UNIVERSITI TEKNOLOGI PETRONAS

REAL TIME DATA ACQUISITION AND MONITORING OF PATIENTS WITH CORONARY HEART DISEASE IN A HOME ENVIRONMENT

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
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Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Agashtteeya Rajendra Prasath

ABSTRACT

The high mortality rate associated with cardiovascular related diseases requires the implementation of a personalised, ubiquitous health monitoring system. With the recent advancements of wireless sensor network technologies, these study proposes a real time data acquisition and monitoring system for patients with a track history of coronary heart diseases based on the implementation of a microcontroller, GSM Module and temperature sensors. This pervasive healthcare system will provide a round the clock monitoring and has an in built alerting mechanism for detecting anomalies in cardiac activities. The aim of the study is to minimize the need for caretakers and help the gravely ill senior citizens to survive an independent life. Apart from that, this study will help reduce the mortality rate of victim by shortening the response time of medical team to the victims. In these study, the proposed design mechanism will consider the following key criteria namely safety, data security, energy efficiency, durability and cost incurred.

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INTRODUCTION

1.1 Background Study

The number of cardiovascular diseases (CVD) is on the rise around the world. This worrying trend has also affected the general population of Malaysians, regardless of age groups, social strata and gender. Although the hereditary traits play an important role, poor dietary intake, alleviated levels of stress and lack of physical workout have aggravated these cardiovascular related diseases. Based on a research carried out by the American Heart Association(AHA), it is estimated that around 83.6 million adults(that is 1 out of 3) of the American general population have one or more types of cardiovascular related diseases. Out of that, around fifty percent of them are categorised as senior citizens(≥ 60 years of age).In the 60 to 70 year old age bracket, 70.2 % percent of men and 70.9% of women have CVD. For the 80 and above age group, 83.0 % of men and 87.1% of women have CVD. The mortality rate due to CVD are higher in people aged 75 and older stands at an alarming 66%.

Next, these study also includes the statistics associated with main subset of CVD which would be coronary heart diseases(CHD) and its associated medical implications namely angina pectoris(chest pains) and heart failures(myocardial infarction and cardiac arrests).The same research carried out by American Heart Association(AHA) found out that for the 60 to 79 years old age group, 21.1 of men and 10.6% of women have coronary heart diseases(CHD). Meanwhile, the percentage increases for the 80+ year old age group to 34.6% of men and 18.6% of women respectively. The average age of the first heart attack is 64.7 years old for a men and 72.2 years for women. The mortality rate due to coronary heart diseases(CHD) are extremely high for people aged 65 years old or older standing at about 80%. In Malaysia, a report published in April 2011 by the World Health Organization deaths due to coronary heart diseases(CHD) reached 22,701 deaths or 22.18% of total deaths. The age adjusted Death rate is 138.75 per 100,000 of population which puts Malaysia in the 57th ranking worldwide.

According to another statistics by AHA, the annual cases of new episodes of angina pectoris(chest pains) are 28.3% for men aged 65 to 74 years of age, 36.3 % for people aged 75 to 84 years of age and 33.0 for those ≥ 85 years of age. For woman of the aforementioned age groups, the rates are 14.1%, 20% and 22.9% respectively. Heart failures are another medical ailment caused by coronary heart diseases(CHD). For the 60 to 79 year old age bracket the following have heart failure, 7.8% of men and 4.5% of women. For the 80+ year old age group, a reported 8.6% of men and a 11.5% of women have heart failures. Cardiac arrest is the stopping of the heartbeat. The heartbeat stops when a person dies from illness or injury, or in the event of a coronary heart disease, the heart beat rate may stop abruptly. The underlying factor that results in a sudden cardiac arrest is a heart attack that results in ventricular fibrillation that is the shrivelling of the heart's lower chambers or the pulseless ventricular tachycardia (extremely rapid but ineffective beating of the heart's lower chambers. This irregular heart rhythm causes the heart to abruptly stop pumping blood. A small number of cardiac arrests are also caused by the extreme slowing of the heart (bradycardia). A victim of sudden cardiac arrest suddenly collapses, is unresponsive to gentle shaking, stops normal breathing and after two rescue breaths, has no signs of circulation such as normal breathing, coughing or movement. Death can occur within minutes if the victim receives no treatment.

Therefore, it is critical to ensure that immediate medical attention is given to patients who had just received a myocardial infarction (heart attack) or cardiac arrest. In these scenario, brain damage can start to occur in just four to six minutes after the heart stops pumping blood. Death may be prevented if cardiac arrest patients receive immediate bystander cardiopulmonary resuscitation(CPR) and defibrillation within a few minutes after collapse. When bystanders perform effective CPR immediately after a sudden cardiac arrest, they double a victim's chance of survival. Cardiac arrest victims can be treated with an electric shock to the heart and thus stopping the abnormal rhythm and allow a normal rhythm to resume. This process is called defibrillation and is done using a defibrillator. The survival rate of patients is directly linked to the amount of time between time of occurrence of cardiac arrest/heart attack to defibrillation. If no bystander CPR is provided, a victim's chances of survival are reduced by a seven to ten percentage with every minute of delay until defibrillation.

The survival rate of a victim of cardiac arrest is only two to five percent if defibrillation is provided more than 12 minutes after collapse. Early CPR and rapid defibrillation amalgamated with an early advanced care can produce high term survival rates for witnessed cardiac arrest. In some cities with public access to defibrillation, where bystanders provide immediate CPR and provide the first shock within three to five minutes, the reported survival rate for victims suffering from a heart attack or cardiac arrest are as high as 48 to 74 percent.

This study primarily focuses on senior citizens because as aforementioned the survival rates of a patient suffering a cardiac arrest or myocardial infarction depends solely on the response time of victims receiving defibrillation of CPR procedures. However in the cases of senior citizens many of them live alone either with their spouses or individually in their own residences. Malaysia has currently an estimated 20 million senior citizens, UN statistics indicates that by the year 2035, Malaysia would have fifteen percent of its population aging 60 years old and above. According to a study, 92.1 % of the senior population lived in private households or dwellings(as part of couples, alone or with others) while another 7.9% of them lived in collective dwellings such as old folks home or other welfare based residences. The majority of the senior citizens aged 65 years old and above lived alone with a percentage of 83.9%.

This solitary living arrangement poses a great challenge to the medical response team since there would be no family members or friends to perform emergency procedures or notify the hospital in the event of a cardiac arrest or heart attack. The victim would have to perform the emergency call to the medical dispatch team on an individual effort. This task would be very difficult keeping in mind the advanced age of these patients and the severity of the cardiac arrest or heart attack.

This study aims to recreate a personalised, ubiquitous healthcare monitoring system for patients with coronary heart disease (CHD). Two major components are required to implement this one to one healthcare monitoring system and that are sensor nodes attached on the patient’s body and base stations that relay vital body parameters such as heart beat rate from the concerned patients to both the nearest medical center for continuous supervision by medical support team and for the patient’s own supervision.

1.2 Problem Statement

Malaysia has a low doctor to patient ratio. The doctor to patient ratio stands at 1: 800 which is relatively low as compared to countries such as Cuba with a doctor to patient ratio of 1:369. This poses a serious problem since there aren’t enough medical professionals to cater to a growing population of patients with coronary heart diseases. Apart from that, accessibility of senior citizens living alone in rural or semi-rural communities to the nearest medical centres are highly restricted due to their advanced age and lack of physical mobility leaving them highest at risk of falling victim to occurrences of cardiac arrest or heart attack.

Apart from that, the next problem as aforementioned is the high mortality rate affecting the general population worldwide, especially senior citizens. This fatality is being caused by the delay in prompt notifications of the medical dispatch team to the suffering victims. The victims provided with cardiopulmonary resuscitation(CPR) or defibrillation may improve their survival rate without any adverse effects such as brain damage or paralysis.

1.3 Objective and Scope of Study

The objective of these study is to develop a personalised, ubiquitous healthcare monitoring system for patients with coronary heart disease(CHD) by developing a prototype combining electrocardiogram(ECG) sensors , an ARDUINO microcontroller and a Global System for Mobile Communication(GSM) module(IEEE 802.21).The scope of study will include the following:-

a) The general overview of pervasive healthcare monitoring system employing other communication protocols such as Zigbee and Bluetooth and Wi-Fi. Apart from that, these study will also include a general insight into the working principles of the electrocardiogram sensor, the GSM module and the Atmel microcontroller.

b) The implementation of a mobile, energy saving prototype integrating the ECG sensor nodes, microcontroller and GSM module thus establishing a constant healthcare monitoring channel that is established between coronary heart disease patients(CHD) and the medical dispatch team.

