REMOTE HEALTH MONITORING
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Department of Electrical Engineering, The University of Nairobi
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DECLARATION

I, Muchisu Albert Milimu, hereby declare that this project report is my original work. To the best of my knowledge, the work presented in this report here has not been presented for a degree in any other Institution of Higher Learning.

...................................................................................... .................................
Signature of student                                                                 Date

This project report has been submitted for examination with the approval of university supervisor(s)

...................................................................................... .................................
Signature of supervisor of student                                                                 Date
DEDICATION

I dedicate this project to my parents Dr. D. M Bulinda and Mrs. Bulinda, my Siblings Stewart, Ellen and Dorothea.
ACKNOWLEDGEMENT

I would like to thank God, for His unending grace and love throughout my academic life. Without it, I would not have made it this far.

I would also like to extend my sincere gratitude to my supervisor, Dr Dharma for his priceless motivation, guidance and support especially in providing circuit components.

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ABSTRACT

With improvement in technology and miniaturization of sensors, there have been attempts to utilize the new technology in various areas to improve the quality of human life. One main area of research that has seen adoption of the technology is the healthcare sector. The people in need of healthcare services find it very expensive this is particularly true in developing countries. With improvement in technology previously expensive hospital equipment have been redesigned using current technology. The developments have seen a trend known as Remote healthcare or previously known as Telemedicine

As a result this project was an attempt to solve a healthcare problem facing the society. The main objective of the project was to design a remote healthcare system. It was comprised of three main parts. The first part being detection of a fall, second being detection of Electrocardiogram commonly referred to as ECG or EKG (heartbeat detection) and the last part was providing the detected data for remote viewing. Remote viewing of the data enables a doctor or health specialist to monitor a patient’s health progress away from hospital premises.

Recent technology trend has seen Smart watches, fitness trackers and Smart phones with portable heartbeat detectors. All these are commonly referred to as wearable technology. These devices are modeled around another developing technology trend referred to as Internet of Things (IoT). The devices are linked to Smartphones that process and backup the information on a server. This information is later reviewed to give the health status or progress of the user.

As the devices are still new to the consumers the cost is still high especially to those in developing countries. The aim of the project was to come up with a Remote Health Detection System that can be made with locally available sensors with a view of making it affordable if it were to be mass produced.
CHAPTER ONE
INTRODUCTION

1.1 Background of the study

What is a Remote Health Monitoring System?

A Remote health monitoring system is an extension of a hospital medical system where a patient’s vital body state can be monitored remotely. Traditionally the detection systems were only found in hospitals and were characterized by huge and complex circuitry which required high power consumption. Continuous advances in the semiconductor technology industry have led to sensors and microcontrollers that are smaller in size, faster in operation, low in power consumption and affordable in cost.

This has further seen development in the remote monitoring of vital life signs of patients especially the elderly. The remote health monitoring system can be applied in the following scenarios:

i) A patient is known to have a medical condition with unstable regulatory body system. This is in cases where a new drug is being introduced to a patient.

ii) A patient is prone to heart attacks or may have suffered one before. The vitals may be monitored to predict and alert in advance any indication of the body status.

iii) Critical body organ situation

iv) Situation leading to development of a risky life threatening condition. This is for people at an advanced age and may be having failing health conditions.

v) Athletes during training. To know which training regimes will produce better results.

In recent times several systems have come up to address the issue of remote health monitoring. The systems have a wireless detection system that sends the sensor information wirelessly to a remote server. Some have even adopted a service model that requires one to pay a subscription fee. In developing countries this is a hindrance as some people cannot use them due
to cost issue involved. There is also the issue of internet connectivity where some systems to operate good quality internet for a real-time remote connection is required. Internet penetration is still a problem in developing countries.

Many of the systems introduced work best in the developed countries where the infrastructure is working perfectly. In most cases the systems are adapted to work in developing countries. To reduce some of these problems there is need to approach the remote detection from a ground up approach to suit the basic minimal conditions presently available in developing countries.

A simple patient monitoring system design can be approached by the number of parameters it can detect. In some instances by detecting one parameter several readings can be calculated. For simplicity considerations parameter detection are:

i) Single parameter monitoring system

In this instance a single parameter is monitored e.g. Electrocardiogram (ECG or EKG) reading. From the ECG or heartbeat detection several readings can be got depending on algorithm used. An ECG reading can give the heart rate and oxygen saturation

ii) Multi parameter monitoring system

This has multiple parameters being monitored at the same time. An example of such a system can be found in High Dependency Units (HDU), Intensive Care Units (ICU), during the surgery at a hospital theatre or Post surgery recovery units in Hospitals. Several parameters that are monitored include the ECG, blood pressure, respiration rate. The Multi parameter monitoring system basically proof that a patient is alive or recovering.

In developing countries, just after retiring from their daily career routine majority of the elderly age group, move to the rural areas. In developed countries they may move to assisted living group homes. This is where a remote health monitoring system can come in handy [1].
1.2 Statement of the problem

REMOTE HEALTH MONITORING

Remote health monitoring can provide useful physiological information in the home. This monitoring is useful for elderly or chronically ill patients who would like to avoid a long hospital stay. Wireless sensors are used to collect and transmit signals of interest and a processor is programmed to receive and automatically analyze the sensor signals. In this project you are to choose appropriate sensors according to what you would like to detect and design algorithms to realize your detection. Examples are detection of a fall, monitoring cardiac signals, brain signal monitoring (EEG), and in-home ultrasound.

Using a single parameter monitoring system an approach to a remote health monitoring system was designed that extends healthcare from the traditional clinic or hospital setting to the patient’s home. The system was to collect heartbeat detection system data and a fall detection system data. The data from the two single parameter monitoring systems was then availed for remote detection.

During design the following characteristics of the future medical applications were adhered to [2]:

a) Integration with current trends in medical practices and technology,

b) Real-time, long-term, remote monitoring, miniature, wearable sensors. Long battery life of designed device

c) Assistance to the elderly and chronic patients. The device should be easy to use with minimal buttons
1.3 Purpose of the study

Design a cardiac signal detector/heart beat detection system, a fall detection system and a remote health monitoring system. A doctor or health specialist can use the system to monitor remotely whether a fall occurred and the heartbeat of the patient or person of interest.

An attempt at designing a remote health care system made with locally available components.

i) The fall detector module comprises of an accelerometer, wireless transmitter and microcontroller. The data collected was transmitted wirelessly to a receiver module.

ii) The cardiac signal detection consists of a non-invasive infrared finger detector, Liquid Crystal Display (LCD), a designed circuit for cardiac signal detection and microcontroller. The detected analog signal was then digitized to give a digital value that was read on the LCD.

iii) A simple server. This hosted a database for both the fall detection data and cardiac signal data to be accessed remotely.
1.4 Objective of the study

Design a Remote health monitoring system (ECG-cardiac signal detector/heart beat detector, a fall detector).

