Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2021, 8(9):216-226

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Development of a Solar-Powered Sphygmomanometer for Measuring Blood Pressure using a Finger Sensor

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Abstract Continuous supply of electricity has become a major issue now-a-days in the hospital for the monitoring and diagnosing of patient his work title "Development of Finger Print Solar Powered Blood Pressure Monitor" is aimed to develop a solar powered finger print sensed blood pressure measurement. It objectives include to develop a device that will measure the blood pressure through the fingertips of its user and will have solar power as an alternative power supply. The system is able measure the systolic and diastolic blood pressure using the infrared light to sense the pulse in the finger. The system was designed and simulated using PROTOUS 8 software. Arduino software was programmed. ATMEG 328 was used as micro controller. MAT 310 sensors was used. After the pretty sensed was developed with its associated electronics components. It was subjected to field test, five (5) was used to test the device. It was tested satisfactory. The result of the proposed device was compared with the conventional sphygmomanometer; it outperforms the existing digital device in terms of Power, accuracy. A solar power finger sensed. Also it can be used in remote area where epileptic power supply or area is where there was no electricity. The entire unit works only with 3V battery and the motor mechanisms are carried out with 1.2V only.

Keywords Finger sensor, Solar Panel, Monitoring Devices

1. Introduction

Recently the have been a high increase of the prevalence of cardiovascular disease, some of the location in the world have reach epidemic level [1]. About 8(eight) million death yearly worldwide died as a result of high blood pressure [2]. However, insufficient Blood pressure control are the major contribution to the disease such as stroke [3] and this has cause a large increase of economic and heart burden in low resource setting particularly in a developing continent like African [4]. In the developed countries, the control rate of hypertensive patients in terms of treatment is at low percent (between 20%-30%) or even much worse [5]. Between Years 1990 and 2020, Hypertension is anticipated to increase by 120% for women and 137% for men in developing countries compared to 30-60% in developed countries [6-7]. According to WHO in Geneva 2005. Even in developed countries, the control of BP is at best 20% to 30% in hypertensive patients receiving treatment, the situation is much worse [5]. The World Health Organization (WHO) has identified the reduction of total cardiovascular risk through integrated management of risk factors, including hypertension, as one of the most effective strategies for addressing the global epidemic of cardiovascular disease [8]. WHO has also recognized that one of the major causes for poor BP control is the unavailability of reliable, easily obtainable, and affordable devices for BP measurement, a problem that is likely to become greater as mercury sphygmomanometers are phased out [9-11]. The problem is exacerbated by the marketing of non-validated BP measuring devices, the overall high cost of BP devices given limited resources available, and a shortage of no physician health workers trained in the technique of conventional BP measurement. A study shows that a new, low-cost, solar-powered blood-pressure–monitoring device (HEM-SOLAR, Omron) is accurate and easy to use and the preferred method of measuring BP in two African countries [12-16].

2. Literature Review

[2] developed an automated solar-powered blood pressure monitor. With progressive integrated circuit technology, the electronic circuit of the device consists of an ultimately small number of components resulting in very low energy consumption which can be supplied with a solar pane. The product underwent field tests in Uganda and Zambia. In the evaluation, healthcare providers used the product in 700 patients and in comparison with conventional method (auscultation), 95% of the providers preferred the product with the reasons of easiness, solar power, and automated measurement. However, the fact that the machine uses cuff means that a measureable amount of time is spent in tying the cuff. [17] proposed a New Solar-Powered Blood Pressure Measuring Device for Low-Resource Settings. A device, which fulfilled stipulated criteria in being inexpensive, semi-automated, and solar powered, In field testing, average SBPs and DBPs were 120.521.6/74.613.8 mm Hg and 122.321.8/71.214.0 mm Hg, respectively, with the auscultatory technique. Between-device agreement in defining SBP was 93.7%. Nevertheless, the fact that the machine uses cuff means that a measureable amount of time is spent in tying the cuff. In the proposed design, the use of cuff is completely absent and subsequently replace with a finger print sensor capable of reading the blood pressure without the use of a cuff [18]. Solar-powered blood pressure monitor may help reduce heart disease rates in poorer countries. Solar energy eliminates the need for expensive rechargeable batteries in remote areas where electricity and the availability of batteries might be scarce, but sunlight is plentiful. The fact that the machine uses cuff means that a measureable amount of time is spent in tying the cuff. In the proposed design, the use of cuff is completely absent and subsequently replace with a finger print sensor capable of reading the blood pressure without the use of a cuff [19]. Development of a Blood Pressure Measurement Instrument with Active Cuff Pressure Control Schemes. They present an oscillometric blood pressure (BP) measurement approach based on the active control schemes of cuff pressure. Furthermore, the proposed active BP measurement approach is capable of measuring BP characteristics, including systolic blood pressure (SBP) and diastolic blood pressure (DBP), during the inflating cycle. Two modes of air injection measurement (AIM) and inaccurate dual-way measurement (ADM) were proposed. According to the healthy subject experiment results, AIM reduced 34.21% and ADM reduced 15.78% of the measurement time when compared to a commercial BP monitor. However, to rectify this major deficit, this paper tends develop a solar powered blood pressure with technical specifications for an accurate and affordable BP-measuring device that will measure the blood pressure through the fingertips of its user. These sensors are performing several tasks that measure the medical parameters. From a single computer, nurses and doctors able to monitor many patients at the same time. Other than that, this system also able to trigger alarm (alerting that some patient needs attention) and keep patients record (the medical parameters).