CHAPTER 2: LITERATURE REVIEW/THEORY

2.1 Literature Review

The monitoring of patients in a hospital based environment is redundant because it consumes a lot of time and inefficient. Apart from that, it takes a lot of man power to oversee the burgeoning number of patients. A research conducted by *Hye Jin Lee, Dong Oh Kim,Bub Joo Kang(2011)* proposes a healthcare monitoring system using Zigbee protocol. The proposed system comprised of two working platforms namely the operating platform whereby signal is acquired whereas the other one is used in the monitoring of ECG signals. The experimental results obtained shows that the Zigbee protocol was able to acquire and successfully transmit the electrocardiogram signals. This project however employed the gradient algorithm for general feature extraction.

Another research conducted by *Guo Jin Lin and Jing Han (2012)* demonstrated the viability of Zigbee network technology in designing a medical monitoring system. The authors implemented a set of RF controller incorporated with a second generation on chip system as the core module, a key node in the monitoring of physiological functions of patients using the Cluster-Tree and the AODVJR routing protocols. This study also reinstated the reliability of the Zigbee network in relaying medical information of patients to base stations and to the nearest medical center.

Another research conducted by *Bonam Kim, Insung Lee and Ilsun You (2007)* implements the session initialization protocol and the Zigbee Network. These research focused on the integration of ECG sensors with low power wireless Zigbee Networks, Remote ECG monitoring and analysis with immediate feedback from the physician over the Internet and finally the system has the ability to store these information in the cloud or a server for further reference. This project demonstrated that the Zigbee network architecture is a great solution in building a multi-hop routing topology combined with its low cost and power consumption. This characteristic thus improves the scalability of the project since many networks can be integrated into the system. However this research has its own setbacks since its cost consuming and would not fit the time constraint of the project carried out by these authors. There are various other technologies that can implement the data rate transfer between devices namely Bluetooth technology and 802.11b (Wi-Fi) network. Based on the research conducted on other communication standards, the following table illustrates the key parameter difference among the three communication standards.

FEATURES	802.11b	Bluetooth	**Zigbee**
Power Profile	Hours	Days	Years
Complexity	Very Complex	Complex	Simple
Latency	3 seconds	10 seconds	30ms
Range	100meter	10meter	70-300meter
Data Rate	11Mbps	1Mbps	250kbps
Security	Authentication Service Set	64 bit,128 bit	128 bit AES and Application user layer defined
Bit Time (micro sec)	0.0185	1.39	4

Table 1: Comparison between the three communication mediums

The table above shows the general difference in major characteristics of the 802.11 b (Wi-Fi) network, Bluetooth and Zigbee protocol. The power profile (power consumption) of the three communication standards is different for 802.11b, Bluetooth and Zigbee devices. Among the three standards, the power consumption of the Zigbee devices is the lowest (years). This long battery life is a critical design consideration since patients with cardiovascular diseases would have to continuously wear it for an extended period of time and the frequency of the patients removing the battery to recharge it can be greatly reduced. Next, the implementation of the Zigbee network is simpler as compared to the schematics of the Wi-Fi network and Bluetooth protocol.

Next, the latency of these three communication protocols is observed. Latency can be defined as the time that it takes to transmit and receive data. The Zigbee displays the lowest data latency (30ms) as compared to the Wi-Fi Network (3 seconds) and the highest data latency is the Bluetooth(10 seconds). Data latency is another critical design consideration since a faster data transfer rate would ensure a faster acknowledgement to the emergency response team and thus patients suffering from a cardiac arrest would receive a prompt response from the emergency dispatch team.

The range of the Zigbee communication protocol is the highest among the three (70-300meters).A higher range covered ensures greater parameter coverage for patients within a home based environment. The Zigbee network is the most secured protocol among the three standards with a 128 bit Advanced Encryption Standard (AES). This encryption standard ensures that brute force attacks by cyber criminals can be minimised. Data security is critical in a world where vast amounts of data are stolen and monitored by criminals with ulterior motive. Next, researches conducted on pervasive healthcare systems using the GSM communication network will be discussed in detail.

A research conducted by *Arulmozhivvarman, Ramachandra Reddy, Rao Tatavarti(2011)* studies the low cost EEG/ECG Signal Acquisition System which is deemed suitable for real time monitoring system and transmission of signals using the widely available GSM network. Their study focuses primarily on acquiring electroencephalography (EEG) signals using data acquisition interfaces(DAQ) to treat neurological disorders in low income countries. Due to the high costs of existing EEG/ECG monitoring equipment, the authors of this study devised an EEG amplifier circuit comprising of a 24 bit simultaneous sampling, gain amplifier and an on board oscillator. The prototype also incorporates all the necessary features found in EEG/ECG applications but with a significant reduction in size, power consumption and cost. This data acquisition interface transmits the EEG/ECG signals to a GSM module which then feeds a live stream onto display monitor and observed by medical professionals. The results obtained by the prototype are within expected range. This study focuses on a non- pervasive healthcare monitoring system whereby patient vital parameters are not monitored remotely.

Another study conducted by *A.Keertika, R.Ganesan(2013)* proposed a pervasive healthcare monitoring system for monitoring oxygen saturation using a combination of sensors, low powered microcontrollers and GSM module. The sensors perform the appropriate measures the levels of oxygen saturation and heart rate and when the monitored parameters exceed the maximum limits, it activates an alarm that communicates periodically to a telemonitoring system employing the GSM modems. This paper discusses wireless wearable sensors that work in hand to monitor vital body parameters such as blood pressure and heart beat rate during daily activities. The pulse oximetry sensor works on the Beer Lambert law that detects oxygen saturation of haemoglobin employing a technique called spectro photometry, which compares the concentration of a solute with the intensity of light transmitted through a solution. Data collected from the pulse oximeter sensors are sent from pulse oximeter sensors through wireless sensor networks and to the base station. Upon reaching, the signal is fed into a Peripheral Interface Controller(PIC) microcontroller and after appropriate signal conditioning is carried out it is sent via a GSM module. A Short Messaging Service(SMS) is sent to the medical patient if it exceeds a certain threshold value.

Besides that another research was conducted by *Wanhong Wu, Jiannong Cao, Yuan Zhaneg, Yong Ping Zheng(2008)* discussing a wearable personal healthcare and emergency aid system. Abbreviated as WAITER, these study proposes a system that continuously monitor vital body signs by employing heartbeat, motion and body temperature sensors. To transmit these raw sensory data, tiny Bluetooth transmitters would be utilised. On the receiving end, a mobile phone fitted with a Bluetooth trans-receiver to obtain the raw data from the sensors to perform real time data processing and serve as a storage space to prevent continuous transmission of redundant data to the healthcare centre which would be cost consuming. The mobile handphones can utilise the GSM module to periodically send the health reports to medical centres and issue timely alerts for medical aid in cases of emergencies. The study considers the user comfort as a main priority in the design and deployment of sensors. Apart from that, the study acknowledges that wireless data transmission cost very high energy consumption and therefore suggests selective data transmission as opposed to continuous transmission of information.

The three vital signal collection devices proposed in these study are the heart beat sensor, motion sensor, and a body temperature sensor. The pulse sensor detects heart beat by photoplethysmography(PPG) technique where a pair of infrared light emitter and detector captures variations of the reflected light by the body surface. As for the motion sensor, a dual axis accelerometer is proposed to detect whether the user has faced any difficulty in movement or suffered from a fall at home. To remain non penetrative, the body temperature is measured only by its skin temperature. The temperature sensor used is a precise integrated-circuit semi-conductor which varies output voltage with temperature proportionally. Information is sent to the data centre equipped with a GSM module. The sensors in the wearable sensors will perform a sampling every 0.05 second which is then transferred to the mobile phone using the Bluetooth trans-receiver. Once the mobile phone detects an anomaly, the in-built GSM module of the phone communicates with the data server at the medical centre to relay vital body signs data. The data server has three functions including 1)receiving the patients hourly reports, 2) authorizing login request for medical dispatch team , and 3) allowing the appropriate parties to access the data and dispatch once alerts are received.

Next, a paper published by *Meiappane.A, Selva Murugan.S, Arun.A,Ramachandran. A(2010)* discusses the web service in health care system using GSM networks. The authors of these papers propose an e-healthcare system built on the framework of GSM network providing support for medical professionals, emergency response team, nurses, and pharmacists and as well for patients to monitor. The healthcare system is tri-layered comprising of the first layer that provides Web Services interfaces. The bottom layer supports the healthcare services. The Services Coordinator sandwiched in the middle holds the flows of messages within the top and bottom layer and vice versa. The authors decide to implement GSM network based healthcare system keeping in mind of data security and privacy issues. Therefore, for applications deployed on devices like PDA's, authentication and session management are tightly controlled and supervised by GSM networks via the Web Services interfaces. The healthcare services of thesestudy's e-healthcare system are provided by both Clinic architecture and Pharmacy architecture.

