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PERFORMANCE COMPARISON OF THE DESIGNED MICROCONTROLLER HEARTBEAT MONITOR AND CLINICAL STETHOSCOPE MEDICAL INSTRUMENTS BASED ON STATISTICAL APPROACH

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ABSTRACT

Heart related diseases are becoming more rampant, which if not properly checked and controlled, will continue to contribute a greater percentage of death rates among the younger generations. Controlling this deadly disease will be initiated by monitoring individual heartbeat rate regularly by a new low cost invented microcontroller based heartbeat medical measuring and monitoring instrument developed using electronic engineering techniques. The developed device uses electric microphone to detect the heartbeat and convert it to alternating current (ac) signal in millivolts, which is later amplified by a non inverting amplifier. A Schmitt trigger (555 timer) coverts the amplified ac signal into a square wave (one pulse is represented by one square). These square waves are used to count the number of squares for 60 seconds and display the result on the liquid crystal display (LCD) screen. The developed device is packaged in a plastic casing with adequate spacing provided to accommodate all components. The mean and standard deviation measured heart beat results obtained using the developed device and conventional clinical stethoscope range from 70.63 to 82.37 beat per minute(bpm) and 69.65 to 81.63 beat per minute(bpm) respectively. The result obtained using the developed device when compared to those obtained from the manual test involving counting of heartbeat fall satisfactorily within the acceptable range of 60 to 120 beat per minute(bpm). This developed device is useful for families, hospitals, clinics, community medical centres and for other medical purposes.

Key words: Microcontroller heartbeat monitor, conventional clinical stethoscope medical instrument, electronic engineering techniques, electric microphone, non inverting amplifier, Schmitt trigger (555 timer), liquid crystal display (LCD)

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1. INTRODUCTION

The heart is one of the most important organs of the human body system, which is located on the left side of the chest cavity. Heart rate or pulse rate is defined as the number of times that the heart beats per unit time. It is basically the number of ventricular contractions of the heart. Pulse rate can be measured at any point of the body where the arterial pulsations are felt on the body's surface. It is a vital parameter to indicate the heart conditions of a human being. During exercises or any other athletic activities, heart rate measurement is always desirable for achieving optimal results as well as for personal safety. A heart pumps oxygen-rich blood into the muscles and receives deoxygenated blood from them. As the oxygen demand increases, the heart rate increases proportionally, providing the oxygenated blood to the muscles. Hence, it is an important indication of oxygen supply in different muscles of the body. The heart beats on an average of 72 beats per minute, in a normal adult, although this figure can differ considerably. As a person stands up, his heart rate increases, whereas it decreases as the person sits down [1]. This range is around 60 to 85 beats per minute. Generally, it is higher in women and decreases with age. In an infant, the heart rate maybe as high as 110 to 160 beats per minute under normal conditions. In a person of age 60, the heart rate can be as low as 60 beats per minute. The blood pressure (BP) can be calculated as: 60beat per minute< heart beats< 120beats per minute- normal heart beat rate. Heart beats<60 beats per minute=Hypotension or low blood pressure, while heartbeats >120 beats per minute=Hypertension or high blood pressure [2, 3, 4, 5].

The heart rate monitor is a monitoring device which allows a subject to measure his or her heart rate in real time or record his or her heart rate for later study. Early models consisted of a monitoring box with a set of electrode leads which attached to the chest. In recent years there has been increasing interest in wearable/mobile health monitoring devices, both in research and industry. These devices are particularly important to the world's increasingly aging population, whose health has to be assessed regularly or monitored continuously. For example, a third or more of the 78 million baby boomers and 34 million of their parents may be at risk for the development of devastating diseases including cardiovascular disease, stroke and cancer[6]. Chronic diseases are becoming the world's leading causes of death and disability, and will account for almost three-fourth of all deaths by 2020. Each year, number of deaths caused by cardiovascular diseases and hypertension is estimated to be 16.7 million and 7.1 million, respectively [6, 7]. Population of diabetic adults is expected to reach 300 million by 2025. The implications of these wearable health monitoring technologies are paramount, since they could:

- Enable the detection of early signs of health deterioration;
- Notify health care providers in critical situations;
- Find correlations between lifestyle and health;
- Bring healthcare to remote locations and developing countries, and transform health care by providing doctors with multi-sourced real-time physiological data.

In recent years, there has been a proliferation of consumer health monitoring devices. A good portion of these devices have been developed for the sports. These are sophisticated watches available today that provide real-time heart rate information and let users store and analyse their data on their home personal computer (PC). Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data for offline processing. One of the most popular remote health systems perhaps is the Astrophysical multi-messenger observatory network (AMON) system, a wearable (wrist worn) medical monitoring and alert system targeting high risk cardiac/respiratory patients. The system includes continuous collection and evaluation of multiple vital signs such as blood pressure (SpO_2), saturation of peripheral oxygen, one lead electrocardiogram (ECG) and two-axis accelerometer, multi-parameter medical emergency detection and cellular connection to a medical centre. Use of wearable monitoring devices that allow continuous or intermittent monitoring of physiological signals is critical for the advancement of both the diagnosis as well as treatment of cardiovascular diseases [8, 9, 10, 11]. The usual clinical or hospital monitoring of physiological events such as the electrocardiogram or blood pressure provides only a brief window on the physiology of the patient because they are likely to fail in sampling rare events that may have profound diagnosis, and they cannot monitor the patient during rest or sleep. The capacity to noninvasively detect physiologic signals greatly facilitates the application of wearable monitoring devices. The continuous measurement of blood pressure serves as one example. Most ambulatory blood pressure monitoring devices rely on the repeated measurement of systolic and diastolic blood pressure at predetermined intervals but do not provide a continuous reading of blood pressure. Although efforts have been made to supply such information by invasive monitoring schemes, they are limited by the potential of untoward events such as arterial damage and infection. Therefore the development of devices that can noninvasively acquire such information is essential. With the advent of advanced telecommunication technology, long-term home care of elderly, or what we call telehealth, is becoming a rapidly growing area of health care industry. The current trend in long-term care is a shift of the delivery system away from institutional care towards home and community-based care. The health care is seeking to reduce some of the inefficiencies of home health care by using state-of-the-art two way medical monitors, such that health care providers can conduct a check-up on a home care patient's vital signs such as pulse rates, blood oxygenation and body temperature. This type of technology could be used round-the-clock with patients suffering from chronicle diseases, including patients with congestive heart failure, pulmonary diseases and permanent disability. Hence, Remote health monitoring has the potential to improve the quality of health services delivered and to reduce the total cost in healthcare by avoiding unnecessary hospitalisations and ensuring that those who need urgent care get it sooner. In addition to cost-effective telehealth, remote health monitoring can significantly contribute to the enhancement of disease prevention, early diagnosis, disease management, treatment and home rehabilitation [12, 13]. The papers presents a user friendly cost-effective designed and developed medical clinical stethoscope, which has the capacity and capability of taking heartbeat of an individual using a clinical stethoscope diaphragm placed over the chest or any other part of the body where pulse can be read while the corresponding heartbeat of the individual is displayed on the screen after one minute, and propose a good model for home health care suitable for the local environment which can provide an innovative solution for the problem of aging, and help in enhancing quality of life.

