Remote Patient Monitor Project

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Course Title: Practices in Electronic Design II

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Abstract

The objective of this project is to design, implement and test the backend for a remote patient monitoring system. This remote system should be able to measure and display on a local and remote device certain conditions medical variable of a hypothetical bed ridden shut-in patient. For this it entails actively monitoring and displaying the following; numerically on the local device and numerically and graphically on the remote device: heart rate, body temperature and sleeping position in bed.

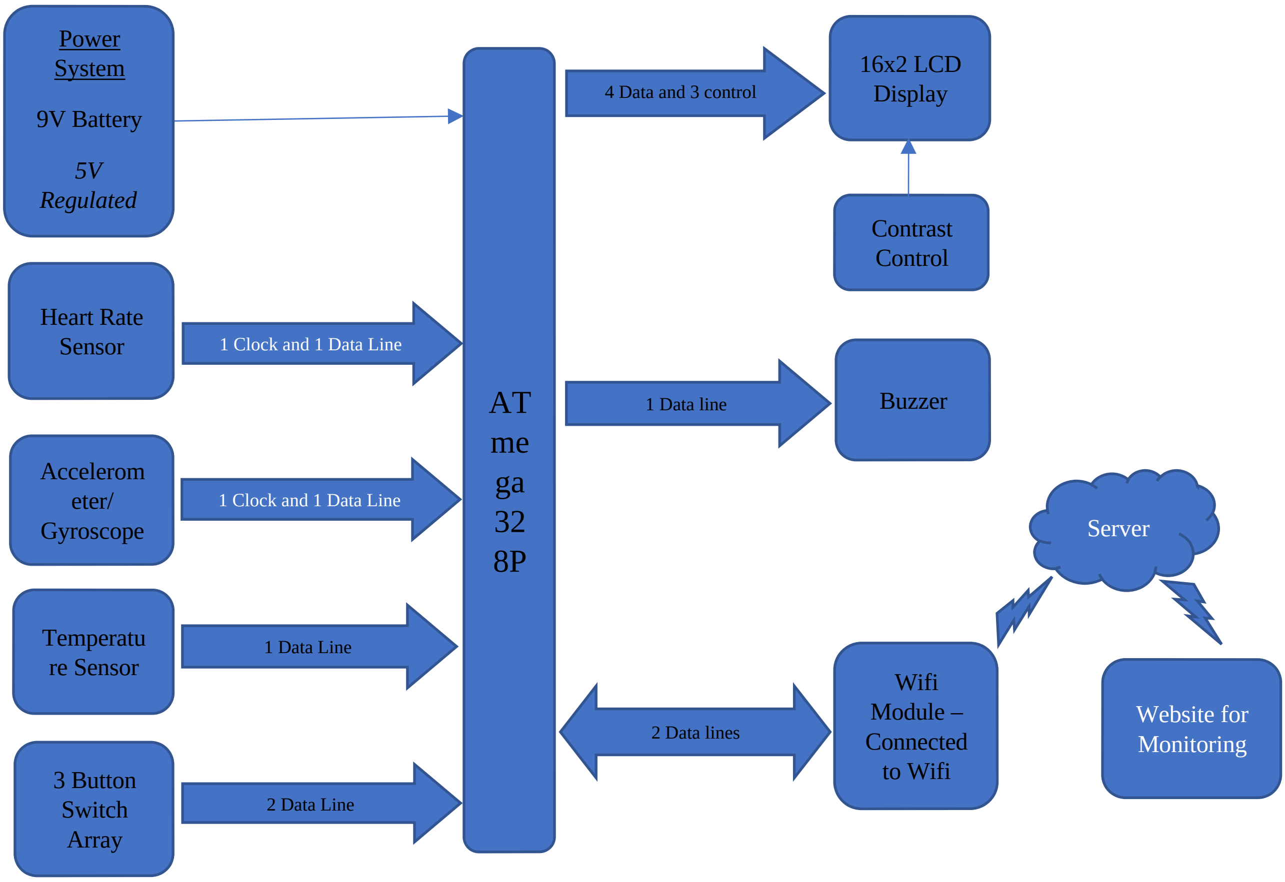
Introduction

Patient monitoring is the continuous observations or measurements of the patient, his or her physiological function, for the purpose of guiding management decisions, including when to make therapeutic interventions, and assessment of those interventions (Gardner & Shabot, 2006). There are several types of patients over the world that need physiological monitoring such as those with life-threatening conditions, in critical psychological state and even the elderly whom have underline sicknesses such as hypertension and diabetic mellitus. Patient monitors are available in most hospitals, however most of these monitoring are local devices that requires devices to be connected to beside computers or monitors, these systems require patients to be at the physical location at the hospital. Furthermore, a doctor or nurse would have to still physically check up on a patient to see their vitals. A problem also arises wherein the capacity of a hospital or a doctor is extremely limited in terms of the number of patients it can accommodate at any given time.

A remote patient monitoring system would allow several patients to be monitored from the comforts of their home which would allow for patients that are in a more critical state to be accommodated at the hospitals. It also improves the capacity of doctors to monitor patients from several locations at single location, which would not be physically possible otherwise and this results in more time for other patients. The system developed enables a patient to measure heart rate and temperature by themselves and the information is immediately sent to the medical practitioner, through a wireless network.

Working Methodology

Block Diagram



Above is the block diagram for the local patient monitoring system. The system consists of a microcontroller core. A 16x2 LCD for display, a 3 button array switch and a 5V regulated power supply to power device inputs (9V battery). It consists of three sensors: heart rate sensor, accerlerometer/gyroscope and temperature sensor which serves as input into the system. The system uses I2C to communicate with the heart rate sensor and the accelerometer/gyroscope, hence these two share a common data and clock line.

Hardware Implementation

For the project following hardware components were used for the implementation of the system

