BACHELOR OF ENGINEERING DEGREE WITH HONOURS IN ELECTRICAL AND ELECTRONIC ENGINEERING

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INTERHOME: EXTENSION ON ASSISTED LIVING

Report By

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DECLARATION STATEMENT

I certify that the work submitted is my own and that any material derived or quoted from the published or unpublished work of other persons has been duly acknowledged (ref. UPR AS/C/6.1, Appendix I, Section 2 – Section on cheating and plagiarism)

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ABSTRACT

This report describes the project work which is based on providing supervision for assisted living residence such as disable or elder people. Here deals to build an embedded device for continuous monitoring their health condition, movement and send data through wireless communication system to the service provider or smart home device.

On the base of this project, proposed a wearable wrist belt for 24 hours patient monitoring service. This report indicates the working stages undertaken to design, development and implementation of the device. It also provides the workout on project management including project time plan and resource analysis.

Finally the report highlights the commercial aspects, product marketability and future development for more successful implementation in different areas of assistive living.

ACKNOWLEDGEMENTS

I would like to thank my supervisor Mr. Johann Siau for his guidance and assisted me during the whole project. During my project when I lost the way, he gave me proper direction of progress. Once again, I would like to thank him for his moral support and giving me his valuable time as well as encourage me to work best.

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GLOSSARY

MEMS- Micro Electro-Mechanical systems.

GPRS- General Packet Radio Service

UMTS- Universal Mobile Telecommunications System

PDA- Personal Digital Assistant.

SPI- Serial Peripheral Interface

IP- Internet Protocol

CPU- Central Processing Unit

SDA- Serial Data Address

SCL- Serial Clock Line

pF/kF- pico farads / kilo farads

LR-WPAN- low-rate wireless personal area networks

DSSS- Direct Sequence Spread Spectrum.

UART- Universal Asynchronous Receive/Transmitters

CTS/ RTS - Clear to Send / Request to Send

GSM- Global System for Mobile Communications

GPIO- General Purpose Input /Output

Li-ion- Lithium-Ion

DIP- Dual In-line Package

MISO - Master Output/Slave Input

MISO- Master Input/ Slave Output

SDO- Serial Data Output.

AC/DC- Access Current /Direct Current

MSOP- Mini Small Outline Package,

USB- Universal Serial Bus

FPGA- field-programmable gate array

PCB- Printed Circuit Board

1 INTRODUCTION

The development in a residential network for smart healthcare is broad up a new horizon for continuous long-term monitoring of assisted and independent-living residents. The introduction part provides the project background, some related works, aims and objectives as well as chapter guideline of the report.

1.1 PROJECT BACKGROUND

Assisted living residences are referred to as who requires assistance for daily living activities. Additionally the residence frequently is coordinated with third party healthcare and service providers on the resident's behalf. Assisted living emerged in the 1990's as the next step of continuing care for people who cannot live independently in a private residence, but who also do not require the 24-hour medical care provided by a nursing home. [2]

The implementation of assisted living technology exists today since 1980s when microelectromechanical systems (MEMS) have been used in the medical industry for a variety of silicon pressure, accelerometer, and custom microstructure applications. [1]

As the world’s population ages, those suffering from diseases of elderly and disability are increasing day by day. So the raising healthcare costs and the increasing elderly population are placing a strain on current health care service. Elderly patient and disable, especially those with chronic conditions, requires long-term monitoring. By using modern home automation system provides those 24 hours monitoring and continuous care in home environment. Different wearable sensors build a sensor network in the device for measuring various data and send to receiver by using wireless communication. This system can be utilized in individual patient home or care home system. So the service providers can monitor a number of patients at a time. Nowadays the care home service providers are using assistive living technology for providing better service.

The sensor network system integrates into a device. Some wearable on the patient and some placed inside the living space such as bed, wall etc. They together inform the healthcare provider about the health status of the resident. Data is collected, aggregated, pre-processed, stored, and acted upon using a variety of sensors and devices. Data can be sending through power line, radio frequency (RF), Wi-Fi, inferred or Bluetooth etc.

1.2 RELATED WORKS

With the population is growing older, the demand for healthcare is growing rapidly. To meet the demand for more healthcare people are starting to look for new healthcare technology in less expensive way. Healthcare for elderly people is a huge area with lots of potentials. So many universities and companies are doing different kind of research within the area.

Imperial Collage of London has developed UbiMon. It is aimed at addressing general issues related to using wearable and implantable sensors for distributed mobile monitoring. [6] UbiMon is a designed device for wearable communicator performing multi-sensor interfacing, automated techniques for integrating multi-sensory data leading to an intervention strategy as well as preliminary clinical evaluation for management of patients with ischemic and arrhythmic heart disease called Cardiovascular disease. [6]

CodeBlue and Mercury are wireless sensor network for medical care. Both are developed by Harvard University. The applications of wireless sensor network technology to a range of medical applications, including pre-hospital and in-hospital emergency care, disaster response, and stroke patient rehabilitation.[3] Mercury includes long sensor node lifetime, autonomous operation, and the need for the system to automatically tune its behaviour in response to fluctuations in radio bandwidth and energy availability.[4] An earlier version of Mercury (v1.0) is used on the patient of Parkinson (Motor neuron disease) and Epilepsy (Brain Disease). [4]

MIT researched on wireless blood pressure monitor system. They have built a wearable blood pressure sensor that can provide continuous, 24-hour monitoring. [11] This device monitors patient high blood pressure and sends data through radio frequency. It could help diagnose hypertension, heart disease as well. [11]

Microsoft Corporation researched on HealthGear. It is a real-time wearable system for monitoring, visualizing and analyzing physiological signals. [12] It is set of non-invasive physiological sensors which wirelessly connected via Bluetooth to a cell phone which stores, transmits and analyzes the data. [12]

BT (British Telecom) and Anchor Trust developed together a system that is capable of monitoring people's movements and looking for deviations from a 'normal' pattern of behaviour that may indicate a potential problem. [9]

European Commission is funded on mobile healthcare project called Mobihealth. It is the implementation of GPRS or UMTS services in healthcare. [10] The system allows patients to be fully mobile whilst undergoing health monitoring. The patients wear a lightweight monitoring system - the MobiHealth BAN (Body Area Network) - which is customized to their individual health needs. [10] So it helps to monitor of patients status and progress as well as quick handling of emergency situations. [10]

Royal Philips Electronics has introduced Lifeline with AutoAlert, a medical alert service which is able to detect falls and call for help for elder people. The alert system consists of pendant-style button. The button is worn around the neck which can be pressed to call for help at any time. [7]

Corventis is maker of wireless CHF (Congestive Heart Failure) monitoring devices that measure heart rate, heart rate variability, respiratory rate, fluid status and activity. [8] Piix designed to remote wireless monitoring technology in proactively managing heart failure patients and reducing hospital readmissions. [8]

CardioNet provides a remote heart monitoring system where ECG signals are transmitted to a PDA (Personal Digital Assistant) and then routed to the central server by using the cellular network. [5]

1.3 AIMS AND OBJECTIVES

The main aim of this project is to design a device which helps assisted living by sending data such as heart beat, pulse reading, blood pressure, temperature or movement etc. through various data transmitting media named Wi-Fi, Bluetooth, Inferred, Radio Frequency or power transmission line etc. Design sensors networking and embedded device which have made it feasible to monitor and provide medical and other assistance to people in their homes. The designed device aims to send data to the existing Smart Home System (InterHome).

The main object can be divided into two parts. First part is to work on hardware and second part is software.

- Choose particular sensor and connection media for those.
  Here choose the LIS302DL accelerometer for movement monitoring and DIS1624 temperature sensor. Both sensors are connectable with I^2C-Bus and SPI**.** Here sensors are connected with I^2C-Bus of Meridian/P microcontroller. The details explanation I^2C-Bus and Meridian/P is give in section 2.4 and 3.2.1.

- Choose a communication medium.
  This is very essential part for this project. As it will decide how the device is communicate with the smart home device. There are many ways to transmit the data through device but here prefer wireless communication via radio frequency (RF). So the device designed with XBee communication system. The details of XBee communication system is given in section 2.6.

- Build the hardware design in breadboard by using required components.
  At first work on paper based designed then work on breadboard design. So after getting all components, designed the system on breadboard. Some components need adaptor to work on breadboard like XBee, IC of MSOP (Mini Small Outline Package) pin. Explanation of connection of breadboard is given in section 4.1.1.

- By using C# or Java write the code for sensor network and microcontroller.
  For this embedded device using Meridian/P microcontroller. So write the programming code for device in C# on .Net Microframework. In section 2.5 details on .NET Microframework is explained.

- Test the whole designed device to the assisted controller.
  After completing the whole design and programming, test the whole system. Sometimes requires modification in hardware design and programming code. The result analysed form the output of the system. The detail provides in Chapter 5.

1.4 PROJECT FEASIBILITY

Before working on this project, the feasibility report is generated. That carried out to determine the working stages, outline design, proposal in terms of software and hardware requirements to handle the completion of the project

Due to recent advances in sensor networks and embedded technologies, designed health monitoring devices have become practically feasible.

1.5 REPORT GUIDELINE

This report provides information on the design and development of assistive living device. A brief outline of the report is given below.

Chapter 1: This chapter introduces with assisted living technology and project background. Some related research from different universities and companies as well as aims and objectives also discussed. It includes the brief description of the organisation of report and project feasibility.

Chapter 2: All background information which is related with this project has been discussed in this section. It covers home automation, InterHome, .NET Microframework, I^2C Bus and XBee communication system.

Chapter 3: This chapter discusses on whole system overview and design. Here shows how the project is designed and forwarded to the development. Also include block diagram of the project and the schematic diagram of the design. Design of each part has been explained in this section. The connections between Meridian/P and all other components are shown here. The components include sensor unit, communication unit and power management unit.

Chapter 4: Discussed on hardware and software implementation in this section. PCB design and Breadboard design are introduced in hardware implementation. The programming code of each component and whole system is explained in software implementation section.

Chapter 5: The output result is analysed in this chapter. The output from accelerometer and temperature sensor is discussed. Analysis of the result is explained in different situations.

Chapter 6: Project management is very essential part in project handling. Time management, resource analysis and risk assessment have been briefly discussed in this chapter.

Chapter 7: This chapter concludes the whole project work. Here discuss on the aims that are given in section 1.3. Also evaluates if any additional objective is done for project work. Commercial aspects of assistive living technology are discussed in this chapter. Future development and recommendations are provided here for more useful applications.

2 SUBJECT REVIEW

Due to high increase the number of aging population expresses that the automatic home monitoring will represent major challenge near future. Advances in communication system, sensors, and embedded devices have made possible to monitor and provide medical and other assistance to assisted people in their homes. With the aid of modern technology make the home more comfortable and caring for elder people. Aging populations will be benefitted from reduced costs and improved healthcare through assisted living based technologies. These systems provide more usability, reliability, and security. This is extensible system that combines software and hardware. The system can also provide information to diverse clinicians on 24 hours based. This report presents the system architecture for extension on assisted living that allows independent, secure, low-cost and emergency detection for assistive people. The approach is based on XBee communication system. The designed device will send data to smart home system. Additionally a server can be connected that collects and maintains assisted persons' records. The designed system shows the feasibility and new opportunity of an approach to assisted living systems.

2.1 HOME AUTOMATION

Home automation is becoming more popular around the world and is becoming a common practice. The process of home automation works by making everything in the house automatically controlled using technology to control and do the jobs that would normally do manually. [13] Nowadays home automation takes care of a lot of different activities in the house. The term may be used in contrast to the more mainstream "building automation", which refers to industrial uses of similar technology, particularly the automatic or semi-automatic control of lighting, doors and windows, heating,

ventilation and air conditioning, and security and surveillance systems. [14] Home automation technique can be applied in the control of home entertainment systems, houseplant watering and kitchen applications. There are four types of home control system named power line carrier system, wireless system, and hardwired system and IP control. [15] Power line carrier system is X10 based system. It operates through existing wire lines. Wireless system is based on the data transmission through radio frequency technology. Hardwired system introduces systems which can operate over high-grade communications cable. IP control means that house operates like its own secure Internet via a Web server, or a computer network. [15] For this project wireless system is used but IP (Internet Protocol) control system can be applicable in future application.

Now home automation focuses on making home for the elderly and disabled more safe and comfortable. Here using home automation system to monitor their daily activities. This system provides more options for the assistive people who would prefer to stay in the comfort of their homes rather than move to a healthcare facility. Home automation is being implemented for assistive living in order to offer more independence and safety.

2.2 SMART HOME

The home which is operating through automated system is called *Smart Home.* Smart Home designs in the concept of Home Automation. The main idea of home automation is to employ sensors and control systems to monitor a dwelling, and accordingly adjust the various mechanisms that provide heat, ventilation, lighting, and other services. [17] In Figure 2-1 shows a house is in the concept of Smart Home where every system is control and monitoring. By definition, a dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed. [18]

This can provide more control and security in different home applications. It provides services in six main areas environmental, security, home entertainment, domestic appliances, information and communication and health care. [18] The assistive people can be monitored 24 hours basis in homely environment. Smart home system provides medication reminder, health monitoring, indication of any emergency situations like fallen. [18]

Figure 2-1: Smart Home [16]

Smart home technology is real, and it's becoming increasingly sophisticated. [19] The idea of Smart Homes carries a vital role in the planning of future housing-based models of care.

2.3 INTERHOME

InterHome, an existing smart home concept which has been designed to test and demonstrate how much greener and secure our homes could be if they incorporated intelligent technologies that adapt to our daily routine. The design of this project demonstrates the interoperability of the unit in a smart home environment. Smart Home which is based on Meridian CPU is known as InterHome. [20]

2.4 I^2C BUS

In this project all the sensors are only connected with microcontroller (Meridian/P) by using I^2C bus. This bus is designed from the manufactures of the component. It is multi-master bus. So more than one device can be connected with this bus shows in Figure 2-2. The I^2C translates into "Inter IC" can be called as IIC or I2C Bus. [21] The bus I^2C as designed by Philips in the early '80s to allow easy communication between components which reside on the same circuit board. Philips Semiconductors migrated to NXP Semiconductor in 2006. [21]

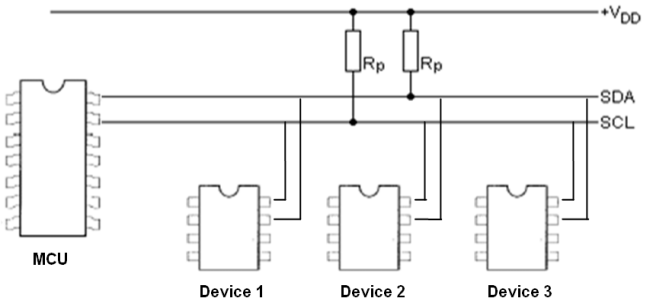


Figure 2-2: Devices connected with Microcontroller using I2C bus

I^2C -Bus requires two bus lines; a serial data line (SDA) and a serial clock line (SCL). [22] It is a multi-master bus including collision detection and arbitration to prevent data corruption if two or more masters simultaneously initiate data transfer. [22] It is serial and 8-bit oriented and bidirectional as well. The data transfers can be made at up to100 kbit/s in the standard/ regular mode or up to 400kbit/s in the fast mode. [22] But now a high speed 3.4 Mbit/s available. [21] This bus can be connected by wires. The serial data (SDA) and serial clock (SCL) carry information between the devices connected to the bus. Every single device is recognized by a unique address. [22] The SDA and SCL lines are pulled up to the supply voltage (3.3V to 5V) with a pull-up resistor. [23] As well as the number of devices connected to the bus is only limited by the bus capacitance is considered of 400pF. [23] This bus is low power consumption and flexible to use.