2. LITERATURE REVIEW

Measurement of pulses and theories related to cardiac activities started developing around 300B.C by the Greeks [1, 11]. Researches on heart rate pulses being used for diagnosis and prognosis purposes were being done. Since then, there has been a continuous development in this field, like the development of a stethoscope for indirect auscultation, the sphygmograph, string galvanometer and even a photoelectric pulse counter or just a stopwatch for measuring the pulse was used. Heart rate monitors should not be confused with the clinical device used by medical professionals. Personal heart rate monitoring devices are more convenient, less bulky, and lightweight, allowing for outdoor usage. Many individuals use heart rate monitors to determine the efficiency of their training [11]. During the mid-1970s, the first concept about the heart rate monitor was conceived by a Finnish professor SeppoSäynäjäkangas, who thought of a way to accurately record heart rates of the Finnish National Cross Country Ski team during training [14]. By the year 1977, professor Säynäjäkangas worked on the idea and developed the gadget giving birth to Polar Electro that became a leading brand in heart monitoring equipment. Older models comprise of electrodes fastened to a person's chest and connected to a battery-operated monitoring box, and later, a plastic chest strap transmits unique wireless signals to the receiver in the form of watches [15]. In 1979, Polar developed the wireless heart rate monitor, and in 1982, it came up with the first wearable heart rate monitor for athletes [11]. In earlier models, the monitoring box consisted of a set of electrodes (or leads) that were attached to the chest. These leads were used to sense the voltage changes due to heart rate changes. Although these models are still available, modern versions consisting of a chest strap transmitter and a wrist receiver were developed. Materials used for the straps have also been changed to give maximum comfort to the patient while monitoring their heart rates. This method was not reliable, accurate or even user friendly as the patient has to be strapped to wires. The discovery that the muscle contractions involve electrical processes dates back to 18th century. It was in 1887, that the first electrocardiogram was used by Waller, who used the capillary electrometer introduced by a French physicist, Gabriel Lipmann in 1875, which used mercury filled capillary immersed in dilute sulphuric acid. This was cumbersome to use and inertia of liquid column limited its frequency range. In 1889, William Einthoven used buckets filled with saline solution as electrodes and all the limbs were placed in these buckets to diagnose the electrical signals and the response of the heart to these signals. The string galvanometer, introduced to the electrocardiogram by a Dutch physiologist named William Einthoven in 1903, was a significant improvement. These were replaced by devices incorporating electronic amplification, which allowed the use of less sensitive but more rugged devices. But unfortunately, this system is too big and expensive to be used for daily purposes like athletic trainings. Therefore, the task was to convert the ECG technology into a more portable system? After intensive research and development, the first wireless and ECG accurate heart rate monitor was finally put on the market by the Finnish firm Polar Electro. And it was then, that the heart rate could be measured accurately without any limitations. To start with the heart rate monitors were almost exclusively of interest to competitive endurance athletes. Athletes quickly recognized that by measuring and monitoring their heart rate during training, they could obtain important information about the training load that enables them to specifically manage their training. In the years that followed, the development and improvement of the monitors continued, so that every year, heart rate monitors advanced in technical sophistication and performance. The ECG accurate determination of the duration of each heartbeat using a small, wireless heart rate monitor was an important technological innovation. Today, the electronic measurement of heart rate and heart rate variability of heart rate due to influences of different factors in both recreational and competitive sports is taken for granted and is indispensible in the monitoring of training load intensity [16].

Over the years, a number of companies began manufacturing heart rate monitors, evolving the simple device that detects heartbeats and incorporating features such as calorie expenditure and fitness exercise diary. Some models detect breathing rate and vital signs related to an individual's cardiovascular fitness. Detailed information may also be downloaded to a computer to keep track of your data. The 21st century marked the introduction of heart rate monitors for runners that include a foot accessory that track speed and distance. Newer generations have fabric heart sensors. For women, specialized sports bra uses this technology eliminating the need for chest straps.Since its development, heart rate monitoring changed the way sports enthusiasts train. With the heart rate monitor, athletes can ascertain that they do not over or under train. Furthermore, given its many capabilities, modern heart rate monitors are a convenient means to help detect early signs of cardiovascular disease. Recently, the home healthcare has been entering a new stage in the digital age. Previous care delivery models included paid nurse visits, traditional phone-based telehealth applications, and assisted living/nursing homecare, each with its own problems [17].

3. MATERIALS AND METHODS

METHOD 1: Microcontroller Heartbeat Monitoring System Design

The designed and developed medical clinical stethoscope has the capacity and capability of taking heartbeat of an individual using a clinical stethoscope diaphragm placed over the chest or any other part of the body where pulse can be read while the corresponding heartbeat of the individual is displayed on the screen after one minute. It involved the design of the hardware and the software systems. The materials considered for the design and development of a microcontroller heartbeat monitoring system are the clinical stethoscope diaphragm, the power unit, the sensory unit, the control unit and the display unit as presented in Figure 1.

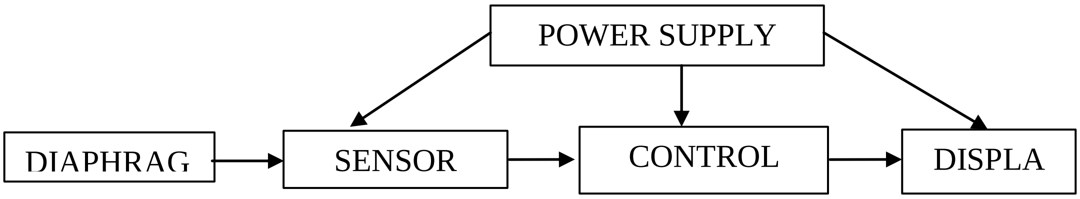


Figure 1 Operational block diagram of a microcontroller heartbeat monitoring design.

