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IoT BASED PATIENT'S HEARTBEAT RATE MONITORING SYSTEM

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Abstract

The main focus of this research is to design a system that detects heart beat rate of a patient using a pulse sensor, monitor the system using Arduino and show the readings in BPM (Beats Per Minute) on the LCD connected to it. In addition to the aforementioned, the system would send the readings obtained to ThingSpeak (the chosen Internet of Things platform) using the Wi-Fi module (ESP8266), so that Heart Beats can be monitored from anywhere in the world over the internet.

In this project, patient's health is continuously monitored and the acquired data is transmitted to an Internet of Things (IoT) platform using Wi-Fi wireless sensor networks; embedded processor supports for analyzing the input from the patient and the results of all the parameters are stored in the database. An ARDUINO board was used to program the ATmega 328 microcontroller.

Keywords— Heart-Beat, Arduino, IoT, Wi-Fi, Microcontroller

Introduction

The World Health Organisation (WHO) defined health in its broader sense in its 1948 constitution as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity *[Huber M, Knottnerus JA, Green, L., van der Horst H, Jadad AR, Kromhout D, Smid H. (2011). "How should we define health?" (PDF). BMJ. 343: d4163. Doi: 10.1136/bmj.d4163.PMID 21791490].*

In many hospitals, provisions are made for the continuous monitoring of a patient's health parameters like the electrocardiographs, heartbeat, temperature amongst others; there is no adequate provision to check the parameters when they return home, hence there is a chance that the disease may resurface. In this system, patient's data heart beat rate will be frequently measured and sent to server using the ESP 8266 module. Period of sending (say every 1 min) can be set, monitoring person learns patient's specific threshold; say the regular body temperature of a patient is 37˚C whereas one person feels feverish if his body temperature is 37.0˚c. By employing an averaging technique over a relatively long time, observer can learn these thresholds for patients. Using the internet, the doctor and any other concerned person(s) can view a patient's health status. When any of the parameter goes beyond the threshold value, the Doctor or whoever is in charge of the monitoring will get an alert notification.

Early detection and diagnosis of potentially fatal physiological conditions such as heart attack require continuous monitoring of patients' health following transfer from hospital to home. Studies have shown that 30% of patients with a discharge diagnosis of heart/failure are re-admitted at least once within 90 days with re-admission rates ranging from 25 to 54% within 3 – 6 months. In response to these types of needs, health monitoring systems are being proposed as a low cost solution. Such a system consists of physiological data that stores, process and communicate through a local manner such as smart phones, personal computers etc. Such systems should satisfy strict safety, security, reliability, and long-term real-time operation requirements.

In this project, a health monitoring system that uses its sensors for collecting data from patients, intelligently predict patient's health status and provides feedback to doctors through the internet is proposed here. The patients would participate in the healthcare process through an internet of things platform, and thus can access their health information from anywhere and at any time.

The Internet has become inherent of our daily life. It has changed how everyone live, work, play and learn, to mention but a few. Internet serves many purposes and its advantages cannot be overemphasized. The next new mega trend is Internet of Things (IoT); visualizing a world where several objects can sense, communicate and share information over a Private Internet Protocol (IP) or Public Networks. The interconnected devices collect the data at regular intervals, analyze and use the obtained data to initiate required action, providing an intelligent network for analyzing data, planning and decision making.

The IoT is a network of physical objects that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet.

Normally it is difficult to keep track of abnormalities in heartbeat count for patient itself manually. The average heartbeat per minute for 25-year old ranges between 140-170 bpm, while that of a 60-year old is between 115-140 bpm, and the body temperature is 37degree Celsius or 98.6 Fahrenheit. Patients are not well versed with manual treatment which doctors normally use for tracking the count of heartbeat. There are various instruments available in markets to keep track of internal body changes. But there are many limitations with regards to the maintenance due to their heavy cost, size of instruments and mobility of patients.