- A 16x2 character line LCD – to display sensor values on local device. HDM16216H-B 16x2 LCD was used.
- 10K Potentiometer – to control the contrast of LCD
- One push button switch – to reset system

- Heart rate pulse sensor module – to measure the pulse rate of the patient. The MAX30102 was used as an integrated pulse oximetry and heart-rate monitor sensor solution.
- Temperature sensor – measure the body temperature of the patient. The LM35 was used.
- Accelerometer/Gyroscope – to determine the speed at which the patient is moving and orientation of the patient on the bed respectively. The MPU6050 will be used as it has both sensors embedded on the same IC.
- Wi-Fi module – to communicate with server over the internet for storage of sensor values into database. The Esp-01 module was be used.
- A microcontroller with a minimum of 16 (7 for the display, 1 for the buzzer and 3 for the switches, 3 for sensors, 2 for wifi module) I/O data lines for data transfer and control signals is required. The ATmega328p microcontroller was used as it met all requirements.
- 16 MHz Quartz crystal – to use as clock source
- Alert: two push button switches, buzzer – to produce sound for the alert, Transistor
- Regulated power supply system: 9V battery, 5V voltage regulator

Heartbeat Sensor

The MAX30102 is based on the principle of photoplethysmography. Saquid et al., (2015) plethysmography is the volumetric measurement of an organ, resulting from fluctuations in the amount of blood or air it contains. Photoplethysmography is plethysmography using optical techniques. Change in blood volumetric levels are coincident to the heart beat and therefore can be used to detect a heartbeat.

The device has two LEDs, one emitting red light, another emitting infrared light. For pulse rate, only the infrared light is needed. Both the red light and infrared light is used to measure oxygen levels in the blood.

When the heart pumps blood, there is an increase in oxygenated blood as a result of having more blood. As the heart relaxes, the volume of oxygenated blood also decreases. By knowing the time between the increase and decrease of oxygenated blood, the pulse rate is determined.

Oxygenated blood absorbs more infrared light and passes more red light while deoxygenated blood absorbs red light and passes more infrared light. This is the main function of the MAX30102: it reads the absorption levels for both light sources and stored them in a buffer that can be read via I2C.

Accelerometer/Gyroscope

Acceleration creates a force that is captured by the force-detection mechanism of the accelerometer. The accelerometer measures acceleration indirectly through a force applied to one of the accelerometer's axes.

A gyroscope is a device that uses Earth's gravity to help determine orientation. Its design consists of a freely rotating disk called a rotor, mounted onto a spinning axis in the center of a larger and more stable wheel. As the axis turns, the rotor remains stationary to indicate the central gravitational pull, and thus which way is down.