As part of the final year study of Electrical and Information Engineering, I, the author was tasked with a project of Remote health monitoring System. The objective of the project was to come up with a system that can monitor and provide physiological information remotely in the home. The monitoring system would be useful for elderly or chronically ill patients who would like to avoid a long costly hospital stay. Wireless sensors would be used to collect and transmit signals of interest and a microcontroller was programmed to receive and automatically analyze the sensor signals. In the project, I was to select the appropriate sensors for signal detection and design algorithms to realize the detection.

The design process was covered from the beginning to the end how a physiological information signal was detected and displayed remotely. To see the final gadget being conceptualized from an analogue electronics through applied and power electronics concepts was interesting. The project set out to prioritize and detect the basic physiological information that required instant intervention i.e. detection of a fall and cardiac signal monitoring and later the brain signal monitoring (Electroencephalogram EEG) and in-home ultrasound.

For the devices that require instant intervention by a specialist doctor it was important that they be autonomous, non-invasive to the patient/users everyday life activities. In this way they were to be easy to use, minimal in size and weight, consume less power for maximum use on a single charge, and functional – able to withstand physical shock in the case of fall detection.

In both cases for accurate physiological signal detection, the circuitry in the detection system was crucial. To be able to accurately collect and manage the signal information Integrated circuits and microprocessors were implemented. This was done to minimize the drift voltages and any white noise that could be picked by the detection system.

Two advantages of the system that clearly come out are that the fall detector allows free movement of the patient or person of interest and the method of acquiring the cardiac signal is non-invasive.
1.5 Significance of the study

Solving the healthcare problem with engineering approach by developing a remote healthcare system. In so doing bridging of the gap between the doctor and patient with modern current available components sensors.

Another significance is giving back to society. This is to help the senior citizens who most of the time are alone and it is common for falls to occur without someone nearby to assist. Falls result in injuries in most of the 75 years and above age group [1] and elderly. Severity of the fall may cause fractures that lead to serious health complications or even fatalities.

This is where a fall detector can come in handy [2]. A fall detector could be configured to detect whether or when a fall occurred. In some cases the patients have memory recall problems, the fall detection system can account for frequency or severity of the falls. The same age group of people are known to have heart problems. A heartbeat detector is also necessary to monitor their heart conditions.

It is also proof of classroom concepts in real life scenarios. The analog and digital electronics learnt is put to practice and tested.

1.6 Limitation of the study and delimitations of the study—scope

The scope of the project was limited to cardiac signal, fall detection and remote viewing of the collected data.

The second Physiological category comprising of EEG monitor and Ultrasound detector were to be designed with more strict specifications. The most important specification considered was that they should be safe to use and accurate. This is because the physiological information being detected determines the severity of a critical life threatening situation.

EEG signal and ultrasound were left out due to financial constraints on the type of probes and ICs needed in detection and time allocated for the project. Sourcing and fabrication of the circuit necessary for the ultrasound and EEG detectors.
1.7 Basic assumptions

Definition of Resistor, capacitor, Inductor, KCL, KVL,

Working of OPAMPS, transistors, microcontroller to microprocessor conversion. Liquid Crystal Displays (LCDs), Light Emitting Diodes (LEDs)

Clocking a microcontroller externally for high frequency applications.

1.8 Definition of terms

i) Microcontroller - A chip that contains the Central Processing Unit (CPU), Non-volatile memory for the program (ROM or Flash) volatile memory for input and output (RAM) a clock and an I/O control Unit. They are commonly referred to as “System on Chip (SoC)"

ii) Transmitter – A circuit setup that generates and transmits electromagnetic waves carrying messages or signals through an antenna

iii) Receiver – A circuit setup that detects a transmitted electromagnetic waves through an antenna.

iv) Baud rate - The baud rate is the rate at which information is transferred in a communication channel. In the microcontroller serial port context, "9600 baud" means that the port is capable of transferring a maximum of 9600 bits per second. Baud rate is always configured as bits per second. [4]
CHAPTER TWO
LITERATURE REVIEW

2.1 Review on remote healthcare monitoring systems

Subject of study “remote healthcare monitoring systems”, covers areas of interest in both electrical engineering and medical field of study. It has led to the direction of Biomedical engineering field of study.

Remote health monitoring systems are generally based on wearable sensors on the patient’s body that collect data remotely and transfer it to a database. The data is then accessed remotely by a doctor or healthcare specialist who monitor and may make a decision based on the data.

Previous research referred to remote “health detection systems” as “mobile health” or “mHealth”. This was because they used mobile phones prior to smartphone era [7]. At that time a mHealth alliance existed that identified barriers, gaps in scaling and use of mobile technology in healthcare [7]. Proactive efforts have seen the barriers in healthcare and mobile communication technology being reduced.

According to the journal of Neuro Engineering and Rehabilitation [5] most of non-invasive techniques used in acquiring critical signals from the human body are of microvolt (μV) nature signal. Signal processing by use of microcontrollers is then done on the detected signals to acquire the meaningful information from the signal data. Errors such as physical body modeling errors, source modeling errors and noise (instrumental or biological) are factored in the computation during signal acquisition and processing.

Advances in wireless sensors and connection of the sensors to networks have led to several new developments that are continuously being adopted by healthcare systems. “The future will see the integration of the abundance of existing specialized medical technology with pervasive wireless networks [5]. They will co-exist with the installed infrastructure, augmenting data collection and real time response” [5]. The author further indicates wearable sensors will create vast amounts of data to be collected and mined for the next generation of clinical trials.
As a result we have seen medical devices incorporated into Smartphones (~ 2011). Other upcoming trends are the Smartphone accessories such as smart watches commonly known as wearable technology. With such improved features physiological processes are collected in a non-invasive, easy to use device.

With the sensors being designed target wearable technology such as watches (Samsung, apple watch) wristbands and others included in high-end cell phones, important health care data is collected and uploaded online instantly. The uploaded data is stored in online storage popularly known as cloud storage. The devices have adopted the Internet of Things (IoT) concept. A data log of a patient can then be generated and kept for reference. This has seen minimal visits to the hospital as doctors or health specialists can intervene in time when a patient’s data chart turns critical from the real-time generated data.

Patients suffering from chronic conditions such as Congestive Heart Failure (CHF), Chronic Obstructive Pulmonary Disease (COPD), diabetes, asthma, hypertension and some other health conditions can benefit from the remote health care management taking advantage of remote patient monitoring technology

Once the patient is referred to the remote healthcare program by a healthcare professional in the hospital or at a primary care facility, they are introduced to a healthcare specialist team that will proceed to track and adjust the execution of the care plan as well as provide support and guidance for the patient.