Here the sensors are connected with microcontroller by using I^2C bus. The device can operate as either a transmitter or receiver, depending on the function of the device. In addition to transmitters and receivers, devices can also be considered as masters or slaves during data transmission. [23] A master is the device which initiates a data transfer on the bus and generates the clock signals to permit that transfer. At that time, any device addressed is considered a slave. [23] Table 2-1 shows its operation. In Section 4.2.4 the operation of this bus is given in details.

Term	Description
Transmitter	The device which sends data to the bus
Receiver	The device which receives data from the bus
Master	The device which initiates a transfer. Generates clock signals and terminates a transfer.
Slave	The device addressed by master

Table 2-1: Device terminology in I^2C bus [22]

2.5 .NET MICRO FRAMEWORK

In this project, an embedded device is designed by using .NET Micro Framework. It does not require an operating system due to have features to operate like a subset of the operating system. [47] The .NET Micro Framework does not operate like traditional operating system and it was developed by Microsoft Research. [47] It works as a bootable run time and its platform can also run in 32-bit processor. [47] The .NET Micro Framework gives user a flexible and powerful for creating an embedded device. It is more applicable in small technology. That's why it was known as SPOT (Small Personal Objects Technology). [47]

The .NET Micro Framework helps to write code more reusable way. This can also extend and modify any existing code easily. It has high level of tools and libraries which help to design the embedded device quickly. The implementation system is very easy and more flexible. Here the Meridian/P is connected with other components. The programming for this project is written in C# in .NET Micro Framework platform.

2.6 XBEE COMMUNICATION SYSTEM

For this project work, build a wireless network by using XBee Modules. The XBee and XBee-PRO OME RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. [25] IEEE 802.15.4 provides a physical layer of low-rate wireless personal area networks (LR-WPAN). [26] This is used due to the lower cost than other wireless communication system. XBee or XBee-PRO RF Modules has ISM (Industrial, Scientific & Medical) frequency band of 2.4GHz. [25] It operates in low operating voltage. It provides more security by using Direct Sequence Spread Spectrum (DSSS). Spread Spectrums transmit much larger bandwidth than the information bandwidth through the channel. [27] Each direct sequence channels has over 65,000 unique network addresses available in XBee coomunication [25]

Here for wrist belt, using XBee modules of Series1. The device is designed with XBee. So it will transmit data to another XBee of the exiting Smart Home system. The key difference between the XBee and XBee-PRO is distance of data transmission. XBee-Pro has long distance of data transmission. XBee Module of Series 2 needs configuration so this will provide more security than Series 1. For this project work XBee-PRO can be

connected on the belt when requires more range and Series 2 for more security. In Table 2-2 shows the specification between XBee and XBee-PRO.

Specification	XBee 802.15.4 (Series 1)	XBee-PRO 802.15.4 (Series1)
Indoor Range	Up to 30m	Up to 100m
Outdoor Range	Up to 100m	Up to 1500m
Transmit Power Output	1mW	60mW
Receive Current	50mA	55mA
Operating Temperature	-40°C to 85°C	-40°C to 85°C
Serial Interface Data Rate	1200 - 115200 bps	1200 - 115200 bps
RF Data Rate	250 000 bps	250 000 bps
Number of Channels	16 Direct Sequence	12 Direct Sequence
Operating Voltage	2.8V-3.4V	2.8V-3.4V

Table 2-2: Specification difference between XBee and XBee-PRO [25]

XBee/XBee PRO is interfaced to a host device through a logic-level asynchronous serial port. [25] Here XBee is connected with the UART pin of the microcontroller (Meridian/P). So the data which is send from Meridian/P that will be received by XBee. As well as it will again operate like vice versa. The details connection between Meridian/P and XBee as well as information of CTS and RTS is given in section 3.2.3. Through its serial port, the module can communicate with any logic and voltage compatible UART shows in Figure 2-3. [25]

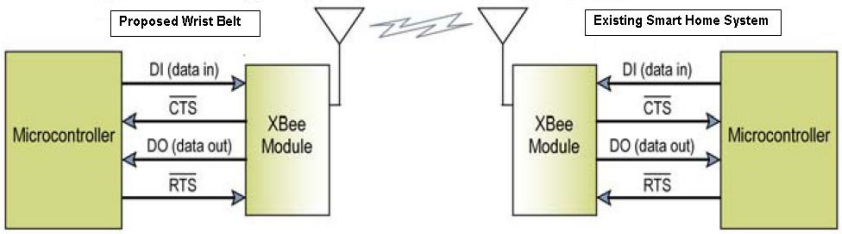


Figure 2-3: Communication between UART pin of Microcontroller and XBee Module [25]

3 PROJECT DESIGN AND DEVELOPMENT

This project is based on the exiting Smart home system called InterHome. Here design a device for assisted living people of the InterHome to provide 24 hours health monitoring service. In section 3.1 have explored the architecture by developing a collection of applications and implementing them in a prototype system. Also describes regarding designed wrist belt. In section 3.2 focuses on only wrist belt. There also demonstrates design of each part of wrist belt like sensor unit, communication unit, power management unit and microcontroller unit. Every unit connects and works altogether. The schematic diagram of the designed system is given in section 3.2.

3.1 SYSTEM OVERVIEW

Main theme of this project is to design a device for assistive residences to monitor their health in 24 hours basis. This is a home automation system. Here propose a wearable wrist belt which is designed with XBee and sensors. LIS302DL and DS1624 are picked as accelerometer and temperature sensor. Additionally a panic button is added in the design for the people who have problems in speech. So they can call for assistance by pressing that button. The detail is explained in section 3.2.2. All components are connected and controlled by Meridian/P microcontroller. An XBee is connected with the wrist belt and another one is connected with existing Smart Home system (InterHome). Both XBee will make a wireless mesh network for data transmission. The whole operation of the system is shown in Figure 3-1.

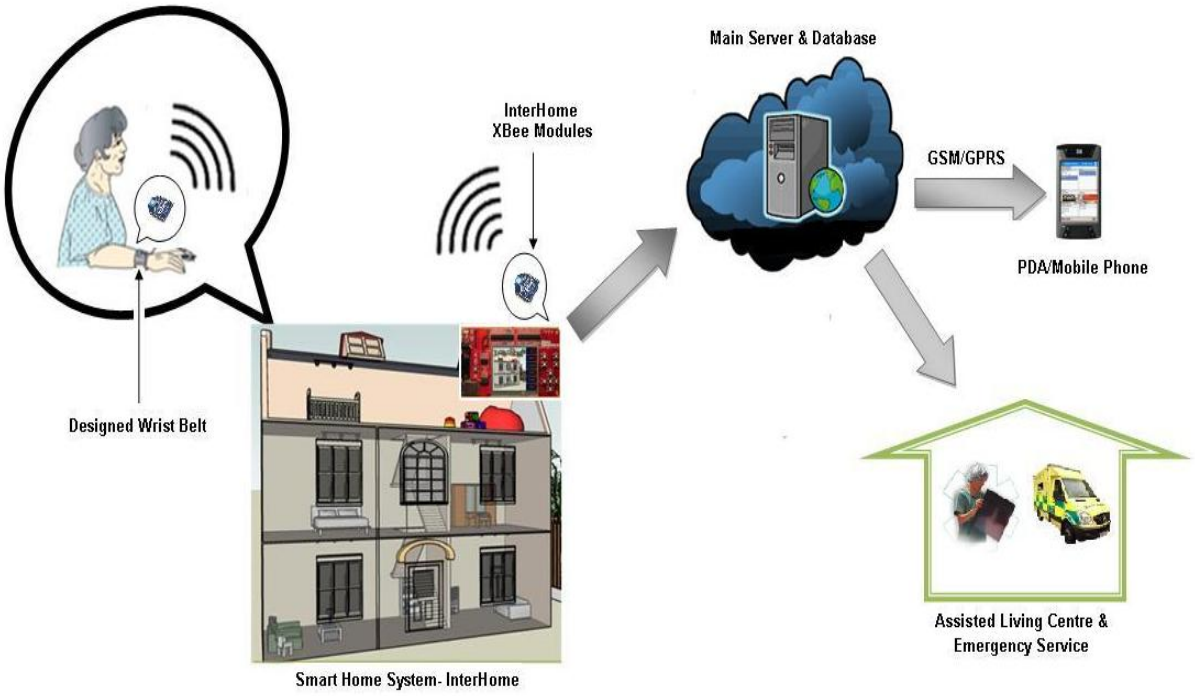


Figure 3-1: System Operation of Wrist Belt and existing Smart Home System (InterHome)

Figure 3-1 shows that an assistive residence of existing InterHome wearing the designed wrist-belt. The belt is build with XBee Module. It communicates with another XBee Module which is connected with InterHome. The wrist-belt sends data to the InterHome system. The InterHome device will send data toward Main Server and Database. The main server sends data again to the assistive living monitoring centre and emergency service. So monitoring centre can monitor the assisted residence on 24 hours basis. If any problem occurs then they can provide quick emergency service. On other hand, the main server can be connected with GSM or GPRS system. For any occurrence it will inform to the PDA or mobile phone. As well as the assistive person's data can be send 24 hours to the PDA or cell phone. This system is also applicable for care home service. By using this system care home service providers can monitor multiple patients at a time.

In Figure 3-2 shows the internal combination of the proposed wrist-belt. The accelerometer LIS302DL and temperature sensors DS1624 are connected with Meridian/P by using I2C bus. The explanation of this bus is given above in section 2.4. A panic button is connected with the GPIO (General Purpose Input /Output) pin of the Meridian/P. The connections between the sensors and panic button are described in sensor unit section 3.2.2. The collected data will send through the XBee Module which connected with the UATR pin of the Meridian/P. The microcontroller can receive or

transmit data through XBee Modules. For this project the microcontroller can only send data to the XBee. Here using light weight rechargeable Li-ion battery. So the wrist-belt works as wireless device and the person is independent to move. So a battery rechargeable system is designed in the wrist-belt. The Power management unit is designed with the battery rechargeable IC MCP73837 and DC-DC convertor. The design and operation of this unit is shown in section 3.2.4. All the components work altogether in the wrist-belt.

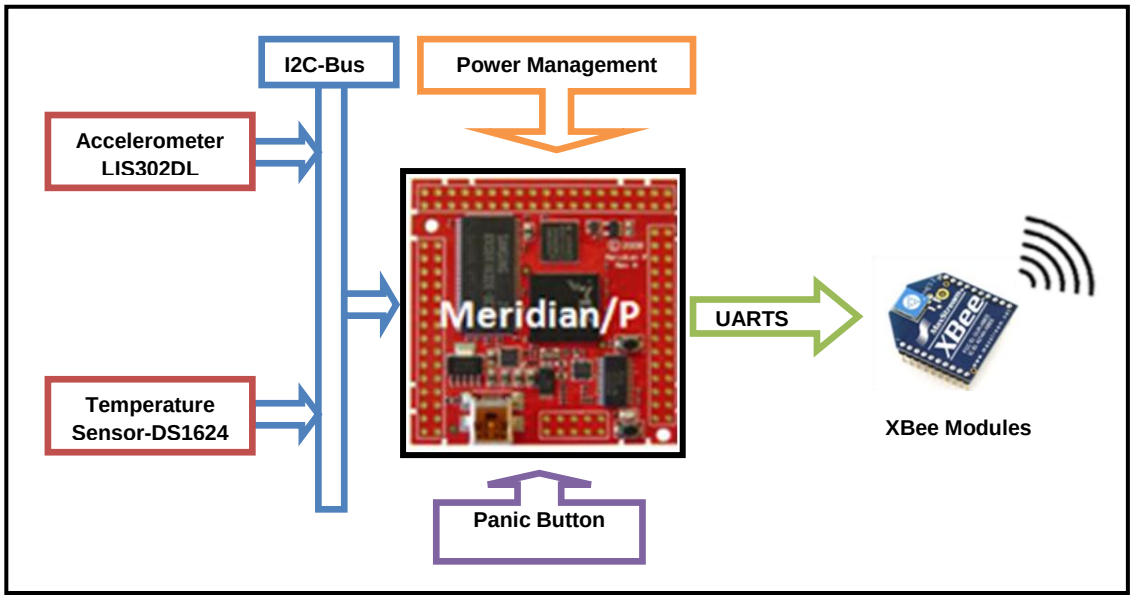


Figure 3-2: Block diagram of the wrist-belt.

3.2 SYSTEM DESIGN

The design of wrist belt is based in four units. Those are given below.

- Microcontroller Unit
- Sensors Unit
- Communication Unit
- Power Management Unit

This section all units are explained with schematic diagram and finally attached all units altogether to design the whole embedded device.

3.2.1 MICROCONTROLLER UNIT (Meridian/P)

For this project Meridian/P Micro Development Board is used as microcontroller. This is the nucleus of this project. Sensors, XBee, Power Management Unit are connected

with this. The whole device is designed on the base of Meridian/P. Meridian/P is combined with a 100MHz Freescale i.MXS ARM920T based processor, 8MByte of SDRAM (running at 96MHz), LCD controller, USB function, GPIO, SPI and I2C bus and serial port. [28] The operating voltage is 5V. It runs on .NET Micro Framework. [28] So for programming use C# in .NET Micro Framework.

Meridian/P has total 27 pins available for use as general purpose input/output pins but 19 of those pins are labelled as GPIO pins, remaining pin are not supported by .NET Micro Framework. [28]

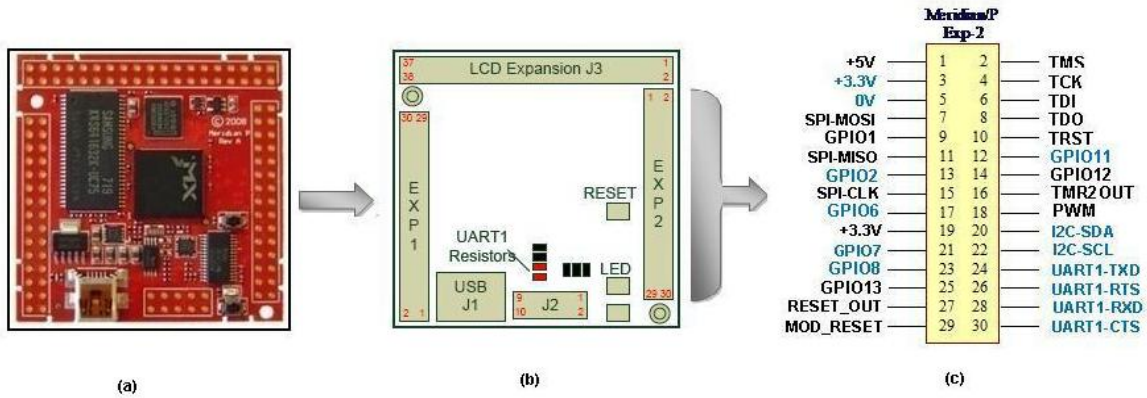


Figure 3-3: (a) View of Meridian/P (b) Available connection [28] (c) Schematic Pin notified Expansion 2 (EXP2) of Meridian/P [28]

For this project, design the device by using only expansion 2 (EXP2). Other connections like LCD Expansion are not used. The pin identification of EXP2 is shown in Figure 3-3. The pins are notified with blue colour those are used for designing. Rest of the pins are in black colour those are not used so left open.