The MPU-6050 has both a gyroscope and an accelerometer embedded on a single device, it reads the acceleration of the device in the x,y,z directions separately and also the rotation of the device on each of its axis (x,y,z). The MPU-6050 then stores the data in a buffer to be read via I2C.

The ideologies that were used to determine that a patient has fallen using the MPU-6050 is that when falling there is a great acceleration in either of the three axis and there is normally a rotation of an object on its axes.

Temperature Sensor

The LM35 is a temperature device with an output voltage linearly proportional to the Centigrade temperature. The low-output impedance, linear output, and precise calibration of the LM35 device makes interfacing to read from this device simple. The LM35 operates over a 0°C to 120°C temperature range, this is suitable for measuring body temperature.

Wifi Module

The module supports standard IEEE802.11 b/g/n agreement, complete TCP/IP protocol stack. It provides unsurpassed ability to embed Wi-Fi capabilities within other systems. For this project it serves as a Wi-Fi adapter, to add wireless internet access to the micro controller-based design with connectivity via the UART interface.

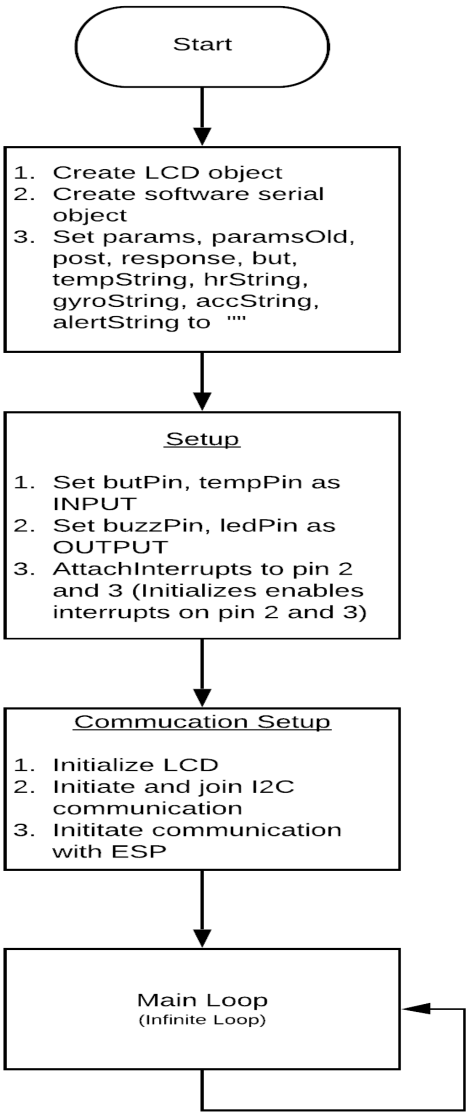
This module also demonstrates sophisticated system fast sleep/wake context switching for energy signal processing, and spur cancellation and radio co LCD interference mitigation.