3. Methodology

A block diagram of of blood Pressure Monitor Mode of Operation was critically analysed and all the components was explained. Hardware components use for the design the prototype and the description was listed, the design analysis and specifications was carried out. The circuit diagram of the proposed design was developed and simulated using Protous 8 software: The circuit diagram of sensor and the overall solar blood monitor and radio frequency. The operating principle of the circuit diagram was discussed. The Arduino Uno was programmed and the finger print device was also programmed with the same framework with Arduino in order to transmit and receive information from the index finger. Finally, the overall solar blood pressure monitor was build considering the design specification and it was validated by testing the performance of the proposed system and conventional system.

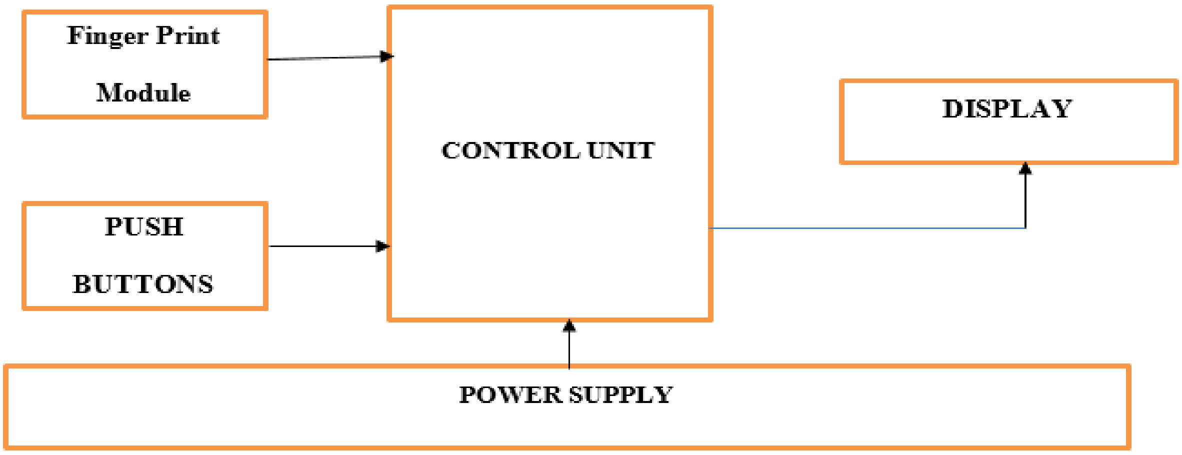

Figure 1: Block diagram of the proposed BP monitoring device

Table 1: Components and Materials Used

1	The Arduino Uno	11	HT 12E Integrated Circuit
2	5 Capacitors (Two 1000µF)	12	LCD display 16x2 lines
3	7 Resistors (Four 1000Ω, One meg ohms kΩ, variable resistor 10ohms, 10k)	13	Buzzer
4	NPN Pole Transistor	14	Switch
5	Wires	15	Push button
6	RF transmitter	16	DC port
7	One solar cells 9V	17	Junction diode
8	Lithum Battery (3.7v)	18	5 watts solar Panel 9V
9	Finger Print Sensor Module	19	Vero board
10	Regulator (5v)	20	Open source Arduino development software