The remote healthcare system offers patients:

i) Access to an application on a mobile tablet or a personal computer that can be used from their home.

ii) Use of an intuitive, step-by-step application based on pre-scheduled questions that they need to answer. In some cases, this can be several times a day.

iii) Seamless integration with electronic medical devices (blood pressure cuffs, etc.) that can capture health data that is shared with the healthcare provider.
The remote healthcare system offers Healthcare specialist, Doctors:

i) Access to a centralized view of all patients on the HHM program, allowing clinicians to tailor workflows, protocols and interventions, creating customized care plans according to a patient’s condition and status.

ii) Easy analysis of results, empowering them to adjust treatment based on best-practice guidelines and protocols.

iii) Alerts and reminders that trigger patient alerts which can be generated by forms created by the clinician or from data obtained from the patient (i.e. high blood pressure alert).

iv) Sophisticated care coordination through better organization of multidisciplinary teams, assignment of interventions and tasks, and the ability to view past, present and future interventions.

v) Asset management, making it easy to manage devices – including location and to whom they are assigned.
**Block diagram of the symbolizing data acquisition system.**

They are the Data acquisition, data processing and data communication unit

![Block diagram of the symbolizing data acquisition system](image)

Fig. 2-1 data acquisition block diagram

![Implementation of the system](image)

Fig. 2-2 Implementation of the system [8]

Legend [8]: A – Activity Sensor (Accelerometer in this case), E – Heart Sensor,

WBAN – Wireless Body Area Network (Wireless transceiver HC11), PS – Personal Server (Raspberry Pi),

2.1.2 Literature review on Cardiac signal detection

Heart is a vital organ whose physiological heartbeat needs to be monitored for everyone. This is more critical for people with heart conditions, athletes, chronically ill and elderly in society. As such it is important to monitor cardiac signals. In hospital a repeated representation of successive heartbeat waveforms is done by Electrocardiogram (ECG or EKG) detector.

Previous attempts at ECG detection had an introduction of basic microcontrollers for the complex signal analysis. With the advancement of technology powerful processors have been included in smartphones that can run apps to assist in signal processing. Smartphones equipped with infrared flash for camera can also be repurposed using an application as cardiac signal detectors. They can remotely do the signal acquisition/detection, processing and communication simultaneously.

Arrhythmias caused by the heart’s electrical conduction system disorders [18]. Irregular heartbeats can cause irregular blood flow to other organs and cause damage to vital organs such as brain. There are three major conditions that can be detected from an ECG plot. Brachycardia (heart rate < 60), tachycardia (heart rate > 100) and an unstable heart rate.

Fig. 2-3 Normal ECG
Fig. 2-4 Normal cardiac signal

Fig. 2-5 Cardiac signal depicting Brachycardia

Fig. 2-6 Cardiac signal representation of Tachycardia
2.1.3 Literature review on fall detection

A fall may be defined as unintentionally coming to the ground by a person. A fall if violent may cause loss of consciousness by a person or a fracture of the bone structure.

Falls in the elderly or chronically ill patient is a major problem in public health as it causes many disabling fractures [17] but also has dramatic psychological consequences which reduce the independence of the person. If a pattern of activities of a person can be detected they can be prevented. As a result fall detector is necessary.

With recent developments in IC industry and telecommunication, system devices that encompass accelerometers and gyro-meters the medical profession has observed and through the help of some engineering some of the sensors can be repurposed. The accelerometer found in some of the smart phones available in shops today can be set to tell when a fall has occurred.

This is more important for chronically ill or elderly people [1]. For the chronically ill or people prone to falls [16] it is important to monitor their particular daily behaviors. The same applies to elderly living on their own. Athletes can also benefit from this by monitoring and logging their training regimes. The human physiological data is collected for their normal situations of activity.

A popular commercial device available in the market that addresses the fall detection issue is the iLife™ fall detector sensor by AlertOne [7]. This is designed specifically for fall detection. An old Smartphone with an accelerometer in it can also be used for fall detection by use of an app. The app accesses the phone hardware interface to get the accelerometer data, process it and upload it to a database via its internet connection.

Previous fall detector systems were huge and cumbersome and had mechanical switches with physical damper springs as tilt sensors. Recent advances in development of Micro Electro Mechanical Systems (MEMs) has seen the sensors miniaturized to small ICs that fit into PCBs and can be made into wearable technology.
**Micro Electro Mechanical Systems (MEMs) sensor**

These are silicon integrated circuits but mechanical in nature. They are manufactured using similar techniques as electronic integrated circuits but instead they are tiny mechanical structures that can interface to electronics [10]. The tri-axis accelerometer is based on a MEMs capacitor (fig. 2.7 a). The MEMs capacitor has two conductive plates that are electrically separated (fig. 2.7 b). The MEMs one has a combed finger arrangement (fig. 2.8) which are parallel surfaces that for a capacitor.

The structure has a weight at one end (fig. 2.8) that is made out of silicon which acts as a suspended mass [11] on a damper spring system. Movements, vibration and even gravity cause this mass to move around. This shifts the comb structure resulting in a change of capacitance (fig 2.9). This is the Micro Electro mechanical system that can detect movement and convert into a capacitance value. Additional circuitry then senses and amplifies the detected change in capacitance and converts it to a voltage which can be processed into a digital value.

![Fig. 2.7 a) MEMS internal structure highlighted](image)

![Fig. 2.7 b) MEMS internal structure highlighted](image)
A Modern MEMs accelerometer (fig. 2.8) has more comb like structures to increase surface area thus increasing the capacitance enabling easier detection of the movement. For axis detection the MEMs capacitor is fitted with comb like structure in the horizontal position for horizontal movement detection (fig. 2.9).
2.2 Overview of Remote health monitoring

Summary of literature review
1. Useful physiological information is collected.
   
   Most important is the cardiac signal. It is proof of life. It is used as a basis for other illness.

2. Why - Tracking the patients’ results on a regular basis, the healthcare team can adjust treatments as required. In the longer term, remote health care management system provides guidance to patients in order to help them learn to live with their life-long conditions.

Overall the Remote health monitoring system offers

i) Increased patient satisfaction and overall quality of care can be found with the use of Remote Health care monitoring. This is, because of closer interaction with health professionals, reduced anxiety as well as fewer emergency-room visits and hospital stays. Patients also value remaining at home for their care, as opposed to being in a hospital.

ii) There is a significant reduction of hospitalizations as patients suffering from chronic diseases are on a Remote healthcare monitoring program, hospital admissions can be reduced greatly. This will reduce strain on hospitals which are mostly filled to above capacity.

iii) The Remote health care solution leads to increased healthcare team productivity, enabling more evidence-based care and more efficient patient case management for more patients. With the Remote health care solution, each healthcare professional can support a much larger group of patients and more efficiently as the system utilizes modern day IT infrastructure.
iv) Enhanced collaboration by the remote health care programs have proven to help
enhance collaboration between healthcare providers. Acute care discharge planning is
enhanced using the remote health care management solution.

Remote health care technology presents an important opportunity to reduce readmissions,
particularly for patients with chronic conditions, such as Chronic Obstructive Pulmonary Disease
(COPD), diabetes or congestive heart failure.
CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Design of the fall detection system

The sensor chosen for fall detection was an accelerometer. Two common types of accelerometers available are the two axis and three axis. The sensitivity of the accelerometer determines its cost with the most sensitive being costly.

