the finger trip and some other body part [6, 7]. After that an embedded system is needed to interface with these body parts which will show the machine-readable digital data from the heart. Among different heart rate monitoring systems, a microcontroller based heart rate monitoring system from finger-trip (with blood volume) is one of the major concerns in biomedical technology. In such type of system, the blood volume within a fingertip changes a little with heart beat as the blood is being pumped [8]. This transform in blood level within the finger artery can be sensed with an uncomplicated optical sensor system and can be further amplified using suitable signal conditioning circuit to produce a pulse of magnitude. These pulses are able to count by a microcontroller chip to exhibit the measured heart rate. This type of system having the ability to clearly present real heart rate using sensors and instantly can display the results via an integrated liquid crystal display (LCD) monitor [9].

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Many researchers have developed and designed the heart rate counting system using microcontroller and finger trip. For example, Ahmed et al. designed a microcontroller (PIC17C44) development board and developed a real-time algorithm for monitoring the heart rate for long-term [10]. Ahamed et al. developed a system for muscle function monitoring using PIC18F4455 microcontroller [16]. Then Jayasree et al. designed and developed a simple hardware setup for sensing blood volume pulse using a PIC microcontroller based for measuring the heart rate [11]. Some other researchers also developed microcontroller based heart rate counting system from fingertip sensor [12-15].

In our development process we used the sensor unit which consists of an infrared (IR) light-emitting-diode (LED) and a photodiode. The IR diode transmits an infrared light into the fingertip (placed over the sensor unit), and the photodiode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, each heart beat slightly alters the amount of reflected infrared light that can be detected by the photodiode. The magnitude of the pulses at the output of the photo diode is too small to be sensed directly by a microcontroller. Therefore, a two-stage high gain, active low pass filter is designed using Operational Amplifiers (Op-Amps) to filter and amplify the signal to appropriate voltage level so that the pulses can be counted by a microcontroller to determine the heart rate and displayed in LCD.

2. MATERIAL AND METHODS

2.1 Hardware System

The design of the hardware is based on an embedded system implementation using the ATmega8 microcontroller from ATMEL, USA. The block diagram of the hardware system is shown in Figure 1. The hardware system includes, IR transmitter that transmits (TX) the code to the IR receiver (RX) in the machine over a local IR link (amplifier and low-pass filter). A microcontroller (MCU) had been chosen in the hardware platform. Then MCU Control the Visual Display by the LCD.

Figure 1 Here

2.2 IR Sensor

The sensor consists of an IR light emitting diode transmitter and an IR photo detector acting as the receiver. The IR light passes through the tissues. Variations in the volume of blood within the finger modulate the amount of light incident on the IR detector. In this design, both the IR transmitter and receiver placed on the same plane and the finger functioned as a reflector of the incident light. The IR receiver monitors the reflected signal. Here, an infrared LED (OPB100EZ) and phototransistor (OPB100SZ) is used as sensor device. Figure 2(a) presents the circuit design of the sensor and Figure 2(b) shows how the sensor working using fingertip.

Figure 2 Here

2.3 Amplifier and Filter Design

Filtering process is required to remove the undesirable noises. The weak nature of the IR signal and the noise affecting on it, requires the implementation of a range of filters and differential amplifiers. The signal conditioning circuit consists of two identical active low pass filters with a cut-off frequency of about 2.5 Hz. Cut Off Frequency $=1/2\pi RfCf = 1/2\times3.1416\times68K\times1uF=2.34$ Hz; where, Rf=R1=R4=68KΩ and Cf=C1 =C3=1μf. This indicates that the maximum measurable heart rate is about 150 bpm. The gain of each filter stage is set to 11, giving the total amplification of about 121. Gain of each stage=1+Rt/Ri =1 + 680KΩ/ 68KΩ=11; where, Rt=R2=R5=680KΩ and Ri=R3=R6=68KΩ. A 1 uF capacitor at the input of each stage is used to block the dc component in the signal. The equations for calculating gain and cut-off frequency of the active low pass filter are shown in the circuit diagram in Figure 3. The two stage amplifier/filter provides sufficient gain to boost the weak signal which is 3-4 mV and coming from the IR sensor unit, and convert it into a pulse. This pulse is counted by microcontroller. Then an LED is used which blinks each time when the heart beat is detected.