4. Design Concepts and Considerations

The proposed was first designed on Proteus 8 and simulated as well after which it was done on bread board for live simulation approach to avoid fatal mistakes during the main implementation on Vero board. The codes were written, compiled and debugged using Arduino IDE before it was copied to the microcontroller using the ATMEL ISP burner. The finger print module was first tested using the capture code and it responded. Other components were tested using the millimeter. Because power is vital part of electronics and every electronic circuit needs power to function the power supply was designed last because the net load of the circuit determines the power system and power rating of every system. A liquid crystal display (LCD) is a thin, flat electronic visual display that uses the light modulating properties of liquid crystals (LCs) was tested. The smoothing capacitors were used to remove ripples after rectification before voltage regulation. Below are approaches taken to design and implement the project.

Table 2: Design Consideration

Blood Pressure Category	**Systolic mm Hg (upper number)**	**Diastolic mm Hg (lower number)**
Normal	Less than 120	Less than 80
Elevated	120 – 129	Less than 80
High blood pressure (hypertension) Stage 1	130 – 139	80 – 89
High Blood Pressure (hypertension) Stage 2	140 OR HIGHER	90 or Higher
hypertensive crisis (consult your doctor immediately)	HIGHER THAN 180	Higher than 120

I. Implementation 1: implementation of Finger Print Sensor Module

The finger print consumes 7.4v power. The components of the finger print sensor are operational amplifier, which will compare the signal from the infrared receive using voltage of 3.3v. It is connected to the Arduinouno device through I2C port. Its function is to sense the index finger through the infrared (i.e. flashes infrared light to the index finger), the electrical pulse cause by the blood flow in the index finger will be interrupt the infrared reception signal of the sensor. The infrared signal is sent to the arduino to calculate the blood pressure signal.

The performance of the infrared sensor when connected the arduino using proteus 8

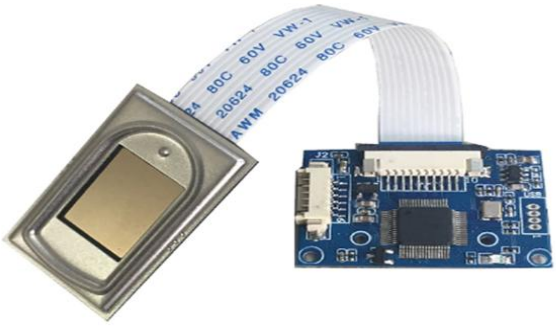

Figure 2: Finger print sensor

II. Implementation 2: implementation of Arduinouno.

The Arduino is used for controlling the whole operation of the BP sensor. Many programming codes have been written and tested to ensure suitable programming codes for BP measurement. The arduino consume 5V from the original 7.4V from Lithium Battery integrated in the casing, the arduino contain an oscillator (ie crystal oscillator). The arduino was firstly simulated to determine values (ADC) and determine the performance of the sensor.

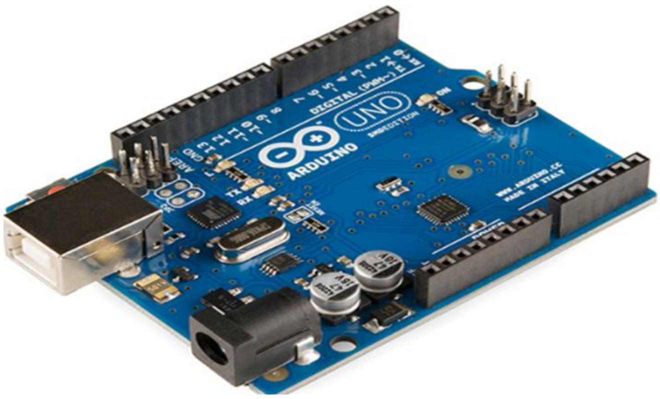

Figure 3: Arduino

Arduino used in this work have input and output port. The sensor is connected to the input port while the liquid crystal display (LCD) is connected to the output port. The arduino receive analog signal from the finger print sensor and it convert it using Analog-digital-converter (ADC) to display using some arithmetic expression to calculate the blood pressure and convert the information to ASCII code, which can be display in LCD.

III. Implementation 3: Simulation of the Prototype

The design was first analyzed on a jotter with block diagram. After the block diagram each component part was simulated on proteus8.

This led to component sourcing. The whole components were tested individually using a multi-meter. From the schematic diagram the circuit was implemented on bread board.