3.1.1 Fall detection description

In this project a simple tri-axis accelerometer was chosen. The accelerometer could detect three values along the X, Y and Z axis. With the aid of a microcontroller and suitable algorithm [6], data from the accelerometer was used to detect a fall. This is then transferred wirelessly for data logging to be viewed remotely by a medical specialist or person interested in the data.

With the accelerometer axis data a threshold [6]value is set. Using the dot product or cross product [9] of the axis data and comparing it with the threshold a fall detection can be achieved. The microcontroller then transmits the data wirelessly to a local database that can be accessed remotely.

A crucial factor to consider while using accelerometers for fall detection is that the readings achieved could give false fall detection. To prevent this placement of the fall sensor is very important. Using various sample test data achieved during the design and following up on past research on the subject study [10] optimal sensor placement is at a central part of the body. The waist section was found to be a considerable position [11] for best detection.

It is important to note that a modern smartphone (~2010) has an accelerometer within its circuit board. The accelerometer can be accessed through the library and an app made to detect and record a fall. During the design consideration, a smartphone method
was ruled out since the phone would end up being damaged during a fall. The method chosen is a low cost and noninvasive alternative to the user. Since the device is being used by a person prone to falls the device is also expected to survive several falls and knocks.

3.1.2 Implementation

Development was done with an accelerometer (ADXL335) microcontroller (ATmega328), Wireless transceiver (HC11 433 MHz) - Transmission mode only

The algorithm design

To detect fall along an axis, the magnitude is considered. This is achieved by a magnitude vector. Consider:

\[ M = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1) \]

Where \( M \) is magnitude

With the accelerometer output data, the angle change can also be calculated using the dot product. To achieve this the instantaneous vector and a reference vector were introduced.

Instantaneous vector is given by

\[ a = (a_x, a_y, a_z) \quad (2.a) \]

Reference vector this is generated when a user stands up. It is given by

\[ b = (b_x, b_y, b_z) \quad (2.b) \]

The using both the Instantaneous vector and Reference vector in the formula

\[ a \cdot b = |a||b| \cos \theta \quad (3) \]

Making the angle as subject

\[ \theta = \cos^{-1}\left(\frac{a \cdot b}{|a||b|}\right) \quad (4) \]
The basic flowchart

Fig. 3-1 Flowchart for fall detection algorithm
The flowchart indicates the microcontroller steps as follows:

a) Set a threshold value.

b) Detect if an acceleration exceeds the threshold.

c) Waits for acceleration to subside and return to relatively normal acceleration.

d) Check user’s orientation.

e) If user is parallel to the ground a fall is detected.

The accelerometer readings were converted to a digital value using an analog to digital conversion in the microcontroller. The base voltage could either be 3.3 volts or 5 volts. If the system was to be designed with emphasis on energy saving the 3.3Volts would fit best. The following table summarizes formula used for the X, Y and Z axes calibration:

<table>
<thead>
<tr>
<th></th>
<th>5 volt</th>
<th>3.3 volt</th>
</tr>
</thead>
<tbody>
<tr>
<td>X axis</td>
<td>$a_x = \left( \frac{ADC_x \times 5}{1024} \right) - 1.64 \div 0.5$</td>
<td>$a_x = \left( \frac{ADC_x \times 3.3}{1024} \right) - 1.64 \div 0.33$</td>
</tr>
<tr>
<td>Y axis</td>
<td>$a_y = \left( \frac{ADC_y \times 5}{1024} \right) - 1.63 \div 0.5$</td>
<td>$a_y = \left( \frac{ADC_y \times 3.3}{1024} \right) - 1.63 \div 0.33$</td>
</tr>
<tr>
<td>Z axis</td>
<td>$a_z = \left( \frac{ADC_z \times 5}{1024} \right) - 1.65 \div 0.5$</td>
<td>$a_x = \left( \frac{ADC_z \times 3.3}{1024} \right) - 1.65 \div 0.33$</td>
</tr>
</tbody>
</table>

Table 3.1 X, Y and Z axes calibration

Where $ADC_x, ADC_y, ADC_z$ for X,Y and Z axes respectively are digital values after analog signal from accelerometer has been passed into the ADC in the microcontroller.

From equation (1) M value was then compared for fall detection using $M > 1.8g$ [13]
3.1.3 MICROCONTROLLER

- Operating voltage – The operating voltage of 5V with a 3.3V option is appropriate because both the accelerometer and wireless transceiver can operate with the 5 or 3.3V power option and output reading values in the range of 0 - 5V.

- Input voltage – The microcontroller was powered by a 9volt battery through a voltage regulator that allows an input voltage range of 7-12V, which is more than sufficient for all peripherals to be used.

- Number of pins – The fourteen digital I/O pins are enough because they were used to interface with three peripherals (LED, transceiver and accelerometer). The number of six analog input pins is sufficient because they will interface with the three outputs from the accelerometer.

- Memory – The flash memory (32KB) is appropriate because the algorithm program designed requires a large amount of memory on the microcontroller for storage. The SRAM of 2KB enough for the algorithms to work with delayed sampling.

- RX/TX pins – The ATMega328 has RX/TX pins, which will be used for serial communication. They also are used in downloading the boot loader into the microcontroller and downloading the C program into it.

- I2C compatible pins – these are setup to accept the accelerometer interface outputs.

- USB communication and programming environment – Used during acquisition of sample test data and interacting with the programming environment.
3.1.4 SENSORS

For appropriate fall detection, the designed device required an:

- **Accelerometer** – Model selected was the ADXL345 triple axis digital accelerometer. It has a wide G range (up to ±16g). The range is very wide considering some severe falls are rated at 8 g’s. Since it is a digital sensor, the resolution can be adjusted and there is less voltage noise, and less calibration.

  The accelerometer chosen model ADXL345 gives tri-axial data and requires a minimum of 3.3V power and is I2c compatible. It interfaces with the microcontroller correctly for accurate readings.

For wireless communication, the wireless transceiver model HC11 (433 MHz) was chosen. Its specifications include transmission of data up to 1Kilometer, supports RX/TX serial communication from 9600bps - 115200bps (bits per second, baud rate), which makes it fully compatible with our AtMega328 microcontroller.

For remote viewing purposes, data obtained in the Fall detection will be referred as DATA1

3.2 Design of the cardiac detection system

The detector was based on a method that was non-invasive to the user. As a result a method involving use of infrared light was devised. It is based on the principle of photoplethysmography (PPG)[12]. The blood volume variation occurs in body tissues as the blood is pumped by the heart. The variation is detected by a light source and a detector and can be used to calculate the heartbeat.