Figure 3 Here

2.4 The Microcontroller Block

An Atmel microcontroller (ATmega8) is used to collect and process data. The ATmega8 has 8k bytes of in-system self-programmable flash along with 512K bytes EEPROM, 1 K byte internal SRAM, three timers, and a 10-bit 6 channel A/D converter. It has RISC architecture and can use oscillators for frequency up to 16 MHz; its power consumption is low. Thus it is ideal to be used as an embedded system. The pulse signal of heart extract from finger is fed to the port PD-4 of ATmega8. The counter of microcontroller is used to measure the pulse rate per minute. Microcontroller also initiates the corresponding command for LCD

Journal of Theoretical and Applied Information Technology
30th April 2014. Vol. 62 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

display. Figure 4 shows the microcontroller block of the system.

Figure 4 Here

2.5 PCB Design and Fabrication

PCB (printed circuit board) circuit design has proposed (Figure 5 (a) and Figure 5 (b)) for attaching hardware devices in the system. The PCB was design by using Proteus 7.7 Professional software (ISIS 7 professional).

Figure 5 Here

2.6 Software Design

Software design includes developing algorithm for the system, allocating memory blocks, writing the separate routines for different interfacing devices and testing them on the designed hardware. Interfacing of the microcontroller with ADC, LCD and Sensor has been carried out using the software modules. The control program is written in basic programming language and compiled by BASCOM-AVR software (it is the Windows BASIC Compiler designed for Atmel's microprocessors). ISIS Proteus7.7 can combine with BASCOM AVR software in order that it can be used also to evaluate programs created using BASCOM AVR. A flowchart of the proposed software is shown in Figure 6.

Figure 6 Here

2.7 System Operation

Figure 7 demonstrates how the system is working as real time. Total six steps were performed to obtain the desired results.

Figure 7 Here

3. RESULTS AND DISCUSSIONS

Analogue signals of heart rate acquired by the sensor through finger and input to PD-4 port of the microcontroller. The system was used to measure the heartbeat rate of a number of male and female volunteers. The results of the developed system compared with a conventional measuring method. These results show acceptable range compare to manual measurement. Another experiment was conducted where we measured the beat rate of two male volunteers at rest. The volunteers then performed some exercise (jogging) for five minutes and their heartbeat rate was subsequently measured. The readings of the device were compared against the manual measurement. The manual measuring data were taken by counting the pulse from the wrist. Overall, the results are in an acceptable agreement with the actual readings. Table 1 shows the ten subject's heart rate with the both ways. Another experiment was done with two subjects (presented in Table 2) where one female and one male was participated

Table 1 Here
Table 2 Here

Finally, the main parameters (specifications) of the developed system are as follows:

- The system is compact, portable and user friendly,
- Can detect the signal (hear rate) in real-time,
- Low power consumption facility,
- The measuring range of the heart rates is within 30-bpm to 300 bpm,
- Recorded data can be transferred to a PC,
- Display unit: 2.4" LCD,
- Internally powered equipment,
- Dimensions: 160 mm (L) x 135 mm (W) x 132 mm (H), weight: 200 g,
- The device has plug-in board and stand-alone product,
- The product is applicable for family, hospital, private clinic, community medical treatment, sports healthcare and other medical purposes. Also, fit for adult and pediatrics.

Our current prototype has some significant limitations, since there is no a built-in design or architectural limitation. But, creating the activation function is a challenge because of the limitations of the attached microcontroller. But, these limitations do not affect the developed system in real life.

4. CONCLUSION

In this paper, the design and development of a microcontroller-based real-time processing heart rate counting system has been presented. The device is portable, durable, flexible, reliable and cost effective. Also, it is efficient, easily estimable data and easy-to-use for the end user. Experimental results have shown acceptable range with actual heartbeat rates. Finally, this handheld system has proven to be an excellent heart rate counting system for the end user. However, further improvement is

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

expected with the upgraded module to improve and simplify the system for the users.