The Clinic architecture supports two interfaces, a Web Server and a Web service interlinked by a GSM framework for the usage of medical staff or patients themselves. The Web server uses the GSM network to access data which enables a higher bandwidth. The architecture also provides support for routine activities of physician by storing information regarding medical practitioner's appointment with patients, notes related to the patient and etc. This architecture sends medical prescriptions from the physician to desired pharmacies over the GSM networks using the Web Service. For instance, Google Maps Web Service is used to locate the pharmacy closest to the patient's home or physician's office. The physician is able to use the Web Server interface to access the e-healthcare system using a computer of Personal Digital Assistant via a GSM network.

On the other hand, the Pharmacy architecture exposes the Web Server and Web Service interfaces. The Web Service interface allows users to access the e-healthcare system at the pharmacy using a browser. The architecture keeps a pharmaceutical report for patient's reference and prescription.. Privileged access are also provided to the pharmacist so that statuses of patients prescriptions can be updated. Patients can also be notified via a GSM network that a prescription is ready to be picked up.

Another study utilising the GSM network was conducted by *Nitin .Jain, Preeti N.Jain, Trupti P.Agarkar(2012).* Their study focused on implementing an embedded, GSM based, multi parameter, real-time patient monitoring system and control for intensive care unit(ICU) patients. Their prototype in addition to continuous real time monitoring and conveying of data is unique because doctor can take preliminary preventive action because of the feedback system built into the GSM module enables the doctor to administer the medications remotely into the patient by knowing the patient's biological parameters. The prototype developed consisted of a cuff assembly, pressure sensor, an analog circuit design comprising of an amplifier and bandpass filter circuit, a ATmega 32 microcontroller and a DC motor. The analogue circuit is fabricated to amplify both DC and AC components of the pressure sensor's signals.

The pressure transducers produce DC output voltage proportional to the applied input differential pressure. The unamplified AC signal is passed on the band pass filter. The filter has a gain of 1 to 4 Hz to attenuate any other signals out of the range of pass band. The AC component from the band pass filter is an important criteria to record the systolic/diastolic pressure of the user. The AC output is passed on to the analog to digital converter in the ATmega microcontroller. The coding of the microcontroller is written in embedded C++, and is burnt into the microcontroller using a flash programmer. The program within the microcontroller starts counting the pulses for 15 seconds and that value is then multiplied by a 4(one minute constitutes sixty seconds) to give an output indicating the number of pulses. This is available at the output of the microcontroller. The GSM module has an RS232 interface for serial communication with an external peripheral. The AT commands are sent by the Hyper Terminal to a GSM module. The output signal storing the vital body parameters of the patient are then relayed back to the Hyper Terminal via the GSM module.

The prototype proposed by the authors work in two conditions that is in normal condition or when temperature crosses threshold condition. In normal operating conditions, biological parameters are measured at fixed intervals of time. This data is stored in memory as history. In between of this, doctors can check current status by choosing an option. In all these instances, patient body temperature is measured continuously. In the second condition, when the body temperature crosses the threshold, system takes current readings and sends a SMS to two physicians simultaneously. After an immediate diagnosis, the doctor is able to administer medicine dosage remotely back to the patient via the GSM network.

Based on the review of the above literature review, the author has proposed a real time healthcare monitoring system of patients with a coronary heart disease in a home based environment utilising the GSM framework after thoroughly reviewing the advantages and disadvantages.

2.2 Theory

2.2.1 GSM Network and GSM Module

The Global System for Mobile Communications (GSM) network is the standard system used by most mobile phone networks around the world. Whether a system uses a cellular network based around broadcast stations or satellite technology connected to signals from orbit, both types can be part of the GSM network. This enables the exchange of information at high-speed data rates via satellites and mobile cellular towers across networks and company lines. In particular, the network has been essential in establishing worldwide access to emergency telephone services using the digits one-one-two (112), redirecting global phone traffic to emergency responders in a user's proximity.

The architecture of the GSM network is depicted graphically below:-

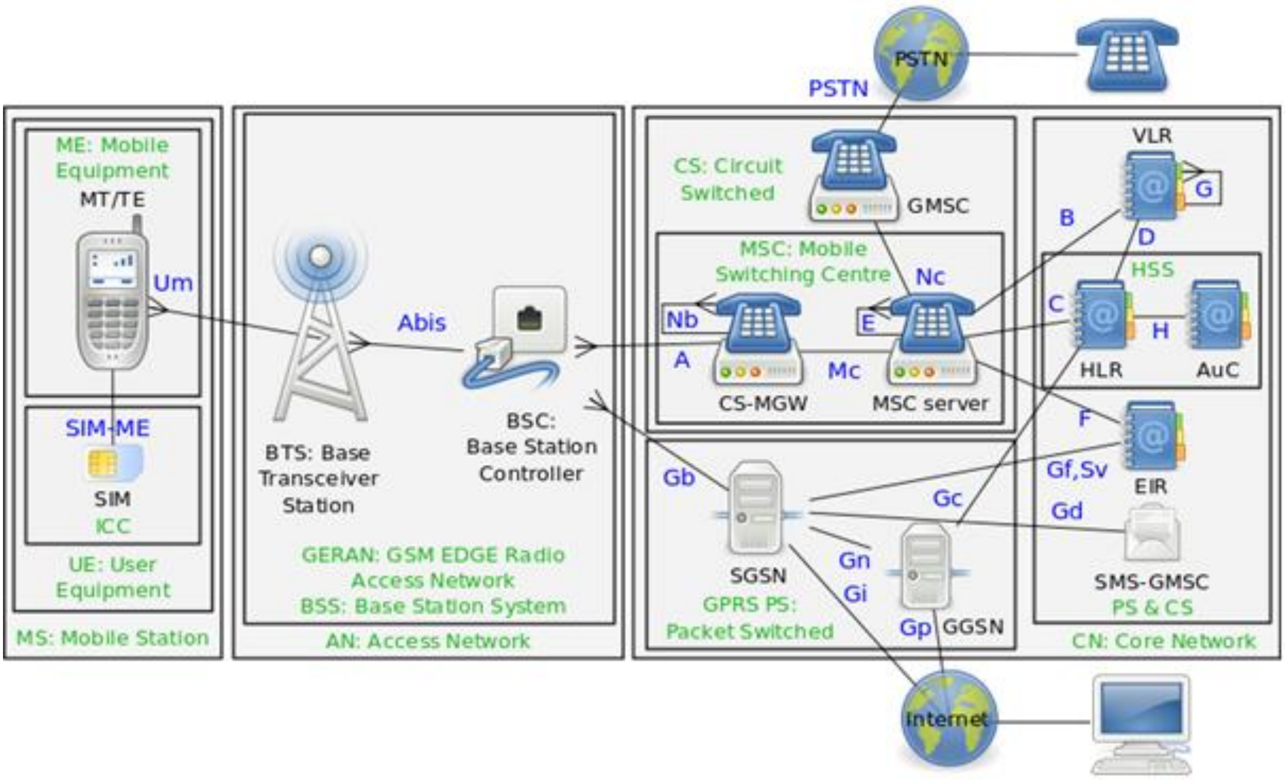


Figure 1: Architecture of GSM network

The GSM technical specifications define the different entities that form the GSM network by defining their functions and interface requirements. The GSM network can be divided into four main parts:

- The Mobile Station (MS).
- The Base Station Subsystem (BSS).
- The Network and Switching Subsystem (NSS).
- The Operation and Support Subsystem (OSS).

<u>GSM Module</u>

GSM modem is specialized type of modem that operates over subscription based wireless networks which is similar to a mobile phone. A GSM modem accepts a SIM card, and basically serves like a “mobile phone” for the personal computer. Traditional modem is attached to computers for ‘dial-up’ to connect with other computer systems. A GSM modem operates in a similar fashion, except that it sends and receives data through radio waves rather than through a standard copper cable telephone line

The module used in this prototype would be the SIEMENS TC35.

This board comes with following features:

- 4.2V Voltage Regulator, rated 3A.
- Proper level shifter for RS232 and DB9 for serial connection to computer COM port.
- Jack for Mic and Earphone (Audio in and out).
- High quality antenna for better signal reception and transmission.
- LED and Buzzer as ring indicator (incoming call).
- Ready with standard 2.1mm DC socket for DC adapter.
- Power from 7 to 12VDC.
- Push button for manual calling and accept call.
- Extend out all TC35 GSM module IO for development usage.
- 2.65V TTL UART pin is available for microcontroller interface.