There are two methods the PPG can be employed. They are:

a) **Transmittance method** - the infrared light is transmitted through a body tissue into an infrared receiver on the opposite side. The resultant light is then used in heartbeat detection. There is limited penetration depth of the light through the organ tissue, as a result the transmittance PPG is applicable to a restricted body part, such as the finger or the ear lobe.

b) **Reflectance method** depends on reflected light into a receiver. This is the method chosen in the project.[13] (See fig 3.1)
Fig. 3.2 Methods of sensor placement [14]

Fig3.2 (a) Light transmitted into the finger pad is reflected off bone and detected by a photo sensor.

Fig3.2 (b) Light transmitted through the aural pinna is detected by a photo sensor.

In either case, the detected light that is reflected from or transmitted through the body part will fluctuate according to the pulsated blood flow caused by the beating heart. Detection then occurs.
3.2.1 Cardiac signal detection using reflectance method

The light is emitted into the finger tissue and the reflected light is measured by the detector. The light does not have to penetrate the body, the reflectance PPG can be applied to any parts of human body. Tissue blood volume is responsible for fluctuation of light absorbed.

![Image](image.png)

*Fig. 3.3 How PPG sensor works*

The detected PPG signal has both AC and DC components. The pulsating changes in arterial blood volume cause the AC component. This is the component that is synchronous with the heartbeat. It is therefore the source of signal of interest. The DC component of the detected PPG signal is as a result of the tissues and the average blood volume. The AC component is superimposed onto a large DC component. AC component must be removed from the DC component to acquire an AC waveform with a high signal-to-noise ratio. AC amplification is thus done to acquire necessary signal of interest with the heartbeat information.
3.2.2 Implementation using reflectance method

To acquire the heartbeat signal of interest the output from the infrared detector is fed through a comparator. Output from detector is first filtered using a two stage High Pass-Low Pass circuit. The signal is then digitized using an analog to digital converter. The digitization is done using a microcontroller. Using an algorithm a digital value of the heartbeat can be displayed on an LCD.

![Circuit schematic for heartbeat detection](image)

The comparator used was OPAMP model LM324 (fig 3.3). The detector output is compared to a threshold voltage. For the first stage, inverting terminals of the OPAMP is connected to voltage divider which is set at threshold Voltage (Vth).

The non-inverting terminal is connected to the detector through 1 microfarad capacitor. When the body tissue is illuminated, the intensity of light reduces. As detected light intensity reduces the resistance increases causing an increase in the voltage drop.
Two scenarios arise (fig 3.4):

i) When high a voltage drop across the detector that is input into the non-inverting input exceeds that of inverting input. A logic high is developed at comparator output. This is useful for detecting the high peak in the heart beat (R in fig 3.4).

ii) Voltage drop across detector is less than that of inverting input. Output is a series of pulses that can be input into the microcontroller. This will assist in detecting any small peak between the major peak in a heartbeat (P,T,U in fig 3.4)

![Fig. 3-5 Representation of a heartbeat](image)

**Circuit explained**

Detector passes more current when it receives more light which in turn causes a voltage drop to enter amplifier circuit. Two consecutive operational amplifier stages to filter out noise and emphasize the peaks. The OPAMPS were contained in the same IC and operates at a single power supply of five Volts DC. The filtering is necessary to block any higher frequency noises present in the signal.

A 1 uF capacitor at the input of each stage is required to block the dc component in the signal. The two stage amplifier/filter provides sufficient gain to boost the weak signal coming from the photo sensor unit and convert it into a pulse.
The frequencies of interest are:

Beats Per Minute BPM is defined as \( BPM = 60 \text{ (Seconds)} \times \text{Frequency (Hertz)} \)

On rearranging, we get \( \text{Frequency (Hertz)} = \frac{BPM}{60 \text{ (Seconds)}} \)

The frequencies of interested using BPM notation are then defined as:

i) **Normal** heart rhythm (Normal sinus rhythm)
   This is between 60 BPM to 100 BPM

ii) Fast heart rhythm (BPM>100 BPM). If the BPM is in this region it could indicate a heart condition known as **Tachycardia**.

iii) Slow heart rhythm (less than 60 BPM) If the BPM is in this region, it could indicate a heart condition known as **Bradycardia**.

**Approach**

1) Real life heartbeat is about 75BPM

\[
\text{Using } \text{Frequency (Hertz)} = \frac{BPM}{60 \text{ (Seconds)}} \quad \frac{75}{60} = 1.25Hz
\]

In the case of 100 BPM = 1.67Hz

Range for normal 1.25Hz to 1.67Hz

2) The range below 1.25Hz

3) The 150BPM range becomes 2.5Hz

The circuit operated within 2.5 Hz

The 1microFarad capacitor between Infrared output and OPAMP stages acts as a DC Blocking capacitor. The circuit is split into stages [19]
Stage 1(a)

The one microfarad capacitor with 68K Ω resistor in parallel formed an initial stage high pass filter. This served as a filter with cutoff frequency \[ f_{c1} = \frac{1}{2\pi RC} = \frac{1}{2\pi(68K\Omega)(10^{-6}F)} = 2.34 \text{ Hz} \]

The signal allowed through the filter has our signal of interest and noise component

Stage 1(b)

Using the LM324 OPAMP single stage with a capacitor of 0.1\ uF parallel with 8.2K Ω to 10K Ω on non-inverting terminal.[19][20]

The OPAMP configuration generates an output voltage proportional to the magnitude and duration that an input voltage signal has deviated from 0 volts. A constant input signal would generate a certain rate of change in the output voltage. It produces a steadily changing output voltage for constant input voltage.

The voltage gain of the configuration is given by:

\[ V_{gain} = (1 + \frac{Z_f}{Z})V_{in} \]

Gain \( A = 1 + \frac{R_F}{R_{IN}} \) gives \( A = 1 + \frac{j\omega C}{R} \)

From stage 1(a) \( f = 2.34 \) but capacitance of 0.1\ uF

\[ \text{gain}A = 1 + \frac{1}{8.2 \times 10^3} = 1.00012 \cong 1 \]
Stage 1(c)

This has the OPAMP in non-inverting configuration but with a low-pass filter configuration on the feedback path [20].

\[ V_{gain} = (1 + \frac{Z_f}{Z})V_{in} \]

Gain \( A = 1 + \frac{R_F}{R_{IN}} \) gives \( 1 + \frac{680 \times 10^3}{6.8 \times 10^3} = 101 \)

To ensure that the cutoff frequency was below the recommended 2.5 Hz, a value of 680k \( \Omega \) resistor can be used. This gives a cut of frequency of 2.34 Hz:

\[ f_{cutoff} = f_{c2} = \frac{1}{2\pi (680 \times 1000)(100 \times 10^{-9})} = 2.3405 \text{ Hz} \]

Just in case the frequency is above 2.5 Hz the resistance value can be reduced to 470k

\[ f_{cutoff} = f_{c2} = \frac{1}{2\pi (470 \times 1000)(100 \times 10^{-9})} = 3.3862 \text{ Hz} \]

The OPAMP was biased at 5 volts. The output was of the two stage OPAMP was input into the microcontroller Atmega328 chip for Analog to Digital conversion. A digital value was to be displayed on a 16X2 LCD.