Powered 4.3V to 5V DC input voltage through USB port (J1) to run Meridian/P. Maximum voltage of Input/ Output pin is 3.3V. The typical power consumption of Meridian/P is only 80mA and operating temperature ratio is 0°C to 70°C. [28] Pin-3 gives +3.3V. So this pin works as supply voltage for all devices. Pin 4 is 0V. So in this design makes it universal ground for all connections.

Meridian/P supports interfacing to device through the internal I2C bus master or SPI (Serial Peripheral Interface). [28] But here choose I2C bus to connect with devices. More information regarding I2C bus is given in section 2.4. So the sensors LIS302DL and DS1624 are connected with I2C bus. To connect with this bus the device has to configurable with this bus by manufacture. The base input frequency to the I2C bus is 96MHz. [28] In EXP2, Pin-20 and Pin-22 are signalled as I2C-SDA and I2C-SCL. Serial

Clock line (SCL) is used to clock data to the bus and Serial Data line for controller send or receive data on this line. [28]

If any of I2C or SPI bus does not use then that pins can be worked as input/output pin. In this design SDA and SCL both are pulled up with 47KΩ resistors.

XBee is connected with UART (Universal Asynchronous Receive/Transmitters) pins for data communication. Meridian/P has two UART pins. Here using UART1 of EXP2. Both UART 1 and UART2 are available serial ports (COM1 and COM2) under the .NET Micro Framework. [28] In this design using all the UART pins of EXP2. The connections between URAT pins and XBee are given in details in Section 3.2.3. There are four UART pins are available in Meridian/P EXP2. A brief description and pin location is given in Table 3-1.

Signal	Pin Location	Description
UART1-TXD	EXP2- Pin 24	Transmitting data line for UART.
UART1-RTS	EXP2- Pin 26	Input line to the Meridian/P.
UART1-RXD	EXP2- Pin 28	Receiving data line for the UART.
UART1-CTS	EXP2- Pin 30	Output line from the Meridian/P.

Table 3-1: UART pins description of Meridian/p [28]

3.2.2 SENSORS UNIT

Sensor Unit is combined with two sensors and panic button. This device is designed with DS1624 temperature sensor and LIS302DL accelerometer. LIS302DL is three-axis accelerometer and DS1624 is digital temperature sensor. Both are enable to connect with I2C serial interface. In this section has explained the connections of both sensors as well as the panic button. Both are using supply voltage and I2C bus from Meridian/P.

Here using DS1624 of 8-pin DIP (Dual In-line Package). DS1624 consists of two seperate functional units. Those are 256–byte non-volatile E^2 memory and direct–to–digital temperature sensor. [29] E^2 Memory are able to store any information depends on the user desires such as frequency compensation coefficients and direct to digital temperature sensor allows the DS1624 to measure the ambient temperature value in a 13–bit word, with 0.03125°C resolution. [29] For this project using direct to digital function. The temperature sensor and its related registers are accessed through the 2–wire serial interface (I2C bus). [29] In Figure 3-4 shows pins identification and

connections of DS1624. The measurring temperature range is -55°C to 125°C. [29]

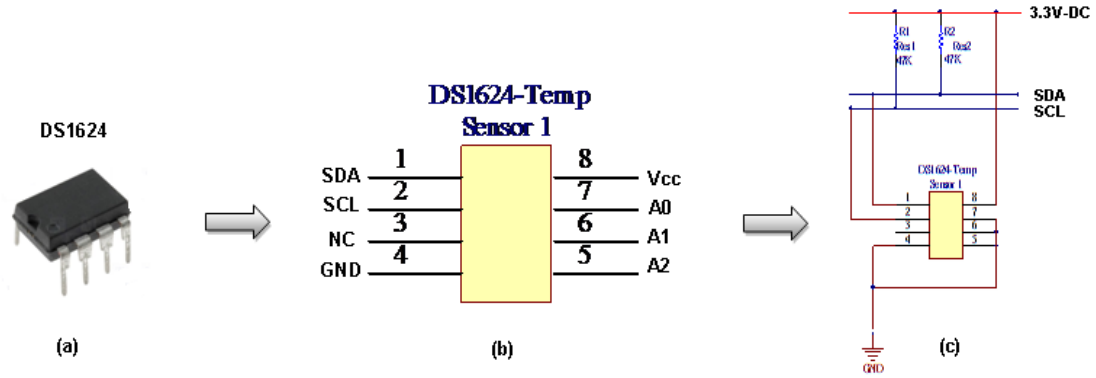


Figure 3-4: (a) View of DS1624 (b) Schematic Pin outline of DS1624 [29] (c) Connection of DS1624

Figure 3-4 shows that Pin-1and Pin-2 is notified SDA and SCL. Both pins are used for I2C bus. So Pin-1 is connected with Pin-20 of Meridian/P and Pin-2 is connected with Pin-22 of Meridian/P. Those are pulled up with 47KΩ resistor. Pin-8 is used for supply voltage so it is connected with Pin-3 of Meridian/P. The output voltage Pin-3 of Meridian/P is 3.3V. DS1624 operates in 2.8V to 5.5V. [29] Pin-3 of this sensor is not connected and Pin-4 is connected with universal ground. Pin-5 to Pin-7, those three pins are called address input pin. [29] In this design all those pins are connected to ground. The input/output capacitance is 10pF and standby supply current is maximum 3µA. [29] Operation of I2C bus and register operations for this sensor is given in section 4.2.1 and section 4.2.4.

In Figure 3-5 shows the view, pins outline and connection of LIS302DL.To monitor the movement of the assisted residence, the wrist-belt is designed with LIS302DL accelerometer. It is an ultra compact low-power (less than 1mW) three axis linear accelerometer. [30] It is designed with sensing element which is capable of detecting the acceleration and an IC interface able to provide the measured acceleration through I2C/SPI serial interface. [30] LIS302DL has dynamically user selectable full scales of ± 2g/± 8g and it is capable of measuring accelerations with an output data rate of 100 Hz or 400 Hz as well as the operating voltage range is 2.16V to 3.6V and temperature range is -40°C to 85°C. [30]

'g' defines the G-forces or gravitational force which is worked with accelerometer [33] It is applicable of the earth, it has two remarkable features: (1) It always directed toward the centre of the earth, and helps in defining the vertical. (2) Directly proportional to the mass of the body. [32] When stationary, the force felt by earth's gravity is 1G, when a body undergoes a change in speed and direction, then the force increases in

proportion to the rate of change. [34] Here 'G' is defined as the acceleration due to gravity, gives feeling of weight for instance a heavier body has less acceleration. [32] The body creates acceleration force in different direction, consequently the force is called Gx,G y and Gz . [32] The measurement information of 'G' and analysis of acceleration due to movement is given in detail in Chapter 5 section 5.2.

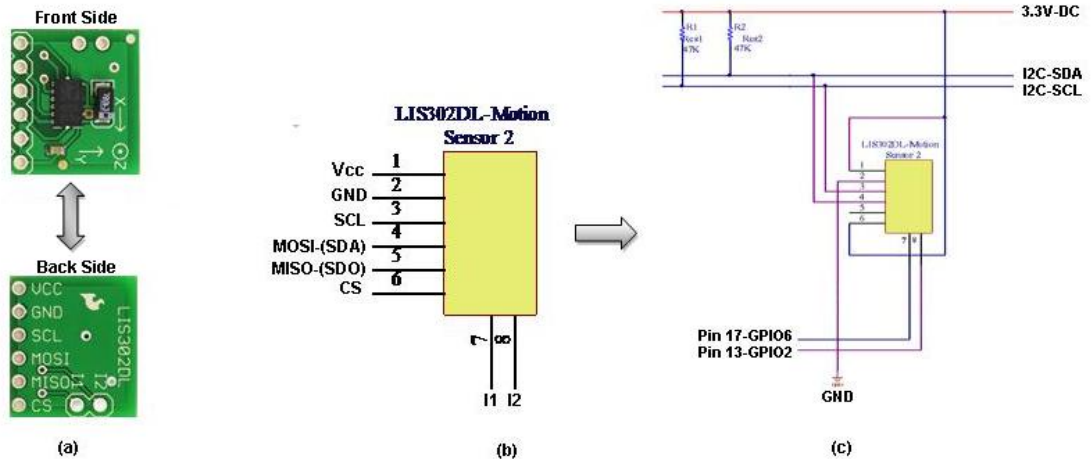


Figure 3-5: (a) View of LIS302DL (b) Schematic pin outline of LIS302DL [30] (c) Connection of LIS302DL

It has 8 pins. Pin-1 is connected with 3.3V of supply voltage which is provided from Pin-3 of Meridian/P. Pin-2 is connected with ground. Pin-3 is SCL. Pin-4 and Pin-5 are notified is as MOSI and MISO. Both pins are used for SPI. MISO (Master Output/Slave Input) and MISO (Master Input/ Slave Output) is used as SDA (Serial Data Address) and SDO (Serial Data Output). [30] [31] Pin-3 and Pin-4 is connected with SCL and SDA. Pin-5 leaves open. Pin-5 is CS. This is I2C or SPI mode selection. [30] The value is 1 for I2C mode and 0 for SPI enabled. [30] So due to using I2C bus connected with supply voltage (3.3V). Pin-7 and Pin-8 is interrupt pin. Both are connected with GPIO pin of Meridian/P. So Pin-7 and Pin-8 are connected with Pin-17 (GPIO6) and Pin-13 (GPIO2) of Meridian/P. The registers mode and bus interface operation is given in Section 4.2.1 and Section 4.2.4.

Panic Button is additionally attached with this wrist belt. In design proposed a panic button which helps assisted people to call for assistance without any speech. This panic button is more applicable some specific people who are unable or hard to speak due to disability. In Figure 3-6 shows the view of proposed panic button, schematic diagram and the connections with Meridian/P.

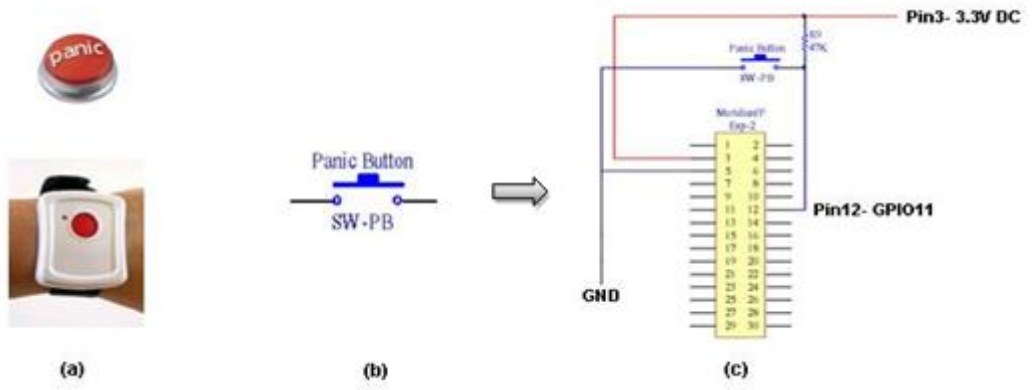


Figure 3-6: (a) Proposed panic button (b) Schematic of Panic Button (c) Connection with Meridian/P

Panic button works as a switch. When panic button is pressed then it makes interruption in the whole system and notified to the InterHome by sending data that assistance is required. It has two pins. One pin is connected with ground and another pin is connected with Pin13- GPIO11 of Meridian/P pull up with 47KΩ resistor. The programming of this panic button given in Section 4.2.2 and the output of panic button is shown in Chapter 5 in Section 5.2.2.

3.2.3 COMMUNICATION UNIT

This unit works only in data transmission operations. The wrist-belt is designed with XBee Module for communicating with InterHome. It is connected directly with Meridian/P microcontroller. The sensor unit sends data to the Meridian/P and it sends data to Smart Home device through XBee. The XBee communication system has been explained earlier in Section 2.6. Figure 3-7 shows the schematic and pin outlines of XBee as well as the connections with Meridian/P. The pins are notified with blue colour means those pins are used for design. Rest of unused pins are connected in a separate hole. So those pins can be used again for different and future applications.

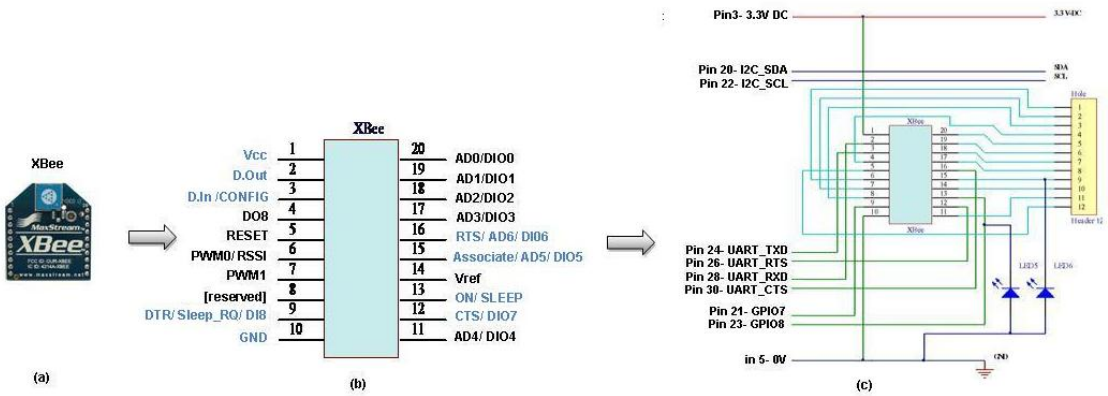


Figure 3-7: (a) View of XBee Module (b) Schematic and Pin identification [25] (c) Connection of XBee

XBee Module of Series1 is used in this device. So it was configured from manufacture. Series 2 needs manually configuration for operation but it provides more security. Some specifications of XBee Modules have given in Table 2-2.

The operation of this unit is based on data receiving and transmitting. So both components are operating as a transmitter and a receiver. The data out from XBee directly enters to Meridian/P. Similarly the data out from Meridian/P directly goes to XBee. Again the data sends towards XBee Module of InterHome. XBee is connected is with Meriden/P through UART pins. Table 3-1 provides information regarding UART pins of Meridian/P.

Pin-1 is connected with the supply voltage 3.3V of Pin-3 in Meridian/P. Pin-10 is connected with ground. Pin-2 is UART data output pin for XBee. [25] So it is connected with Pin-28 of Meridian/P. Pin-28 of Meridian/P is UART1-RXD. This is UART data input pin for Meridian/P. Data received in this pin is processed by internal UART. [28]

In other way, Pin-2 of XBee is UART data input pin. [25] So here makes a connection of this pin with Pin-24 of Meridian/P. Pin-24 of Meridian/P is notified as UART1-TXD. This is transmitting data line for UART. [28] So data is transmitted form Meridian/P to XBee.

Pin-9 and Pin-13, both are connected with GPIO pins of Meridian/P. Pin-9 is an input pin for sleep control line and Pin-13 is an output pin for ON/Sleep mode indicator. [25] Pin-9 is connected with Pin-21of Meridian/P (GPIO7) and Pin-13 is connected with Pin-23 of Meridian/P (GPIO8).