These materials are briefly discussed as follows:

- Clinical Stethoscope Diaphragm: A clinical stethoscope diaphragm takes the biological sound (heart beat) and delivers it on to the microphone.
- Power Unit: The power unit consists of a 9 volts battery and a voltage regulator with voltages ranging from +3 to +5 respectively. A Voltage regulator provides a specified, constant and stable DC supply to a circuit. An integrated circuit of LM7805capable of producing an output voltage of +5 volt sis required to power the circuit.
- Sensor Unit: The designed sensor unit comprises of microphone, preamplifier and Schmitt trigger achieved via the use of a 555 timer in monostable mode[18, 19, 20].

The microphone is connected to a resistor in order to achieve a very small output voltage (millivolts) needed to amplify the signal as shown in Figure 2.

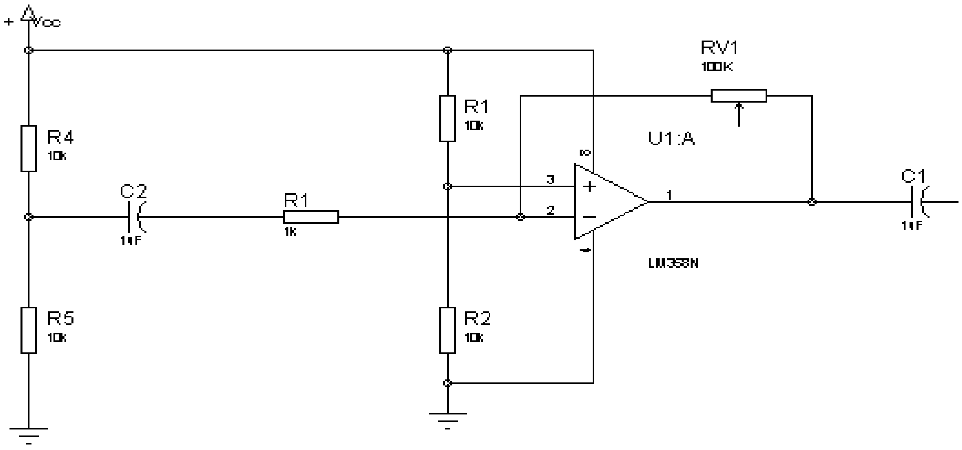


Figure 2 Amplifier circuit design.

Usually, when the sound is detected, the output voltage signal,(Vout), is sent to the amplifier via a coupling capacitorthat blocks all DC signal and allows the free flow of AC signal. The potential divider placed at the non inverting input divides the input voltage of + 5 volts into two equal parts giving 2.5 volts.

Hence,

$$V(t) = \frac{R_2}{R_1 + R_2} \times V_{cc} \qquad (1)$$

$$\text{If } R_1 = 10\Omega$$

$$\mathrm{V(t)} = 2.5$$

Then,

$$V(t) = \frac{R_2}{10 + R_2} \times 5$$

$$2.5(10 + R_2) = R_2 \times 5$$

$$25 + 2.5R_2 = 5R_2$$

$$25 = 5R_2 - 2.5R_2$$

$$25 = 2.5R_2$$

$$R_2 = \frac{25}{2.5} = 10k\Omega$$

The output voltage of the amplifier is now given by;

$$V_{out} = \left(\frac{R_2}{R_1}\right) V_{in} \qquad (2)$$

Where;

R_2/R_1 = Amplification factor.

Amplifying factor = $100K/1K$ =100

The gain in amplification =100

The output of the amplifier is coupled into a Schmitt trigger which is made with a 555timer via a coupling capacitor.

Schmitt trigger is realized by the use of 555timer made from a monostable multivibrator and the schematic diagram is given in Figure 3 below.

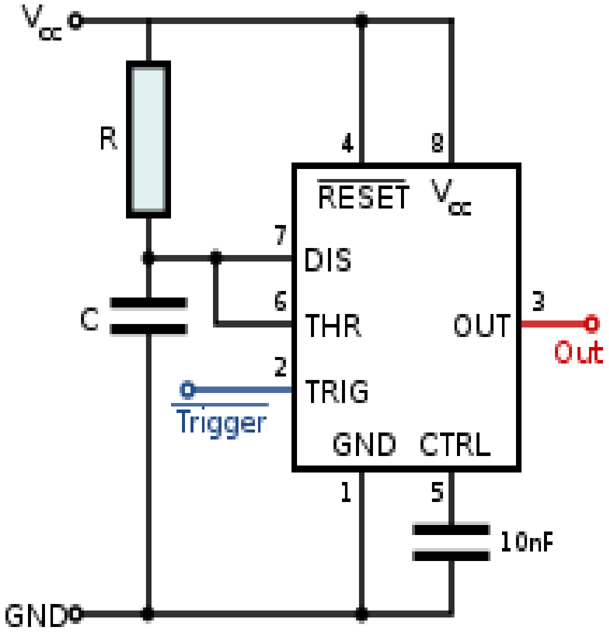


Figure 3 Schematic of a 555 timer in monostable mode.

In the monostable mode, the 555 timer acts as a "one-shot" pulse generator. The pulse begins when the 555 timer receives a signal at the trigger input that falls below a third of the voltage supply. The width of the output pulse is determined by the time constant of an RC network, which consists of a capacitor (C) and a resistor (R) as shown in figure 3. The output pulse ends when the voltage on the capacitor equals 2/3 of the supply voltage [12, 19]. The output pulse width can be lengthened or shortened to the need of the specific application by adjusting the values of R and C.

The output pulse width of time *t*, which is the time it takes to charge C to 2/3 of the supply voltage, is given by:

$$t = RC\ \ln(3) \equiv 1.1\ RC \qquad (3)$$

Where t is in seconds,

R is in ohmsand

C is infarads.

The time span between the two triggering pulses is greater than the RC time constant is a major barrier in using the 555 timer integrated circuit in monostable mode. Hence, the Schmitt trigger circuit is presented in Figure 4.