Researchers have been able to come up with biomedical sensors like temperature sensor, heartbeat rate sensor, blood pressure sensor that are integrated on single on-chip sensor and used for monitoring the health condition of a patient. If any varied change takes place, a notification is given; this notification would help to take an appropriate action at a specific period of time. This would save patients from further health risks that may arise in the future and would also enable the doctor to take the appropriate action at the right time.

Internet of Things (IoT) - driven health and wellness monitoring systems enable remote and continuous monitoring of individuals, with applications in chronic conditions, such as obesity, hypertension, diabetes, hyperlipidemia, heart failure, asthma, depression, elderly care support, preventive care, and wellness.

The IoT paradigms can play a significant role in improving the health condition and wellness of subjects by increasing the availability and quality of care, and dramatically lowering the treatment costs and frequent travels. The IoT-driven healthcare system employs networked biosensors to simultaneously collect multiple physiological signals and wireless connectivity to share/transmit gathered signals directly to the cloud diagnostic server and the caregivers for further analysis and clinical review.

II. DESIGN METHODOLOGY

This section explains the design and implementation of the overall system. The system has the following sub-units: power-supply unit, sensing unit (pulse sensor), controller unit, transmission unit (Wi-Fi Module) and output unit (liquid crystal display and ThingSpeak). These sub-units are also made of some components which have their individual specifications based on their datasheets. Proper design calculations and implementation of the design have been carried out on each of the units to ensure that the whole system functions properly and as expected.

Proteus 8.6 is the software used for the simulation of the project while Arduino IDE was the software used to create the source code. Set of instructions mirroring the flowchart was written in the Arduino IDE as part of the software design which was eventually transferred to the microcontroller (ATMEGA 328) using the Arduino development board via a USB cable.