REFERENCES

[1] D. Ibrahim and K. Buruncuk, "Heart Rate Measurement from the Finger Using a Low-Cost Microcontroller," Near East University, Faculty Of Engineering, TRN, 2005.

[2] V. K. Yeragani, et al., "Heart rate and QT interval variability: abnormal alpha-2 adrenergic function in patients with panic disorder," Psychiatry research, vol. 121, pp. 185-196, 2003.

[3] J. M. Dekker, et al., "Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes The ARIC Study," Circulation, vol. 102, pp. 1239-1244, 2000.

[4] R. H. Durant, et al., "Reliability and variability of heart rate monitoring in 3-, 4-, or 5-yr-old children," Medicine and science in sports and exercise, vol. 24, p. 265, 1992.

[5] M. Lester, et al., "The effect of age and athletic training on the maximal heart rate during muscular exercise," American heart journal, vol. 76, pp. 370-376, 1968.

[6] R. Kojima and Y. Nosé, "Rhythmical fluctuation of arterial pressure after implantation of cardiac prosthesis," Artificial organs, vol. 18, pp. 621-626, 1994.

[7] P. Galen, et al., "Systems And Methods For Detecting And Monitoring Arrhythmias Using the PPG," ed: US Patent 20,120,310,100, 2012.

[8] G. Parati, et al., "Spectral Analysis of Blood Pressure and Heart Rate Variability in Evaluating Cardiovascular Regulation A Critical Appraisal," Hypertension, vol. 25, pp. 1276-1286, 1995.

[9] S. Kara, et al., "Low-cost compact ECG with graphic LCD and phonocardiogram system design," Journal of Medical Systems, vol. 30, pp. 205-209, 2006.

[10] F. Ahmed, et al., "A portable recorder for long-term fetal heart rate monitoring," Microprocessors and Microsystems, vol. 26, pp. 325-330, 2002.

[11] V. Jayasree, et al., "Design and Development Of a Simple Hardware Setup for Sensing Blood Volume Pulse and a PIC Microcontroller Based Heart Rate Meter," in Biomedical and Pharmaceutical Engineering, 2006. ICBPE 2006. International Conference on, 2006, pp. 256-258.

[12] H. Chatterjee, et al., "A microcontroller based system for real-time heart rate estimation from ECG signal," in India Conference (INDICON), 2012 Annual IEEE, 2012, pp. 1020-1025.

[13] J. Prasath, "Wireless monitoring of Heart Rate using Microcontroller," International Journal of Advanced Research in Computer Science and Electronics Engineering (IJARCSEE), vol. 2, pp. pp: 214-219, 2013.

[14] S. F Babiker, et al., "Microcontroller Based Heart Rate Monitor using Fingertip Sensors," Khartoum University Engineering Journal, vol. 1, 2011.

[15] Y.-C. Wei, et al., "Design of a microcontroller-based real-time heart rate variability measurement system using a low-complexity R-peak detection algorithm," Instrumentation Science & Technology, vol. 41, pp. 274-289, 2013.

[16] N. U. Ahamed, K. Sundaraj, and T. S. Poo, "Design and development of an automated, portable and handheld tablet personal computer-based data acquisition system for monitoring electromyography signals during rehabilitation," Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine, vol. 227, pp. 262-274, 2013.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