Circuit Operation

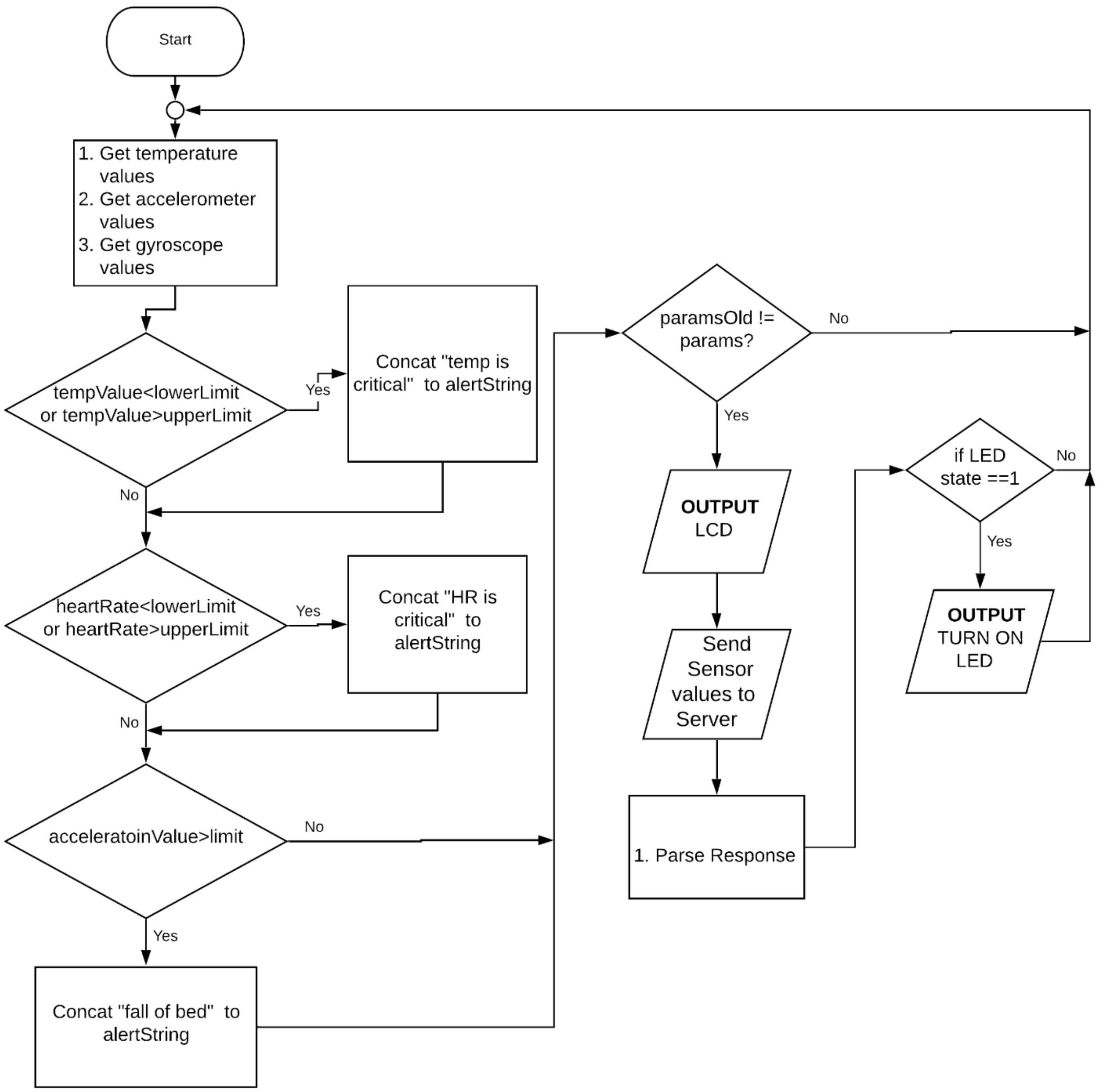
The ATMega328P will be reading the states of the sensors (temperature, gyroscope, accelerometer and heartrate) and displaying heartrate, temperature on the local LCD device. The microcontroller was programmed to also determine the position of the patient on the bed using the data collected from the MPU-6050. Additionally, if the patient has fallen from the bed or their heartrate or temperature is too high or too low, the buzzer is activated, and warning messages displayed on the LCD screen. When the alert button is pressed the buzzer sounds to indicate that the patient needs help and a corresponding message is also displayed on the LCD screen. After every three seconds, ATMega328P uses the ESP to make POST requests, to send the circuit information to the server. The server will then read these states and display numerically and graphically the data received. An alert will be displayed on the webpage each time the alert button is pressed.

Flowcharts

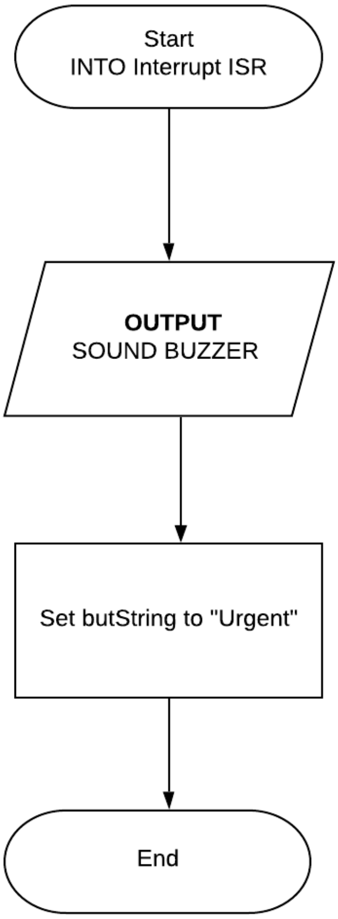
The Flowchart below gives the overall view of the project software indicating the setup of the microcontroller and including the proposed peripherals to be utilized. External interrupts will be utilized to respond to button press. More detailed design of the firmware is in the additional flowcharts.