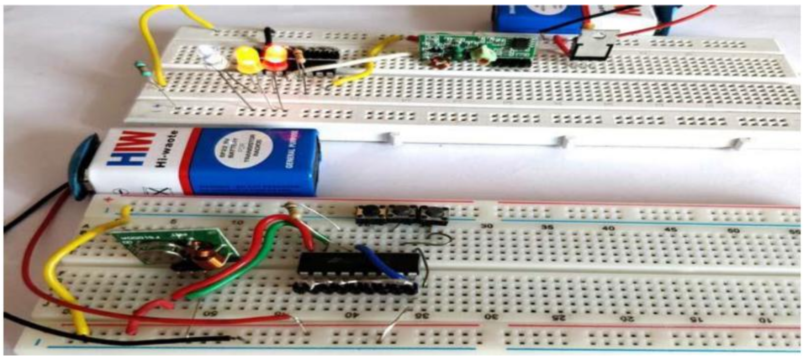

Figure 4: RF circuit on bread board

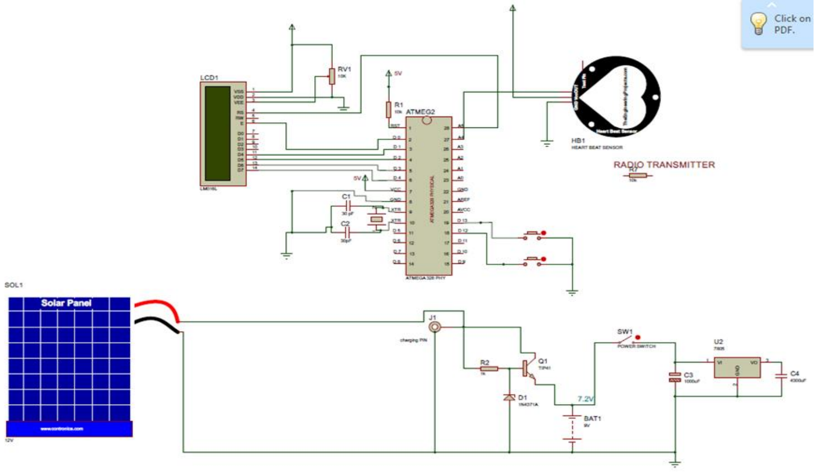

Figure 5: Overall Blood Pressure Circuit Diagram

When the design was confirmed working the components were transferred to the vero board for soldering.

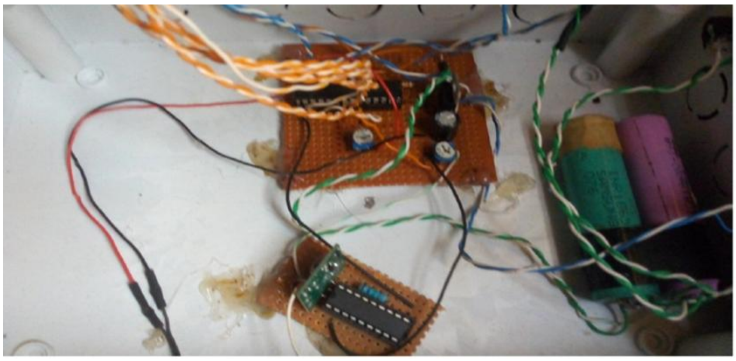

Figure 6: Blood pressure monitors bread board

After soldering the circuit was tested and it was working well. Finally, the project packaging. The project was packaged in adoptable box casing of 9 X 4 X 1inch box. The body was lapped with black emboss card to give it a smooth finishing

Figure 7: Overall design of proposed Blood pressure

5. Results

This paper develops a programming code to determine the blood pressure level with respect to the design in table with World health organization blood pressure standard range. Hence the programming code has been tested and validated with the existing digital device developed by Omron. A field work was conducted with the proposed device and the existing device simultaneously. The proposed blood pressure sensor use and index finger tip to take the reading while the existing device developed by Omron used cuff that will place on the right hand side. The systolic and diastolic pressure is determined when there are significant peaks. At early stage, based on the data acquired from several experiments conducted, the following categories of people was tested using the proposed finger print, solar blood pressure and the existing digital monitor

a. Children between the ages of 5-10
b. Young adult between the ages 15-25
c. Adult between the ages of 20-45
d. Older people between the ages of 50 -90