CTS and RTS, Both pins are common in Meridian/P and XBee. CTS means Clear-To-Send and RTS means Ready-To-Send. [25] In Meridian/P, Pin-30 is identified as UART1-CTS which is an OUTPUT signal from Meridian/P and Pin-26 is notified as UART1-RST that is an INPUT line to the Meridian/P. [28]

So CTS-pin of XBee is connected with the RTS-pin of Meridian/P. That means data is flowing from XBee to Meridian/P. In other hand, RTS-pin of XBee is connected with CTS-pin of Meridian/P. Now the data is moving from Meridian/P towards XBee. This operation is shown in Figure 2-3.

Here Pin-12 is a digital input/output pin for XBee; notified as CTS. [25] It is connected with Pin-26 of Meridian/P (UART1-RTS). Pin-16 (RTS) of XBee is connected with Pin-30 of Meridian/P (UART1-CTS).

Additionally two leads are connected with Pin-13 and Pin-15 of XBee; details are given in hardware implementation Section 4.1.

3.2.4 POWER MANAGEMENT UNIT

The designed wrist-belt is portable which provides more independent and flexible movement for assistive residence. So here offers charging system for rechargeable light weight Li-Ion battery. The power management unit consists of DC-DC converter, charging unit and Li-Ion battery. The rechargeable battery provides power for the microcontroller Meridian/P. The testing battery is 3.7V and energy storage capacity is 1230mAH. Figure 3-8 shows the RECOM DC-DC convertor, Schematic of MCP73837 as well as IC placed on MSOP adaptor and schematic USB or AC-DC adaptor.

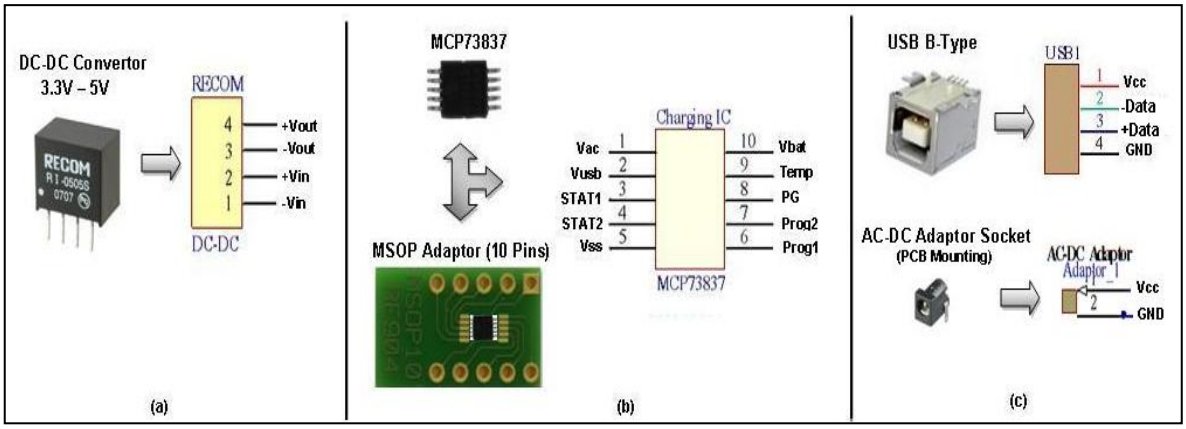


Figure 3-8: (a) Schematic of DC-DC convertor [36] (b) Schematic of MCP73837 [35] (c) USB and AC-DC adaptor socket.

Charging unit is designed with the base on the MCP73837. MCP73837 is battery charging IC with variable voltage regulation range 4.2V to 4.5 and the supply voltage of this is 6V. [35] It works as a charge management controller which integrated autonomous power selection and reverse discharge protection. [35] Autonomous power selection means it has auto selection mode of power source. By using this IC, battery can be charged through USB port or AC-Dc adaptor. When both are connected then it will automatically take power from adaptor. Temperature range of this IC is -40°C t0 85°C. [35]

Here using MCP73837 dimension of 3 mm by 3 mm MSOP. [35] It is very small. To design on the breadboard, this chip is attached on MSOP adaptor shows in Figure 3-8(b). Schematic of Power Management Unit is shown in Figure 3-9 which includes Dc-DC convertor and power source options (USB and Adaptor).

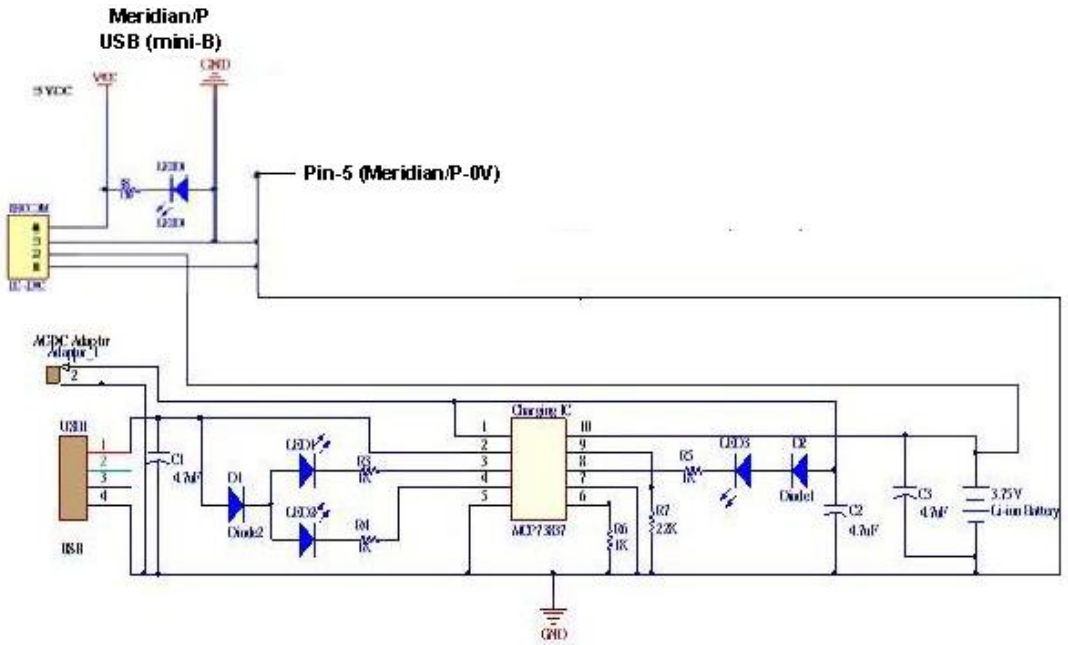


Figure 3-9: Schematic of whole Power Management Unit

Pin-1 is connected with USB port and Pin-2 is connected with AC-DC adaptor socket. Both are connected with a capacitor 4.7µF with ground. [35] The capacitors are connected for constant voltage supply.

Pin-3 and Pin-4, both are charge status output pin. [35] In design both are connected LED with 1kΩ resistor and diode (IN4007). In other way both can be interfaced by microcontroller. [35] Pin-5 is battery management 0V reference so it is connected to the ground. [35]

Pin-6 is PROG1 which is for current regulation setting with AC adaptor and Pin-7 is PROG2 for current regulation setting with USB port. [35] PROG1 is connected with 1kΩ resistor to the ground. It now works in fast mode If PROG1 is float then the IC works as standby mode and the resistor value range is 1kΩ to 10Ω. [35] PROG2 is digital input selection which is for USB port. It works in logic; Low or High. [35]

One unit load charge current when logic Low is selected and five unit loads charge current if logic High is selected. [35] In this design connected to the ground means logic Low. Otherwise proposes to connect a switch which helps to operate charging in different mode.

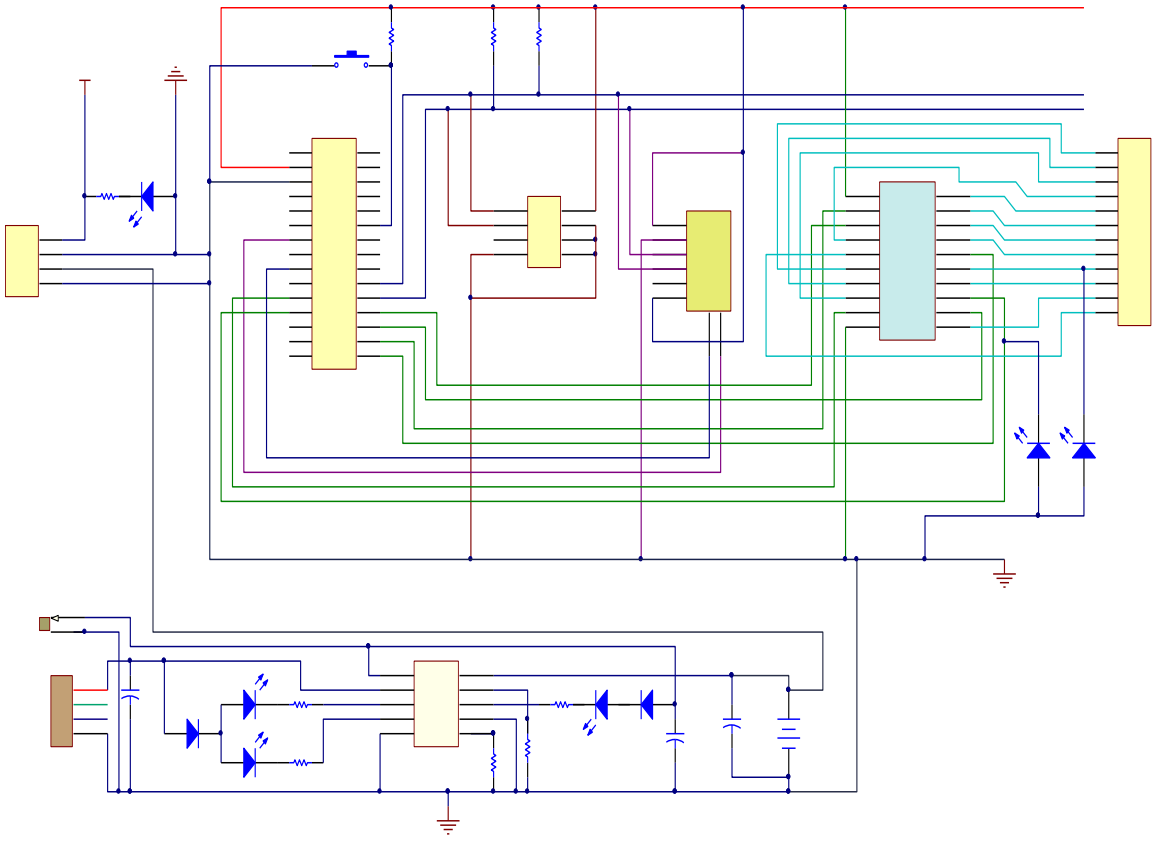
Pin- 8 is called PG (Power-Good) that is for input power supply indication. [35] So Pin-8 is connected with LED, diode (IN4007) and 1kΩ resistor. When power is supplied then is ON.

Pin-9 is for measuring temperature of battery so it is connected with Thermistor. In this design Thermistor is not used. This pin is very essential. If this pin is connected with ground then the battery would not be charged. As the supply voltage drains quickly. As there is an internal 50µA current source for biasing and the thermal resistor range is 2kΩ to 50kΩ. [35] So in this design Pin-9 is connected with 22kΩ resistor.

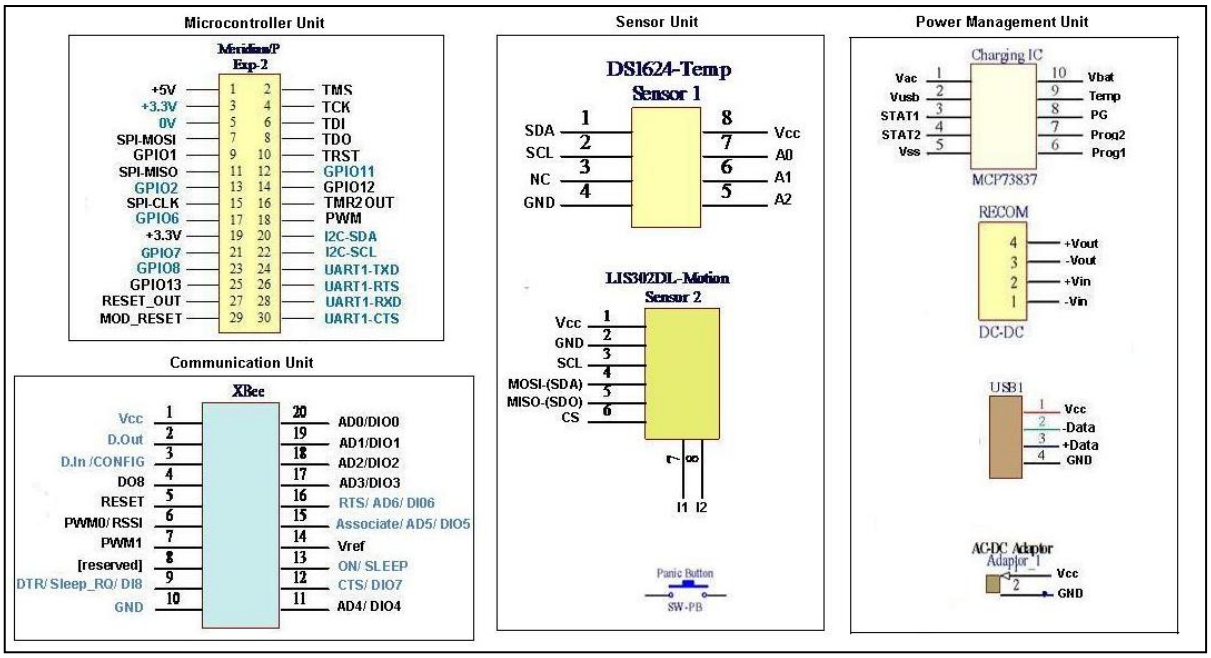
Pin-10 is for Li-Ion battery and ensures to connect with a minimum of 1µF by pass to Pin-5 for loop stability at the time of the battery disconnection. [35] So Pin-10 is connected with positive side of battery and pulled down with 4.7µF for loop stability

The output voltage of Li-Ion battery is approximately 3.75V. But Meridian/P operates in 4.3V to 5V and requires 80mA current as well as it is powered by USB (mini-B). [28] So here use DC-DC step up convertor RECOM. Using RECOM model number ROXX05S which converts 3.3V DC to 5V DC and output current is 200mA. [36] Schematic diagram and pins notification of RECOM are shown in Figure 3-8(a). Pin-1 is $-V_{in}$ and Pin-3 is $-V_{out}$. So both pins are connected with ground. Pin-2 is $+V_{in}$ and Pin-4 is $+V_{out}$. The output from battery (3.75V DC) is connected with Pin-2 ($+V_{in}$). So Pin-4 ($+V_{out}$) gives minimum 5V Dc output voltage which is connected with Vcc wires of Meridian/P USB mini-B (red colour). The wires for data are not being used. So the ground of Meridian/P USB mini-B (Black colour) connects with universal ground. So the wrist-belt runs with rechargeable battery and works as a portable device. The implementation of this unit details in breadboard design in Section 4.1.1

The connections of every unit have described above. All units work simultaneously. In Figure 3-10 show the schematic diagram of the proposed wrist belt. This diagram consists of all units where red colour line provides supply voltage of 3.3V DC and black colour line is universal ground.



(a)



(b)

Figure 3-10: (a) Schematic of the proposed wrist-belt (b) Pin outline of each component

4 IMPLEMENTATION

The proposed design is applied on hardware and software implementation for testing and analysis. After designing on breadboard, the programming code is implemented. So this section describes hardware and software implementation of the proposed design.