The Flowchart below gives the expanded view of the Loop Function. This section controls the local system display and reads data from sensors to display information on LCD and send data captured to webserver.

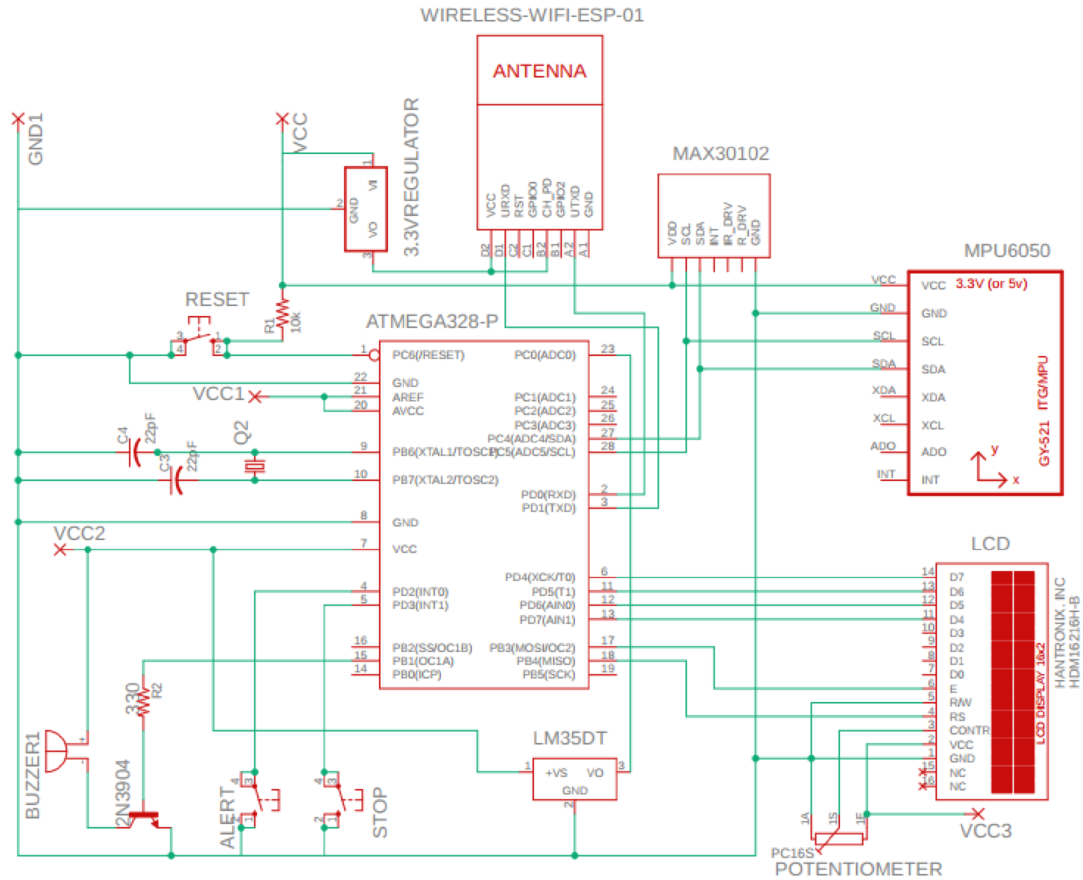


The flowchart below gives the External Interrupt Service Routine. An interrupt is generated any time the alert button is pressed, associated with pin 2.