Besides the dial-up connection, GSM modem can also be used for sending and receiving SMS which is also one of the key features of GSM modem. In this issue, .Some of the features of this GSM Modem are as follow:

- · RS-232 Interface
- · Tri-Band: GSM900, GSM1800 and GSM1900
- · Support TCP/IP
- · Support standard extended open AT commands
- · Support GPRS class 10
- · Support PDU and Text mode for SMS

The following diagram shows the pin placement on the Siemens TC 35 GSM module:-

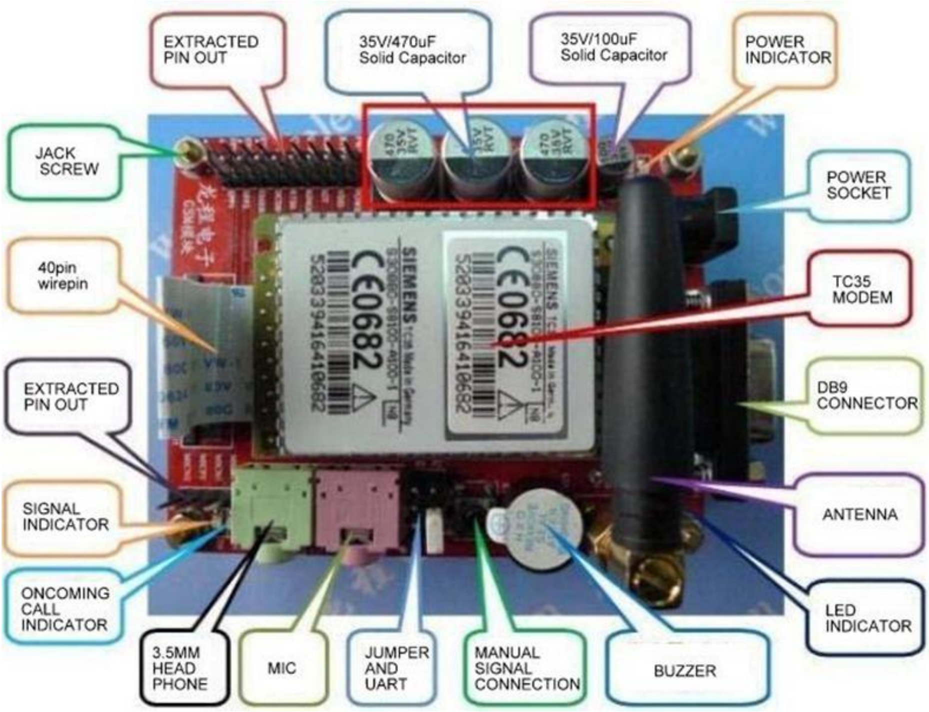


Figure 2: Pin placement on Siemens TC 35 GSM module

2.2.2 ARDUINO Microcontroller

Arduino is an open source single-board microcontroller designed to implement as many electronic multidiscipline projects as possible. Arduino hardware consists of a simplified open source hardware designed with a 8 bit Atmel AVR microcontroller The software system comprises of a standard programming language compiler and a boot loader that is performed on the microcontroller. Boot loading is the initial set up procedure that is performed when a computer power is switched on.

The unique aspect of the Arduino microcontroller is that it has interchangeable modules known as shields. These modules communicate with the Arduino board directly over various input and output pins. However these buses can be identified via specific addresses and registers. These shields can be stacked up and be utilised either individually or in parallel.

Most ARDUINO boards include a 5 volt linear regulator and a 16 MHz crystal oscillator (or ceramic resonator in some variants). All Arduino boards are programmed with an external RS-232 serial connection. These boards contain a simple level shifter circuit to convert between RS-232-level and Transistor -Transistor Level (TTL) signals..The following figure illustrates the various ports installed on the Arduino Microcontroller.

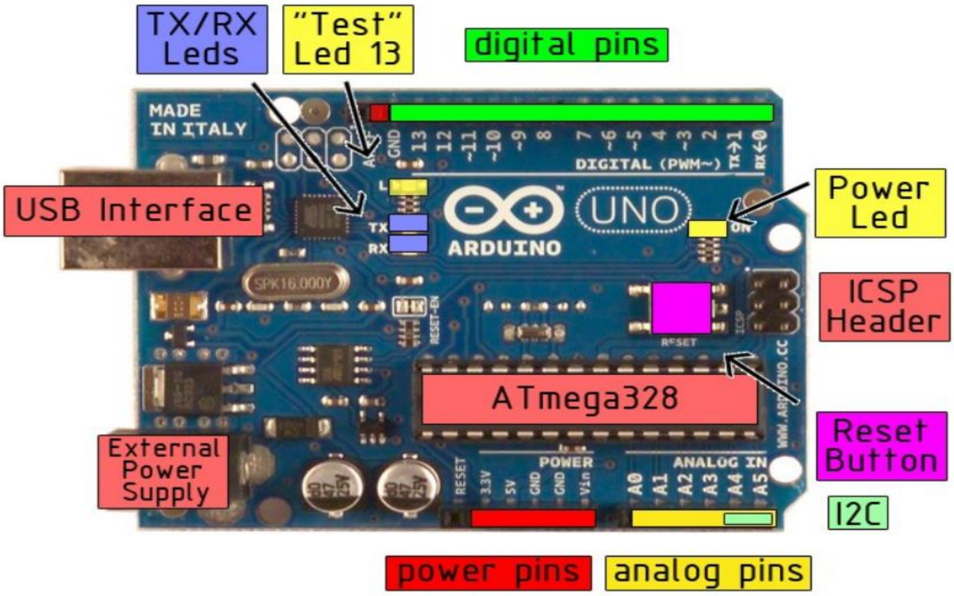


Figure 3: Port on the Arduino Microcontoller

The author has used the ATmega 328p, an Arduino compatible microcontroller for this project. The key parameters of the microcontroller are as follows:-

Parameter	Value
Flash(Kbytes)	32Kbytes
Pin Count	32
Maximum Operating Frequency	20Mhz
CPU	8-bit AVR
Number of Touch Channels	16
Max I/O Pins	23
Ext Interrupts	24
USB Speed	No
USB Interface	No

Table 2: Key Parameters of Atmel Microcontroller

2.2.3 LM 350 Precision Integrated Circuit Temperature Sensor

For these study, the author has decided to use precision integrated temperature sensors as opposed to the electrocardiogram sensors due to the fact that ECG sensors require signal conditioning circuits which would increase the technical complexity and additional costs to the project. Since these prototype main purpose is to demonstrate the proof of concept that healthcare monitoring of patients can be executed via a GSM network, the physical input variable for these instance can be just temperature readings to demonstrate proof of concept. Another reason that temperature sensors are employed as opposed to ECG sensors because signal conditioning circuits are required if ECG sensors are employed

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. No external calibration is required for the LM 35 and the typical accuracy ranges are ±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range. The LM35's low output impedance, linear output, and precise inherent calibration make it a viable option as the main sensor employed in these study. It can be used with a single power supply, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is designed to operate over a 205° range that is from a low of -55° to a high of +150°C temperature range, while the LM35C is rated for a -40° to +110°C range (-10° with improved accuracy).

The pin layout of the LM 35 are graphically demonstrated below:-

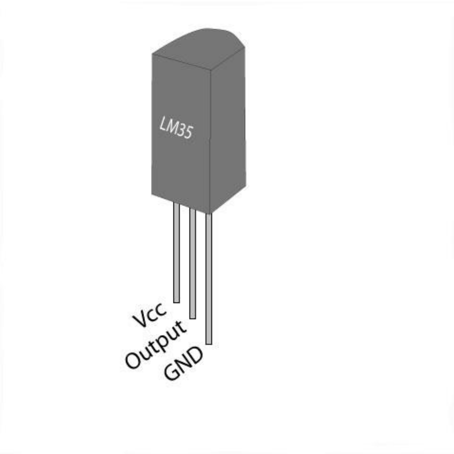


Figure 4: Pin Layout of LM 35 Temperature Sensor

Pin No	Function	Name
1	Supply Voltage;5V(+35V to -2V)	V_{CC}
2	Output Voltage(+6V to -1V)	Output
3	Ground(0V)	Ground

Table 3: Functions of each pins of an LM 35 Temperature Sensor

CHAPTER 3: METHODOLOGY

3.1 Flow of Methodology

This report constitutes the sequential progress of the research and development of this prototype. The first phase of the project began with the requirements involved. Preliminary research involving the case study was extensively studied. The statement of problem and background study was studied by analysing various scholarly articles and publications related to the study. Apart from that, the review of literature was also carried out as a precursor before the project planning to judge the viability of the project. Finally, the last procedure in the first phase is the project planning. Cost estimates were conducted to ensure that the finances of the prototype do not overshoot. As equivalently important as money, the time constraints of project was also given due attention. A Gantt chart was tabulated to ensure that work flow progress and key milestones are achieved within the stipulated time given by the academy institution, which is exactly twenty eight weeks.

Next, moving on the second phase of the project, is the design of the electronic circuit and procurement of materials required for the project. The circuit was designed using Easily Applicable Graphical Layout Editor(EAGLE) software. Google Sketch software was also used in the design process to complement the EAGLE software. After that, the circuit was tested in Simulated Program with Integrated Circuit Emphasis(SPICE) software, a general purpose software that simulates different circuits and performs various analysis of electrical and electronic fabrication circuits including time domain response and etc.