For remote viewing purposes, data obtained in the Heartbeat detection will be referred as DATA2

Programming environment

Processing is a free. Open source cross platform programming language for people who want to create images and animations.

It was created in 2001 by Casey Reas and Ben Fry at MIT Media Lab.

To download, update reference http://processing.org
3.3 Design of the remote detection system

Data from the fall detector (DATA 1) and Heartbeat detection system (DATA 2) was transferred for remote viewing. DATA1 was transferred through a wireless transceiver from Atmega328 and received by another Atmega328. Both data1 and data2 was transferred serially to the Raspberry Pi.

Raspberry Pi has a Broadcom chip. It had a scaled down version of Linux OS (Raspbian Jessie) running on it. This provides an environment for access of the General Purpose Input Output pins (GPIO) for external circuit to be connected to it. For remote viewing of the fall detection data (DATA1) and Heartbeat detection data (DATA2) the raspberry pi acted as a server. With the raspberry pi the main objective of the research project “Remote Health Detection system” was achieved.

Fig. 3-6 System block representation
3.3.1 Raspberry Pi specifications

The version used was Raspberry Pi model B+ version 1.2. The chip specification summary is below [15]:

<table>
<thead>
<tr>
<th>Device</th>
<th>Raspberry Pi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>B+ version 1.2</td>
</tr>
<tr>
<td>Operating System</td>
<td>Linux (Raspbian Jessie)</td>
</tr>
<tr>
<td>System-on-a-chip (SoC)</td>
<td>Broadcom BCM2835 (CPU + GPU. SDRAM is a separate chip stacked on top)</td>
</tr>
<tr>
<td>CPU</td>
<td>700 MHz ARM11 ARM1176JZF-S core</td>
</tr>
<tr>
<td>GPU:</td>
<td>Broadcom Video Core IV, OpenGL ES 2.0,OpenVG 1080p30 H.264 high-profile encode/decode</td>
</tr>
<tr>
<td>Memory (SDRAM)</td>
<td>512 MiB</td>
</tr>
<tr>
<td>USB ports:</td>
<td>4 USB 2.0 (via integrated USB hub in LAN9514)</td>
</tr>
<tr>
<td>Video outputs:</td>
<td>HDMI</td>
</tr>
<tr>
<td>Audio outputs</td>
<td>TRS connector</td>
</tr>
<tr>
<td>Onboard Storage:</td>
<td>Micro Secure Digital / Micro SD slot</td>
</tr>
<tr>
<td>Onboard Network:[</td>
<td>10/100 wired Ethernet RJ45</td>
</tr>
<tr>
<td>Low-level peripherals:</td>
<td>40 General Purpose Input/output (GPIO) pins, Serial Peripheral Interface Bus (SPI), PC, PS, I2C IDC Pins, Universal asynchronous receiver/transmitter (UART)</td>
</tr>
<tr>
<td>Power ratings:</td>
<td>~650 mA, (3.0 W)</td>
</tr>
<tr>
<td>Size:</td>
<td>85.0 x 56.0 mm x 17mm</td>
</tr>
<tr>
<td>Weight:</td>
<td>40g</td>
</tr>
</tbody>
</table>

Table 3.2 AtMega microcontroller summary

For remote viewing demonstration the device was operated headless. Headless operation means no screen was attached via the HDMI port. It was connected onto a network and it recorded the necessary data for remote viewing.

Schematic [15]

Datasheet ref [15]
CHAPTER FOUR
RESULTS AND ANALYSIS

4.1 RESULTS

4.1.1 Fall detection results

SAMPLE RAW VALUES

1a) Accelerometer at rest on table (X=0, Y=0, Z=90) RESTING FACE UP

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>331</td>
<td>335</td>
<td>406</td>
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<tr>
<td>331</td>
<td>335</td>
<td>406</td>
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<td>335</td>
<td>339</td>
<td>410</td>
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<td>331</td>
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<td>331</td>
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<td>335</td>
<td>339</td>
<td>408</td>
</tr>
</tbody>
</table>

Table 4.1 Accelerometer resting face up

1b) Accelerometer at upside down on table AXIS TILT (X=0, Y=180, Z=180) RESTING OR FALL

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
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</thead>
<tbody>
<tr>
<td>329</td>
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<td>271</td>
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<tr>
<td>329</td>
<td>326</td>
<td>271</td>
</tr>
</tbody>
</table>

Table 4.2 Accelerometer upside down
1c) Accelerometer at AXIS TILT SENSOR FACING ME (X=0, Y=+90, Z=+90 (OR 180))
SIDEWAYS

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
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</thead>
<tbody>
<tr>
<td>263</td>
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<td>339</td>
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<tr>
<td>264</td>
<td>333</td>
<td>337</td>
</tr>
</tbody>
</table>

*Table 4-3 Accelerometer facing user*

1e) Accelerometer at AXIS TILT SENSOR FACING COMP(X=0, Y= -90, Z= -90(OR 0))
SIDEWAYS

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
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<tbody>
<tr>
<td>266</td>
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<td>263</td>
<td>331</td>
<td>340</td>
</tr>
</tbody>
</table>

*Table 4-4 Accelerometer top facing away from user*
1 f) Accelerometer at AXIS TILT SENSOR TO THE LEFT SIDEWAYS (X= +90, Y=0, Z= -90(OR 180)) NORMAL - CHECK FOR TILT

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
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<tr>
<td>400</td>
<td>329</td>
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</tr>
</tbody>
</table>

Table 4.5 Accelerometer left tilt detection

1 g) Accelerometer at AXIS TILT SENSOR TO THE RIGHT-SIDEWAYS (X= -90, Y=0, Z=90 (OR 0)) UPSIDE DOWN

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
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<tbody>
<tr>
<td>333</td>
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</tbody>
</table>

Table 4.6 Accelerometer right tilt detection
4.1.2 Cardiac signal results

a) First stage of OPAMP output

![First stage of OPAMP output](image)

Fig. 4-1 First stage of OPAMP output

b) Second stage of OPAMP output

![Second stage of OPAMP output](image)

Fig. 4-2 Second stage of OPAMP output
c) Second stage of OPAMP output (with infrared sensor input)

![Image of second stage of OPAMP output](image)

Fig. 4.3 Second stage of OPAMP output (with infrared sensor input)

d) Comparison of input and output signal seen as a stream

![Image of comparison of input and output signal](image)

Fig. 4.4 Comparison of input and output signal seen as a stream
e) Output signal seen as a stream on an oscilloscope
4.1.2 Raspberry pi

REMOTE GPIO ACCESS

Fig. 4-6 Linux terminal GPIO access screenshot
4.1.3 Pc to raspberry pi connection

```plaintext
Wireless LAN adapter WiFi:
  Connection-specific DNS Suffix          : fe80::9def:d52c:3688:960b%21
  Link-local IPv6 Address                 : fe80::9def:d52c:3688:960b%21
  IPv4 Address                           : 192.168.43.7
  Subnet Mask                            : 255.255.255.0
  Default Gateway                        : 192.168.43.1

Tunnel adapter isatap.{E2DD59E4-D38B-482F-9FE5-00E8ACEE6ED}:
  Media State                             : Media disconnected
  Connection-specific DNS Suffix          :

Tunnel adapter Teredo Tunneling Pseudo-Interface:
  Media State                             : Media disconnected
  Connection-specific DNS Suffix          :
```

Fig. 4-7 Remote access LAN Addressing
CHAPTER FIVE
SUMMARY OF THE STUDY, CONCLUSION AND RECOMMENDATIONS

5.2 Summary of the study

The remote patient monitoring system was researched, designed and presented around the concept of Internet of things. Personal physiological data from the patient is collected that simulates fall detection and the heartbeat. The readings are collected in a simple local database and can be viewed remotely by a doctor or Healthcare giver. The data can also be used in research on medical issues affecting the elderly or chronically ill.