4.1 HARDWARE IMPLEMENTATION

This section provides hardware implementation of the design. In this project at first the design is tested by using breadboard design. After hardware testing, the programming code is applied. Breadboard is a prototype for the proposed wrist-belt device. This is not final product. When the breadboard design is finished then upgrades the design in PCB (Printed Circuit Board). PCB provides the pattern for manufacturing. So PCB design includes in hardware implementation describes in Section 4.1.2. .

4.1.1 BREADBOARD DESIGN

Breadboard design gives more flexibility in design. This does not require any soldering. So the components can be added or removed at any time. The main design can be modified at any time. Figure 4-1 shows the view of breadboard.

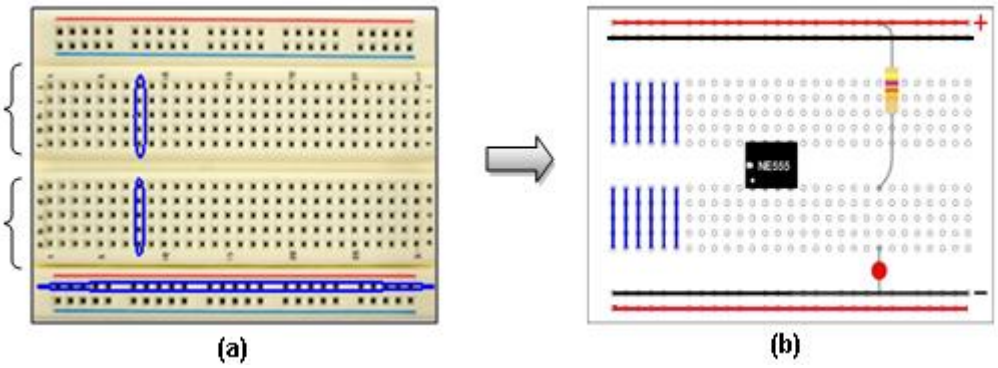


Figure 4-1: (a) View of Breadboard and (b) its operation. [37]

Breadboards have many small socket holes approximately 0.1" on grid. [37] In the centre, there is no connection. DIP ICs are placed on it. Two blocks of 5 holes are placed both sides of the centre line. Those are vertically internal connected which remarked with blue line in Figure 4-1 (a) and (b). The top and bottom rows both are connected horizontally. These two lines of top or bottom can be used as positive and negative polarity of power supply.

In Figure 4-1 (b) shows that an IC on the centre line. So it all of its pins are connected separately. Also shows that a LED is connected with a resistor.
In this project some components requires separate adaptor to place on the breadboard such XBee and Charging IC (MCP73837).

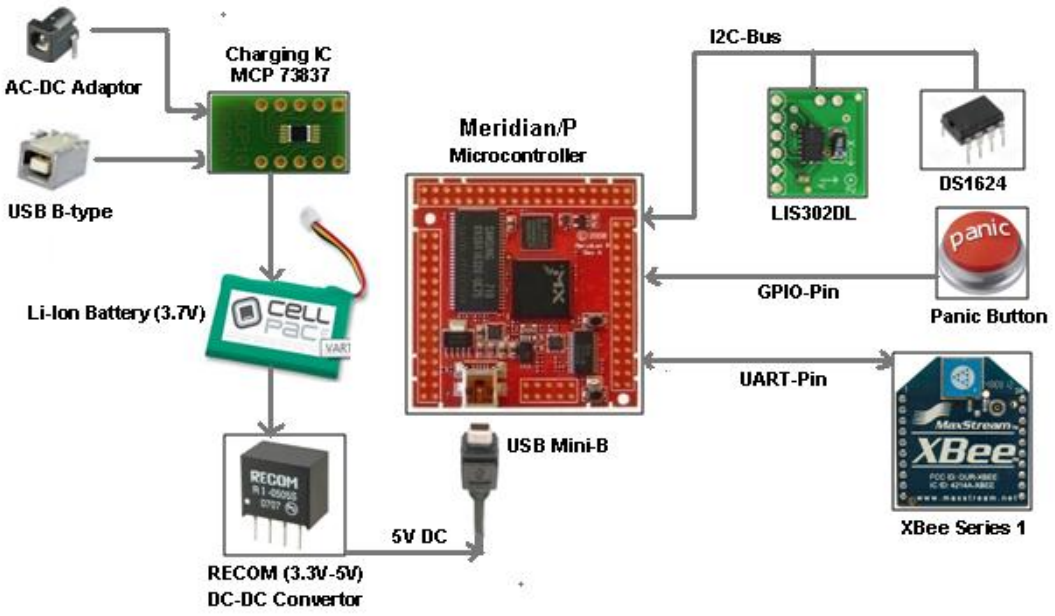


Figure 4-2: The concept for Hardware design

Figure 4-2 shows how the all components are connected with Meridian/P. The hardware implementation is based on this concept. Sensors are connected with I2C bus and XBee Module is connected by UART pins. Panic button is connected with GPIO pin of Meridian/P. The charging unit is connected with Li-Ion battery and power sources. The battery can be charged in two ways; USB or AC-DC adaptor. From powers source 5V Dc supplies to charging IC and it charges the battery (3.75V). The battery is connected with RECOM DC-DC convertor. It converts 3.3V DC to 5V DC. So the output pin connected with USB mini-B. That USB connects with Meridian/P. So Meridian/P runs continuously. Breadboard design is shown in Figure 4-3.

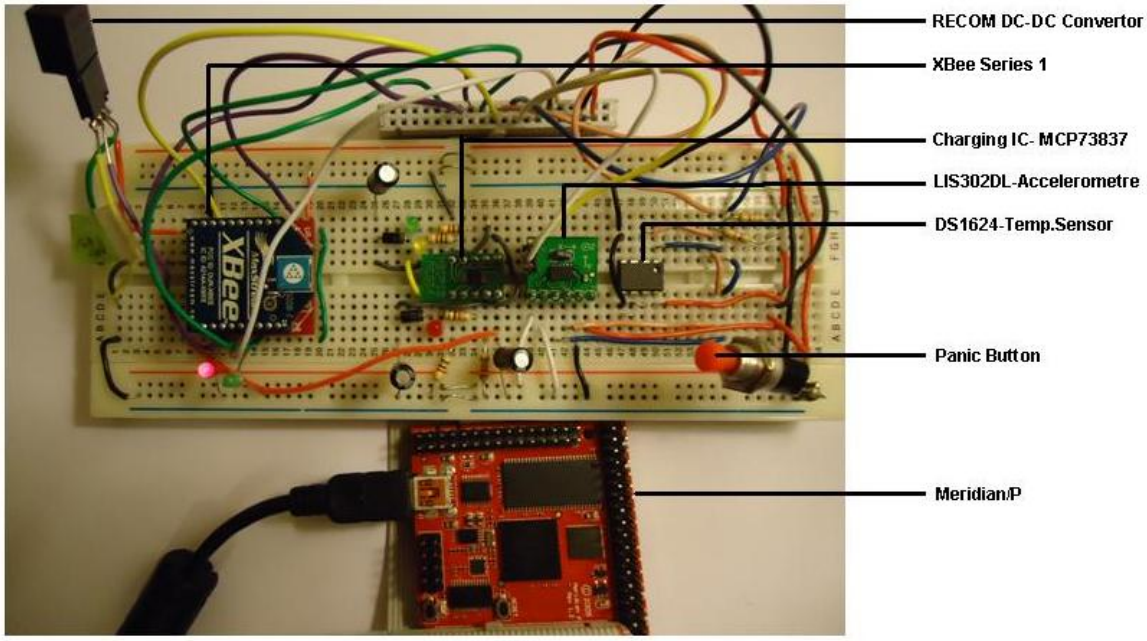


Figure 4-3: Breadboard design of the proposed wrist-belt

4.1.2 PCB DESIGN

Nowadays PCB design is widely used in electric connection system in manufacturing. PCB means Printed Circuit Board. This is design for manufacturing. The Printed Circuit method was invented by Paul Eisler of the UK in 1943. [38] He provided method on the conductive pattern of circuit on a layer of copper foil. [38] Later on the multi-layer and through-hole technique was modified by Hazeltyne of the USA in 1961. [38]

Printed circuit board can be constructed in three different ways; single-sided, double-sided and multi-layers. [38] As well as two other different techniques for electrical connection in PCB board; through-hole technology and surface-mount technology. [38] Surface-mount technology applied to reduce the size of every component. In this project, PCB is designed by using multilayer and through-hole technology.

Here the proposed PCB is designed by using Altium Designer 6.0. This is software for electronic product development. Altium Designer is used for multi-purpose. Altium Designer is more applicable for FPGA –level designing, PCB layout designing and manufacturing.

- At first create a PCB project.
  New project is created by selecting **File>> New >> Project >> PCB Project** from the menu. Project appears in Project browsers. Project name ends with a

.**PrjPCB** extension. Rename the new PCB project by selecting **File >> Save Project As**. Then type the name in the filename field and clock on **Save**.

- Then design schematic under that project.
  Right click on the name of the project then click **Add New To Project >> schematic**. Drag the components from **Library Browser** and design the schematic. Some components are not available in Library Browser. So need to design the schematic for those components.

- Design schematic for new component.
  Right-click on *Project Name* then selects **Add New To Project** then *Schematic Library*. Then click on ***Tool >>New Components***. A dialogue box appears there write down the name of the component. Draw a rectangle by clicking **Place >> Rectangle**. Then add require pins with the rectangle by clicking **Place >> Pin**. This will save on PCB Project under Schematic Library Document by clicking **File >> Save**.

- Add new designed component in Library Browser.
  The design component requires adding to the Library. The components can be added by selecting **Design >> Browse Components**. The **Library Window** appears on the screen. Click on **Search** on then Library Search Window opens. Then mark on Library Path. Gives direction of the path where the component is saved. Then click on **Search**. Finally all comments of the path appear in Library Browse. So drag and add on schematic sheet.
- Design the Footprint for the new component.
  Footprint design of the component is essential for designing PCB. Without footprint PCB cannot be designed. Footprint shows on PCB. Design new footprint for new component by right clicking on Project name then **Add New to Project >>PCB Library**. A blank PCB library Window appears. **Select Tool >>Component Wizard** then PCB Component Wizard Box comes out. Here using DIP IC and measurement unit is in metric. So click **Next >> Select Unit (Metric-mm)>> select Dual-line Package (DIP)**. Click **Next >> Modify the dimension**. It helps to modify dimension by changing value. Then click **Next >> Modify Pin Distance**. This is distance between two pins. Then click **Next >> Modify the width of outline**. Then click **Next >> Change Pin Number**. So this is for

changing pin numbers. Components are varied in pin numbers and configurations. The dimension, pin number and outline width must be similar with the component. All information regarding this can be found in datasheet of the component. Then click **Next >> Change** the Name. So write down the name for the component. Then select **Next >> Finish**.
Then Footprint appears in PCB Library Window. To save click File >> Save. So it saves under PCB Library Document.

- Add new Footprint with the new component
  Now the designed foot print needs to add with the component. So double click on the component from the Library Browser. Then Component Properties Window appears. Select on **Model for (Components_name) >> Add >> FootPrint >> ok**. Then PCB Model Window comes out. Click **Foot Print Model >> Browse**. Select the designed footprint. Then click **Select Footprint >> ok**. So the footprint is added with component and shows on the Component Properties Window.

- Draw the exact size of the PCB board.
  This step is to insert the circuit design on PCB. Click **Home >> Printed circuit Board Design >>PCB Documents Wizard**. Then PCB Documents Wizard window appears. Here using metric unit so select **Metric**. Select **Custom >> Rectangle** as in this project designing rectangle shape device. There are different shapes in the custom option. The size of rectangle modifies. Then select **Next**. The window shows **Single and Power Line** selects **2** and **Thruhole** selects **Two track**. As in this design using PCB of two layers. Then select **Next >> Finish**. So the PCB comes with green colour rectangle.

- Insert the whole schematic diagram on the PCB Board.
  After that transfers the schematic diagram into the PCB. Now selects schematic diagram window then clicks **Design >> Update PCB.doc**. A window appears which shows the connections of all components then selects **Execute Changes**. It takes few seconds for executing. Footprint of all components with connection appears in the PCB window. Then the components are dragged in the green colour PCB board. If all connects are correct then it converts in brown colour.

The dimension of Meridian/P is 38mm x 38mm. So PCB of the proposed wrist-belt is based on this dimension. This proposed PCB will be connected on the top of Meridian/P.

Figure 4-4 shows two PCBs which are designed during work on this project. Figure 4-3(a) is designed without power management unit. The schematic diagram of the wrist-belt shows in Figure 4-4(b) which is inserted on the PCB boards in Figure 4.3(b). But it designed on 48mm PCB board.

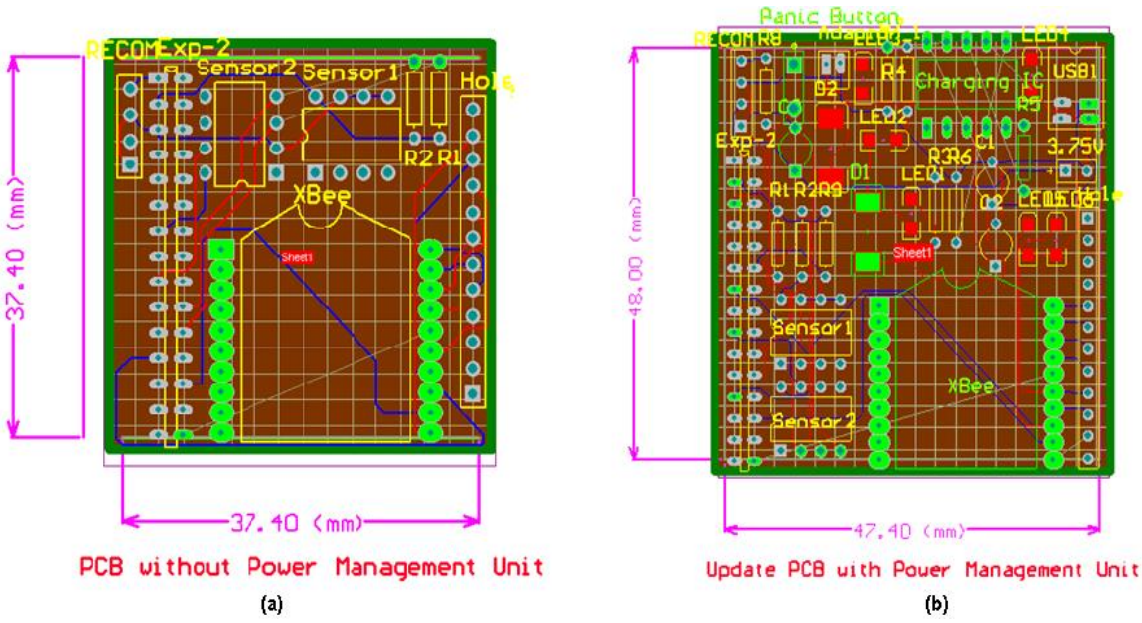


Figure 4-4: (a) PCB without Power Management Unit-37.4 mm (b) PCB with Power Management Unit-48 mm.

In PCB all components are connected with electrically. The connections show lines on the board. Every component is soldered on the board. PCB design is more applicable to reduce the size of circuit. This is less expensive and more reliable way to design for manufacturing.