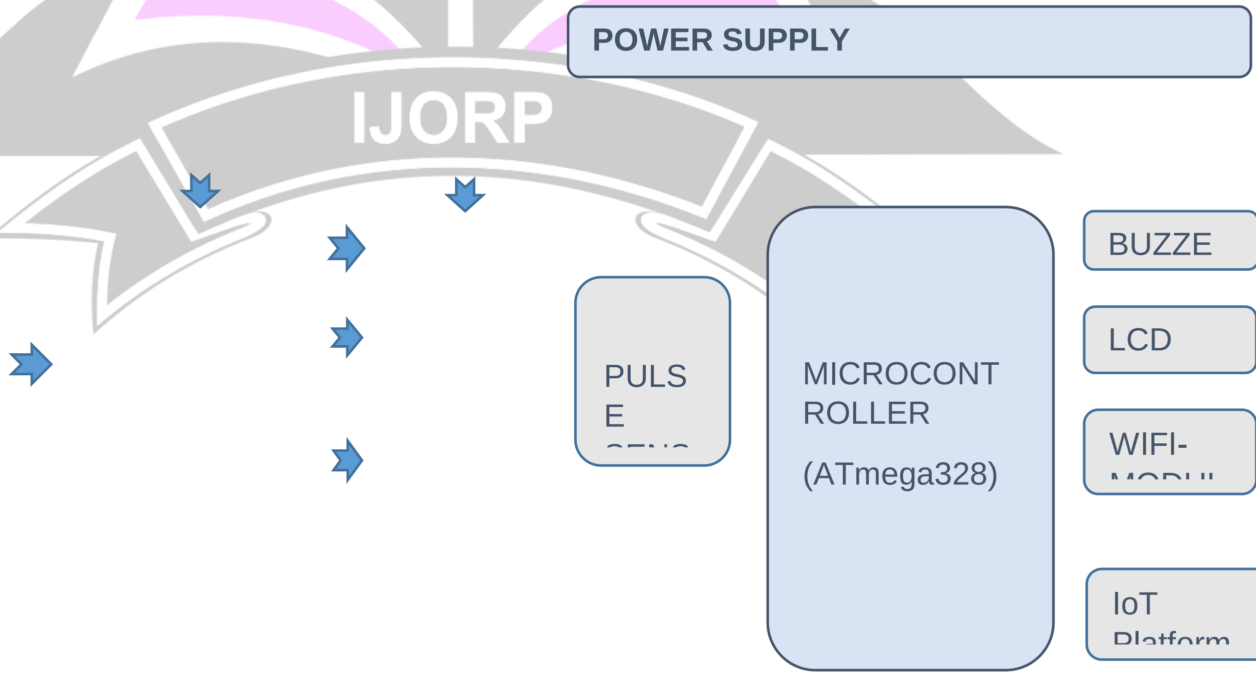

Fig. 1. Block Diagram of the System

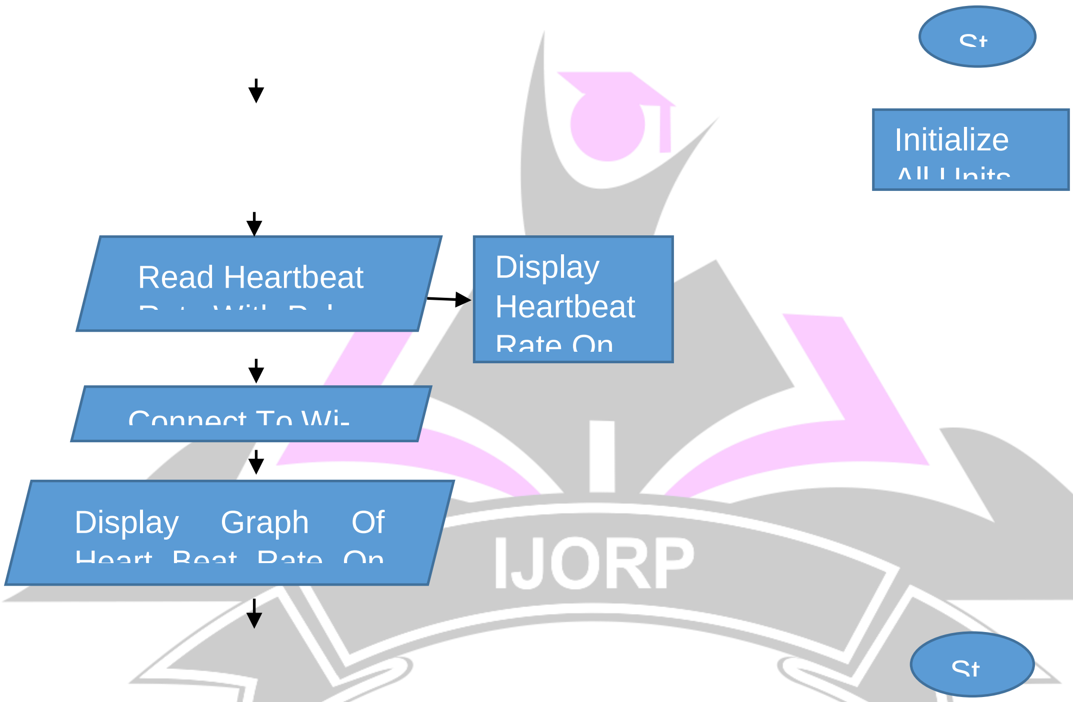

Fig. 2. Flow Chart of the System's Operation

A) Design of the Power Supply Unit

The power supply unit consists of a 240V/12V AC, 50Hz step down transformers, filters and a voltage regulator. The power unit is the unit that energizes all other units of the system. Functionally, the power supply converts AC Voltage of 50Hz power line to DC voltage. In this design, 5V and 3.3V DC are used. The process for the conversion of AC supply to DC is called "**rectification**". It has the following components:

- Step down transformer
- Rectifier

- Filter
- Voltage Regulator

This can be represented in block diagram below:

