Design of a Vital Signs Checking System for School Clinic Services

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ABSTRACT: Vital signs monitoring and check-up are very important to maintain the well-being of a person. It gives an outlook of the totality and general condition of a person's health. Conventional ways of vital signs reading have been proven to be accurate and useful and used throughout the medical field. Because of many technological advancements in the different areas of the society, the trend for the development of different kinds of a health monitoring system is continuously growing. Professionals from medical and technological fields refer to it as E-health, or the automated collection, management, use, storage and sharing of healthcare information that improves the quality of life. In line with this, the study focuses on the design and development of a Vital Signs Checking System. The design of a Vital Signs Checking System initializes in the analysis by specifying the system requirements and applying various design concepts. Also, the system is implemented in Higher Educational Institution (HEI) medical clinic to minimize the amount of time needed to take the vital signs of a patient. The prototype test results showed that the prototype has an overall accuracy of 93.35% and 1.05 minutes faster than using manual vital signs readings.

KEYWORDS: *vital signs checking, respiratory rate, blood pressure, body temperature, pulse rate*

1.0 INTRODUCTION

Humankind's thirst for new technology is seemingly unquenchable. The demand for technological advancements grows as humans move forward with modern-day living. Information and communication technologies have penetrated almost all aspects of everyday life, including the medical field [1]. Technology has always been at par with the needs of medicine and has continuously grown to cater to the increasing demand for medical technology. Throughout history in the medical field, the examination of vital signs has been an essential component of inpatient care. Performing general observations on a patient includes a complete physical examination. The patient's vital sign monitoring provided on the initial observation carried out essential activities in the medical field. The monitoring activity can help identify most of the critical health condition if performed regularly and correctly. The patient's physiological state determines the protocols of treatment to follow, provides critical information needed to make life-saving decisions, and confirming responses on procedures produced [2].

The four classic vital signs are respiratory rate, body temperature, pulse rate, and blood pressure introduced into clinical practice many years ago [3-5]. The vital signs monitoring included in the significant activities for emergency nursing care is part of an essential secondary assessment [6]. Moreover, other parameters can be measured and part of vital human signs like The electrocardiogram (ECG) and oxygen saturation in the blood (SpO_2), as mentioned in the studies of [7-10].

Conventional ways of gathering vital signs are usually through invasive vital signs monitoring. The manual process of vital signs reading is also known as the traditional process of checking a patient's vital signs. Reference [11] states that the normal range of vital signs measurement changes in terms of the age and medical condition of a patient. Furthermore, health care professionals such as nurses, physician, or a physician's assistant are those responsible for recording a patient's vital signs. Reference [12] asserts that the measurements were recorded by nurses on the patient vital signs monitoring chart and then synchronized to the central server daily. Performing invasive analysis involves direct insertion into the human body of a sensor or probe. This approach is very challenging technically, as sensor performance (sensitivity, response time, and linearity) can deteriorate due to interactions between the sensor materials and the biological environment, such as blood or interstitial fluid [13]. However, non-invasive are those that do not involve a break in the skin. There is minimal or no contact with the internal body cavity.

In the present day, the use of non-invasive medical instruments is now expanding. The medical services in the Philippines are striving to follow with the technological and medical advancement of the world. Although some of these services like reading for a patient's vital signs consumes a significant amount of time. A registered nurse who started working at the HEI Medical Clinic noted that using the conventional ways of vital signs checking does not take too long unless there is a minimal number of patients. However, as the number of patients piles up for their medical check-up, it suddenly becomes quite difficult to accommodate such a large number, and thus, the problem of time efficiency arises. In line with this, this study aims to produce a vital sign checking system that will benefit the HEI Medical Clinic by minimizing the amount of time needed to take the vital signs of a patient.

2.0 METHODOLOGY

A well-conceived and well-designed system begin with requirements definition. The goal of the requirements identification process is to capture a formal description of the complete system. The output of the requirement analysis phase is the requirement

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specification of the system. There are factors in selecting the hardware components, and changing the parts after building the prototype of the system is cumbersome [14]. The design of the prototype of the vital signs checking system is an embedded system in nature that involves the process of transforming the requirements into a working system taking into consideration hardware and software components in a unified way.
The block diagram of the vital signs checking system, as shown in Figure 1, described the different components and materials that made up the system. The system made use of an Arduino microcontroller module as the central processing unit controls. The microcontroller unit interprets the data inputs from four distinct vital signs sensors where a Liquid Crystal Display shows the four separate vital signs data output [15]. The diagram is the most basic and initial step of designing the system setup for the vital signs checking because it shows the valuable parts needed for the assembly of the prototype.