Schematic diagram

Schematic Diagram Showing Local System Setup

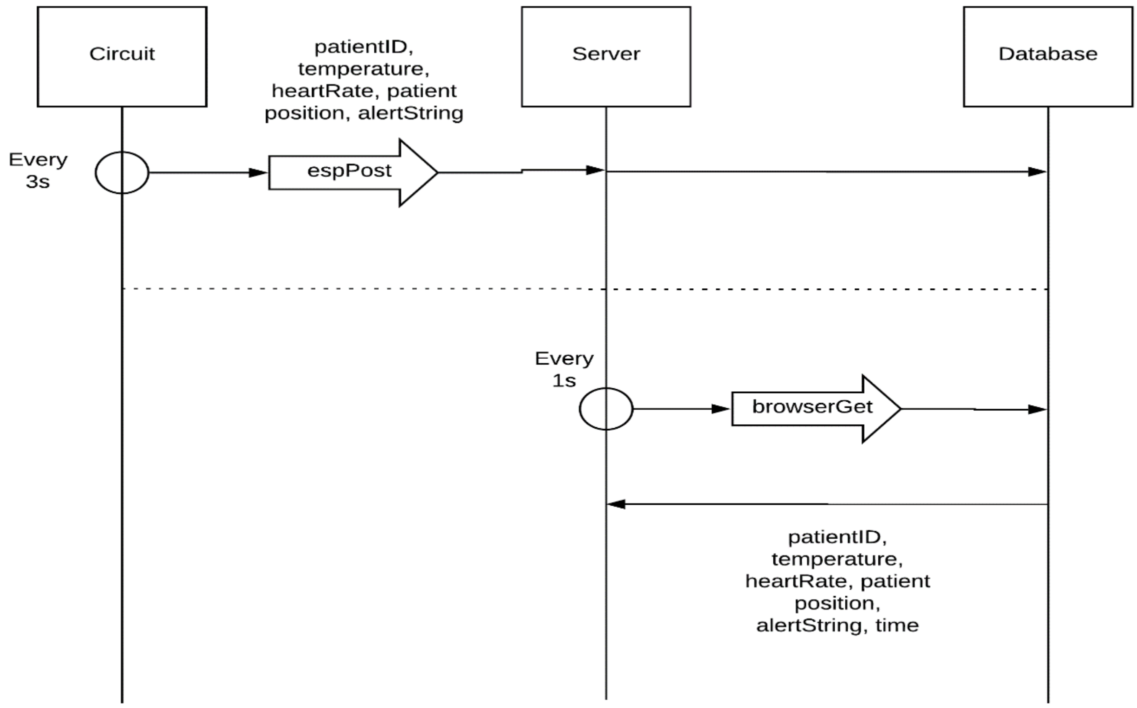


Software Implementation

Server and Webpage Operation

The server accepts POST requests containing information about the patient from the local system. It uses the information from the requests to display various information about the patient numerically on the webpage, including patient ID, body temperature, heart rate, sleeping position, call for help (alert) or whether the patient has fallen from the bed. The webpage also displays in real time graphically the heart rate and body temperature of the patient on the from the server. The server also displays an alert on the screen if the alert button is pressed or in the instance of undesired readings from the patient being captured (if the temperature or heartrate is too low or if the patient has fallen). All values handled by the server, patient ID, temperature, heartrate, patient position, alertString are stored in a MongoDB database and retrieved when necessary (by ajax calls to the webserver) from the webpage for displaying. The date and time at which the data was retrieved by the server was stored along with other patient information to attach the time for which the information about the patient was determined. A table was also created in the webpage to display all received information about the patient for each viewing and to review patient vitals at important events such as when the patient falls, or their heartrate of temperature is too high.

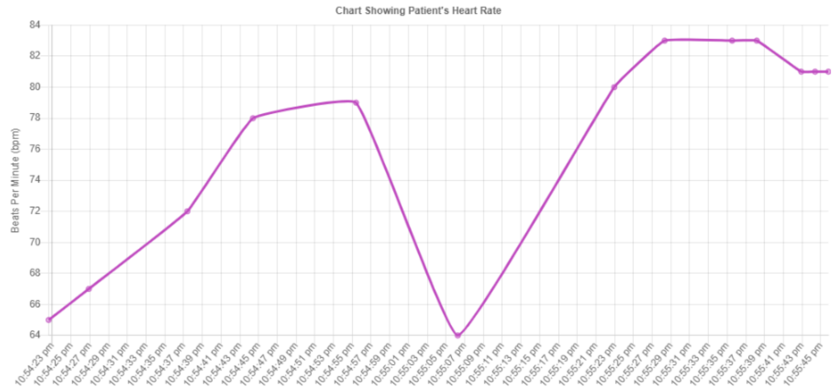
The diagram below shows this communication in detail:



NodeJs environment was used to host the webpage and create and communicate with a MongoDB database. JavaScript language was used to create the website. JavaScript used to call server and get the data from server. It displays each graph on the webpage according to the time and date. Chart.js, a data visualization tool was used to create the graphs on the webpage.