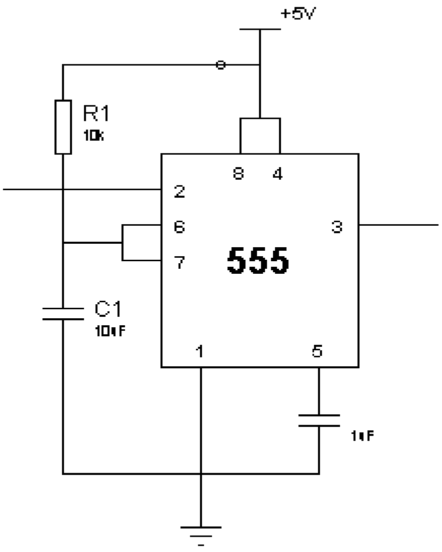


Figure 4 Schmitter trigger circuit.

Usually, the human heart at normal condition beats 72 times per minute. Therefore, one heart beat takes $60\text{sec}/72\text{beats} = 0.8\text{seconds}$.

A 0.3seconds pulse width is achieved using RC circuit. The controller is programmed to achieve 0.5sec delay so as to get 0.8sec delay.

Hence,

$$T = 1.1 \times RC \qquad (4)$$

Setting the value of C equal to 10μf gives R value as follows:

$$\mathrm{R} = \frac{\mathrm{T}}{1.1 \times 10\mu\mathrm{F}} = 27\mathrm{K}\Omega$$

CONTROL UNIT:

The microcontroller 89S52 adopted in control unit is connected in Figure 5.

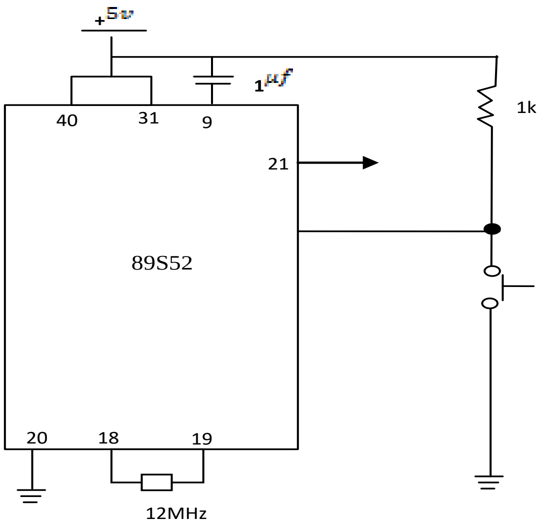


Figure 5 Control unit.

The type of microcontroller used in the control unit design is a family of the 8051.The 8051 is a flexible microcontroller with a relatively large number of modes of operations. The type of 8051 used is 89S52 in which the program written on it is an assembly language program. The AT89S52 implements 256 bytes of on-chip RAM. The upper 128 bytes occupy a parallel address space to the Special Function Registers (SFR). That means the upper 128 bytes have the same addresses as the SFR space but are physically separate from SFR space. When an instruction accesses an internal location above address 7FH, the address mode used in the instruction specifies whether the CPU accesses the upper 128 bytes of RAM or the SFR space. Microcontroller is made up of 40pins and also 4 input and output ports namely P0, P1, P2, P3 e.t.c. The AT89S52 is a low-power, high-performance CMOS 8-bit microcomputer with 8Kbytes of Flash programmable and erasable read only memory (PEROM) [21, 22]. The device is manufactured using Atmel’s high-density non-volatile memory technology and is compatible with the industry-standard 80C51 and 80C52 instruction set and pin out.

The on-chip flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications [21, 22, 23].

Pins 40and 9 are connected to Vcc, via a reset capacitor whereas pin20 is grounded. The terminals of 12MHZ crystal are to pins 18 and 19 respectively. The 1kΩ resistor is a pull up resistor and the push button is used to activate the initial timer within the controller as shown in Figure 5.

DISPLAY UNIT

The display unit adopted in design consist of a 7.5 Liquid Crystal Display(LCD) screen. The heartbeat counted is taken from the diaphragm to the sensor unit. The control unit displayed the output from the sensor unit on the liquid crystal display screen in a friendly way. The value of the heartbeat of each individual is displayed on the screen of the LCD within 60seconds as shown in Figure 6.

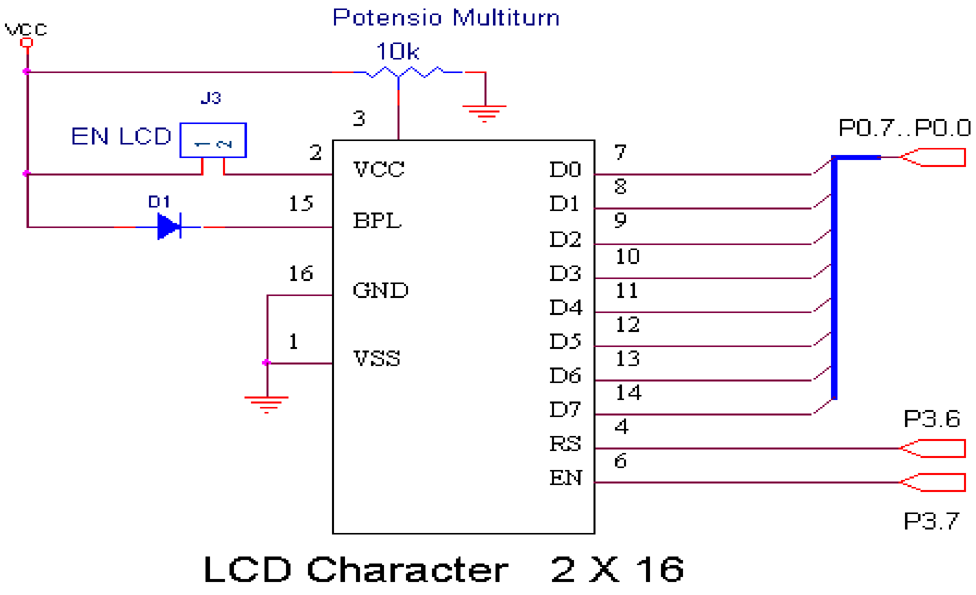


Figure 6 Liquid crystal display (LCD) configuration

The liquid crystal display (LCD) can be implemented for several applications including water heater, mixers, furnaces, incubators, thermal baths, air conditioners, snow meters and heat exchangers [24].