4.2 SOFTWARE IMPLEMENTATION

The programming code is written for this device in C# on .NET Micro Framework. The .NET Micro Framework is earlier in Section 2.5. The code is written by using Microsoft Visual Studio 2008. This section points out the code for every component.

Meridian/P runs in .NET Micro Framework. It requires downloading Device Solution SDK to work on this microcontroller. Version 3 is used for this project. As well as download .NET Micro Framework 3.5 from Microsoft Website.

Open a new project by selecting **New >> Project**. The window appears shown in Figure 4-5. Select **Micro Framework >> Console application >> OK**.

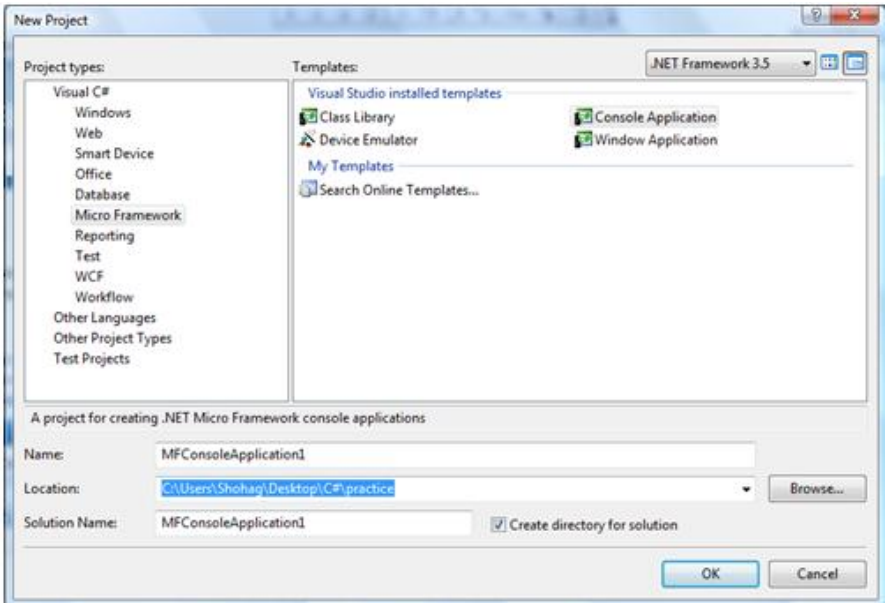


Figure 4-5: New Project window for creat new porject

Then the main project window opens. Sloution Explore windows is in the right-hand side of the main window. Wirte the C# code in Program.cs file. To write the code requires add Refererences. Sometimes requires writing code against an external component so the project must first contain a reference to it. References can be added by right-clicking on the **Reference>> Add References**. Then Add Reference box appears. Select the particular reference and **OK**.

Six references are used in this project shows in Figure 4-6.

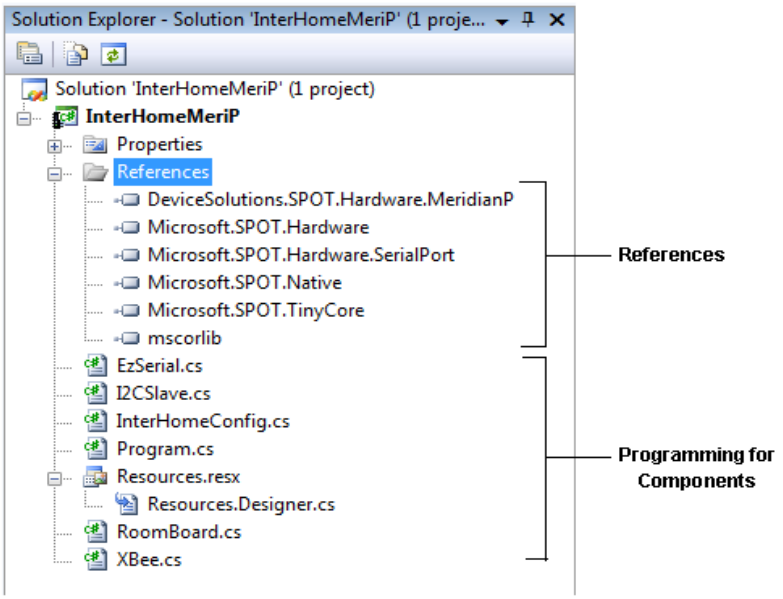


Figure 4-6: Solution Explorer window.

In the code references are added at the beginning then the code is written under public class shows in Figure 4-7. To write reference, starts with using-statement.

```
using System;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using System.Threading;
using DeviceSolutions.SPOT.Hardware;

namespace InterHomeMeriP
{
    public class Program
    {
```

Figure 4-7: Writing references in main programming code.

In this project temperature sensor and accelerometer is coded in RoomBoard.cs. I2C-Bus and serial port are coded separately. All the components are altogether coded in Program.cs.

4.2.1 TEMPERATURE SENSOR AND ACCELEROMETER

In this project using DS1624 as temperature sensor and LIS302DL accelerometer. The codes are for the sensors in RoomBoard.cs shows in Figure 4-8.

DS1624

Program.cs | Object Browser | RoomBoard.cs* | InterHomeMeriP

InterHomeMeriP.RoomBoard

```
public class RoomBoard
{
    #region Drivers for on-board devices

    internal sealed class DS1624
    {
        Fields

        Constants

        Constructors

        Members

        /// <summary> ...
        public byte Config...

        IDisposable Members
    }
#endregion
```

(a)

LIS302DL

Program.cs | Object Browser | RoomBoard.cs* | InterHomeMeriP

InterHomeMeriP.RoomBoard

```
internal sealed class LIS302DL
{
    Fields

    Constants

    Constructors

    Members

    IDisposable Members
}
```

(b)

Figure 4-8: (a) Code for DS1624 (b) Code for LIS302DL

The code is under the class in different block such as Fields, Constants, Constructors etc. To create the block writes down #region region_name. Every block differs in function.

Fields That is for I2C bus configuration. This provides option for time for I2C bus.

Constants It is for declaring the registers. The default address is associated on Slave Address (SDA) for both sensors. The address is 8-bet length.

For DS1624 has seven bits of control byte. The control byte is defined with four bit control code that is 1001 binary and this can operate Read and Write operations. [29] The control byte comes after the START condition from the master device. Three bits are left from control byte. The last three bits are called device select bits (A2, A1and A0). [29] The last bits can perform “Read” and “Write” operation. When last bits are “1” then it works as “Read” operation and “0” for “Write” operation. [29] Here the last bits set all “0”.

Default address for DS1624 is 01001000 in binary. So the number converts in Hexadecimal. It is 48. The all register values for DS1624 insert in constant shows in Figure 4-9(a).

DS1624

```
#region Constants

const int TIMEOUT = InterHomeConfig.I2C_TIMEOUT;
const int BUS_SPEED = InterHomeConfig.I2C_BUS_SPEED;
const byte DEFAULT_Address = 0x48;
const byte REG_IO = 0x00;
const byte REG_MEMORY = 0x17;
const byte REG_CONFIG = 0xAC;
const byte REG_TEMP = 0xAA;
const byte REG_START = 0xEE;
const byte REG_STOP = 0x22;

#endregion
```

(a)

LIS302DL

```
#region Constants

const int CLOCK_Rate = 100;
const byte DEFAULT_Address = 0x1C;
const byte REG_WHO_AM_I = 0x0F;
const byte REG_CTRL_REG1 = 0x20;
const byte REG_CTRL_REG2 = 0x21;
const byte REG_CTRL_REG3 = 0x22;
const byte REG_HP_FILTER_RESET = 0x23;
const byte REG_STATUS_REG = 0x27;
const byte REG_OUTX = 0x29;
const byte REG_OUTY = 0x2B;
const byte REG_OUTZ = 0x2D;
const byte REG_FF_WU_CFG_1 = 0x30;
const byte REG_FF_WU_SRC_1 = 0x31;
const byte REG_FF_WU_THS_1 = 0x32;
const byte REG_FF_WU_DURATION_1 = 0x33;
const byte REG_FF_WU_CFG_2 = 0x34;
const byte REG_FF_WU_SRC_2 = 0x35;
const byte REG_FF_WU_THS_2 = 0x36;
const byte REG_FF_WU_DURATION_2 = 0x37;
const byte REG_CLICK_CFG = 0x38;
const byte REG_CLICK_SRC = 0x39;
const byte REG_CLICK_THSY_X = 0x3B;
const byte REG_CLICK_THSZ = 0x3C;
const byte REG_CLICK_TimeLimit = 0x3D;
const byte REG_CLICK_Latency = 0x3E;
const byte REG_CLICK_Window = 0x3F;

#endregion
```

(b)

Figure 4-9: (a) Register declaration of DS1624 (b) Register declaration of LIS302DL

Similar to the DS1624, the accelerometer defines the default address by SDA. In LIS302DL the 6 bits after the START signal contains the slave address. When the SC is HIGH then START operates at HIGH to LOW operation on the data line. [30]

Master transmits this and makes the bus busy. The last bit (8th) depends on Master's receiving or transmitting mode to the slave. [30] So first Bit is START and then next 6-bit is Slave Address. In this accelerometer Slave Address is 001110 in binary. [30] The last bit is LSB which can be modified by SDO pin. When SDO is connected with supply voltage then LSB is '1'. [30] On other hand if connects with ground (GND) then LSB '0'. In this design SDO is grounded so LSB is '0'. [30]

So default address of LIS302DL is 00011100. [30] Now convert in hexadecimal that is "1C". All registers including default register mapping show in Figure 4-5(b). There all values are inserted in constant.

Constructors It defines as class methods that executed when an object is created [39] Here the objects are defined in Constant block.

The constructor is called I2C bus time out, bus speed and default address for DS1624 and addressed clock rate and default address for LIS302DL.

Members It is located the resister mapping except default register. It defines the register address operation mode. Both sensors are worked as a slave device. After START the slave address is sent. I2C Slave Address can operate in Read/Write Mode. In this block the operation mode is defined. If the register address is only Write-mode then it works in set-statement. When the register address is only Read-mode then it works in get-statement. In other hand when the register address is in Read/Write then it uses both statements. The output can get from only Read type register.

Figure 4-10 shows the Member-Block only for the Start Conversion Temperature register of DS1624. Here using only set-statement as the I2C Slave Address of Start Conversion register is only in Write-mode.

```
#region Members

public byte StartConversion
{
    set
    {
        try
        {
            /*
            using (I2CSlave _slave = new I2CSlave(_deviceAddress))
            {
                _slave.WriteRegister(DS1624.REG_START, _dataBuffer);
            }
            */
            I2CSlave.WriteRegister(config, REG_START, _dataBuffer, TIMEOUT);
        }
        catch (System.IO.IOException e)
        {
            Debug.Print(e.Message);
        }
    }
}
```

Figure 4-10: Code for inside the memory-block of DS1624

In LIS302DL, Ctrl_Reg3-register is mapped in Read/write mode and HP_Filter_Reset-register is only Read mode. Figure 4-11 shows that both statements are used for Ctrl_Reg3 register and only get-statement is used for HP_Filter_Reset-register.

```
public byte Ctrl_Reg3
{
    set
    {
        I2CSlave.WriteRegister(_deviceConfig, LIS302DL.REG_CTRL_REG3, value, _timeOut);
    }
    get
    {
        I2CSlave.ReadRegister(_deviceConfig, LIS302DL.REG_CTRL_REG3, _dataBuffer, _timeOut);
        return _dataBuffer[0];
    }
}

public byte HP_Filter_Reset
{
    get
    {
        I2CSlave.ReadRegister(_deviceConfig, LIS302DL.REG_HP_FILTER_RESET, _dataBuffer, _timeOut);
        return _dataBuffer[0];
    }
}
```

Figure 4-11: Code for inside the memory-block of LIS302DL

`IDisposable Members` This requires for dispose any objects. It performs to release any allocated resources. This method is not applied in this project.

DS1624 starts conversion at the register value of EE in hexadecimal. [29] The measurement range for LIS302DL accelerometer is ±2g to ±8g. [30] But it depends on the Full Scale (FS) selection, the default of FS is '0' for acceleration range of ±2g. [30] If FS bit of the register sets to '1' then it measures acceleration at the range of ±8g. [30] FS bit is used in CTRL_REG1. This is 8-bit register and the value is 20 in hexadecimal. The bit outlines are described in Table 4.1.

CTRL_REG1 (20h)

CTRL_REG1 (20h) register

DR	PD	FS	STP	STM	Zen	Yen	Xen

CTRL_REG1 (20h) register description

DR	Data rate selection. Default value: 0 (0: 100 Hz output data rate; 1: 400 Hz output data rate)
PD	Power Down Control. Default value: 0 (0: power down mode; 1: active mode)
FS	Full Scale selection. Default value: 0
STP, STM	Self Test Enable. Default value: 0 (0: normal mode; 1: self test P, M enabled)
Zen	Z axis enable. Default value: 1 (0: Z axis disabled; 1: Z axis enabled)
Yen	Y axis enable. Default value: 1 (0: Y axis disabled; 1: Y axis enabled)
Xen	X axis enable. Default value: 1 (0: X axis disabled; 1: X axis enabled)

Table 4-1: Register CTRL_REG1 description [30]

The output data range of I2C bus picks 100Hz by selecting DR equals to ‘0’. Here FS sets to ‘1’ as well as enable x, y and z axis. The power down control sets to ‘0’. So the value for Zen, Yen and Xen sets to ‘1’. In this project self test mode is not used. So STP and STM sets to ‘1’. So set the value for CTRL_REG1 is 01100111 in binary. If converts the value in hexadecimal is 67.

So writes the code for accelerometer and temperature sensor. The output data of accelerometer is read by OUT_X, OUT_Y and OUT_Z register. The written code for temperature sensor and accelerometer is shown in Figure 4-12.

```
public  RoomBoard(int address)
{
    _address = address;
    _temp = new DS1624(_address);
   _accelometer = new LIS302DL ();

    _outputs = new bool[8];
    _inputs = new bool[8];

    for (int i = 0; i < _outputs.Length; i++)
        _outputs[i] = false;

       _temp.StartConversion = 0xEE;

       _accelometer.Ctrl_Reg1 = 0x67;

}

public int[] GetAccelerometerValue()
{
      int[] xyz = new int[3];

      xyz[0] = _accelometer.OutX;       //The output value for x-axis.
      xyz[1] = _accelometer.OutY;       //The output value for y-axis.
      xyz[2] = _accelometer.OutZ;       //The output value for z-axis.

    //Debug.Print(_accelometer.ToString());
   return xyz;
}
```

Figure 4-12: Measurement code for temperature sensor and accelerometer

4.2.2 PANIC BUTTON

The panic button is connected with a GPIO11 of Meridian/P. Define the panic button as ipPanic by using interrupt port in main function. The port resistor mode is disabled and indicated GPIO 11. If panic button is pressed then the system is interrupted by defining time.