PATIENT: 0001

Heart rate:	81bpm
Temperature:	34.3°C
Position on Bed:	Face Up
Accleration:	2m/s

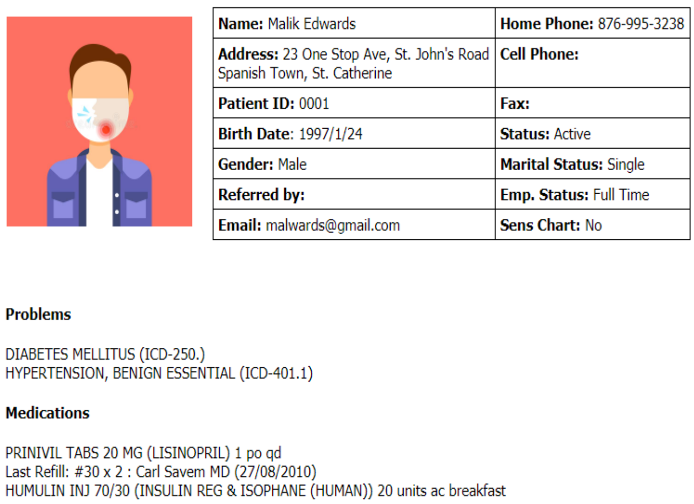


Picture showing patient vitals being displayed numerically and graphically

TABLE SHOWING PATIENT'S VITALS

ID #	Heart Rate (bpm)	Temperature (°C)	Postition	Accleration (m/s)	Alert	Time
0001	81	34.3	Face Up	2		Fri May 29 2020 22:55:45 GMT-0500 (Eastern Standard Time)
0001	81	34.3	Face Up	2		Fri May 29 2020 22:55:44 GMT-0500 (Eastern Standard Time)
0001	81	34.3	Face Up	2		Fri May 29 2020 22:55:42 GMT-0500 (Eastern Standard Time)
0001	83	34.3	Face Up	2		Fri May 29 2020 22:55:38 GMT-0500 (Eastern Standard Time)
0001	83	34.3	Face Up	2		Fri May 29 2020 22:55:35 GMT-0500 (Eastern Standard Time)
0001	83	35.2	Face Up	2		Fri May 29 2020 22:55:28 GMT-0500 (Eastern Standard Time)
0001	80	35.2	Face Up	2		Fri May 29 2020 22:55:22 GMT-0500 (Eastern Standard Time)
0001	64	33.2	Face Up	2		Fri May 29 2020 22:55:06 GMT-0500 (Eastern Standard Time)
0001	79	33.2	Face Up	2		Fri May 29 2020 22:54:55 GMT-0500 (Eastern Standard Time)
0001	78	33	Face Up	2		Fri May 29 2020 22:54:44 GMT-0500 (Eastern Standard Time)
0001	72	33	Face Up	2		Fri May 29 2020 22:54:37 GMT-0500 (Eastern Standard Time)
0001	67	34.45	Face Up	2		Fri May 29 2020 22:54:26 GMT-0500 (Eastern Standard Time)
0001	65	34.45	Face Up	2		Fri May 29 2020 22:54:22 GMT-0500 (Eastern Standard Time)

Picture showing patient information logged to the table on webpage



Name: Malik Edwards	**Home Phone:** 876-995-3238
Address: 23 One Stop Ave, St. John's Road Spanish Town, St. Catherine	**Cell Phone:**
Patient ID: 0001	**Fax:**
Birth Date: 1997/1/24	**Status:** Active
Gender: Male	**Marital Status:** Single
Referred by:	**Emp. Status:** Full Time
Email: malwards@gmail.com	**Sens Chart:** No

Problems

DIABETES MELLITUS (ICD-250.)
HYPERTENSION, BENIGN ESSENTIAL (ICD-401.1)

Medications

PRINIVIL TABS 20 MG (LISINOPRIL) 1 po qd
Last Refill: #30 x 2 : Carl Savem MD (27/08/2010)
HUMULIN INJ 70/30 (INSULIN REG & ISOPHANE (HUMAN)) 20 units ac breakfast

Picture showing patient information card on webpage

Conclusion

A fully operational remote patient monitoring system was created using an ATmega328P. The remote patient system designed, using block diagram, flowcharts. A patient’s vitals including heartrate temperature, could be determined using sensors from a local device and sent over Wi-Fi for a medical practitioner to monitor the patient effectively whilst not being at the physical local of the patient. Specialized software to design circuit schematic and develop program code.