Children between the 1ages of 5-14

Table 3: The comparison of systolic/diastolic reading between proposed solar BP sensor and existing digital BP monitor

No of test	**Proposed solar BP monitor (mmHg)**		**Existing digital monitor (mmHg)**		**Percentage error (%)**	
	SBP	**DBP**	**SBP**	**DBP**	**SBP**	**DBP**
1st Test	134.22	80.5	131	73	2.458015	10.27397
2nd Test	129.93	79.85	131	83	0.816794	9.457831
3rd Test	131.49	81.39	132	81	0.0386364	15.2963
4th Test	129.93	78.98	132	83	1.568182	13.22892
5th Test	132.47	85.77	128	76	3.492188	12.85526
Standard Deviation (mmHg)	1.8253	2.6504	1.6432	4.4944	Average (%) 1.744308	Average (%) 12.22246

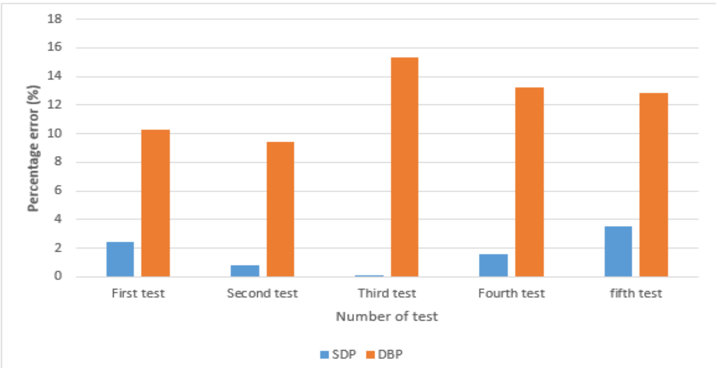

Figure 8: Percentage error (%) between proposed solar BP sensor and existing digital BP monitor SBP AND DBP of Children between the 1ages of 5-10

Table 3 shows random test conducted on children between the ages of 5-10 within trans-Ekulu Enugu. The percentage error and the standard deviation for both systolic and diastolic blood pressure for existing digital blood pressure and the proposed solar power were determined. From the field test conducted, the existing blood pressure was accurate and the external power source act as advantage over the existing digital. The use of index finger for the proposed blood pressure monitor poses as an added advantage over the existing digital blood press monitor. Figure 8 show the Percentage error (%) between proposed solar BP sensor and existing digital BP monitor Children between the 1ages of 5-10. The arduino programming code depending on the finger print sensor signal where the electrical pulse cause by the blood flow in the index finger will be interrupted the infrared reception signal of the sensor.

Young adult between the ages 15-25

Table 4: The comparison of systolic/diastolic reading between proposed solar BP sensor and existing digital BP monitor

No of test	Proposed solar BP monitor (mmHg)		Existing digital monitor (mmHg)		Percentage error (%)	
	SBP	DBP	SBP	DBP	SBP	DBP
1st Test	132.23	80.7	131.1	75	0.8619	7.0632
2nd Test	130.22	81.8	132.1	79	1.4437	3.4229
3rd Test	129.38	79.4	131	81	1.2521	1.9753
4th Test	129.50	83.2	131	88	1.1583	5.4545
5th Test	131.60	81.4	133.1	83	1.1269	1.9277
Standard Deviation (mmHg	1.2746	1.4	0.8779	4.8979	Average (%) 1.1686	Average (%) 3.96872

Figure 9: Percentage error (%) between proposed solar BP sensor and existing digital BP monitor SBP and DBP of Young adult between the 1ages of 15-25

Table 4 shows random test conducted on Young adult between the ages of 15-25within trans-Ekulu Enugu. The percentage error and the standard deviation for both systolic and diastolic blood pressure for existing digital blood pressure and the proposed solar power were determined. From the field test conducted, the existing blood pressure was accurate and the external power source act as advantage over the existing digital. The use of index finger for the proposed blood pressure monitor poses as an added advantage over the existing digital blood press monitor. Figure 9 shows the Percentage error (%) between proposed solar BP sensor and existing digital BP monitor Young adult between the 1ages of 15-25. The arduino programming code depending on the finger print sensor signal where the electrical pulse cause by the blood flow in the index finger will be interrupted the infrared reception signal of the sensor

Adult between the Adult ages of 26-49

Table 5: The comparison of systolic/diastolic reading between proposed solar BP sensor and existing digital BP monitor