Figure 4-13 shows that GPIO pin is defined by using if-statement. By using Thread.sleep method sets priority for interrupt and duration. Here sets 500ms for panic button. By pressing button the system interrupts for 500ms and sends the data through serial port to XBee. Here use debug.print so it prints the text by string and xbee.Write Data method. So the receiver prints the same statement “Need Assistant”. The code shows in Figure 4-13.

```
static void ipPanic_OnInterrupt(uint data1, uint data2, TimeSpan time)
        {
           bool GPIO_Pin11 = true;

        //    while (false)
        //    {
              if (ipPanic.Read() == true)
              {
                  GPIO_Pin11 = !GPIO_Pin11;
                  Thread.Sleep(500); //Thrad used for time. So it will stop for 500ms.
                  Debug.Print(DateTime.Now.ToString() + "|" + ipPanic.Read().ToString());
                  text += DateTime.Now.ToString();
                  Debug.Print("Need Assistance");
                  xbee.WriteData("Need Assistance");
              }

       //     }
        }
```

Figure 4-13: Programming code for Panic Button

4.2.3 EMBEDDED DEVICE

The concept of this project is based on an embedded device. This section introduces how the code addressed all components together. The code for embedded device is written in Program.cs. In Figure 4-14 shows that the components are defined under the class library. Then each component is defined. Here XBee using COM1 serial port and declares RoomBoard. It prints “initialising...” when the device starts debugging. When initialising completes then a massage appears on screen “initialising complete”.

```
namespace InterHomeMeriP
{
    public class Program
    {
        private static RoomBoard room1;
        private static XBee xbee;
        private static string text;
        private static InterruptPort ipPanic;

        public static void Main()
        {
            Debug.Print("Initialising...");

            room1 = new RoomBoard(0);
            xbee = new XBee("COM1");
            xbee.DataReceived += new XBee.DataReceivedHandler(xbee_DataReceived);

            ipPanic = new InterruptPort(MeridianP.Pins.GPIO11, true, Port.ResistorMode.Disabled,
            Port.InterruptMode.InterruptEdgeHigh);
            ipPanic.OnInterrupt += new NativeEventHandler(ipPanic_OnInterrupt);

            StartTimer();

            Debug.Print("Initialisation complete");

        }
```

Figure 4-14: A part of code for embedded device in Progarm.cs

Figure 4-15 shows the output code is written. The output comes out in text. First it shows the temperature, then the value of x-axis, y-axis and z-axis of the accelerometer. It prints on during debugging as well as it shows in text on the receiver. The received data from the device is shown and analysed Section 5.2.

```
static void xbee_DataReceived(object sender, XBeeDataReceivedEventArgs e)
        {
            Debug.Print("Received something");
        }

        private static void UpdateTick()
        {
          Thread.Sleep(200);
          text = room1.Temperature.ToString() + "|" + room1.GetAccelerometerValue()[0].ToString() + "|"
             + room1.GetAccelerometerValue()[1].ToString() + "|" + room1.GetAccelerometerValue()[2].ToString()+ "|";

            text += DateTime.Now.ToString();
            Debug.Print(text);
            xbee.WriteData(text);
        }
```

Figure 4-15: Code for output of the embedded device.

4.2.4 I2C-BUS OPERATION

DS1624 and LIS302DL are connected with Meridian/P through I2C two wires bus. This bus is described in section 2.4. It has data transmission protocol. The device is worked as “transmitter” when the device sends data to the bus. [29] It acts as “receiver” when receives data from the bus. The device is called “master” when it controls the data, and if the device is controlled by the master then called “slave”. [29] DS1624 and LIS302DL, both are worked as slave device shows in Figure 4-16. [29] [30] Both sensors operate in START and STOP condition. The “master” generates a clock signal is Serial Clock (SCL). [29]

```
public static class I2CSlave
    {
        private static I2CDevice _slaveDevice = new I2CDevice(new I2CDevice.Configuration(0, 0));

        private static byte[] _registerBuffer = new byte[1] { 0x00 };
        private static byte[] _writeBuffer = new byte[2] { 0x00, 0x00 };
```

Figure 4-16: Code from I2C.cs

When the data and clock lines both are in HIGH then the bus is not in busy condition. So that is time to transfer data. In I2C bus, data transfer starts when the bus is not busy. [29][30]

If the data line changes from HIGH to LOW but the clock line remains HIGH. The situation is called START condition. There one clock pulse per bit of data. [29]

After START condition the data is valid till the data line remains HIGH of the duration of clock signal. [30] Unlimited data can be transferred after START condition till STOP, but it is specified by the “master” device.

The bus can transfer data in two modes explained in Section 2.4. Those are called regular mode (100Kbit/s) and fast mode (400kbit/s). [22] Here the sensors can run transfer in both mode but selects regular mode (100Kbit/s) for both sensors.

After receiving data, the receiving device generates an acknowledgement. It is compulsory to transfer data with acknowledge. [30] During the acknowledge pulse the transmitter release the data line. The data line stables LOW at the HIGH period of acknowledgement related clock signal. [30]

When stops generating acknowledge bit on the last byte then the “master” sends notification of the data ending. [30] The slave makes the data line form LOW to HIGH and the “master” initialises STOP condition. [30]

4.2.5 SERIAL PORT

Here using standard serial port COM1 in .NET Micro Framework. XBee communicates by using serial port.

```
public static void Main()
        {
            Debug.Print("Initialising...");

            room1 = new RoomBoard(0);
            xbee = new XBee("COM1");
            xbee.DataReceived += new
            XBee.DataReceivedHandler(xbee_DataReceived);
```

Figure 4-17: Code written in main function declares XBee.

5 TESTING AND RESULT ANALYSIS

The proposed device is testing after designing the hardware and programming. This chapter describes on the results which got from the hardware and software implementations. In Section 5.1 focused on the hardware testing. This testing is basically based on the breadboard design. But software testing is on the programming code and analysed on the outputs that get from the designed device in Section 5.2.

5.1 HARDWARE

After designing the circuit on the breadboard measures the output voltage of different points by using multi-meter. The whole device is powered by Meridian/P. Pin-3 of Meridian/P is used here as source for 3.3V for the sensors. The system requires approximately 305mA current that is measured by multi-meter. Some components are connected with LED in the breadboard. Those LEDs give indication. Those LEDs can be used for testing as well.

Two LEDs are connected with XBee module. Pin-13 of XBee defines as Module Status Indicator and Pin-15 is notified as associate indicator. [25] Pin-13 connects with red colour LED and Pin-15 connects with green colour LED. When the system is running then the Red-LED turns ON and Green-LED blinks continuously is shown in Figure 5-1

Three LEDs are used in Charging IC. Pin-8 is for power supply indication which is connected with Red-LED. Pin-3 and Pin-4 are called STAT pin for charging IC. [35] The details of connection are provided in Section 3.2.4. Green-LED connects with Pin-3 and Yellow-LED connects with Pin-4. When the Li-Ion battery is on charged then the Red-LED and Yellow-LED turn on. When it finishes charging then both LEDs are turned OFF. Green-LED is for charging status indicator which is for interfacing by microcontroller.

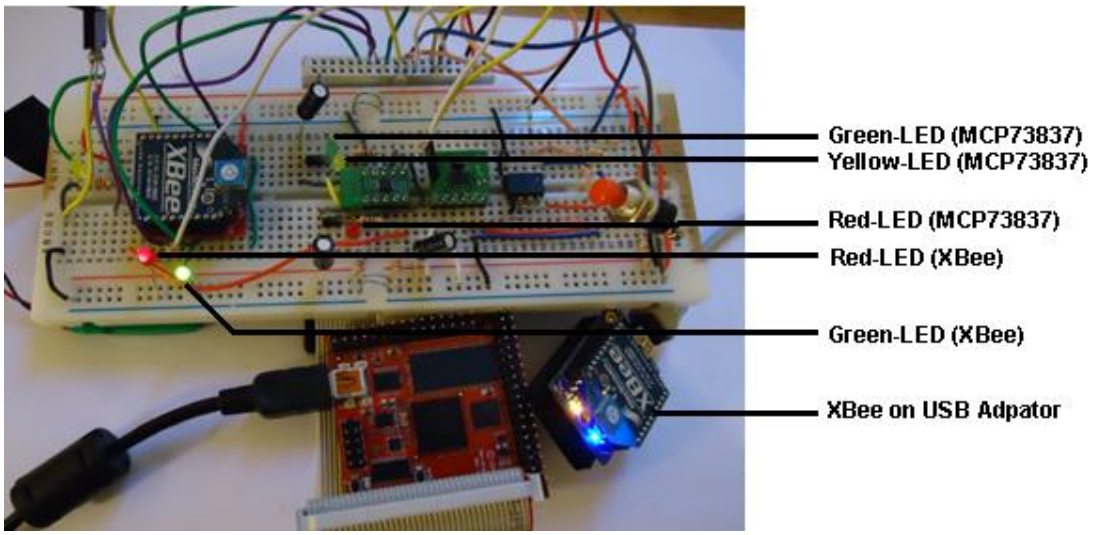


Figure 5-1: Hardware Testing

A Yellow-LED connects with RECOM DC-DC converter. This converts 3.3V DC to 5V DC. The Li-Ion battery is connected with V_{in} -pins (Pin-1 and Pin-2). These pins are used for input supply. The LED is connected in series with V_{out} -pins (Pin-3 and Pin-4). It turns ON when the system runs by the battery. That means the supply voltage has converted.

After designing on breadboard, the transmission of the system can be checked by using another XBee. This separate XBee is connected on the XBee USB Adaptor shows in Figure 5.2. This is counted as receiver XBee.

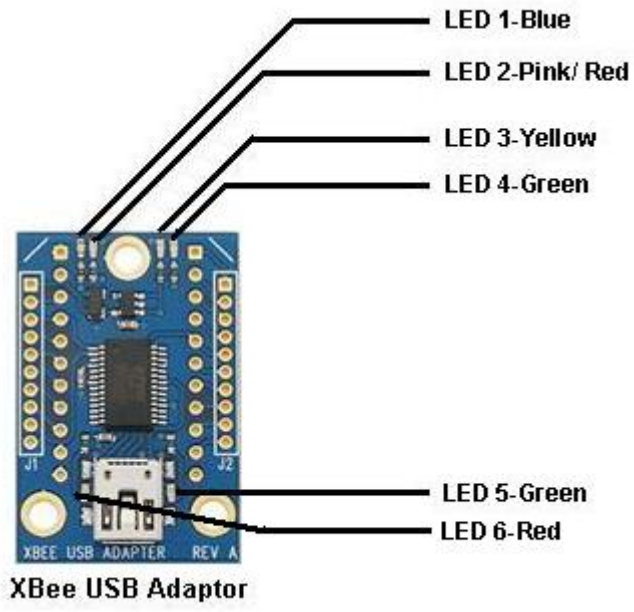


Figure 5-2: XBee USB Adaptor [40]

When the designed system turns OFF means no data transmission then LED-1(Blue) and LED-5 (Green) turn OFF. LED-2 (Pink/Red) consists of two LEDs. LED-2 turns in Red colour and it blinks. LED-3 (Yellow) and LED-4 (Green) turn ON.

If the designed device turns ON then the receiving XBee changes the colour of LEDs. LED-1(Blue) turns ON and LED-2 turns ON in Pink colour with blinking that means the receiving XBee has got network of another XBee. That shows in Figure 5-1. As well as the transmission process is running. LED-3 (Yellow) and LED-4 (Green) keep ON.

LED-6 (RED) turns ON at the beginning.

The designed hardware device is working properly. The system is tested and analysed in above.

5.2 SOFTWARE

The programming code is written in C# language on .NET Micro Framework. It is written in Microsoft Visual Studio 2008.The written code is applied on the hardware design through Meridian/P. So the designed device is connected with a PC. The code is implemented on the device through that PC. The code has already discussed in Section 4.2.

The accelerometer measures the body movement form -8g to +8g. G-force or Gravitational Force is described earlier in Section 3.2.2. It can be varied in different axis. In this section the output of the device is analysed. The measurements of LIS302DL and DS1624 describe in this section.

The accelerometer measures the movement according to x-axis, y-axis and z-axis. The G-force can be found in three position of the body. Gx is the movement for front-to-back, Gy is for side-to-side and Gz is for head-to toe. [34]

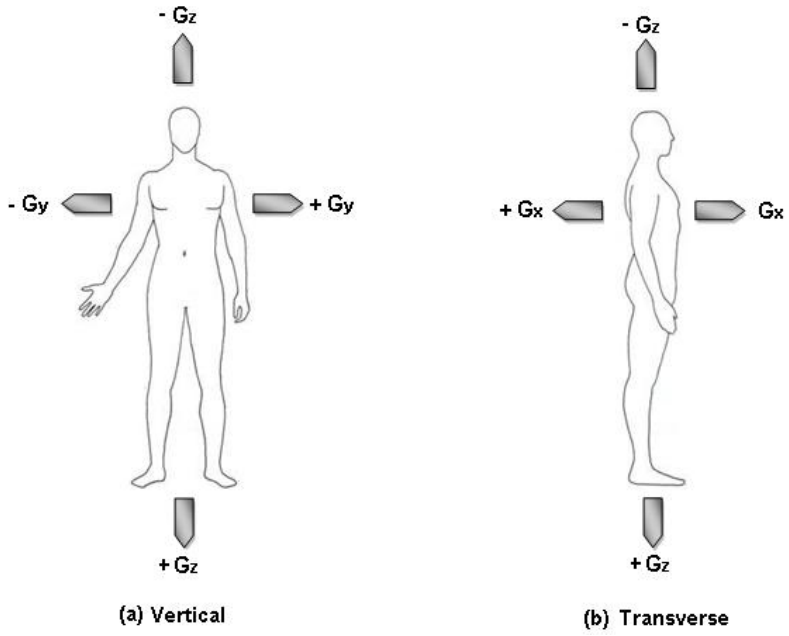


Figure 5-3: (a) Direction of G-force of body in vertically (b) Direction of G-force in transversely [34]

Figure 5-3 (a) shows that Gy varies side-to-side vertically. If the body moves towards left hand side then Gy is positive. [34] That means Gy is increasing. If it moves right hand side then Gy is negative. It means theat Gy is decreasing.

Figure 5-3 (b) shows that Gx changes front to back in transverse way of the body movement. It increases if body moves forward. [34]

Gz is common in both Figures. It varies in the movement of head to toe. Gz changes from high and low at the time of the body moving towards the space. [32]

So here the LIS302DL accelerometer gets data in Gx, Gy and Gz according to the movement of body. By pressing **F5** in Microsoft Visual Studio 2008 debugs the whole programming code. The output box shows the output of the system. All data come out together. Then the designed device moves in different directions.

First data is for temperature sensor, then x-axis, then comes y-axis and z-axis. The date and time show after those values.

5.2.1 OBSERVATIONS FOR TEMPERATURE SENSOR AND ACCELEROMETER

For testing the temperature, touched the temperature sensor. The output value of DS1624 increases towards high. The sensor gets the body temperature and increases to high. It goes low after releasing the touched body.

The values of LIS302DL differ in movement of the device. The accelerometer is tested free-fall and analysed the data in various positions that explained below.

At first observation makes the device still or slightly moves. If the designed device does not move fast or remain still then the value is not rapidly increased or decreased. Figure 5-4 shows the output of the system with graph. The graph is drawn according to the output data. In the graph Blue-line is for x-axis, Red-line is for y-axis and Green-line is for z-axis. No axis gives any extreme high value. So it is not falling or moving fast towards any direction.