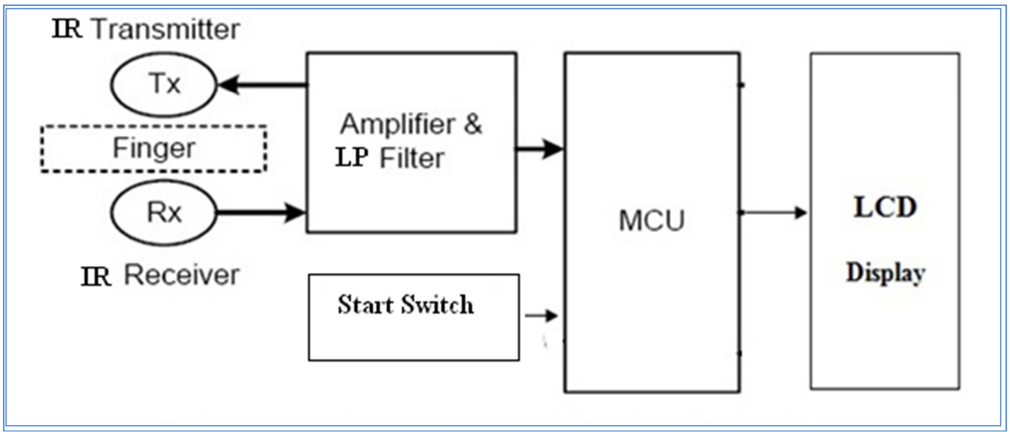
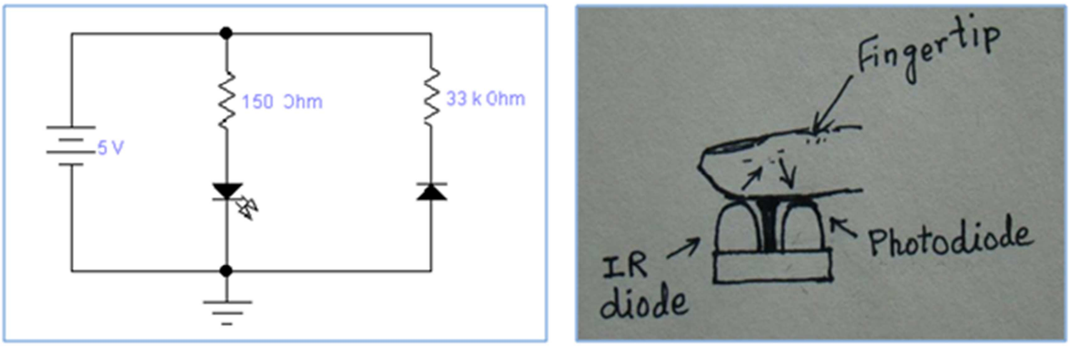


Figure 1: Block Diagram Of Heart Rate Counting System



(a) (b)

Figure 2: (A) Schematic Of The Fingertip Sensor Circuit, (B) Illustration The Operation Of Fingertip Sensor

Journal of Theoretical and Applied Information Technology
30th April 2014. Vol. 62 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