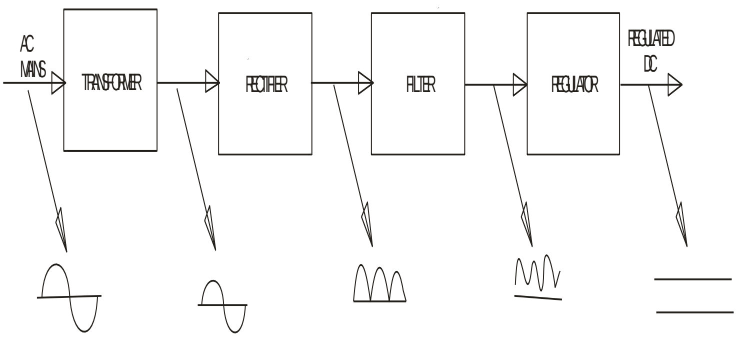

Fig. 3a. Block Diagram Showing Parts of a Power Supply

Step-down Transformer

The step down transformer reduces the alternating input voltage to a lower level. In this design, a 240V AC is stepped down to 12V AC which is then further rectified and regulated to 5V DC. The design parameters relevant to the transformers are as follows:

- Primary Voltage; 220V
- Secondary Voltage; 12V
- Output current; 1.5A

The output power can be calculated as follows:

$$P_{Out} = I_{out} \times V_{out} \quad (1) \qquad P_{out} = 1.5 \times 12 = 18 Watt$$

The 240V AC is stepped down to 12V AC using a transformer

$$V_{peak} = \sqrt{2} \times V_{rms} \quad (2)$$

$$= \sqrt{2} \times 18 = 25.46\text{V}$$

Rectifier

A full-wave bridge rectifier is used to achieve the conversion of the 18V AC as shown in the figure below

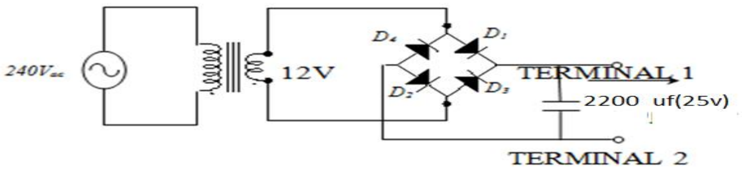

Fig. 3b. Rectifier Circuit

When terminal 1 is positive with respect to 2, diodes D1 and D3 conduct. When terminal 2 is positive with respect to 1, diodes D2 and D4 conduct, thereby giving a pulsating D.C output as shown below, the simulated bridge circuit is also shown.

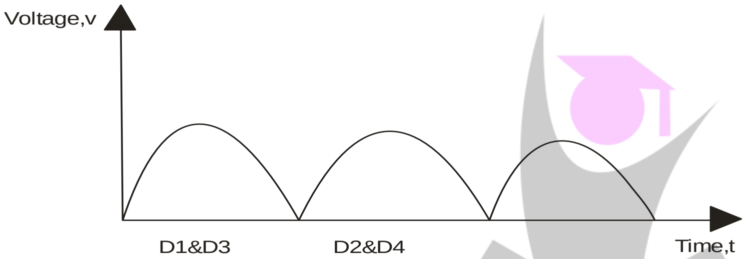

Fig. 3c. Diode Behavior Graph

This project uses four IN4007 diodes for full-wave rectification

$$V_{dc} = \frac{2}{\pi} \times V_{Peak} \quad (3)$$

$$V_{dc} = \frac{2}{\pi} \times 25.46 = 16.20V$$

Filter

The filter smoothens the pulsations present in the output voltage supplied by the rectifier. In practice, no filter gives output voltage that is ripple-free as that of a battery, but it considerably reduces the ripple to a certain extent. A capacitor is used to achieve the filtering as shown figure 3b above.

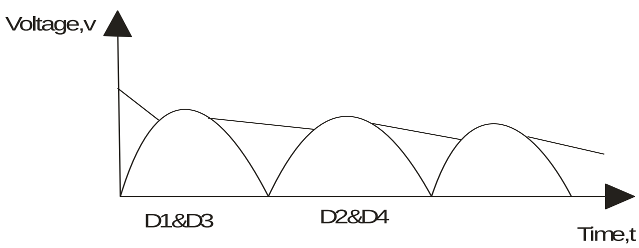

Fig. 3d. Rectified and Filtered Output

$$V_{dc} = V_s / (1 + \frac{I_{dc}}{4fCV_s}) \quad (4)$$

The Equation above refers to the relationship between the filter capacitor and other supply parameters.