Further Work

- The system currently uses acceleration and rotation on axes to determine if a patient has fallen. It does not take into consideration the actual distance the device has move to whether the patient would have moved a distance that suggests they fell. The addition of a sensor that can determine the distance an object has moved can make the fall detection circuitry more robust.
- The system can also be expanded by the addition of other sensors such as air quality, humidity and blood sugar level sensors.

- The date and time of when information is recorded is currently implemented on the server side, it would be more ideal to let the local circuit retrieved the date and time from an NTP server once every twenty four hours and locally manage the time and attach a timestamp to each data recorded by the circuit.
- Although would require more stable bandwidth, a surveillance feature for patients that are bed ridden could be added for the medical practitioner to see real time images of what is happening.

Acknowledgements

I would like to express my sincere gratitude to my parents and friends who have been helpful towards the successful completion of this assignment. Secondly, I would like to thank lab instructors Mr Mario Eunick, Mr Shane Smith and Mr T. Edwards for guiding and helping me with adequate information and tools to complete this project.

References

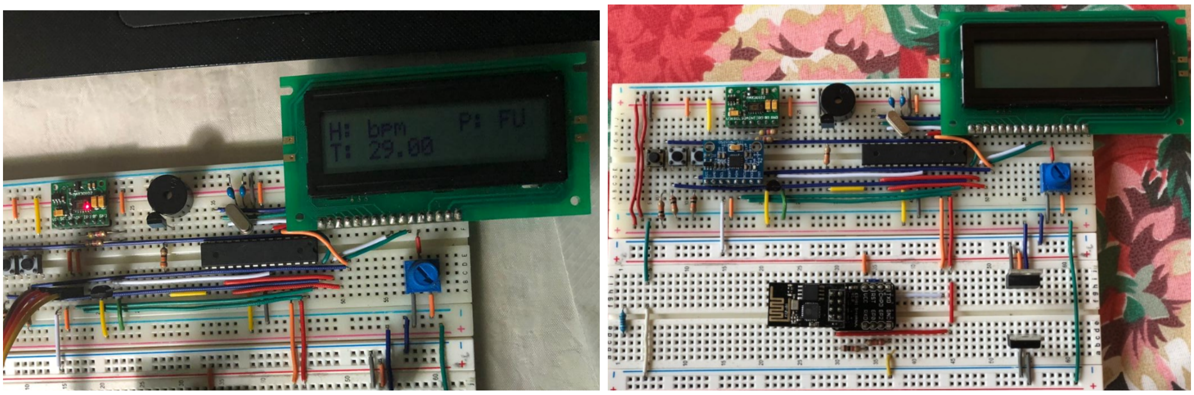
Alam. (2019, December 18). Interfacing MAX30100 Pulse Oximeter Sensor with Arduino. Retrieved May 29, 2020, from https://how2electronics.com/interfacing-max30100-pulse-oximeter-sensor-arduino/

Gardner, R. M., & Shabot, M. M. (2006). Patient-Monitoring System. In *Medical Informatics: Computer Applications in Health Care and Biomedicine* (pp. 443–484). New York: Springer Science Business Media.

Saquib, N., Papon, M. T. I., Ahmad, I., & Rahman, A. (2015). Measurement of heart rate using photoplethysmography. *2015 International Conference on Networking Systems and Security (NSysS)*. doi: 10.1109/nsyss.2015.7043525

Appendix

Pictures



Pictures showing the breadboard prototype of the circuit

CONNECTION OF LOCAL SYSTEM TO SERVER HAS BEEN LOST

Heart rate:	81bpm
Temperature:	34.3°C
Position on Bed:	Face Up
Accleration:	2m/s

Picture showing error message displayed if local system loses connection to server.