On security of the data, the database system is protected Advanced Encryption Standard (AES). This generates the secret key which can be used to decrypt the patients’ records ensuring that only authorized personnel access the data. This safeguards the patients’ records from unauthorized users and hackers who may want to intercept.
5.3 Conclusion

The main objective of the experiment was successfully achieved. All the three individual modules namely Heart beat detection module, fall detection module and remote viewing module gave out the intended results.

The designed system modules can further be optimized and produced to a final single circuit. More important fact that came up during project design is that all the circuit components used in the remote health detection system are available locally.

With development in the integrated circuit industry, Micro Electro Mechanical Systems (MEMs) and microcontrollers have become affordable, have increased processing speeds, miniaturized and power efficient. This has led to increased development of embedded systems that the healthcare specialists are adopting. These embedded systems have also been adopted in the Smartphone technology.

With increased internet penetration in most developing countries through mobile phones, its uses such as Internet of things (IoT) will become adopted at a faster rate. The Remote Health Care system utilizes these concepts to come up with a system for better quality of life for people in society.

From an engineering perspective, the project has seen concepts acquired through the electrical engineering study period being practically applied. The Electric circuit analysis knowledge was used during design and fabrication of the individual modules. Electromagnetic fields analysis used in the wireless transmission between microcontrollers and Software programming used during programming of the microcontrollers to come up with a final finished circuit system.
5.4 Recommendations

1) In fall detection the accelerometer and the microcontroller worked fine. I would recommend adding a gyro-meter and GPS to the setup. This would pinpoint accurately the fall detection.

2) Repurpose an old Smartphone and use the onboard circuit and sensors (Accelerometer, gyrometer and GPS) for fall detection study in baby cots, luggage or motorcycles, bicycles or cars.

3) Making a Smartphone app to read onboard sensors and remotely detect physiological data. Mainly to be used as a fitness tracker. Borrowed from smartwatches concept

4) Further investigations for the heartbeat detection on what other physiological measurements can be analyzed from the heartbeat data e.g. the oxygen content in the blood. A temperature sensor can also be introduced.

5) For the remote viewing of data I recommend more projects requiring use of I2C bus and SPI bus on the raspberry Pi or any microcontroller. This will encourage more research in the field of Internet of things (IoT)

6) For all remote data viewing improve on security of system and data viewed over the web
5.5 Suggestion for further study

a) Physiological data collection
   1. Home Ultrasound
   2. Brain signal monitoring

b) Remote viewing of data
   1. Problems associated with having data online. Tackle Distributed denial of service. DDOS, and Data privacy/security especially of medical systems.
REFERENCES


[6] The University of Alabama in Huntsville 301 Sparkman Drive, Huntsville, AL 35899
   Emails: milenka@ece.uah.edu, chrisaotto@yahoo.com, jovanov@ece.uah.edu
   http://www.ece.tufts.edu/ee/194HHW/papers/milenkovic_compcomm06.pdf


Department of Computer Science, University of Virginiahttp://www.cs.virginia.edu/~adw5p/pubs/d2h206-health.pdf

Wireless Sensor Networks for In-Home Healthcare: Potential and Challenges
ISSN: 22311963

[12] WIRELESS SENSOR NETWORK BASED HEALTHCARE MONITORING SYSTEM FOR HOMELY ELDERS
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[16] MONITORING BEHAVIOR IN HOME USING A SMART FALL SENSOR AND POSITION SENSORS Norbert Noury (1), Thierry Herd(1), Vincent Rialle(1), Gilles %one(1), Eric Mercier(2), Gilles Morey(3), Aldo Mor0(3), Thieny Porcheron(3) (1) TIMC-IMAG equipe pISFV - UMR CNRS 5525 -Domaine La Merci - 38700 La Tronche, France Tel+33 (0)4 76 63 71 57, EmailNorbert.Nouy@imag.fr (2) ATMEL -Avenue de Rochepleine BP 123 - 38521 St Eg6ve (3) ATRAL s.a. - Rue du pr6 de l’Orme - 38926 Crolles

[17] Fall detection – Principles and Methods - N. Noury, Senior Member, IEEE , A. Fleury, Student Member, IEEE, P. Rumeau, A.K. Bourke, G. Ó Laighin, V. Rialle, J.E. Lundy

[18] Arrhythmia Detection Based on ECG Signal using Android Mobile for Athlete and Patient 1.Sugondo Hadiyoso, 2.Koreedjanto Usman, 3.Achmad Rizal 1Telkom Applied Science School, 2,3School of Electrical Engineering Telkom University Bandung, Indonesia 1sugondo@telkomuniversity.ac.id, 2koredjanto@telkomuniversity.ac.id, 3achmadrizal@telkomuniversity.ac.id

## APPENDICES

### COST ANALYSIS

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity</th>
<th>Reference(s)</th>
<th>Value</th>
<th>Stock Code</th>
<th>Unit Cost</th>
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<td>C2,C4</td>
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<td>CLASS 10 MEMCARD</td>
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<td><strong>TOTAL</strong></td>
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Code
DATA 1 – ACCELEROMETER AND TRANSMISSION

/*
RF Blink - Transmit sketch

Written by ALBERT MUCHISU
Date: 20 March 2016
Arduino IDE version 1.6.4

Transmitter: HC11 433mhz
Description: A simple sketch used to test AD345 Accelerometer 433mhz
RF transmission.

const int groundpin = 18; // analog input pin 4 -- ground
const int powerpin = 19;  // analog input pin 5 -- voltage
const int xpin = A3;      // x-axis of the accelerometer
const int ypin = A2;      // y-axis
const int zpin = A1;      // z-axis

//
unsigned int xfall=0; // variable used to store xfall data
const unsigned int upperFallThreshold = 399; //upper fall threshold value
const unsigned int lowerFallThreshold = 387; //lower fall threshold value

#define rfTransmitPin 4 //RF Transmitter pin = digital pin 4
#define ledPin 13       //Onboard LED = digital pin 13

