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Research Article

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Development of a Dual Powered Electronic Stethoscope, with Audio Volume Control

Babalola S. Abioye*, Ike Oluka, Nwobodo-Nzeribe, N. Harmony

Department of Biomedical Engineering, Faculty of Basic Medical Science, Enugu State University of Science and Technology, Enugu State, Nigeria
Corresponding Author: e-mail:patrick.ide@esut.edu.ng, Tel: +2347030285833

Abstract A stethoscope is a device used by medical proctioner to listen to the sound that is coming out internally from human body or an animal and blood pressure (BP) in arteries. Nowadays, stethoscopes are in two forms which are acoustic stethoscope and electronic stethoscope. The most versatile among the two been the electronic stethoscope. But this electronic stethoscope has short comings like single listeners, one source of power no external audio output and no sound frequency indicators. All these shortcomings are the basis of this research study, the researcher want to design and develop another type of electronic stethoscope which will have dual power supply (high reliability), audio volume control and external speaker (high audibility for more than one listeners), audio frequency level indicator (high efficiency). To achieve all these, the study is going to develop the dual power system which will involve battery with solar power charging the battery, as well as power backup. The study will also develop and simulate the stethoscope using Simulink and Protus software during the design of the stethoscope circulatory like signal pre-amplification, signal conditioning, signal power amplification, audio volume control and output units were designed. Lastly the study will develop the prototype and the testing of performance, reliability and efficiency which will be compared with the existing acoustic stethoscope.

Keywords Electronic Stethoscope, Audio Volume Control

1. Introduction

The medical portable device; stethoscope history can be traced as far back as 1816, it was invented by a French physician named RENE LAENUEC by using a long rolled paper tube to funnel the patient sound from the chest to his ear rather than directly placing his ear on the patient chest [1] and [2] Few changes has been made to improve on stethoscope, each design with its own shortcomings. Electronic Stethoscope has been designed and developed before, but used only battery power supply [3] and [4]. Hence this study take into consideration, the latest electronic Stethoscope in market and its shortcomings like no volume control, single power supply, no other output indication apart from the sound produced. Thus this study produce stethoscope with dual power supply, volume control and external speaker jack as well as the audio frequency control indicators. The stethoscope used by the medical personnel is one of the most important diagnostic tools [5];[6];[7]. In the medical world over almost two centuries, the stethoscope has been changed and refined often, but it has never strayed too far from the original design [8]. Only that the Wooden tube first used by RENE THEOPLULE, has been greatly improved on [3] and [9]. But up till now, stethoscope still have some shortcomings that need to be improved on [10]. Medical doctors and Nurses need to listen to patient heart beat and breathing sounds during surgery and anesthesia Cure [11]. Manual acoustic stethoscope is for a single listener, hence a stethoscope that can produce an audible sound for everybody hearing will be suitable [12] and [13]. The previous electronic stethoscope developed used battery only as a source of power. It also has fixed volume, while some are still using earphone only [14]. Hence, in order to improve on current electronic stethoscope, a more reliable power supply must be used, also a variable volume control for both general and confidential listening is needed [15], to increase the sensitivity of the med. Personnel to the reading of the stethoscope, LEDs are used as indicators for the readings [16] and [17]. This shortcoming and how to overcome them is the major concern of this study. The aim of this research work is to produce a stethoscope with dual power supplies (reliability), varying volume control (audibility), incorporated with earphone jack and LEDs reading indicators (flexibility) and also portable.

2. Materials and Methods

The materials used (both electronic components, casing and rubber tubing) are selected locally. After known the value of resistance for the resistor to offer, then colour code was used to select actual value of the resistor.