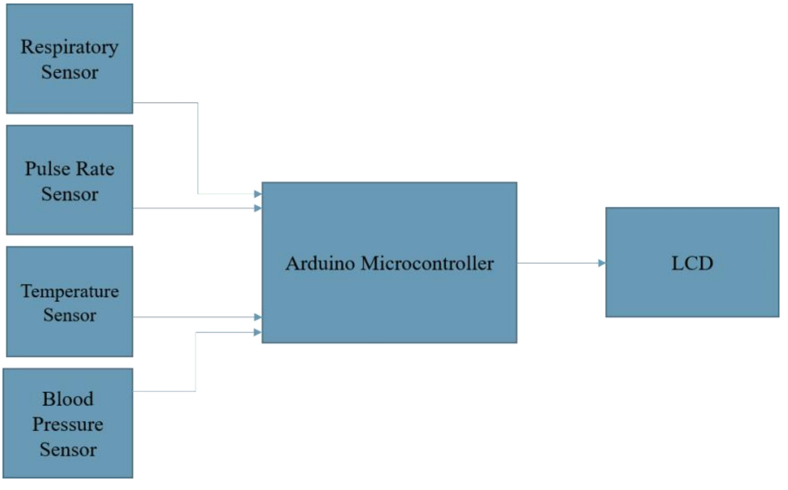

Figure 1: The block diagram of the vital signs checking system

The circuit layout, as shown in Figure 2, is the keymap of the connections of the hardware components that comprise the totality of the working prototype. The circuitry represents the backbone of the physicaland digital operation and functionality of thefabricated prototype.

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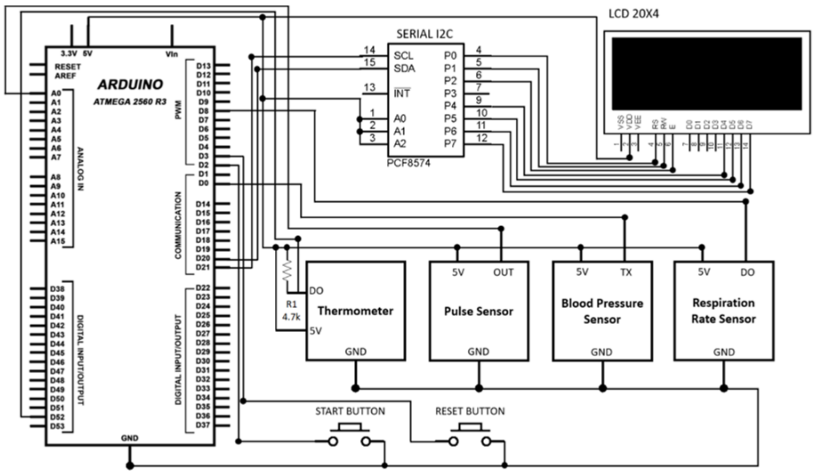

Figure 2: Circuit diagram of the vital signs checking system

Event-driven System Architecture is used to develop the circuit diagram. This architectural style involves a microcontroller, in which case the researchers used Arduino Mega 2560 to interact and control the various components connected to it. The microcontroller recognizes each element attached to it and vice versa. The four separate sensors, along with the LCD and pushbuttons, are all connected to the microcontroller module.

The Arduino, along with the rest of the sensors used for providing the vital signs data, already has its pre-fabricated modules and circuit design except the temperature sensor (DS18B20), which needed a 4.7k ohms resistor to regulate it. The components are all connected to the GND, 5V, and specific pins for data output. Thus, the overall circuit design for this prototype provides the various connections and pin configuration of integrating the multiple modular sensors to the Arduino along with the addition of the Liquid Crystal Display, its Serial I2C, and push buttons used for start and reset.

2.1 Respiratory Sensor Circuit Diagram

Figure. 3 shows the pin configuration of the Thermistor Thermal Temperature sensor to the Arduino Mega 2560. It is capable of measuring the respiratory rate by directing airflow from the mouth of the patient towards the module, sensing the change of temperature state as the person breathes in or out. The blade is connected to the GND and 5V of the Arduino. The DO of the thermistor module is connected to the pin 8 PWM of the Arduino Mega 2560.