No of test	Proposed solar BP monitor (mmHg)		Existing digital monitor (mmHg)		Percentage error (%)	
	SBP	DBP	SBP		SBP	DBP
1st Test	129.3	82.1	134.2	80	3.6512	2.5578
2nd Test	131.2	84.20	132.1	85	0.6813	0.9412
3rd Test	134.2	89.20	134.5	87	0.2230	2.4664
4th Test	136.1	87.5	134.0	86	1.5429	1.7142
5th Test	134.0	90.2	133	89	0.7462	1.3304
Standard Deviation (mmHg	2.7986	3.3744	0.9915	3.3604	Average (%) 1.3689	Average (%) 1.802

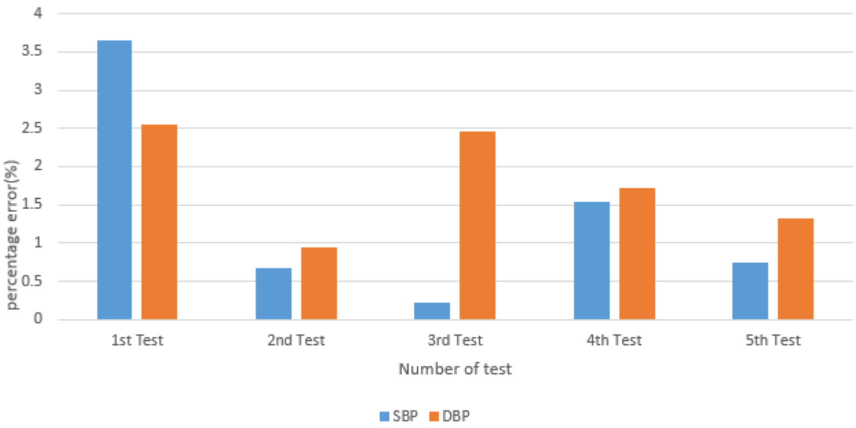

Figure 10: Percentage error (%) between proposed solar BP sensor and existing digital BP monitor SBP and DBP of Adult between the 1ages of 26-49

Table 5 shows random test conducted on adult between the ages of 26-49 within trans-Ekulu Enugu. The percentage error and the standard deviation for both systolic and diastolic blood pressure for existing digital blood pressure and the proposed solar power were determined. From the field test conducted, the existing blood pressure was accurate and the external power source act as advantage over the existing digital. The use of index finger for the proposed blood pressure monitor pose as an added advantage over the existing digital blood press monitor. Figure 10 show the Percentage error (%) between proposed solar BP sensor and existing digital BP monitor adult between the 1ages of 26-49. Since, the programming codes is much depending on the finger print sensor signal where the electrical pulse cause by the blood flow in the index finger will be interrupt the infrared reception signal of the sensor, the controller sometimes captured the noise other than the oscillation of the pressurized artery.

Older people between the ages of 50 -90

Table 6: The comparison of systolic/diastolic reading between proposed solar BP sensor and existing digital BP monitor

No of test	**Proposed solar BP monitor (mmHg)**		**Existing digital monitor (mmHg)**		**Percentage error (%)**	
	SBP	**DBP**	**SBP**	**DBP**	**SBP**	**DBP**
1st Test	132.4	91.0	134.2	92	1.3413	1.0869
2nd Test	138.2	90	139.2	93	0.7184	3.2258
3rd Test	141.2	89	141.8	94	0.4231	5.3191
4th Test	148.6	92.4	147.9	93	0.4710	0.6451
5th Test	150	95.2	151.2	95	0.7936	0.2101
Standard eviation (mmHg	7.3275	2.3362	6.7905	1.1402	Average (%) 3.7474	Average (%) 10.487

Table 6 shows random test conducted on Older people between the ages of 26-49 within trans-Ekulu Enugu. The percentage error and the standard deviation for both systolic and diastolic blood pressure for existing digital blood pressure and the proposed solar power were determined. From the field test conducted, the existing blood pressure was accurate and the external power source act as advantage over the existing digital. The use of index finger for the proposed blood pressure monitor poses as an added advantage over the existing digital blood press monitor. Figure 11 show the