$Where \quad V_{dc} = expected\ DC\ output\ from\ regulator$

$f = supply\ frquency$

$I_{dC} = output\ curent\ of\ regulator$

$V_S = transformer\ secondary\ voltageC = capacitance\ of\ the\ filter$

It is preferable to choose a filtering capacitor that will hold the peak to peak ripples at approximately 10% of the peak voltage. Therefore;

$$V_{ripple} = 0.1V_{Peak} \quad (5)$$

$$= 0.1 \times 16.97 = 1.62V$$

$$But\ also; V_{ripple} = \frac{1}{2} fc\ (for\ full\ wave)$$

$Where\ I = current\ taken\ by\ load$

$f = frequency\ of\ supply\ voltage$

$C = filtering\ capacitor$

$$C = \frac{1}{2} fV_{ripple}$$

$$C = \frac{0.17}{3\times50\times1.62} = 668\mu F$$

For the purpose of this paper, a capacitor of 2200μF is used.

Power supply and current consumption

All esp8266 arduino compatible modules are expected to be powered with **DC current** from any kind of source that can deliver **stable 3.3V** and **at least 250mA**. Also, **logic signal** is rated at **3.3V** and the RX channel is protected by a 3.3V divisor step-down. One has to be careful when using this module with Arduino or other boards which supplies 5V, because the module usually **do not come with overpower protection** and can be easily destroyed.

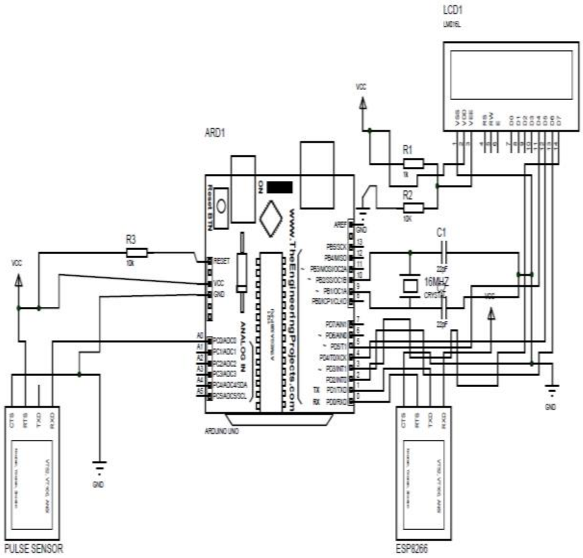

Fig. 4. Complete Circuit Diagram

III. Result

The circuit for this project was first implemented on a breadboard, and later transferred to the printed circuit board so it could be soldered. Moderate amount of heat was ensured to be applied during soldering to avoid damaging the board and the components since most of the components have low heat resistance. The test equipment are as follows:

- Breadboard – Used for prototyping the project without soldering
- Digital Multimeter- Used to measure voltage, current, resistance and check for continuity
- Light Emitting Diodes
- Arduino Sketch
- Proteus Simulation Software

Test of the Power Supply Unit (PSU)

Results obtained from the power supply unit are as shown in the table below:

Table 1. Power Supply Unit Result

Transformer	Theoretical Voltage(V)	Measured Voltage(V)
Input voltage	240	236

Output voltage	12	11.6
Rectifier LM7805	**Theoretical Voltage(V)**	**Measured Voltage (V)**
Input voltage	12	11.7
Output voltage	5	4.8

The test results in the table above are of two categories:

- Theoretical voltage value.
- Measured voltage value.

The theoretical input voltage value of the transformer was discovered to vary from its measured voltage value by 4V, and that of the output voltage varied by 0.6V.

Also, it was observed that the theoretical input voltage value of the regulator varied from the measured voltage value and the same thing applied to the output values of the regulator. The reason for these variations might be due to loss of electrical energy.

The power supply unit of +5V and +12V were tested for the output voltage under no-load and full-load conditions.

Under no-load, the voltage of +5V supply section was measured to be 5.0V; while that of the +12V supply was measured to be 12.00V. At full-load, the voltages were measured as 4.8V and 11.7V respectively.