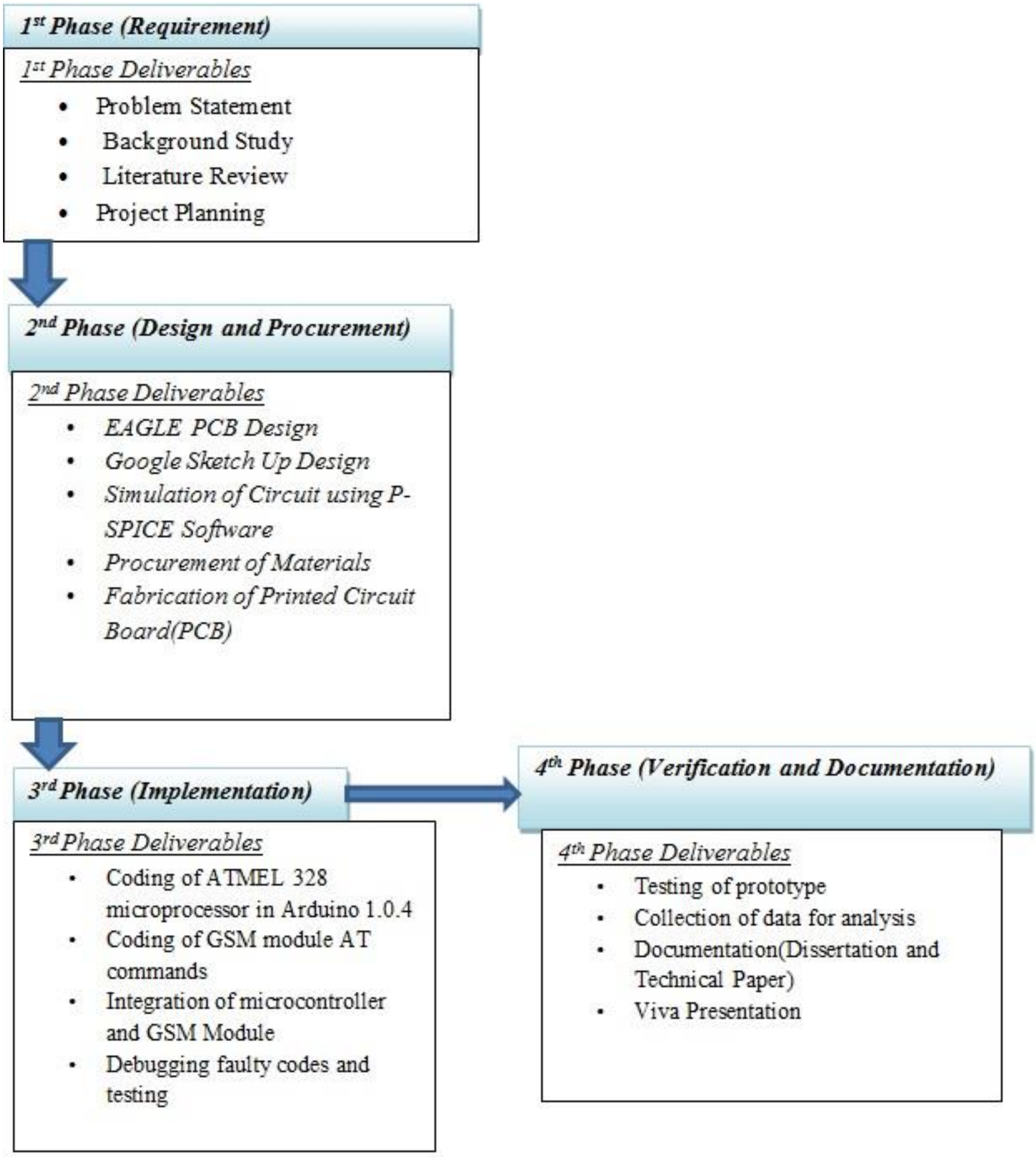
After the design and testing of the circuit was completed, procurement of materials required was executed. The final step in the second phase of the project was to fabricate the circuit board. The fabrication of the printed circuit board(PCB) was executed by outside vendors. This was done to ensure that the soldering of the ports on the circuit would be free of imperfections.

The third phase of the project was the implementation phase. Upon collecting the fabricated PCB board back from the vendor, the coding of Atmel 328p microcontroller commenced. The codes was written in Arduino 1.0.4, an integrated development environment(IDE) which is a cross platform application written in Java and is derived from the IDE for the Processing programming language and the Wiring Projects. The coding were written in C++ language and burned on the microcontroller using a flash programmer. The AT commands for the GSM module was also written in the Arduino 1.0.4 software. As soon as the coding was completed, the ATMEL microprocessor was integrated with the GSM module. The wiring connections linking the two devices were established and testing was conducted to gauge the effectiveness of the prototype.

The final stage of this project is the verification and documentation phase. The prototype was tested many times whereby simulating the real scenario and sending a Short Messaging Service (SMS) to the author's mobile phone whenever the minimum and maximum threshold temperature was exceeded. After some coding issues, debugging steps were taken to rectify the problem. When the prototype was completed, results of the prototype were taken for review and analysis. The final stage of this phase involves the documentation of the study via publications of a dissertation and a technical paper.

The methodology employed in these study is modelled after the waterfall model method, which is a sequential design process frequently used in the software development process in which progress is seen as flowing steadily downwards(replicating a waterfall) through the phases of Conception, Initiation, Analysis, Design, Construction, Testing, Implementation and Maintenance. The waterfall model strictly implies that one should move to the next phase only when the preceding phase is completed and perfected.

The graphical representations of the methodology used in these study is shown in the following page:-



The Gantt Chart of these project will be displayed in the following page:-

3.2 Gantt Chart

Research Activities	***FYP I***														***FYP II***													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review Report	X	X	X	X	X																							
Extended Proposal Report	X	X	X	X	X	X	X																					
Extended Proposal Defence								X	X																			
EAGLE PCB Design									X	X	X																	
P SPICE Simulation									X	X	X																	
Procurement of Materials					X	X						X																
Fabrication of PCB Board												X	X	X														
Submission of Interim Report													X	X														
Coding of Microcontroller															X	X	X	X	X	X								
Coding of GSM Module																			X	X	X							
Integration of GSM module and Microcontroller																						X						
Testing and Debugging of Prototype																							X	X	X			
Submission of Progress Report																									X			
Submission of Dissertation																										X	X	X
Submission of Technical Paper																										X	X	X
Viva Presentation																												X

CHAPTER 4: RESULTS

4.1 Design of PCB Board and Pin Layout Configurations

The design of programmable circuit board(PCB) was the first step initiated in the overall fabrication of the prototype. Google Sketch Up software and the EAGLE(Easily Applicable Graphical Layout Editor) were the programs used to draw out the built in circuit connections between the microcontroller, temperature sensor and the transmission and receiving ports all on the board itself. The PCB design schematics are shown in the figure below.

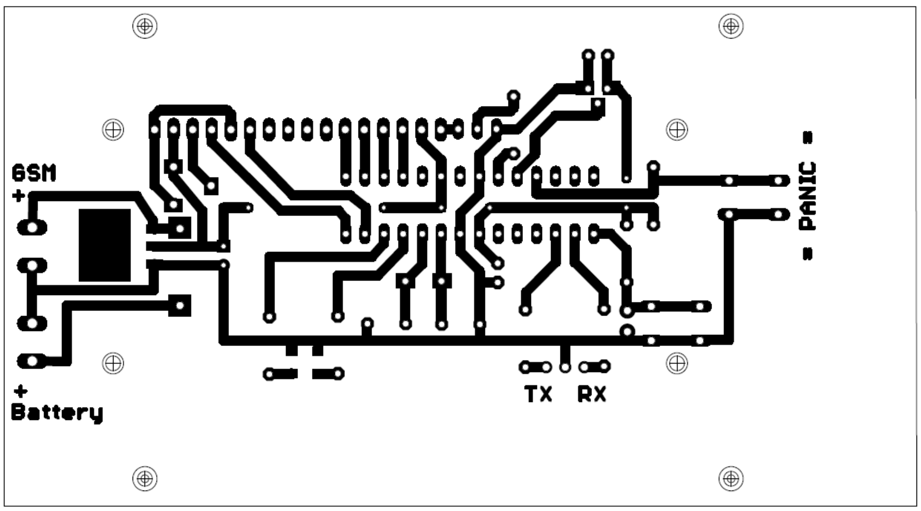


Figure 5: EAGLE Programmable Circuit Board(PCB) Drawing

The schematics above show the EAGLE layout demonstrating the connections of the entire board. On the left of the board, the output port to the GSM module and power source of the board is placed. In the middle portion of the board, the entire connections were made to house the ATMEL 328p microprocessor and the LM Temperature sensor that will monitor the temperature fluctuations(temperature is the variable that will mimic the electrocardiogram signal as the input variable for this prototype). On the bottom portion of the board the transmission and receiving ports are housed. Finally, on the far right of the board, the panic button function is integrated. This panic button serves as manual mechanism in case the device fails to send a Short Messaging Service(SMS) automatically even after the temperature minimum and maximum are reached.