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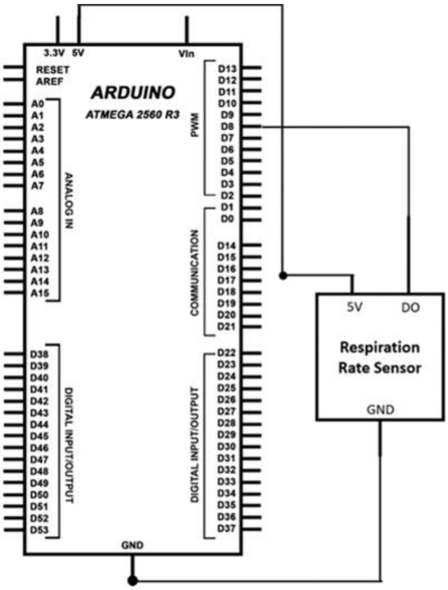
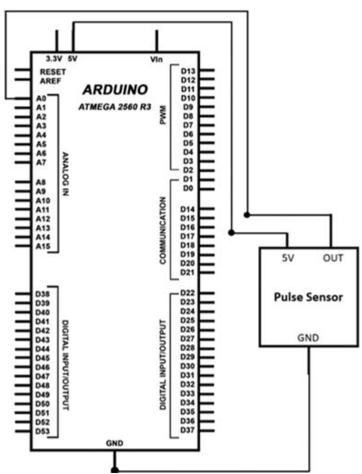


Figure 3: Schematic Diagram for the Respiration Rate Sensor Connection

The thermistor module produces an output of digital switching of either 0 or 1 (high or low) depending on the change of temperature. Thus, the thermistor module is capable of reading the respiratory rate through directing airflow from the mouth of the patient towards the unit, sensing the shift in temperature state as the person breathes in or out. The device can be calibrated by adjusting the temperature detection threshold using the potentiometer on the module.

2.2 Pulse Sensor Circuit Diagram

The diagram of Heart Rate Monitor kit used as the pulse sensor, as shown in Figure 4, act as a simple pulse sensor to the fingertip. The pre-fabricated sensor is connected to the GND and 5V. The DO part of the sensor is connected to the pin 0 Analog In of the Arduino. The pulse sensor monitor heartbeat to obtain live heart-rate data projects and medical equipment.



ISSN- 2394-5125 VOL 07, ISSUE 15, 2020

Figure 4: Schematic Diagram for the Pulse Sensor Connection

2.3 Temperature Sensor Circuit Diagram

The temperature sensor or thermometer used for this study is a DS18B20 digital thermometer. Figure 5 shows the circuit diagram of the temperature sensor. The Dallas 18B20 has no pre-fabricated module, unlike the three sensors used for reading the respiratory, pulse, and blood pressure.

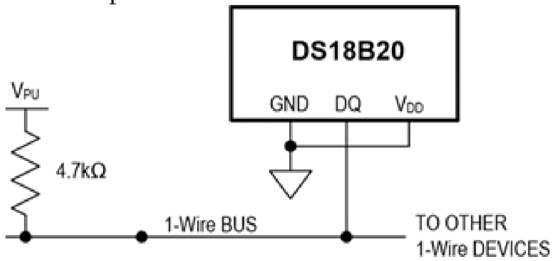


Figure 5: Circuit Diagram of the Temperature Sensor

The schematic diagram of the temperature sensor, as shown in Figure 6. The temperature sensor is connected to the GND and 5V with its DO connected to the pin 52 Digital Input/Output. The DS18B20 uses a 4.7k-ohm pull-up resistor for its bus data line because, at 5V, most current can flow through the resistor. A 1mA or 0.001A current flows into a 5k-ohm resistance. But having the exact 5k-ohm resistance might be too high for the sensor to receive not enough parasitic power to function.