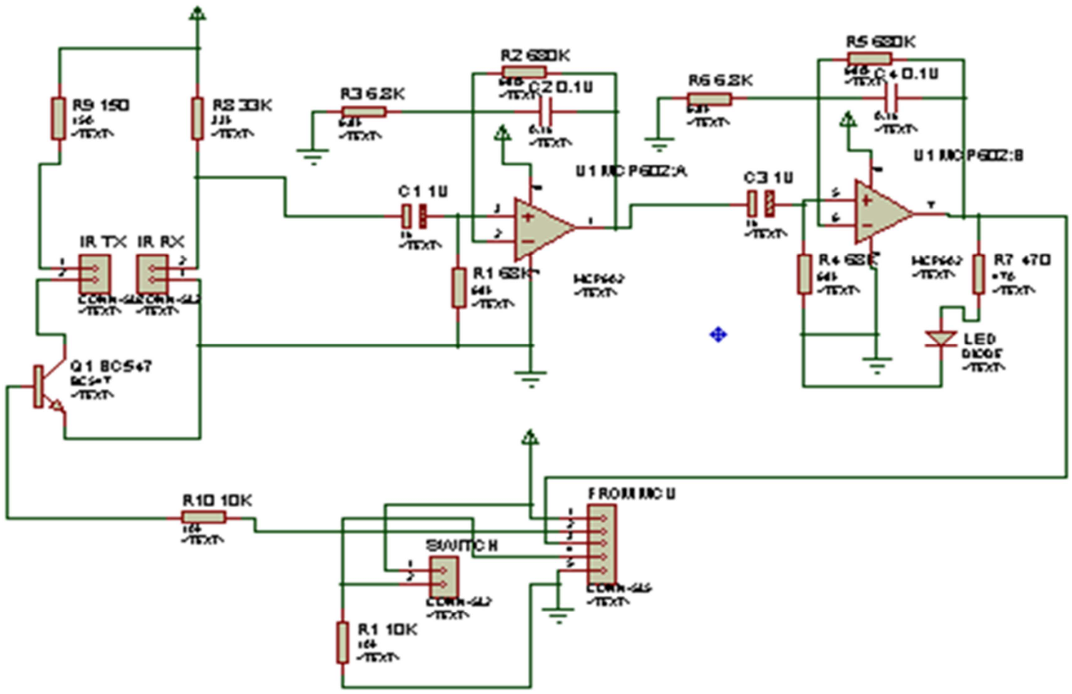


Figure 3: Schematic Of Filter And Amplifier Designed On Proteus 7.7 