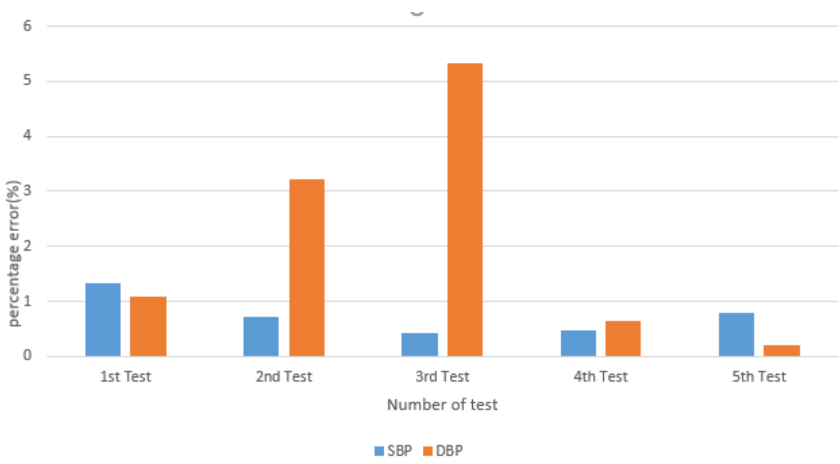

Figure 11: Percentage error (%) between proposed solar BP sensor and existing digital BP monitor SBP and DBP of Older people between the 1ages of 50 -90

Percentage error (%) between proposed solar BP sensor and existing digital BP monitor Older people between the 1ages of 50 -90.

The arduino programming code depending on the finger print sensor signal where the electrical pulse cause by the blood flow in the index finger will be interrupt the infrared reception signal of the sensor pressurized artery

5. Discussion

The proposed device Provide a fingerprint sensor configured for detecting a pulse of a human. The finger print sensor used in the design was connected to the Arduino device via port 12Cport. The major function was to sense the index finger through the infrared light, it is also achieving by flashing light to the index finger and hence the electrical pulse cause by the blood flow in the index finger will interrupt the infrared reception signal of the sensor. The infrared signal is sent to the Arduino to calculate the blood pressure signal. Furthermore, current automatic solar Blood Pressure devices as report by [2] does not have this features. This proposed prototype has advantage over the existing research where cuff is used. However, the fact that the machine uses cuff means that a measureable amount of time is spent in tying the cuff in the case pediatric patients. In the proposed design, the use of cuff is completely absent and subsequently replace with a finger print sensor capable of reading the blood pressure without the use of a cuff. These advantages in the sense that it saves time and increase the number of patients being tended to per time.The proposed device use solar as an external power source is good advantage. Today's world is energy driven and batteries have become an integral part as an energy source considering the technological advances in consumer electronics to electric vehicles, renewables, and smart grids. Batteries are energy limited and require recharging. Recharging batteries with solar energy by means of solar cells can offer a convenient option for smart consumer electronics. Meanwhile, batteries can be used to address the intermittency concern of photovoltaics. The proposd device was compare with the work done OMRON HEALTHCARE (2008). Omron develop blood pressure monitors for the series, a manual upper-arm and automatic upper-arm model. In their work, when fully charged (requires approximately 15 hours with the manual model and 24 hours with the automatic model), the manual model can take measurements more than 280 times and the automatic model more than 100 times. The developed solar in this work outperform in terms of powers retention after several measurements (i.e. 20 hours after taking more 500 patient).Conventional design of solar charging batteries involves the use of batteries and solar modules as two separate units connected by electric wires. Advanced design involves the integration of in situ battery storage in solar modules, thus offering compactness and fewer packaging requirements with the potential to become less costly. This advancement can be advantageous for consumer electronics where space, size, and packaging requirements hold greater value. Three major metrics, namely energy density, efficiency, and stability, have been addressed by presenting relevant challenges and potential opportunities. The integrated design is still in the early R&D phase. There is a need for innovative designs that explore high-capacity, efficient, and stable materials.Meanwhile, to demonstrate its practical viability, this integrated design should also focus on real-world applications such as wearables that demand specific requirements of energy and power.

6. Conclusion

In summary, the following could be concluded from the research work. The prototype developed has the functional measurement as the Digital Blood pressure unit and the cuff mechanism was replacing by finger print. The prototype is design by considering all the user friendly features and the utilization of this prototype doesn't require much knowledge to analyze the Blood Pressure values. In the future we the paper recommends the Development of new methods (the programming codes) needs to be identified. It may use the mathematical technique like neural network. The selection of suitable pressure sensor also needs to be done. The integration of solar cell and device in one package Selection of the chassis device in term of packaging.

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