Table 1: Materials used are:

S/N	Component	Rating
1.	Electrets mic	
2.	Stethoscope head	
3.	Capacitors C1, €2, C3	O.I.μ.F
4.	Capacitor C4	1 μ F
5.	Resistors R1, R2, R5, R9, R10	10kΩ
6.	Resistors R3 and R7	4.7kΩ
7.	Variable resistors VR1 and VR2	50k Ω and 100kΩ
8.	Feedback resistor RF1	9.1kΩ
9.	Feedback resistor RF2	400kΩ
10.	Speaker	100Ω
11.	Battery (rechargeable)	9 volts
12.	Solar panel	9 volts,
13.	Connecting wires	
14.	Circuit board	
15.	Plastic casing	

2.1 Methodology I Design of Dual Power Unit.

The battery used is 9volts dual power supply unit rechargeable battery. Hence the selection of the solar panel will depends on the rating of battery. Hence two 5 watts solar panel are connected in series to charge the battery:
That is for the battery
Power = current x voltage, P = 1v = 1.0A x9 volt = 9.0 watts
For the solar panel: Series connection = (5+5) watts = 10 watts
Hence p = IV, 10 watts = 1 x 9 volts, I = $\frac{10\ watts}{9\ volts}$ = 1.11 Ampere, 1 solar $\cong 1.0\ Ampere$
1 battery $\cong 1.0\ Ampere$
Hence the solar panel choose can successfully and effectively charge the battery. The reverse voltage from the battery will be flowing to the solar panel unit. Hence to prevent this reverse voltage and draining of the batter a power diode is used to connect solar panel and the battery which allow only one way (from solar panel to the battery) flow. Hence single 1N4001 power diode is used.

2.2. Methodology II: Signal acquisition unit

Four different sensing transducers were considered but only the best one is selected.

- Microphone was considered during the design but the sound produced is much distorted by interference. Hence refined cardiac sound cannot be reproduced.
- Piezoelectric ceramic plate was considered, this produced a refined cardiac sounds but with little distortion from the friction between the skin and the sensor.
- Accelerometer was considered, which produced refined cardiac sound, no interference or distortion but very expensive, hence to produce stethoscope at cheaper rate and easy repair and maintenance, accelerometer was not selected.

- Stethoscope head coupled with electrets microphone; this produced the best cardiac sounds, very cheap and a very refined sound when the microphone was place some distance away from the stethoscope head. That is inside the tube.

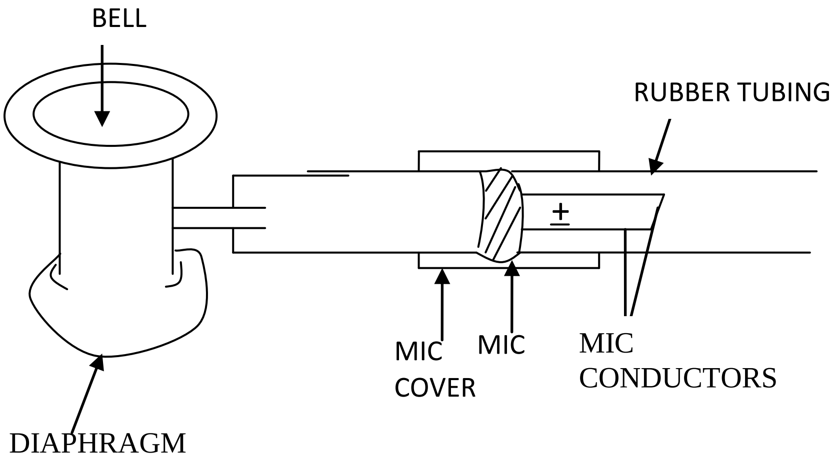


Figure 1: Stethons Head and Electric Microphones

2.3 Methodology III: Signal conditioning, amplification and volume control units.

I. Signal conditioning:

Was designed using a low pass filter with ratings:

1) Frequency $Fc = \frac{100}{2\pi} = 159H_3$
2) Gain AF = 10
3) Voltage input $Vin \cong 4volts - 9volts$ from the designed circuit diagram, no voltage drop across the inputs of an OP-AMP, and no current enters. Hence the negative input