The figure succeeding these paragraph illustrates the PCB drawing through the Google Sketchup application for a clearer graphical description.

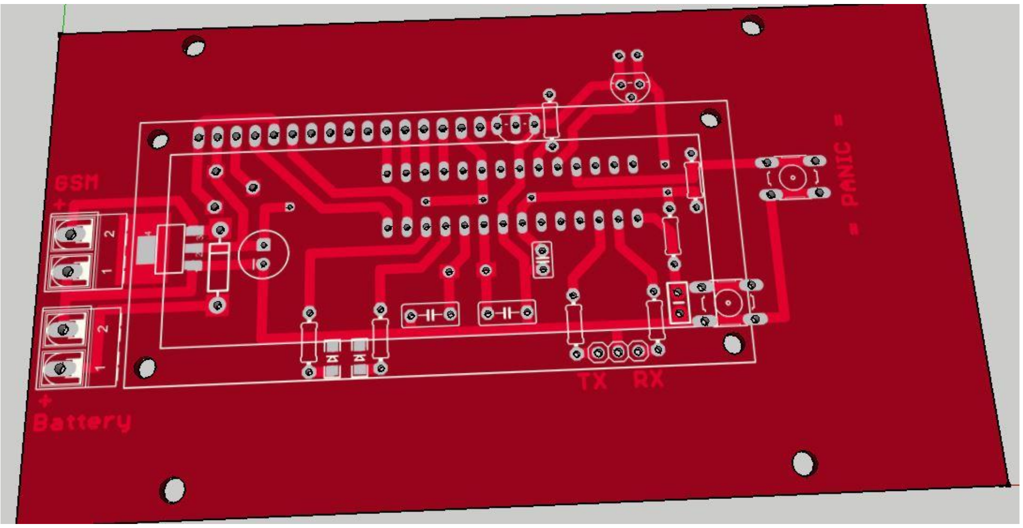


Figure 6: PCB Drawing using Google SketchUp

Figure X shows the layout diagram of the protoype in a electronic diagram schematic drawn in the EAGLE software. Each I/O pin has its distinct functions and provide to the overall functioning of the prototype.

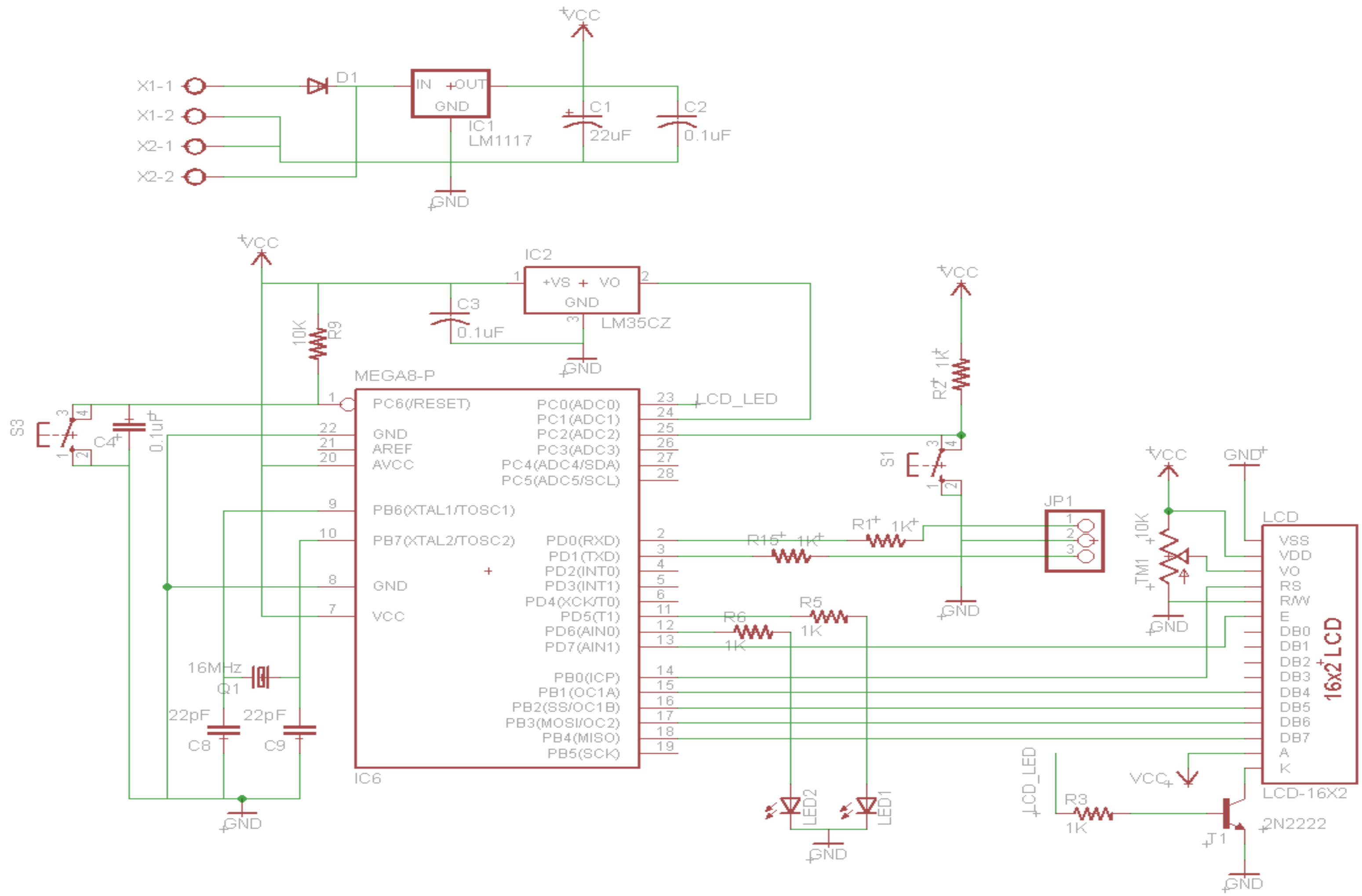


Figure 7 : Electronic Circuit Schematic Diagram in EAGLE Sofware

4.2 Programming of ATMEL 328p Microprocessor

The operating principles of the prototype are arranged in the following order:-

- The temperature of the external surroundings are consistently monitored and fed to the ATMEL 328P microprocessor.If the readings dont dip below the minimum threshold or exceed the maximum threshold, the LED's shine without blinking and no message is sent to the GSM module and the intended end receiver(medical response team) is notified.
- However, in the event where these temperature thresholds are exceeded, then the LED's begin to blink indicating that the ATMEL Microprocessor has received the input from the temperature sensor and has prepared the necessary responses that is to send a message to the nearest medical response team via the GSM module.

The coding on the following page are written for the temperature control sensor which will continously monitor the surrounding temperature for any significant changes. As aforementioned, in these prototype, temperature will be the key input physical variable replacing the electrocardiogram signals(ECG) of a patient

```
#include <LiquidCrystal.h>
#include <EEPROM.h>
#include "def.h"

#define LABEL          "Heart rate mon"
#define VERSION        "V1.0"
#define LCD_LIGHT      A0
#define HEART_SENSOR A1
#define EMG_SWITCH    A2
#define GREEN_LED     5
#define RED_LED       6
#define SAMPLE_CYCLE 200

#define GMS_MODEM_DLY  350

int totalTEMP = 0, COUNTER = 0, BLINK=0, PRESSED_DLY, PRESSED = 0, PULSE=0, TIMEOUT=0, ALARM=0, SMS_SENDED=0;
char buff[30];

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(8, 7, 9, 10, 11, 12);

void setup()
{
  Serial.begin(9600);

  pinMode(5, OUTPUT);
  pinMode(6, OUTPUT);
  pinMode(LCD_LIGHT, OUTPUT);
  pinMode(HEART_SENSOR, INPUT);

  EEPROM_readAnything(0, EPROM_DATA);    // Read data from flash

   // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  digitalWrite(LCD_LIGHT,1);             // Turn on LCD back light
  // Print a message to the LCD.
  lcd.print(LABEL);
  lcd.setCursor(1,1);
  lcd.print(VERSION);
  delay(2000);

  while( digitalRead(EMG_SWITCH) == 0 )  // default EPROM
  {
      strcpy(EPROM_DATA.GSM_SMS_NO,"+60164510398");
      strcpy(EPROM_DATA.USERNAME, "USER" );
      strcpy(EPROM_DATA.CONTACT, "60164510398" );
      strcpy(EPROM_DATA.MEDICAL_REF, "A123456789" );
      EPROM_DATA.minLevel = 30;
      EPROM_DATA.maxLevel = 38;

      EEPROM_writeAnything(0, EPROM_DATA);    // Write data to flash
      lcd.clear();
      lcd.print("Factory Default");
      delay(5000);
  }
```