Electronic Design Suite

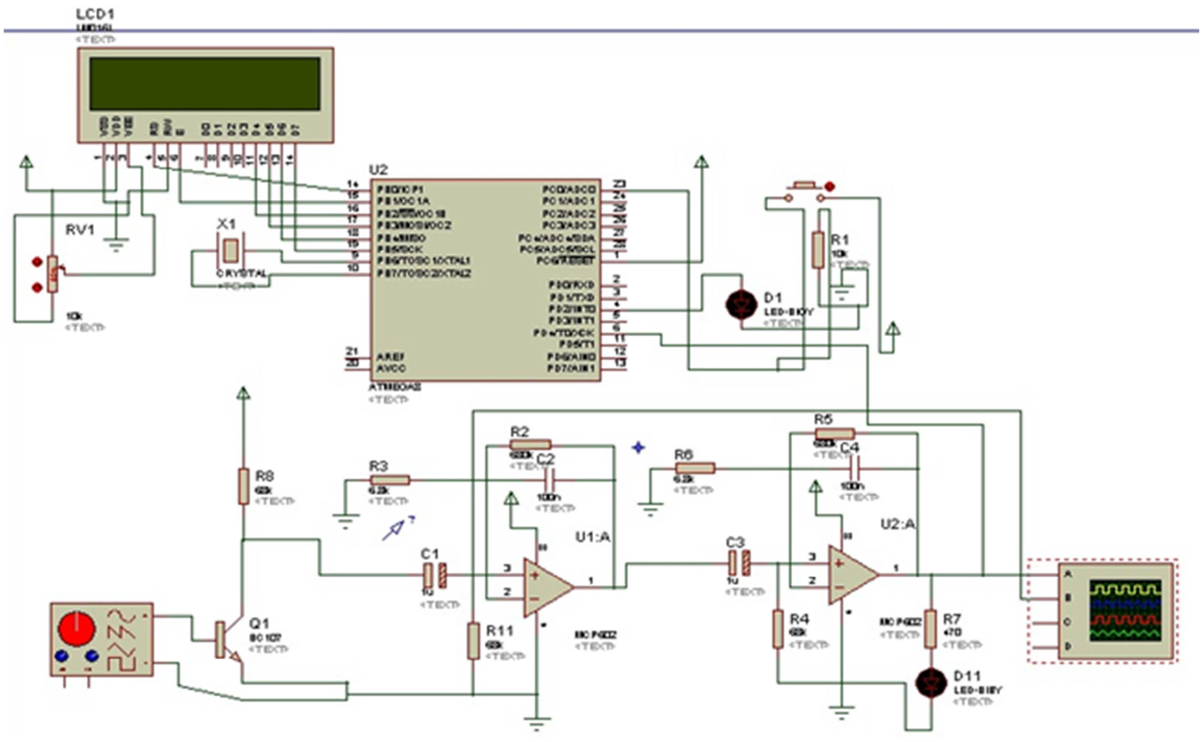
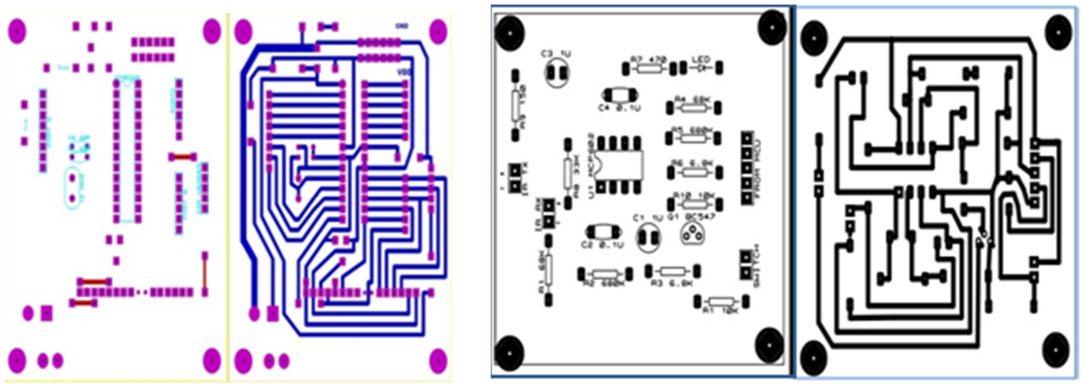