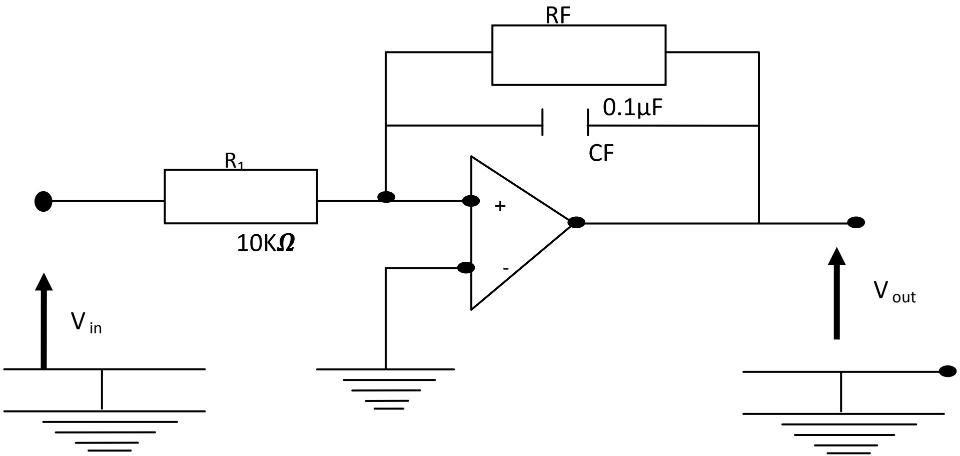
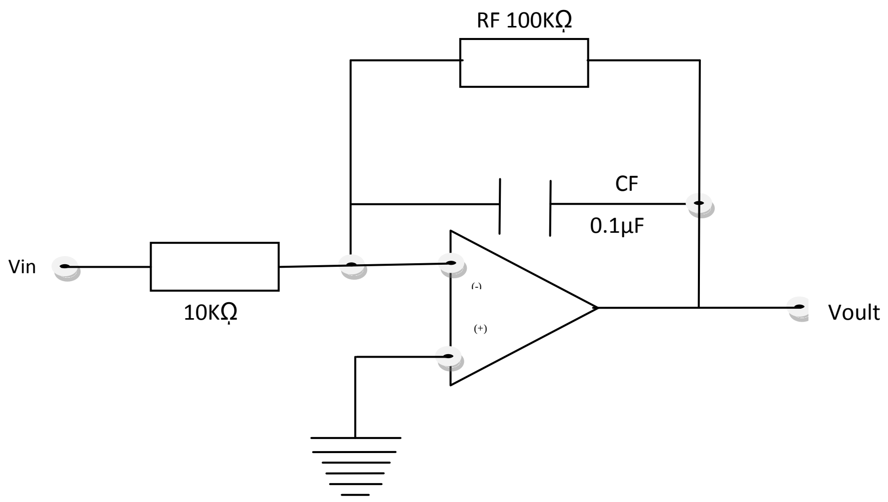


Figure 2: The design low pass filter



II. Signal pre-amplification

A common emitter n-p-n transistor is used:

- Transistor is used because of smaller voltage input to set it in operation 0.2v (silicon), 0.6v (germanauar).
- N-p-n transistor is used because of its high stability capacity when self-bias. Instead of p-n-p.
- Common emitter bias method is used because it works perfectly on low input resistance (20Ω) and medium output resistance (30kΩ).

Hence the following design formulars are used.