Table 1. Functions of liquid crystal display (LCD) pins

Pin number	Symbol	Function
1	V_{SS}	Ground voltage
2	V_{DD} or Vcc	+3v or +5v
3	Vo	Contrast voltage
4	RS	Register select 0=Instruction register 1= data register
5	R/W	Read/write 0=write mode 1=read mode
6	E	Enable 0=start to latch data to LCD character 1= disable
7	DB0	H → L Data bit 0
8	DB1	Data bit 1
9	DB2	Data bit 2
10	DB3	Data bit 3
11	DB4	Data bit 4
12	DB5	Data bit 5
13	DB6	Data bit 6
14	DB7	Data bit 7
15	A/Vee	LED +
16	K	LED -

The complete designed diagram of a microcontroller based heartbeat monitor is presented in Figure 7

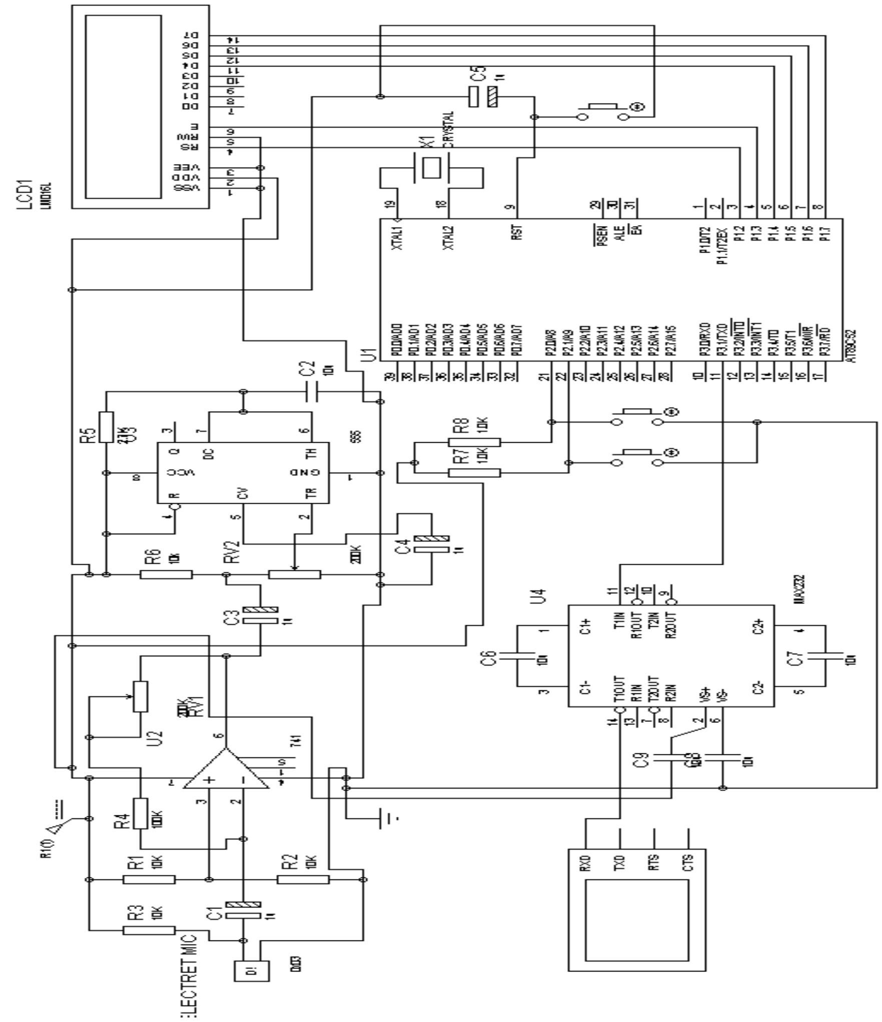


Figure 7 Complete circuit design of a microcontroller based heartbeat medical monitoring device**.**

The microphone inserted into a clinical diaphragm stethoscope senses heart beat and convert it to AC voltage signal in millivolts, which is then amplified, and later converted to square waves via a Schmitt trigger designed from a 555 timer adopted in this work. This square waves are counted by the controller and displayed on the screen after the start count button is pressed. When 60seconds elapses, no count will be recorded after. The result of the number of counted heartbeat is then displayed on the screen.

The output voltage V_{out}signal is determined using this expression:

$$V_{out} = \frac{X_{total}}{X_{total} + (2 \times 10^3)} \times 5 \qquad (5)$$

$$V_{out} = 2.2 \times 10^{-5}$$

The output wave from the pulse shaper and time shaper is seen to be squared from the oscilloscope, going from high to low as shown in Figure 8.

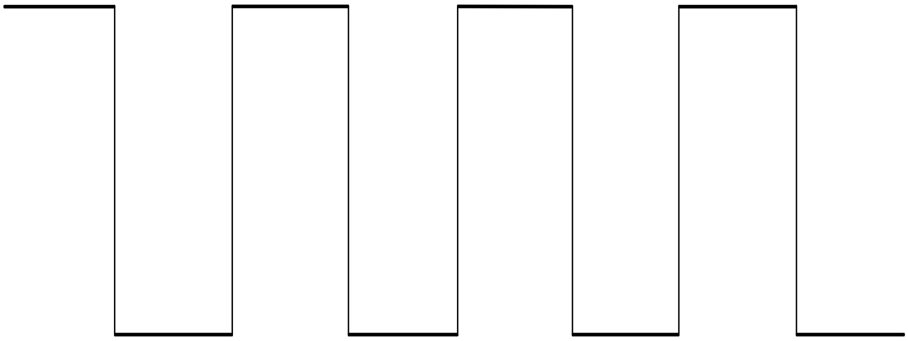


Figure 8: Output waveform from wave shaper and timer stage.

The device called “PROGRAMMER” is traditionally used to get program code into the target PIC. There are many programmers for PIC microcontrollers, ranging from the extremely simple designs to intelligent programmers that can verify the device at several supply voltages. Many of these complex programmers use a pro-programmed PIC themselves to send programming commands to the PIC that is to be programmed.

The program is written in assembly c++ language. Figure 9 depicts a algorithm for measuring the heart rate.