The coding continues in the following page:-

```
void loop() {


  // Turn on the display:
  lcd.display();

  // Emergency button Pressed
  PRESSED_DLY = 0;
  while( digitalRead(EMG_SWITCH) == 0 )  // Button pressed
  {
      PRESSED_DLY++;
      digitalWrite(RED_LED,PULSE);
      PULSE = ~PULSE;
      delay(100);
      if( PRESSED_DLY >= 20 )  PRESSED = 1;
      BLINK = 1;                         // Turn on LCD back light
      TIMEOUT = 5;                       // LCD back light timeout
  }

  if( PRESSED == 1 )
  {
     PRESSED = 0;
     Init_GSM();
     SMS();
  }

  totalTEMP = totalTEMP + ReadTEMP(analogRead( HEART_SENSOR ));

  if( COUNTER >= SAMPLE_CYCLE )
  {
      totalTEMP = totalTEMP / SAMPLE_CYCLE;
      COUNTER = 0;

      if( totalTEMP > EPROM_DATA.maxLevel ||                  // Alarm trigger
          totalTEMP < EPROM_DATA.minLevel )  ALARM=1;
      else                                   ALARM=0;

      if( ALARM == 1 )
      {    BLINK = ~BLINK;

           if( SMS_SENDED == 0 )
           {
             Init_GSM();
             SMS();
             SMS_SENDED = 1;

           }
      }
      else
      {
          if( TIMEOUT > 1 )   TIMEOUT--;          // Count down LCD back light
          else
          {     BLINK = 0;          // Turn off LCD back ligh
                SMS_SENDED = 0;
          }
      }

      PULSE = ~PULSE;
      digitalWrite(LCD_LIGHT, BLINK);      // Control LCD back light

      sprintf( buff, "Heart Rate:%d",totalTEMP );

      lcd.setCursor(1,1);
      lcd.print( buff );
  }
  else  COUNTER++;


  digitalWrite(GREEN_LED,PULSE);
  digitalWrite(RED_LED,SMS_SENDED);
```

The coding for the definition of the Short Messaging System(SMS) is shown below(def.h). This provides the character size of each string which will be defined in the serial I/O port.

```
#define LF 10
#define CR 13
#define RX_BUFFER_SIZE 256
#define TX_BUFFER_SIZE 128
#define INBUF_SIZE 64

#define MSP_IDENT                    100

struct config_msg
{
   char GSM_SMS_NO[20];
   char USERNAME[50];
   char CONTACT[20];
   char MEDICAL_REF[30];
   int  minLevel;
   int  maxLevel;
} EPROM_DATA = { "","","","",0,0 };
```

The coding for the temperature sensor that receives the input variable(surrounding temperature) and links to the temperature control(temp_control) are as follows:-

```
void TEMP_init () {

    totalTEMP = 0;

  for(uint8_t i=0; i<50; i++ )
 {
    totalTEMP += ReadTEMP(analogRead( HEART_SENSOR ));
    delay(50);
 }

  totalTEMP = totalTEMP/50;
}

int ReadTEMP( int value )
{
  return (value*0.4882);
}
```

The coding that integrates the ATMEL 328p microcontroller and the GSM module are known as AT commands. It is shown below:-

```
void Init_GSM()
{
  // set the SMS mode to text
    char buff[30];

    sprintf( buff, "ATZ%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);

    sprintf( buff, "AT+CMGF=1%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    sprintf( buff, "AT+CSCS=\"GSM\"%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);
}

void SMS()
{   char buff[100], buff2[30];

    sprintf( buff, "AT+CMGS=%s\r", EPROM_DATA.GSM_SMS_NO );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Patial:%s\n", EPROM_DATA.USERNAME );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Emergency Contact:%s\n", EPROM_DATA.CONTACT );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Medical Ref:%s\n", EPROM_DATA.MEDICAL_REF, char(0x1a) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    Serial.print( char(0x1a) );

}
```

This line of coding is essential because it configures the GSM Module to deliver the Short Messaging Service. It receives data from the Temp_Control coding lines and once exceeded, delivers a SMS to the specified number. Note the first line highlighted in red

“AT+CMGS”. This line signals the GSM Module to send a text message rather than make a voice call. The subsequent highlighted portions of these coding will be the SMS’s content. For instance, “Medical Reference” will be present in the SMS because it is defined in the GSM AT command coding above.

There are two triggering mechanism for the prototype namely the auto triggering mechanism and the manual triggering mechanism. For the auto triggering mechanism, the minimum temperature is set to 27 degree Celsius and the maximum is set to 38 degree Celsius. The temperature sensors are set this way to mimic the electrocardiographic activities of a patient when the individual suffers from a cardiac arrest or heart attack. In the event of a cardiac arrest, the pulse rate drops to zero(mimicked by minimum temperature threshold of sensor) and during a heart attack the pulse rate spikes dramatically(mimicked by the maximum temperature threshold of sensor). When these thresholds are exceeded, the medical dispatch team are immediately notified via SMS without the need for the patients to press any switches. In the manual triggering mode, the victim can manually activate the alerting mechanism (the SMS for these instance) via the Panic Button installed on the prototype. Based on the trials conducted with the prototype, the time taken to send a SMS when the temperature drops below the minimum or maximum or manually(when the user presses the "Panic" button) is recorded as following:-

Trial	Temperature	"Panic" Button Pressed	Time taken to Send SMS(s)
1	27	No	Not Send (still did not exceed min)
2	26	No	Sent(5.45 s)
3	26	No	Sent(6.75s)
4	27	Yes	Sent(6.34s)
5	25	No	Sent(4.89 s)
6	20	No	Sent(5.35s)
7	30	Yes	Sent(6.01s)
8	31	Yes	Sent(5.25 s)
9	35	Yes	Sent(6.94 s)
10	37	No	Not Sent(still did not exceed max)
11	38	No	Not Sent(still did not exceed max)
12	39	No	Yes(4.78 s)
13	40	No	Yes(5.85s)
14	40	Yes	Sent(6.37s)

Table 4: Time taken to send a SMS both through auto or manual triggering mechanism

The prototype took the minimum time of 4.89 seconds to send a SMS to the author's mobile phone and a maximum of 6.94 seconds. The variation between the minimum and the maximum time to send the SMS is small. The prototype also responded to the "Panic" button pressed. The panic button simulates a manual trigger mechanism in the event a patient suffers from chest pains prior to a cardiac arrest. On the other hand, the temperature control trigger mechanism simulates the auto triggering of the prototype in the event the victim falls unconscious after suffering a cardiac arrest or heart attack, a message will still be sent to the medical dispatch team. Overall, the results are favourable since all messages are sent less than 10 seconds either using the auto or manual triggering mechanism which met the target requirements and objectives of these study. The mobile phone of the author represents the medical dispatch team "hotline" number .

The following images show the front and rear view of the prototype:-

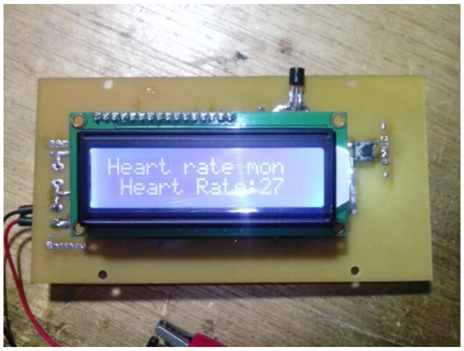


Figure 8: Front View of Prototype

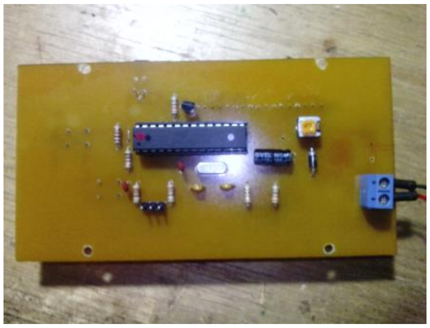


Figure 9: Rear View of Prototype

CONCLUSION

These study has demonstrated the potential use for Global System for Mobile Communication(GSM) network in providing a stable and secure platform for a ubiquitous and personalised healthcare monitoring system. Utilising the wide reach of the GSM framework, it is possible to create a comprehensive pervasive healthcare monitoring system network covering not only coronary heart disease patients but other group of patients suffering from other illnesses like diabetes or high blood pressure. This paper has proposed and developed an ubiquitous healthcare monitoring system combining the temperature sensor network, a microcontroller, a Printed Circuit Board (PCB) and GSM module working coherently to provide an alerting mechanism from the patient to the medical centres. The system configuration includes both the software and hardware designs. The hardware design included the integration of sensors, electronic components, microcontroller and GSM module together while the software design included the development of coding to link the sensors, microcontroller and GSM module so that they speak the same “language”. These study aims to reduce the high mortality rate associated with coronary heart disease by reducing the emergency response time of victims. Results from these studies have been very encouraging and satisfies the objectives laid out by the author in these project. However, due to the limited constraint of time and resources, these project’s potential has not been realised potentially. Therefore, it is hoped that further improvisations can be added to these study to improve the reliability of the prototype. For instance, extra features such as Global Positioning System(GPS) trackers could be fitted onto the prototype to enable the victims to be monitored outside their house or residences thus not restricting their mobility. Another feature that could be added would be the data logging feature which can store medical data, e,g heart beat sample rates. This stored data log of medical parameters can be handed over to medical practitioners during medical check-ups so that a database can be created for each individual.