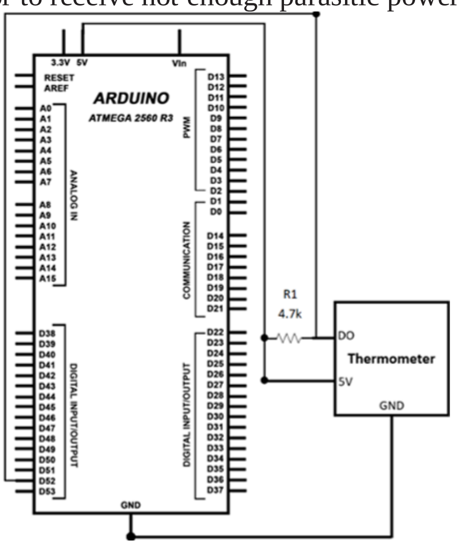


Figure 6: Schematic Diagram for the Temperature Sensor Connection

2.4 Blood Pressure Circuit Diagram

The researchers used an off-the-shelf customized blood pressure monitoring (BPM)

ISSN- 2394-5125 VOL 07, ISSUE 15, 2020

device, integrated into the system by tapping to the transmit and receiver nodes. The blood pressure device connected to the GND and 5V using the transmit node connected to the pin 0 communication of the Arduino, as shown in
the circuit diagram in Figure 7.

The relay the systolic and diastolic data recorded by the BPM is via the wires connected in the Arduino module. The output data is displayed in an LCD module.

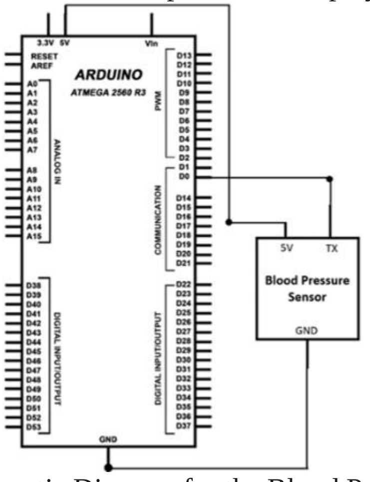


Figure 7: Schematic Diagram for the Blood Pressure Sensor Connected in an Arduino

3.0 RESULTS AND DISCUSSIONS

The fabrication of the prototype includes the integration of the hardware (circuit) and software (program) requirements for the output of this study.

3.1 Fabrication of the Prototype

The sketch for the prototype was developed using Arduino IDE. The development includes testing the hardware components one by one through running sample code. After testing each part, the components were integrated according to the design of the flowchart. The code for the prototype was written in the simplest way possible to eliminate complexities and unnecessary code elements that might take a load on the processing speed of the microcontroller module. All the design concepts discussed in the system design contributes to the development of the prototype.

After designing the circuit and considering the schematic diagram for the system, the final layout was considered substantially integrating the hardware components. The manual testing of the sensor modules checks whether the output is serving its purpose. All the sensor modules, function buttons, and LCD monitors were soldered. The wires are encased in a thermal heat-shrinkable tube to keep them neat and adequately placed. The four separate vital signs sensors are mounted in their respective casings relative to the point of contact to the patient's body. The housing of the prototype was sealed and tightened, ready for the test runs. The fabricated prototype of the vital signs checking

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system is shown in Figure8.

Figure 8: The prototype of vital signs checking system

3.2 Testing and Evaluation Results

The testing and evaluation period determines the smallest margin of error. The method of testing and evaluation is achieved through purposive feedback from identified respondents. The calibration of each sensor is dependent on the normal range of the four vital sign parameters for Adults. The result of the trials, as shown in Table 1, shows the values of the vital signs taken from the prototype and compared to the values using manual vital signs readings.The fifteen test trials were taken with the manual process of vital signs checking compared to the values taken using the fabricated vital signs checking system. The compared values margin of error is computed for each trial to determine the accuracy of the readings using the prototype.

Table 1: Accuracy test of the prototype

Trial	Using the Vital Signs Checking Prototype				Using BPM off-the-shelf device			
	Respiratory	Pulse	Temperature	Blood Pressure	Respiratory	Pulse	Temperature	Blood Pressure
1	17	62	35.50	113/77	17	62	36.04	100/80
2	13	62	35.50	113/74	13	65	36.04	100/80
3	19	61	35.00	109/72	20	62	36.14	110/70
4	19	66	36.00	111/70	19	66	36.04	100/80
5	16	55	35.00	107/70	16	56	36.34	100/70
6	15	58	35.50	108/69	15	59	36.24	100/70
7	18	58	36.00	110/73	18	59	36.14	110/70
8	18	66	36.50	110/70	18	65	36.54	110/70