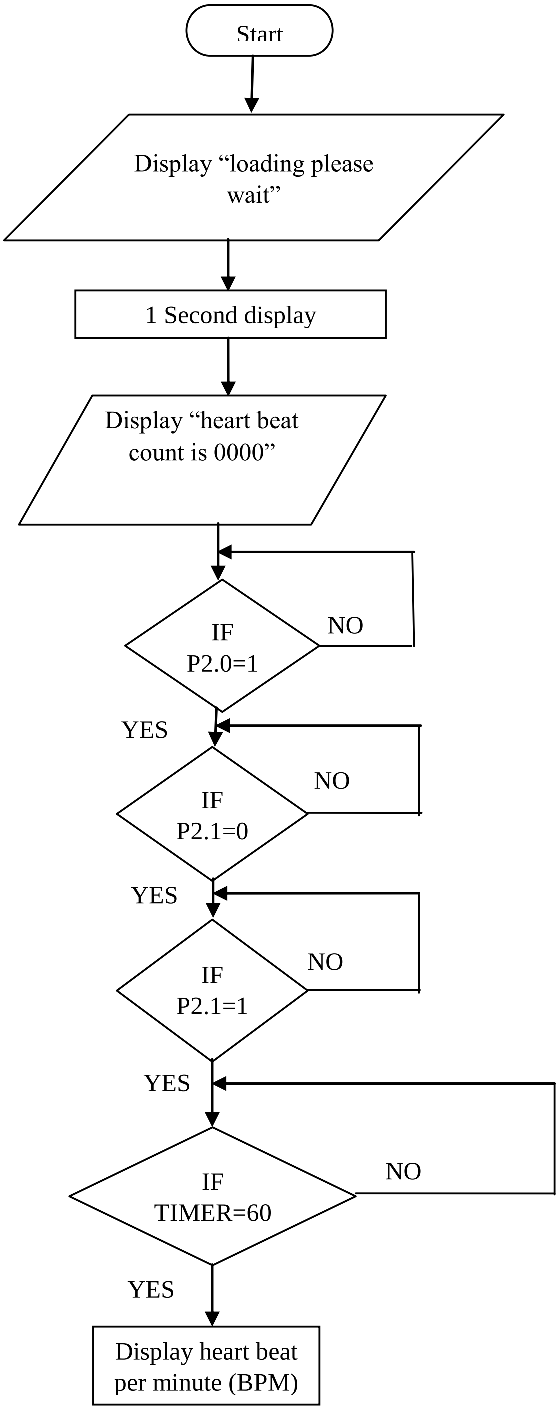


Figure 9 Algorithm development for count and display heart rate.

METHOD 2: Statistical Analysis Developed and Conventional Clinical Stethoscope Devices

Here, performance comparison between two varying quantities are determined using individual heartbeat rate count data obtained from the developed device(X) and the conventional clinical stethoscope(Y) respectively. The mean, standard deviation and correlation values obtained for both the developed device(X) and the conventional clinical stethoscope are evaluated as follows [25]:

$$\text{Mean} = \bar{X} = \frac{\Sigma X}{n} \text{ (mean for developed device)} \quad (6)$$

$$\text{Mean} = \bar{Y} = \frac{\Sigma Y}{n} \text{ (mean for clinical stethoscope)} \quad (7)$$

Where,

X = Individual heartbeat rate count data using developed device

Y = Individual heartbeat rate count data using conventional clinical stethoscope

n = Number of sampled individual

$$\text{Standard Deviation for developed device} = \text{SD} = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}} \quad (8)$$

$$\text{Standard Deviation for clinical stethoscope} = \text{SD} = \sqrt{\frac{\Sigma(Y-\bar{Y})^2}{n-1}} \quad (9)$$

$$\text{Correlation(r)} = \frac{n(\Sigma XY)-(\Sigma X)(\Sigma Y)}{\sqrt{[n\Sigma \text{x}^2-(\Sigma X)^2][n\Sigma Y^2-(\Sigma Y)^2]}} \quad (10)$$

$$\bar{X} = \frac{\Sigma X}{n}$$

$$\bar{X} = \frac{77+78+82+76+79+79+65+82+67+80}{10}$$

$$\bar{X} = 76.5 \text{ Beat per minute (bpm)}$$

$$\bar{Y} = \frac{\Sigma Y}{n}$$

$$\bar{Y} = \frac{75+75+80+74+76+80+62+80+71+82}{10}$$

$$\bar{Y} = 75.5 \text{ Beat per minute (bpm)}$$

Standard deviation for the developed device is computed as follows:

$$\text{SD} = \sqrt{\frac{\Sigma(X-\bar{X})^2}{n-1}}$$

$$\text{SD} = \sqrt{\frac{[(310.5)}{(10-1)]}}$$

$$\text{SD} = \sqrt{\left(\frac{310.5}{9}\right)}$$

$$\text{SD} = \sqrt{34.5}$$

$$SD = 5.87$$

Therefore, the measured heart beat using the developed device ranges from:

$\bar{X}$ ± SD = 76.5 ± 5.87

= 70.63 to 82.37 beat per minute (bpm)

These values are within the acceptable range of 60 to 100 beat per minute (bpm) earlier stated as the normal heartbeat rate for an adult.

The result above is for the developed device

Standard deviation for the conventional clinical stethoscope is computed as follows:

$$\text{SD} = \sqrt{\frac{\Sigma(Y-\bar{Y})^2}{n-1}}$$

$$\text{SD} = \sqrt{\frac{[(308.5)}{(10-1)]}}$$

$$\text{SD} = \sqrt{\left(\frac{308.5}{9}\right)}$$

$$\text{SD} = \sqrt{34.28}$$

$$SD = 5.85$$

Therefore, the measured heart beat using the conventional clinical stethoscope ranges from:

$\bar{Y}$ ± s.d = 75.5 ± 5.85 = 69.65 to 81.63 beat per minute (bpm)

These values still fall within the acceptable range of 60 to 120beat per minute (bpm) earlier stated as the normal heartbeat rate for an adult

The correlation of the results obtained from the two heartbeat monitoring devices is evaluated as follows:

$$\text{Correlation(r)} = \frac{n(\Sigma XY)-(\Sigma X)(\Sigma Y)}{\sqrt{[n\Sigma \mathrm{x}^2-(\Sigma X)^2][n\Sigma Y^2-(\Sigma Y)^2]}}$$

$$r = \frac{(10 \times 58040) - (765 \times 755)}{\sqrt{[(10 \times 58833) - (765)^2]} \times \sqrt{[(10 \times 57311) - (755\ )^2]}}$$

$$r = \frac{580400 \ - 577575}{\sqrt{(588330 - 585225)} \times \sqrt{(573110 - 570025)}}$$

$$r = \frac{2825}{55.72 * 55.54}$$

$$r \ = \frac{2825}{3094.98}$$

$$r \ = \ 0.913$$

$$r \ = \ 0.913$$

The result presents a strong positive correlation.