Voltage Regulation (V.R) is given as

$$V.R = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100\% \quad (6)$$

Where; $V_{NL} = No - load\ voltage$

$V_{FL} = Full - load\ voltage$

Voltage regulation for units on 5V supply is

$$V.R = \frac{5.0 - 4.8}{5.0} \times 100\% = 4.00\%$$

Voltage regulation for the unit on 12V supply is

$$V.R = \frac{12.0 - 11.7}{12.0} \times 100\% = 2.50\%$$

$$V.R = 2.50\%$$

Reason for the variations;

The theoretical laws stated have some assumptions in order to obtain ideal value of AC Voltage source through measurement such as constant pressure, temperature, mechanical strains etc. But when experiment is performed and current passes through the conductor, it leads to heating up of conductor and temperature does not remain constant does leading to some error.

HEARTBEAT RATE RESULTS

The heart rate was obtained using the pulse sensor in this project. The circuit is supplied by 5V power. A fingertip was placed on the sensor and a black material was used to wrap the fingertip together with the sensor to avoid environmental light interference and in order to obtain a better result. The output result was displayed both on a liquid crystal display (LCD) and on an IoT platform (ThingSpeak). The output result of the heartbeat rate on the IoT platform was represented to a certified doctor to determine its accuracy. He stated that the signal is not as accurate as it should be because the pulse sensor used in the project cannot really give a precise value of heart rate. He further stated that it takes a very good sensor which would be more expensive to give more accurate value, but the pulse sensor is okay for a student's project sake.

Graphical Representation of the Heartbeat Rate on ThingSpeak

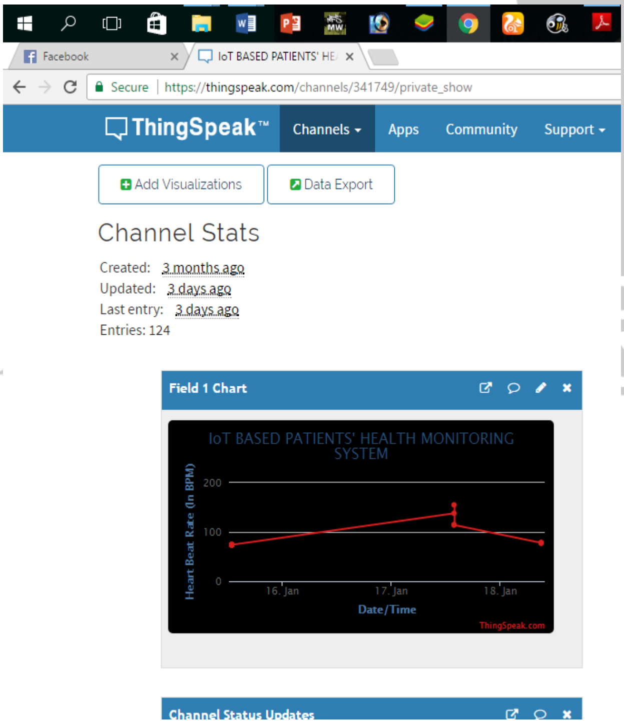

Fig. 5. Graphical Representation of the Heartbeat Rate on ThingSpeak.

IMPLEMENTATION OF THE SYSTEM

Fig 6: Internal view of the system I

Fig. 7. Internal view of the system II

IV. CONCLUSION

The system presented in this paper would go a very long way in easing the stress patients go through when visiting hospitals for regular checkups.

Furthermore, the quality of life of patients would be improved.

The aim of developing this project which is to present a means of keeping track of a patient’s health status using Internet of Things (IoT) was achieved as the prototype provides a means of continuously monitoring a patient’s heartbeat rate to detect and predict heart attack and generate an alarm. The buzzer turns ON when heart rate exceeds or goes below a specified threshold level.

In the future, a more precise ECG sensor can be used for the sensing to give much more accurate heartbeat readings; also, voice notification can be added to the project to remind patients when to take medication and the dosage.

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