- Transistor rating from the manufacturer
    a. Cut-off frequency = $100H_3 - 200H_3$
    b. Common emitter current gain = Hfe =100
    c. Base biased current 1B = 0.9MA.Max. Hence from Ohms Law V = IR

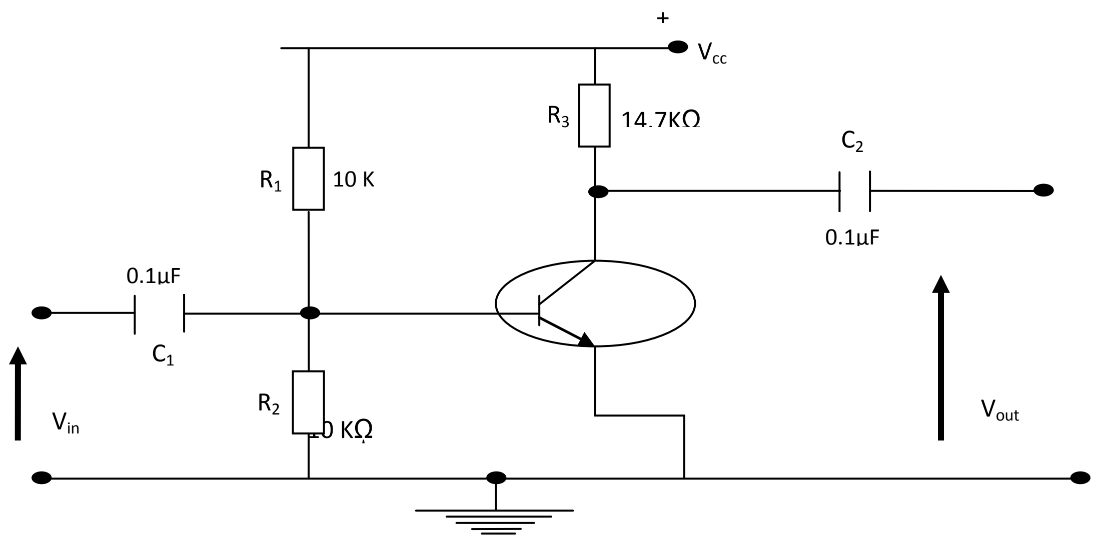


Figure 4: Signal Pre-Amplification

Power amplification integrated circuit TDA 2003A used was selected based on the following design calculations [8] and [18]. The required gain for the power AMP is 40 [32dB]. What are the values of resistors necessary to produce 40 [32dB) signal output. Input resistor $R_{in} = 10k\Omega$.Then by rearranging the closed – 100p voltage gain formula, we can find the new value required for the feedback resistor R_f using the equation below [19] and [20]

Gain = $\frac{R_F}{R_{in}} = R_f = R_{in} \times Gain$

Remember that low pass filter input is also 9.1kΩ. And thus 10kΩ resistor selected. Therefore the low pass filter will work perfectly with the amplification unit without much signal distortions.