APPENDICES

Attached in the appendix is the full coding lines of the prototype:-

GSM MODULE

```
void Init_GSM()
{
  // set the SMS mode to text
    char buff[30];

    sprintf( buff, "ATZ%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);

    sprintf( buff, "AT+CMGF=1%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    sprintf( buff, "AT+CSCS=\"GSM\"%c", char(CR) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);
}

void SMS()
{   char buff[100], buff2[30];

    sprintf( buff, "AT+CMGS=%s\r", EPROM_DATA.GSM_SMS_NO );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Patial:%s\n", EPROM_DATA.USERNAME );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Emergency Contact:%s\n", EPROM_DATA.CONTACT );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);

    sprintf( buff, "Medical Ref:%s\n", EPROM_DATA.MEDICAL_REF, char(0x1a) );
    Serial.print( buff );
    delay(GMS_MODEM_DLY);
    Serial.print( char(0x1a) );

}
```

TEMPERATURE SENSOR

```
void TEMP_init () {

    totalTEMP = 0;

  for(uint8_t i=0; i<50; i++ )
 {
    totalTEMP += ReadTEMP(analogRead( HEART_SENSOR ));
    delay(50);
 }

  totalTEMP = totalTEMP/50;
}

int ReadTEMP( int value )
{
  return (value*0.4882);
}
```

SMS INFORMATION DEFINITION

```
#define LF 10
#define CR 13
#define RX_BUFFER_SIZE 256
#define TX_BUFFER_SIZE 128
#define INBUF_SIZE 64

#define MSP_IDENT                100

struct config_msg
{
   char GSM_SMS_NO[20];
   char USERNAME[50];
   char CONTACT[20];
   char MEDICAL_REF[30];
   int  minLevel;
   int  maxLevel;
} EPROM_DATA = { "","","","",0,0 };
```

SERIAL I/O PORT

```
static uint8_t checksum;
static uint8_t indRX;


void serialCom() {
  uint8_t c;
  char buff[50];

  static uint8_t offset;
  static uint8_t dataSize;
  static enum _serial_state {
    IDLE,
    HEADER_START,
    HEADER_END,
  } c_state = IDLE;

  while (Serial.available()) {

    uint8_t bytesRXBuff = ((uint8_t)headRX)%RX_BUFFER_SIZE; // indicates the number of occupied bytes in TX buffer

    if (bytesRXBuff > RX_BUFFER_SIZE - 40 ) return; // ensure there is enough free TX buffer to go further (40 bytes margin)

    c = Serial.read();
    Serial.write(c);

    if (c_state == IDLE) {
      c_state = (c=='$') ? HEADER_START : IDLE;

      if( c == '?' )
      {
        Serial.println( "" );
        Serial.println( "Help :-" );
        Serial.println( "$sms={SMS no}                  Example : $sms=+60161234567" );
        Serial.println( "$name={Patient name}           Example : $name=Patient name" );
        Serial.println( "$contact={Patient contact}     Example : $contact=Patient contact" );
        Serial.println( "$ref={Patient medical ref}     Example : $ref=ABC 0123" );
        Serial.println( "$high={value for above alarm} Example : $high=38" );
        Serial.println( "$low={value for below alarm}  Example : $low=30" );
      }else if( c == '!' )
      {
        EEPROM_readAnything(0, EPROM_DATA);    // Read data from flash

        Serial.println( "" );
        sprintf( buff, "sms=%s", EPROM_DATA.GSM_SMS_NO );
        Serial.println( buff );
        sprintf( buff, "name=%s", EPROM_DATA.USERNAME );
        Serial.println( buff );
        sprintf( buff, "contact=%s", EPROM_DATA.CONTACT );
        Serial.println( buff );
        sprintf( buff, "ref=%s", EPROM_DATA.MEDICAL_REF );
        Serial.println( buff );
        sprintf( buff, "high=%d", EPROM_DATA.maxLevel );
        Serial.println( buff );
        sprintf( buff, "low=%d", EPROM_DATA.minLevel );
        Serial.println( buff );
      }


      headRX = 0;
    } else if (c_state == HEADER_START) {
        bufRX[headRX] = c;
        if (++headRX >= RX_BUFFER_SIZE) headRX = 0;
      c_state = (c==CR) ? HEADER_END : HEADER_START;
    }

    if (c_state == HEADER_END) {
      c_state = IDLE;
      evaluateCommand();
    }
  }
```

Continued in next page:-

```
void evaluateCommand() {
  char buff[100], cmd[10];
  char c, *p;

        strcpy( buff, "" );
        for (int x=0; x<headRX; x++)
        {  c = char(bufRX[x]);
          strncat( buff, &c, 1 );
        }

     p = strtok( buff, "=" );
     strcpy( cmd, strupr(p) );

     if(p != NULL)        p = strtok(NULL,",");

     if( strcmp( cmd, "SMS" ) == 0 )
     {  strcpy(EPROM_DATA.GSM_SMS_NO, p);
     }else if( strcmp( cmd, "NAME" ) == 0 )
     {  strcpy(EPROM_DATA.USERNAME, p );
     }else if( strcmp( cmd, "CONTACT" ) == 0 )
     {  strcpy(EPROM_DATA.CONTACT, p );
     }else if( strcmp( cmd, "REF" ) == 0 )
     {  strcpy(EPROM_DATA.MEDICAL_REF, p );
     }else if( strcmp( cmd, "HIGH" ) == 0 )
     {  EPROM_DATA.maxLevel = atoi(p);
     }else if( strcmp( cmd, "LOW" ) == 0 )
     {  EPROM_DATA.minLevel = atoi(p);
     }

     EEPROM_writeAnything(0, EPROM_DATA);
}
```

TEMPERATURE CONTROL

```
#include <LiquidCrystal.h>
#include <EEPROM.h>
#include "def.h"

#define LABEL        "Heart rate mon"
#define VERSION      "V1.0"
#define LCD_LIGHT    A0
#define HEART_SENSOR A1
#define EMG_SWITCH   A2
#define GREEN_LED    5
#define RED_LED      6
#define SAMPLE_CYCLE 200

#define GMS_MODEM_DLY  350

int totalTEMP = 0, COUNTER = 0, BLINK=0, PRESSED_DLY, PRESSED = 0, PULSE=0, TIMEOUT=0, ALARM=0, SMS_SENDED=0;
char buff[30];

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(8, 7, 9, 10, 11, 12);

void setup()
{
  Serial.begin(9600);

  pinMode(5, OUTPUT);
  pinMode(6, OUTPUT);
  pinMode(LCD_LIGHT, OUTPUT);
  pinMode(HEART_SENSOR, INPUT);

  EEPROM_readAnything(0, EPROM_DATA);    // Read data from flash

   // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  digitalWrite(LCD_LIGHT,1);              // Turn on LCD back light
  // Print a message to the LCD.
  lcd.print(LABEL);
  lcd.setCursor(1,1);
  lcd.print(VERSION);
  delay(2000);
```

```
  TEMP_init();

}

void loop() {


  // Turn on the display:
  lcd.display();

  // Emergency button Pressed
  PRESSED_DLY = 0;
  while( digitalRead(EMG_SWITCH) == 0 )  // Button pressed
  {
      PRESSED_DLY++;
      digitalWrite(RED_LED,PULSE);
      PULSE = ~PULSE;
      delay(100);
      if( PRESSED_DLY >= 20 )  PRESSED = 1;
      BLINK = 1;                          // Turn on LCD back light
      TIMEOUT = 5;                        // LCD back light timeout
  }

  if( PRESSED == 1 )
  {
     PRESSED = 0;
     Init_GSM();
     SMS();
  }

  totalTEMP = totalTEMP + ReadTEMP(analogRead( HEART_SENSOR ));

  if( COUNTER >= SAMPLE_CYCLE )
  {
      totalTEMP = totalTEMP / SAMPLE_CYCLE;
      COUNTER = 0;

      if( totalTEMP > EPROM_DATA.maxLevel ||                  // Alarm trigger
          totalTEMP < EPROM_DATA.minLevel )  ALARM=1;
      else                                   ALARM=0;

      if( ALARM == 1 )
      {    BLINK = ~BLINK;

           if( SMS_SENDED == 0 )
           {
             Init_GSM();
             SMS();
             SMS_SENDED = 1;

           }
      }
```

REFERENCES

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