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

  //ACCELEROMETER
  pinMode(groundpin, OUTPUT);
  pinMode(powerpin, OUTPUT);
  digitalWrite(groundpin, LOW);
  digitalWrite(powerpin, HIGH);
  //TRANSMISSION
  pinMode(rfTransmitPin, OUTPUT);
}
pinMode(ledPin, OUTPUT);
}

void loop(){
xfall = analogRead(xpin);

Serial.print("X = ");
Serial.print(analogRead(xpin));  // print a tab between values:
Serial.print("\t Y= ");
Serial.print(analogRead(ypin));  // print a tab between values:
Serial.print("\t Z= ");
Serial.print(analogRead(zpin));
Serial.println();  // delay before next reading:
delay(3000);

// for(int i=400; i>5; i=i-(i/3)){  //
// for(int xfall=400; xfall>10; xfall=xfall-10){  //
if(xfall<upperFallThreshold){
digitalWrite(rfTransmitPin, HIGH);  //Transmit a HIGH signal
digitalWrite(ledPin, HIGH);  //Turn the LED on
//delay(2000);  //Wait for 2 second
Serial.print("low ");
}
if(xfall>lowerFallThreshold){
digitalWrite(rfTransmitPin, LOW);  //Transmit a LOW signal
Serial.println(rfTransmitPin);
digitalWrite(ledPin, LOW);  //Turn the LED off
delay(2000);  //Wait for 2 second Variable delay
Serial.print("high ");
}
}
DATA 2 – RF RECEIVING AND PI SPI communication

/*
RF Blink - Transmit sketch
Written by ALBERT MUCHISU
Date: 20 March 2016
Arduino IDE version 1.6.4
Transmitter: HC11 433mhz
Description: A simple sketch used to test AD345 Accelerometer 433mhz RF receiving.
-----------------------------------------------------------------------------------*/

#define rfReceivePin A0  //RF Receiver pin = Analog pin 0
#define ledPin 13        //Onboard LED = digital pin 13

unsigned int data = 0;   // variable used to store received data
const unsigned int upperThreshold = 70;  //upper threshold value
const unsigned int lowerThreshold = 50;  //lower threshold value

void setup(){
  pinMode(ledPin, OUTPUT);
  Serial.begin(9600);
}

void loop(){
  data=analogRead(rfReceivePin);    //listen for data on Analog pin 0
  if(data>upperThreshold){
    digitalWrite(ledPin, LOW);   //If a LOW signal is received, turn LED OFF
    Serial.println(data);
    delay(4000);
  }
  if(data<lowerThreshold){
    digitalWrite(ledPin, HIGH);   //If a HIGH signal is received, turn LED ON
    Serial.println(data);
    delay(4000);
  }
}
SPI communication with RASPBERRY PI

Written by ALBERT MUCHISU

Date: 20 March 2016

Arduino IDE version 1.6.4

Description: A simple sketch used to SPI communication with RASPBERRY PI

#include "RCSwitch.h"
#include <stdlib.h>
#include <stdio.h>

RCSwitch mySwitch = RCSwitch();

void setup() {
  Serial.begin(9600);
  // Transmitter is connected to Arduino Pin #10
  mySwitch.enableTransmit(10);

  // Optional set pulse length.
  // mySwitch.setPulseLength(320);

  // Optional set protocol (default is 1, will work for most outlets)
  // mySwitch.setProtocol(2);

  // Optional set number of transmission repetitions.
  // mySwitch.setRepeatTransmit(15);
}

void loop() {
  /* Same switch as above, but using decimal code */
  mySwitch.send(5393, 24);
  delay(1000);
  mySwitch.send(5396, 24);
  delay(1000);
}
/* Same switch as above, but using binary code */
/* mySwitch.send("000000000001010100010001"); */
delay(1000);
mySwitch.send("000000000001010100010100");
delay(1000); /*

delay(2000);
//mySwitch.send(4212181, 24);
*/

}
AtMega328pu pinout

Fig. 4-8 Atmega328PU pin configuration
Datasheet page showing ATmega328 internal construction

2. Overview

The ATmega48PA/88PA/168PA/328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48PA/88PA/168PA/328P achieves throughputs approaching 1 MIPS per MHz, allowing the system designer to optimize power consumption versus processing speed.

2.1 Block Diagram

Figure 2-1. Block Diagram

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting

56
Raspberry pi GPIO pin configuration

Raspberry Pi2 GPIO Header

<table>
<thead>
<tr>
<th>Pin#</th>
<th>NAME</th>
<th>NAME</th>
<th>Pin#</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>3.3v DC Power</td>
<td>DC Power 5v</td>
<td>02</td>
</tr>
<tr>
<td>03</td>
<td>GPIO02 (SDA1, PC)</td>
<td>DC Power 5v</td>
<td>04</td>
</tr>
<tr>
<td>05</td>
<td>GPIO03 (SCL1, PC)</td>
<td>Ground</td>
<td>06</td>
</tr>
<tr>
<td>07</td>
<td>GPIO04 (GPIO_GCLK)</td>
<td>(TXD0) GPIO14</td>
<td>08</td>
</tr>
<tr>
<td>09</td>
<td>Ground</td>
<td>(RXD0) GPIO15</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>GPIO17 (GPIO_GEN0)</td>
<td>(GPIO_GEN1) GPIO18</td>
<td>12</td>
</tr>
<tr>
<td>13</td>
<td>GPIO27 (GPIO_GEN2)</td>
<td>Ground</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>GPIO22 (GPIO_GEN3)</td>
<td>(GPIO_GEN4) GPIO23</td>
<td>16</td>
</tr>
<tr>
<td>17</td>
<td>3.3v DC Power</td>
<td>(GPIO_GEN5) GPIO24</td>
<td>18</td>
</tr>
<tr>
<td>19</td>
<td>GPIO10 (SPI_MOSI)</td>
<td>Ground</td>
<td>20</td>
</tr>
<tr>
<td>21</td>
<td>GPIO09 (SPI_MISO)</td>
<td>(GPIO_GEN6) GPIO25</td>
<td>22</td>
</tr>
<tr>
<td>23</td>
<td>GPIO11 (SPI_CLK)</td>
<td>(SPI_CE0_N) GPIO08</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>Ground</td>
<td>(SPI_CE1_N) GPIO07</td>
<td>26</td>
</tr>
<tr>
<td>27</td>
<td>ID_SD (PC ID EEPROM)</td>
<td>(PC ID EEPROM) ID_SC</td>
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<td>29</td>
<td>GPIO05</td>
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<td>GPIO13</td>
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<td>36</td>
</tr>
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<td>37</td>
<td>GPIO26</td>
<td>GPIO20</td>
<td>38</td>
</tr>
<tr>
<td>39</td>
<td>Ground</td>
<td>GPIO21</td>
<td>40</td>
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</table>

Fig 4-9 Raspberry Pi GPIO pin configuration