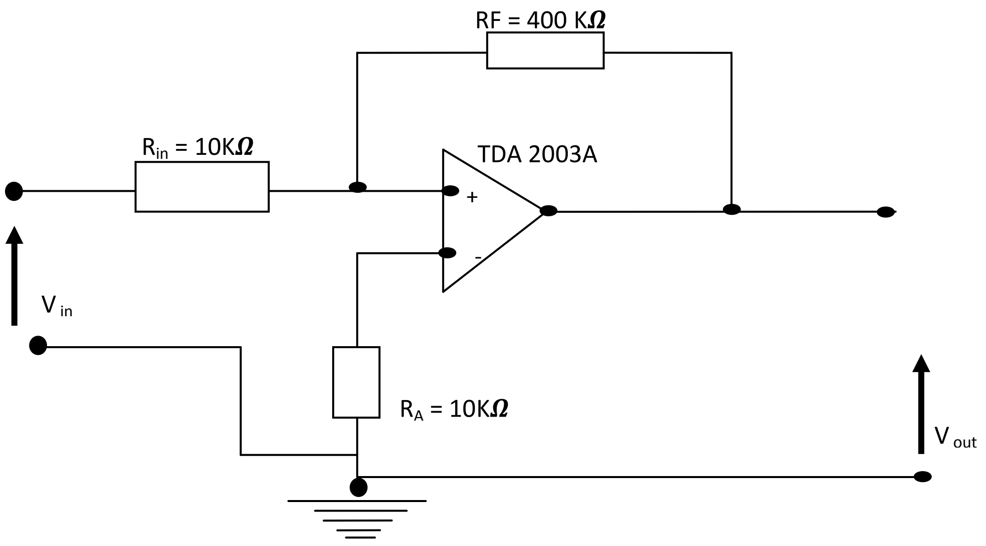


Figure 5: Power amplification circuit design

III. Audio volume control and output units

Volume control is achieved connecting 100kΩ variable resistor the output section of the device. Thus after volume control unit the output is divided to two; with one output goes to the inbuilt and outside speakers respectively. While the second output is connected to the audio frequency indicator (LEDs) using an integrated circuit LM3915.

This LM3915 has two channels

Channel 1 (9 pins)

1- Input pin.

5- Output pins

1- Power input pin

1- GND

1-NC

Hence only channel 1 is used.

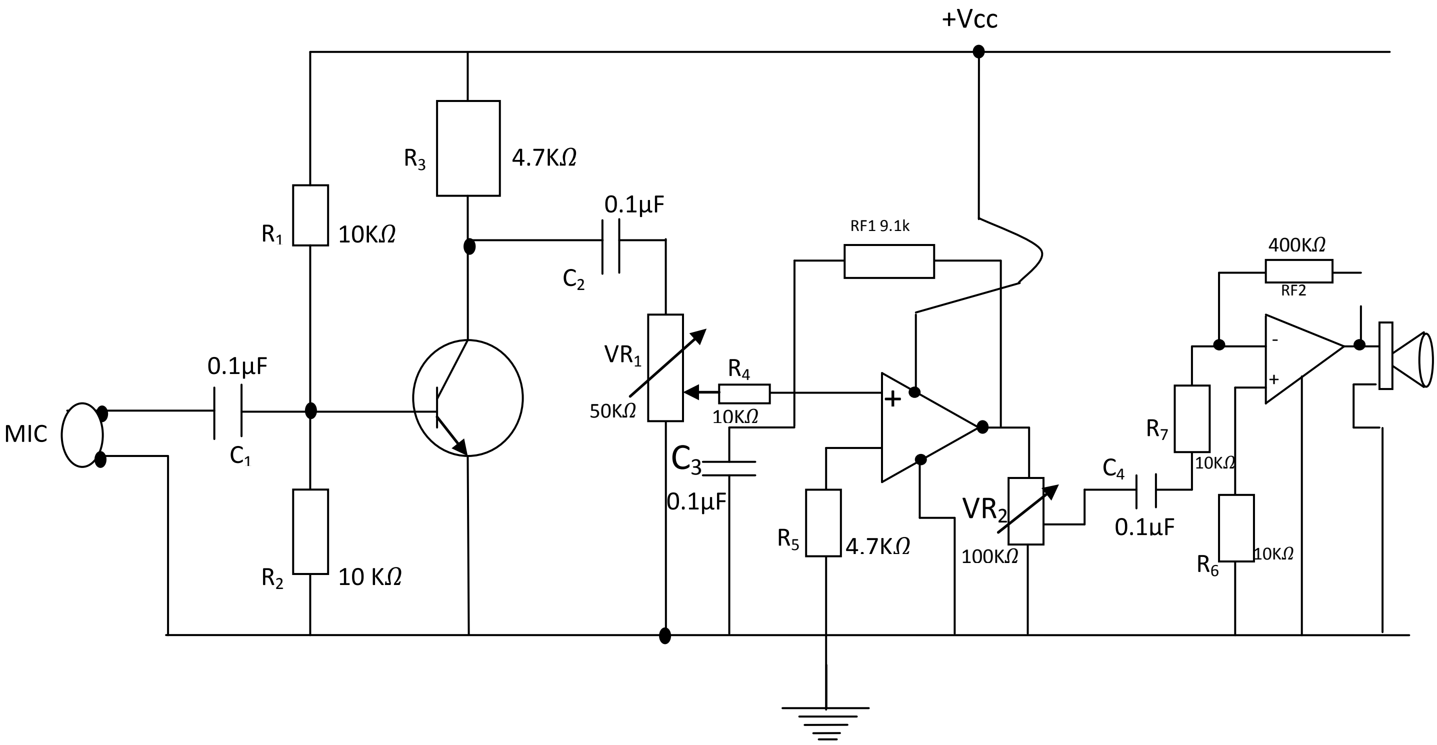


Figure 6: Final circuit diagram of the dual powered electronic stethoscope

3. Implementation

The final circuit diagram was produced using protus software and the simulation was also done the same software; after which the first prototype was produced.