ISSN- 2394-5125 VOL 07, ISSUE 15, 2020

9	19	63	35.50	90/83	20	64	36.00	90/80
10	16	65	36.00	91/82	16	65	35.14	90/80
11	17	59	35.60	109/79	17	60	36.14	110/80
12	17	64	35.50	92/87	17	65	36.14	100/80
13	16	66	36.00	100/82	16	66	36.34	100/80
14	18	65	35.80	110/83	19	64	36.24	110/80
15	20	68	36.00	113/78	20	68	36.04	110/80

Table 2 shows the accuracy-test measurement of the prototype. The values with 0% mean that there is no margin of error between the two compared readings. As the values increases to positive, the margin of error also increases. However, the values with a negative margin of error mean that the accepted value is lower than the measured value, thus increasing the margin of error to a negative. The instance of having negative value happens on the blood pressure readings because the sphygmomanometer gauge has fixed value displayed in tens and hundreds, while the blood pressure sensor on the prototype device has free-ranged values. The computation results describe that the respiratory sensor has an average accuracy measurement of 1.02%, followed by the pulse sensor with 0.87%, then the temperature sensor with 1.13% and the blood pressure -3.63%.

Table 2: Accuracy measurement of each sensor

Trial	**Respiratory**	**Pulse**	**Temperature**	**Blood Pressure**
1	0.0%	0.0%	1.5%	-17.4%
2	0.0%	4.6%	1.5%	-22.2%
3	5.0%	1.6%	3.2%	3.7%
4	0.0%	0.0%	0.1%	-26.9%
5	0.0%	1.8%	3.7%	-7.0%
6	0.0%	1.7%	2.0%	-9.6%
7	0.0%	1.7%	0.4%	4.1%
8	0.0%	-1.5%	0.1%	0.0%
9	5.0%	1.6%	1.4%	3.6%
10	0.0%	0.0%	-2.4%	1.4%
11	0.0%	1.7%	1.5%	-0.3%
12	0.0%	1.5%	1.8%	15.4%
13	0.0%	0.0%	0.9%	2.4%
14	5.3%	-1.6%	1.2%	3.6%
15	0.0%	0.0%	0.1%	-5.4%
AVERAGE	**1.02%**	**0.87%**	**1.13%**	**-3.63%**

After the accuracy test, the prototype was subjected into a time test. The reading duration of the prototype device will be compared to the reading duration taken with the manual process of vital signs checking. Table 3 gives the results of the time test. The device is in a clear advantage of time efficiency than that of the manual process of vital signs checking. It ties up with 60 seconds of respiratory rate reading but is on a clear advantage on the pulse and temperature readings with both 14 seconds of reading duration compared. However, on the blood pressure reading, the manual process is on the advantage with only 19 seconds of time duration compared to the 25 seconds of blood pressure reading using the prototype device. Overall, the prototype device is still time efficient with a total time duration of only 1.88 minutes compared to the manual process of vital signs reading with a total time duration of 2.93 minutes giving a time difference of 1.05 minutes.

Table 3: Time measurement of each sensor

Vital Signs Sensor	**Using the Vital Signs Checking Prototype**	**Using BPM off-the-shelf device**
Respiratory Rate	60 sec	60 sec
Pulse Rate	14 sec	60 sec
Temperature	14 sec	37 sec
Blood Pressure	25 sec	19 sec

4.0 CONCLUSION

With all the data presented and aforementioned in this study, it can be stated that a Vital Signs Checking Device is fabricated to lessen the time of taking the vital signs of a patient using the manual process of vital signs checking.

The design of a Vital Signs Checking System was accomplished through analysis and design by specifying the system requirements and applying various design concepts. The system is the culmination of all the design concepts and methods taken by the researchers to develop this study. The prototype is tested in terms of its accuracy and time efficiency. The test results showed that the prototype has an overall accuracy of 93.35%. It is determined by subtracting the summation of the margin of error of each sensor to 100%. In terms of time efficiency, the results showed that the prototype is 1.05 minutes faster than using manual vital signs readings.

For the improvement of the prototype, it is recommended the addition of an RFID System for easier identification of records, a Database System for the easier keeping of documents, and a replaceable or rechargeable battery on the set-up of the prototype to promote portability if and only needed.

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