Figure 4: Illustration Of The Microcontroller Design

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195



(a) *(b)*

Figure 5: Top And Bottom Surface Of The PCB Layout (A) Microcontroller Unit (B) Sensor Unit

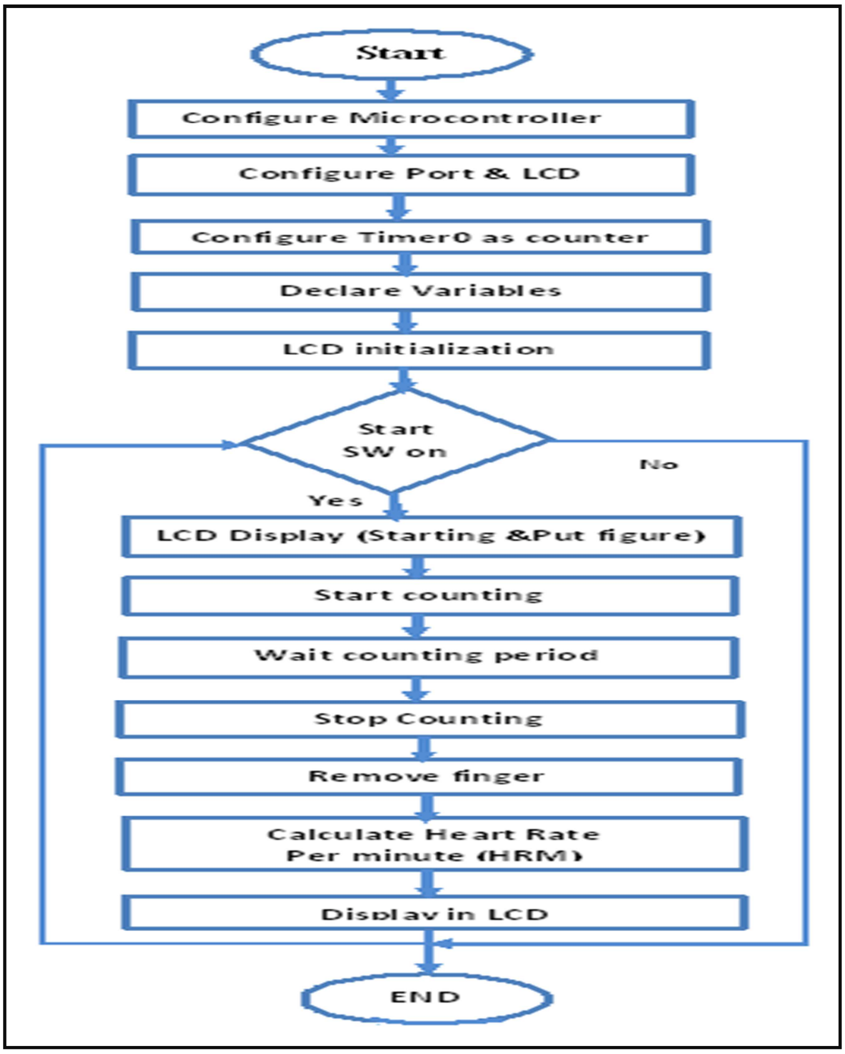


Figure 6: Flowchart Of The Software

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

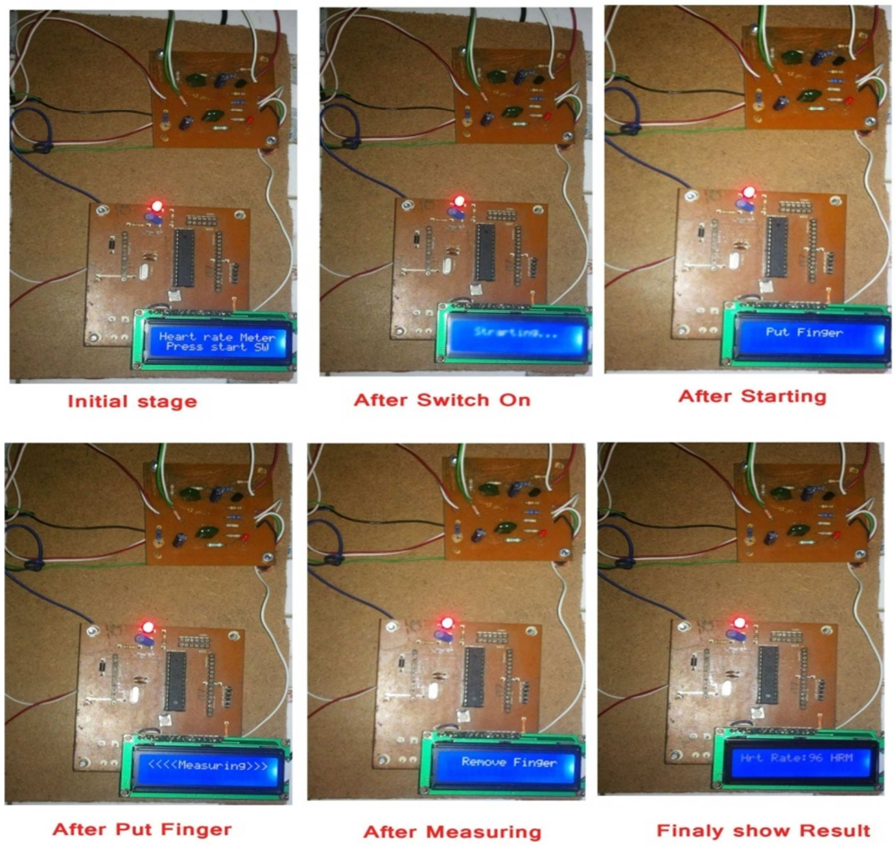


Figure 7: Developed System In Working Environment

Table 1. Results Of Measurement Of 10 People Heart Rate Per Minute

Subject	Gender	Age	Heart beat by developed system	Heart beat by Manually	Error %
Subject 1	Male	22	85	84	1.04%
Subject 2	Male	22	84	82	2.38%
Subject 3	Male	20	78	78	0%
Subject 4	Male	22	90	87	3.33%
Subject 5	Male	32	100	102	2%
Subject 6	Female	22	76	77	1.32%
Subject 7	Female	40	104	103	0.96%
Subject 8	Female	20	68	66	1.47%
Subject 9	Female	22	72	71	1.38%
Subject 10	Female	22	84	85	1.19%

Table 2. Measurements Of Heartbeat Rate Before And After Exercise Using The Developed Device Together Wrist Measurements.

Subjects	Gender	Age	Condition	Heart beat by developed system	Heart beat by Manually
Subject 1	Male	24	Before exercise	64	65
			After exercise	90	88
Subject 2	Female	15	Before exercise	90	88
			After exercise	110	106