4. Results and discussions

Results

Ten different individuals were used to test the effectiveness of the electronic stethoscope designed and constructed by the researcher.

Table 2: Test Results of Acoustic and Electronic Stethoscope

Subjects	Acoustic stethoscope	Electronic stethoscope
A	$\frac{110}{80} mmHg$	$\frac{115}{80} mmHg$
B	$\frac{105}{78} mmHg$	$\frac{110}{70} mmHg$
C	$\frac{100}{80} mmHg$	$\frac{100}{80} mmHg$
D	$\frac{112}{80} mmHg$	$\frac{110}{80} mmHg$
E	$\frac{115}{70} mmHg$	$\frac{115}{70} mmHg$
F	$\frac{110}{80} mmHg$	$\frac{110}{80} mmHg$
G	$\frac{110}{70} mmHg$	$\frac{110}{70} mmHg$
H	$\frac{100}{80} mmHg$	$\frac{100}{80} mmHg$
I	$\frac{110}{70} mmHg$	$\frac{110}{70} mmHg$
J	$\frac{115}{80} mmHg$	$\frac{110}{70} mmHg$

Both the traditional acoustic stethoscope and the designed electronic stethoscope were used one after the other on a single individual. The results gotten from the ten individuals are compared and the efficiency of both traditional acoustic stethoscope and the designed electronic stethoscope are also calculated. The results are as given in the table 2.

Table 3: The Bp results and time responses of both traditional acoustic stethoscope and designed electronic stethoscope.

Acoustic stethoscope pulse pressure	Electronic stethoscope pulse pressure	Acoustic stethoscope mean pressure	Electronic stethoscope mean pressure
30mmHg	35mmHg	95 mmHg	98mmHg
27 mmHg	40	86 mmHg	90mmHg
20 mmHg	20	90 mmHg	90 mmHg
22 mmHg	40	96 mmHg	90 mmHg
45 mmHg	45	93 mmHg	93 mmHg
30 mmHg	30	95 mmHg	95 mmHg
40 mmHg	40	90 mmHg	90 mmHg
30 mmHg	30	85 mmHg	85 mmHg
40 mmHg	40	90 mmHg	90 mmHg
25 mmHg	40	98 mmHg	90 mmHg
Total = 305 mmHg	**Total = 325 mmHg**	**Total = 918 mmHg**	**Total = 911 mmHg**

5. Discussion

The pressure in the aorta and on the brachial and other large arteries in a going adult human rises to a peak value (systolic pressure) of about 120mmHg during each heart cycle and falls to a minimum value (diastolic pressure) of about 70mmHg. The arterial pressure is conventionally written as systolic pressure over diastolic pressure for instance 128mm/70mmHg. One millimeter of mercury equals 0.1331cPa. So in S1 units 16.0/9/3kpa. The pulse pressure is the difference between the systolic and diastolic pressure, it is normally about 50mmHg. While the mean pressure is the average pressure throughout the cardiac cycle. Because systole is shorter than the diastole, the mean pressure is slightly less than the value halfway between systolic and diastolic pressure. The pressure falls slightly in the large and medium sized arteries because their resistance to flow is small, but falls rapidly in the small arteries and arterioles, which are the main sites of the peripheral resistance against which the heart pumps.

Deviation between standard and ASPP = (100-62)% = 38%

Deviation between standard pulse pressure efficiency and ESPP efficiency = (100-6)% = 34%.