4. RESULTS AND DISCUSSION

Both the developed device and conventional clinical stethoscope are tested on selected individuals of different ages and their results are tabulated and presented in tables 2 to 6 for comparison. The heartbeat rate measurement result of selected individuals between the ages 26 to 70 years obtained using digital medical developed device is shown in table 2. It can be deduced from this table that the average value of the individual heartbeat rate is 76.5 beat per minute (bpm), which is closer to the normal individual heartbeat rate of 72 beat per minute (bpm). Table 3 shows the selected individual heartbeat rate between the ages of 26 to 70 years obtained using a manual conventional clinical stethoscope. An average value of 75.5 beat per minute (bpm) closer to normal individual heartbeat rate of 72 beat per minute (bpm) is observed.

Table 2 Heartbeat rate measurement result obtained using the digital developed device.

S/N	INDIVIDUALS	SEX	BEAT PER MINUTE(bpm)	AGE (YRS)
1	A	M	77	32
2	B	M	78	33
3	C	M	82	35
4	D	F	76	26
5	E	F	79	27
6	F	M	79	31
7	G	M	65	70
8	H	M	82	32
9	I	M	67	30
10	J	M	80	33
AVERAGE			76.5	34.9

Table 3 Heartbeat rate measurement test values obtained using the conventional clinical stethoscope.

S/N	INDIVIDUALS	SEX	BEAT PER MINUTE(BPM)	AGE (YRS)
1	A	M	75	32
2	B	M	75	33
3	C	M	80	35
4	D	F	74	26
5	E	F	76	27
6	F	M	80	31
7	G	M	62	70
8	H	M	80	32

9	I	M	71	30
10	J	M	82	33
AVERAGE			75.5	34.9

Table 4 shows the statistical analysis of the selected individual heartbeat rate obtained using digital medical developed device and manually conventional clinical stethoscope between the ages of 62 to 82 years. This implies that the heartbeat rate of every individual relates linearly with the number of years. Trend equations are used to estimate the standard deviation and the linear correlation. It can be observed that both the digital medical developed device (X) and manually conventional clinical stethoscope (Y) recorded standard deviation values of 5.87 and 5.85 beat per minute (bpm) respectively. The two heartbeat rate monitoring devices present a strong positive linear correlation estimation value of 0.913 as shown in Table 4.

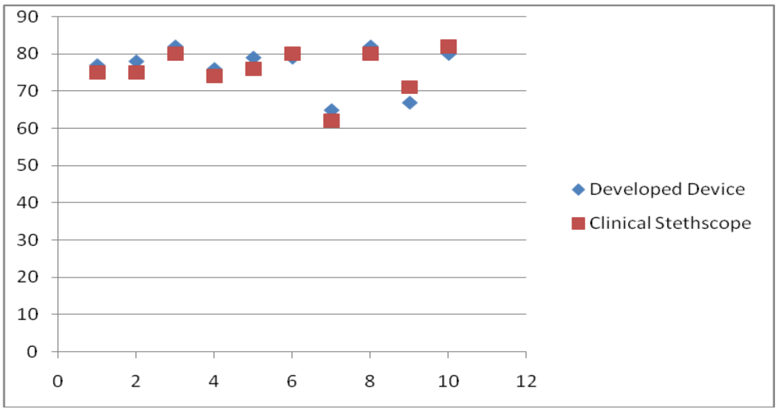
Table 4 Statistical analysis evaluation heartbeat rate results of both the developed device and conventional clinical stethoscope.

S/N	**INDIVIDUALS**	**X (BPM)**	**Y(BPM)**	**X^2**	**Y^2**	**XY**	**$(X - \bar{X})^2$**	**$(Y - \bar{Y})^2$**
1	A	77	75	5929	5625	5775	0.25	0.25
2	B	78	75	6084	5625	5850	2.25	0.25
3	C	82	80	6724	6400	6560	30.25	20.25
4	D	76	74	5776	5476	5624	0.25	2.25
5	E	79	76	6241	5776	6004	6.25	0.25
6	F	79	80	6241	6400	6320	6.25	20.25
7	G	65	62	4225	3844	4030	132.25	182.25
8	H	82	80	6724	6400	6560	30.25	20.25
9	I	67	71	4489	5041	4757	90.25	20.25
10	J	80	82	6400	6724	6560	12.25	42.25
		$\Sigma X = 765$	$\Sigma Y = 755$	$\Sigma X^2 = 5883$	$\Sigma Y^2 = 5731$	$\Sigma XY = 5804$	$\Sigma(X - \bar{X})^2 = 310.5$	$\Sigma(Y - \bar{Y})^2 = 308.5$
	STANDARD DEVIATION (SD)	**5.87**	**5.85**					
	CORRELATION (r)	**0.913**						

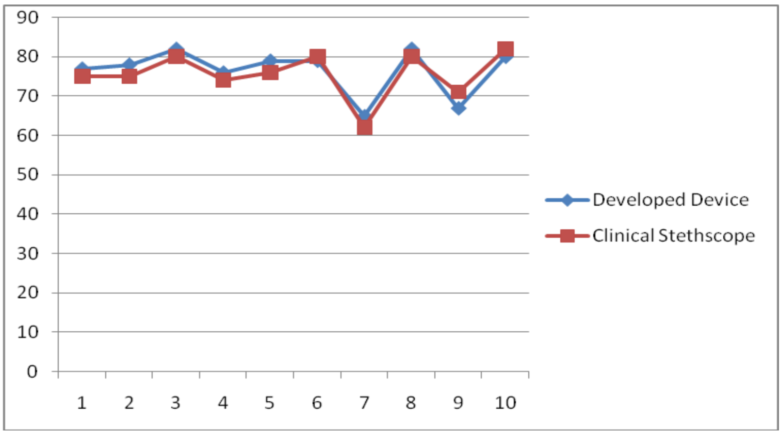
Table 4 Statistical analysis evaluation heartbeat rate results of both the developed device and conventional clinical stethoscope.