Deviation between efficiency in ASPP and ESPP = (38-34)% = 4% which shows that ESPP is more effective with deviation of 34%. And since the different between the efficiency of the two designs stethoscope is only 4%, shows that the two methods can still use by medical practioners.

Standard mean pressure = $\frac{120+70}{2} = \frac{(190)}{2} = 85$

ASMP = $\frac{918}{10} \cong 92$

ESPP = $\frac{911}{10} \cong 91$

Hence the difference between the two designs is 92-91=1.0mmHg and the deviation between ASMP and SMP = 92-85=7mmHg.

Between ESMP and the SMP = 91-85 = 6mmHG.

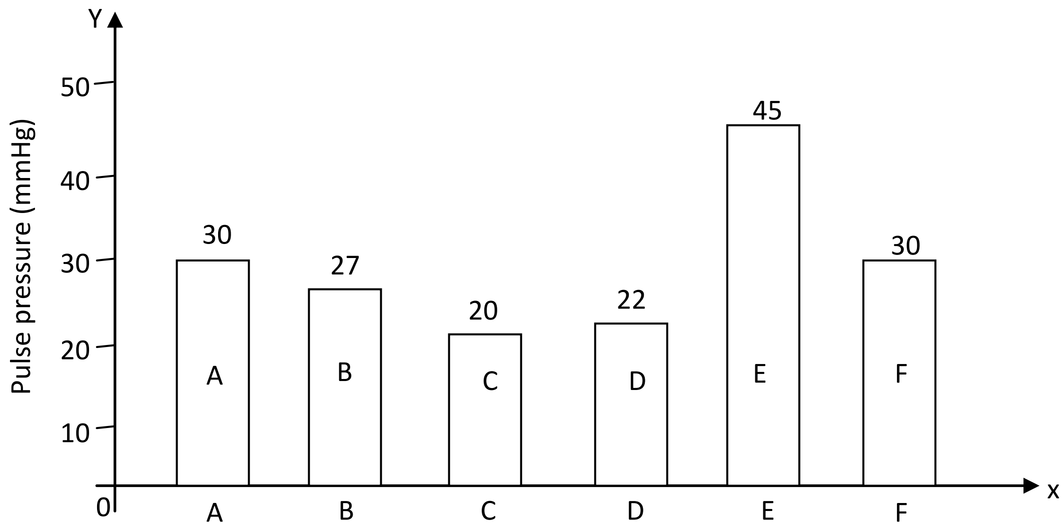


Figure 1: Graph of pulse pressure from acoustic stethoscope. Individual subject.

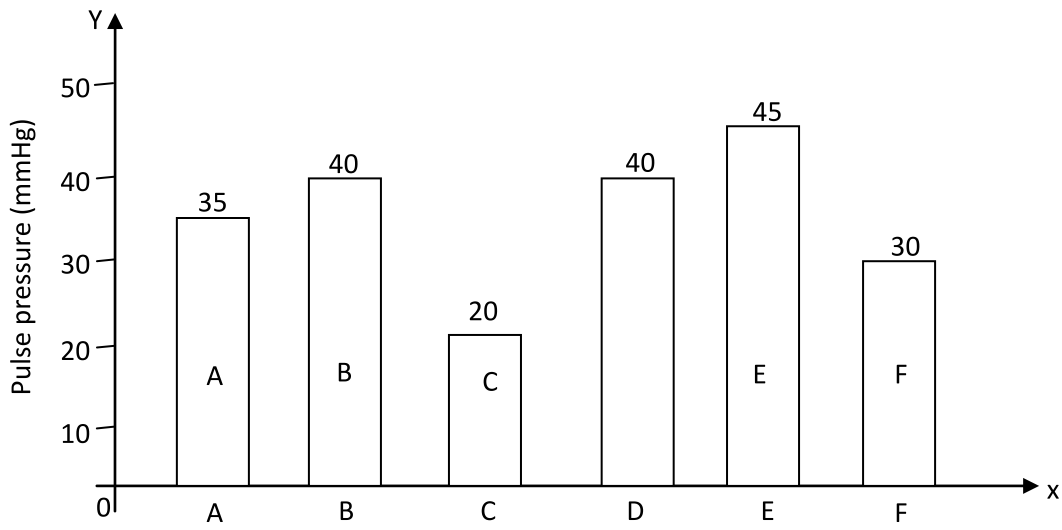


Figure 2: Graphof pulse pressure from electronic stethoscope. Individual subject

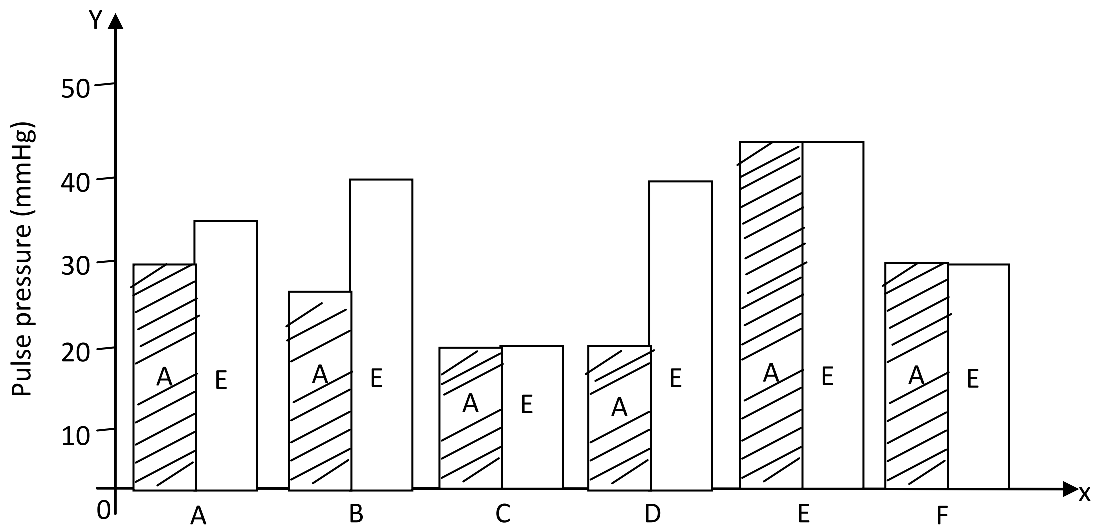


Figure 3: Combined graphs of pulse pressure from acoustic stethoscope and the developed electronic stethoscope. Individual subject.

From the combined bar graph above, using the following data interpretation procedures:

1. Look for overall pattern, then deviation from the patter.
2. Look for extreme values and gaps.
3. Locate center and spread of the distribution.

Compare graph with the same seal –look for maximum and minimum (world health Organization, data interpretation seal (2015). Hence considering overall pattern and deviation; the electronic stethoscope have higher bar (more effective). Also by considering extreme values and gaps the bars for both acoustic and electronic have the same value which means that the traditional acoustic stethoscope can be used to standardized the developed electronic stethoscope. Considering the centre and the spread of the distribution; the developed electronic stethoscope shows high efficiency. Considering the maximum and minimum values of the two stethoscopes, we have the same values; which means that the traditional acoustic stethoscope can be favourably use to standardize or calibrate the developed electronic stethoscope.

4. Conclusion

From the above cited aim and objectives of the research work, it can therefore be concluded that the designed electronic stethoscope can be used comfortably in the hospitals since it produced exalt heart sound, more reliable due to dual power supply. And can both be used confidentially when using separate external earphone or generally by many users at the same time when the inbuilt speaker is used with volume control to increase the volume. Hence, the developed electronic stethoscope is very flexible, reliable and versatile (can be used to measure blood pressure, heart pulse as well as vibration sounds from other abdominal visceral) with high precision readings.

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