The linear correlation graphs for digital developed device and manually clinical stethoscope presented in Figure 10 (a) and (b) showed that the digital developed device is a good substitute for the clinical device.

The heartbeat rate measurements of the sixteen (16) individual younger generations between the ages of 26 and 47 years are taken using digital developed device and recorded in Tables 5 to 6, and graphically shown in Figure 11 (a) and (b) respectively. The average heartbeat rates of the two categories of the younger generation obtained using digital developed device are 81.3 and 78 beat per minute (bpm) respectively.



(a)



(b)

Figure 10 Represents (a) Correlation representation for the developed device and clinical stethoscope using Scatter chat, (b) Correlation representation for both the developed device and clinical stethoscope using Line graph

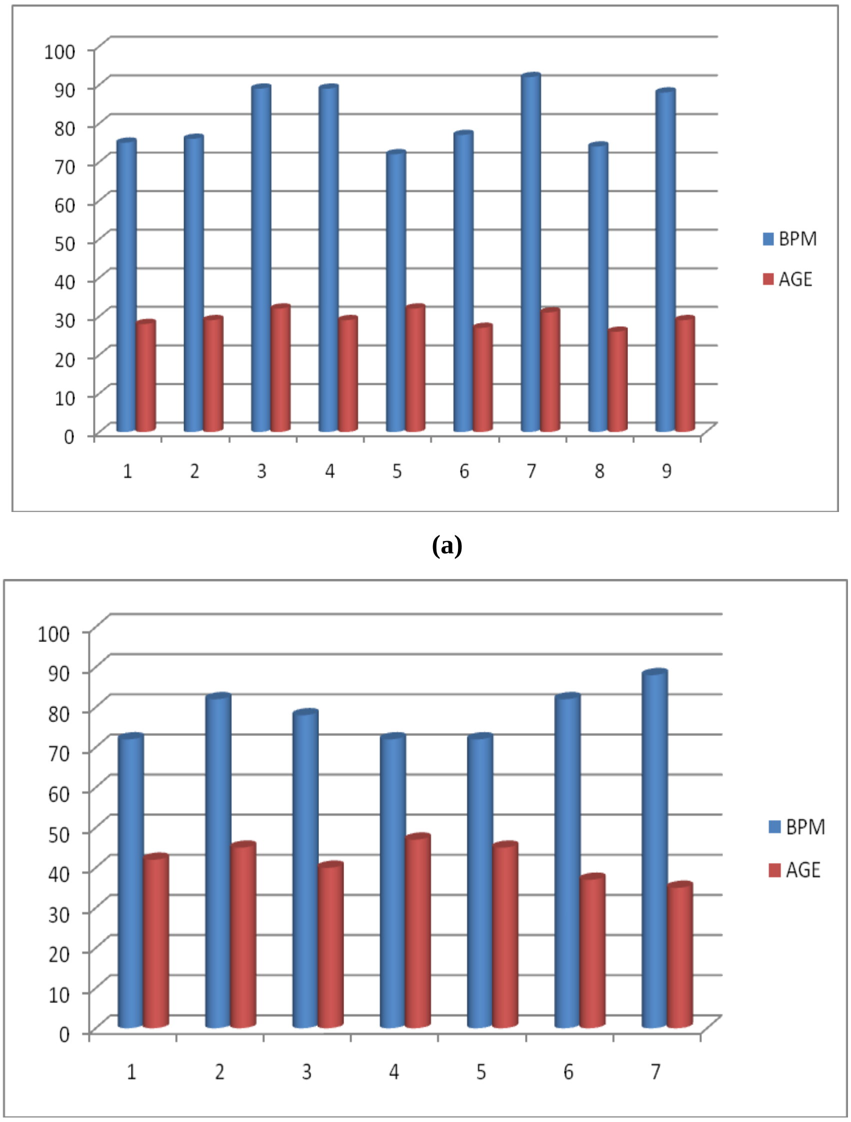
Table 5 Confirmatory Test Result for Ages 27 – 32 obtained using digital developed device.

S/N	SEX	HEARTRATE (BPM)	AGE
1	M	75	28
2	F	76	29
3	M	89	32
4	F	89	29
5	M	72	32
6	M	77	27
7	M	92	31
8	M	74	26
9	M	88	29
AVERAGE		81.3	29.2

Table 6 Confirmatory Test Result for Ages 35 – 47 obtained using digital developed device.

S/N	SEX	HEARTRATE (BPM)	AGE
1	M	72	42
2	M	82	45
3	M	78	40
4	M	88	35
5	M	82	37
6	M	72	47
7	M	72	45

AVERAGE	78	41.6



(a)

(b)

Figure 11 Represents (a): Graphical representation of BPM and AGE for Ages 27-32, (b) Graphical representation of BPM and AGE for Ages 35-47

Generally, the results of the average value, the standard deviation value and the linear correlation value generated between the two medical devices showed that the digital developed device is a good substitute for the manually clinical device. The developed device is very easy to operate and does not require any expertise. The developed device eliminates error due to lack of concentration which is mostly experienced while using the manually clinical device. The developed device allows room for improvement as the microcontroller can be programmed to perform other special functions.

The heartbeat rate of young individuals is relatively high as the average beat per minute of nine sampled individuals is 81.3bpm for average age 29.2, and relatively low in adults as the average heartbeat per minute is 78 beat per minute for average age of 41.6 as shown in tables 5 to 6, and the relationship between age and heartbeat rate of the individuals sampled is presented in graphical forms in figures 12 to 13.

5. CONCLUSIONS

The heartbeat counter design and implementation is achieved with minimal deviation. The output signal from the heart is sensed, amplified and counted in a heartbeat counter. The heartbeat counter serves also as an electronic stethoscope.

A low cost, low power heart rate monitoring using microcontroller technology adequately acquires biological signal, adequately amplified the biological signal, ADC conversion of analog signal, functional heart rate counter, heartbeat rate liquid crystal display (LCD)and the use of low power components for battery operation.

It can therefore be concluded that the heart rate can be measured whenever a pulse or pulses pass through the diaphragm chambers of the device. Subsequently, this signal is fed into a digitizing circuit which converts these random signals into a square wave. These pulses are then counted with the help of the microcontroller and the result is displayed on the liquid crystal display (LCD) screen. The digital developed device possess advantageous quality of simplicity in construction, ease of use, durability, portability, very effective and efficient in heartbeat rate measurement over the manually conventional clinical stethoscope.

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