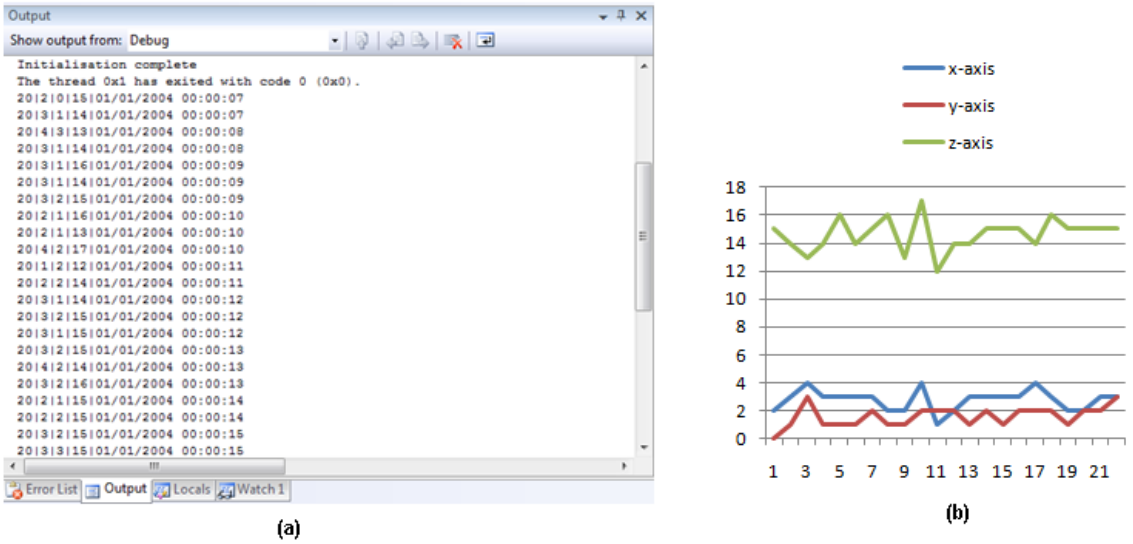


Figure 5-4: (a) Data of normal movement (b) Graph of the normal movement

The device moves falling towards forward in second observation. After few seconds the value of x-axis is increased rapidly. If the body moves forward then Gx increases. [35] So the x-axis gets high value for accelerometer. The x-axis value remains HIGH for long time as the observation time was long for slowly failing towards front. The data and the graph shows in Figure 5-5.

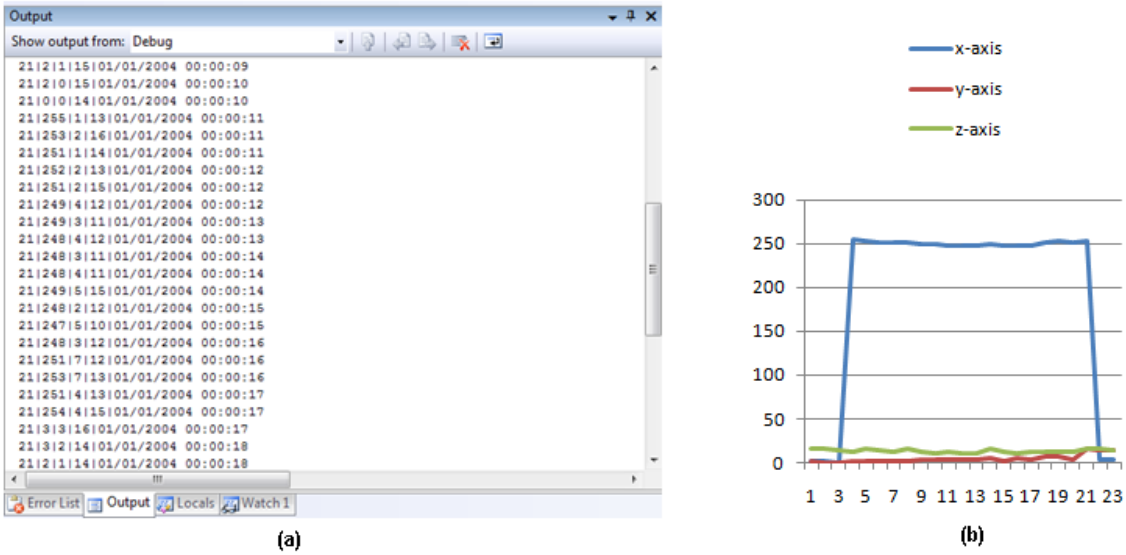


Figure 5-5: (a) Data of falling towards forward (b) Graph of the output

For third observation, the designed device moves towards left hand side in front direction. So the output data of x-axis and y-axis increase at a time. Because the device moves forward so x-axis remains HIGH. As well as the device moves toward left hand side so y-axis increases. After few seconds x-axis, y-axis and z-axis all are remain stable shows in Figure 5-6. That means no fast movement. So the device falls towards left hand side in forward direction and there is no rapid movement after falling.

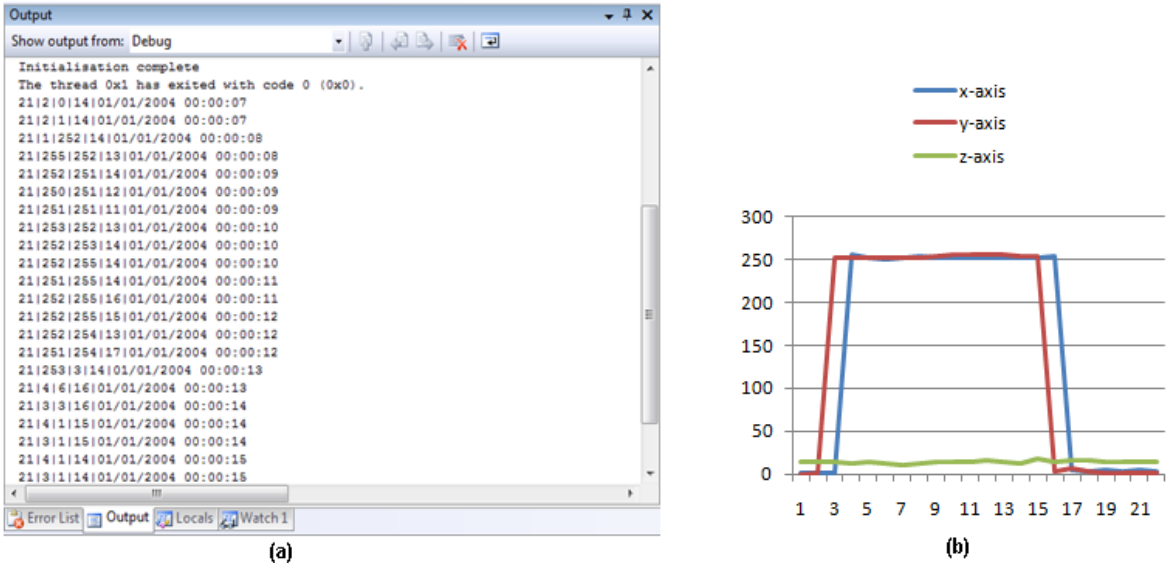


Figure 5-6: (a) Data of falling towards left-hand side in forward way (b) Graph of the output

The device is tested failing towards right in forward direction at the last observation of accelerometer. Gy gets decreasing for right side movement of the body. [34] The value of x-axis goes HIGH due to rapid moving towards forward. The y-axis values decrease

as the device moves on right hand side. All are shown in Figure 5-7. Similar to the rest 2nd and 3rd observations, after few seconds the data remain stable. So there is no extreme movement of the body after falling on the surface.

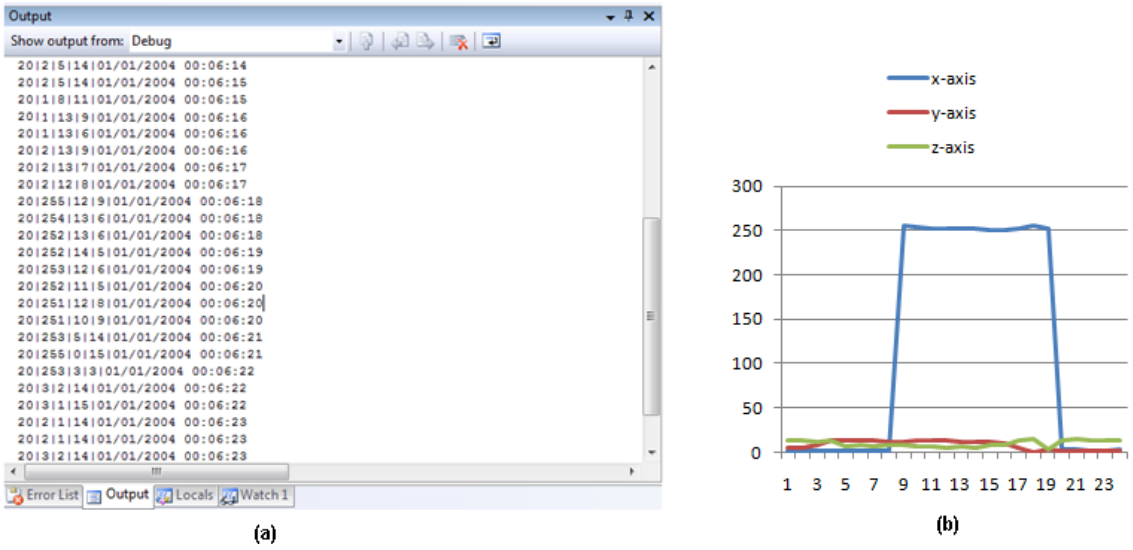


Figure 5-7: (a) Data of falling towards right-hand side in front way (b) Graph of the output.

From these observations, it is identified temperature, falling and movement of the user of this proposed wrist-belt.

5.2.2 OBSERVATION OF PANIC BUTTON

Panic button is connected with a GPIO pin of Meridian/P. This button is used for asking help. When the button is pressed then the system is interrupted. The system sends data for this interruption. If the button is touched by no means the system will not be interrupted. So it can not send data for asking help. For asking assistance, the button needs to hold for few second. After pressing the button, it shows on the output window in Figure 5-8.

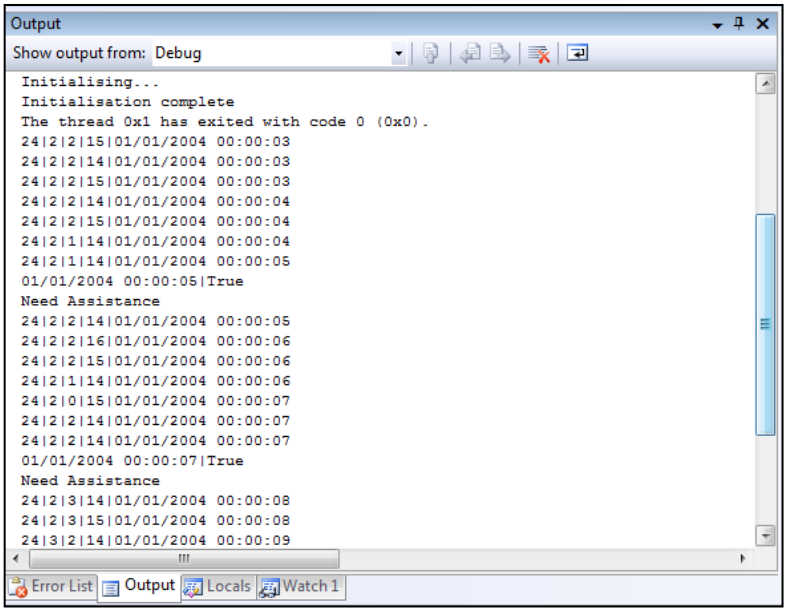


Figure 5-8: Operation of Panic Button

5.2.3 OBSERVATION OF DATA TRANSMISSION

The wrist-belt monitors the user for 24 hours. So the data transmissions never stop. For testing here uses another XBee Module as receiver. The receiver XBee is connected with the InterHome system. The receiver XBee is connected on the top of XBee USB Adapter. There are some LEDs with USB. Those show some indications as well. The details are given in Section 5.1 on hardware testing. To observe the data transmission use PuTTY in the PC.

PuTTY works as an open source terminal emulator application for SSH, Telnet and Rlogin network protocol. [41] The given protocols are used for operating a remote session on the PC through a network. [41] It shows the display of the running session.

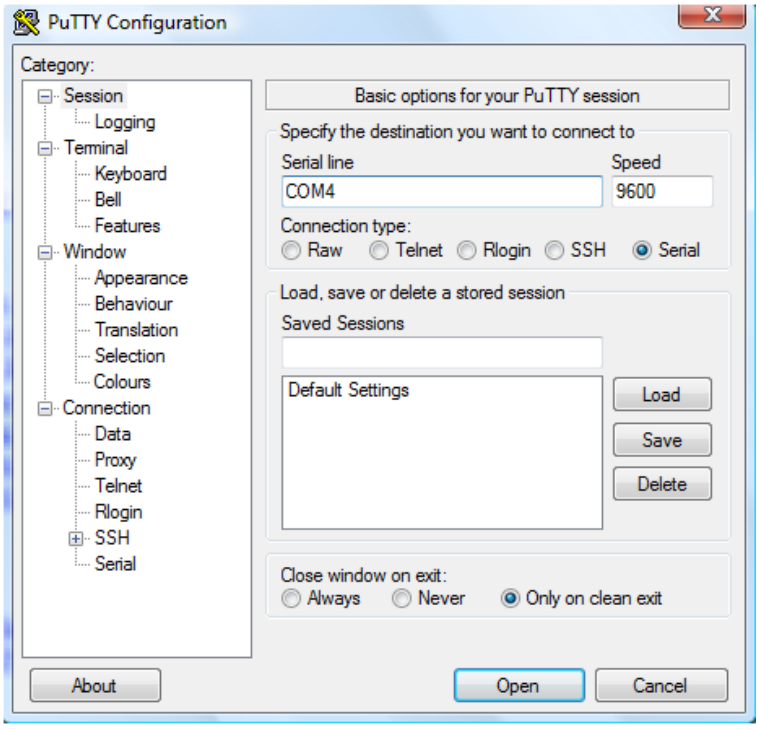


Figure 5-9: PuTTy window

PuTTy runs in all operating system. The PuTTY comes out with the window shows in Figure 5-9. Serial port is used as connection mode for this project. When the receiving XBee connects with USB adaptor then after installation it informs about the connected serial line. “COM4” is used as serial line with interface speed of 9600 bps. All are selected in Figure 5-9.

PuTTy runs after selecting **Open**. Two XBees are connected in a network. The designed wrist-belt sends data and the receiving XBee is picked those data. The data is sending through wireless network continuously. The device sends the data of temperature sensor and accelerometer shows in Figure 5-10. In case of emergency, if the users press panic button for asking help. It shows on the PuTTY display window by writing “Need Assistance”. It is marked by blue underline in Figure 5-10.

Figure 5-10: Data transmission in running session of PuTTY by using COM4

The display window of PuTTY is normally in black colour. But Figure 5-10 is inverted for clear observation.

CH-6 PROJECT MANAGEMENT

Proper project management requires to progress for a project. This chapter focused on project time management, resource analysis and risk assessment. At first made an effective project plan. Literature search was done at the beginning of the project. Then researched on the require components. After that a paper based design was made. The design implemented on the breadboard. So the hardware design can be modified. Some modifications have done. The programming code applied on hardware design after working on the programming. Then whole designed device was tested.

6.1 TIME MANAGEMENT

Time management is essential in project. The Project plan is made on the consideration of components ordering. Testing is very time consuming part of the project. In every step of progress is checked. So the project is tested at the time of designing and implementation. Sometime many components require extra time to receive. In that time the project is progressed by developing another area. Some allocated tasks are worked at a time. The proposed project plan is shown in Figure 6.1 with the based on working days.

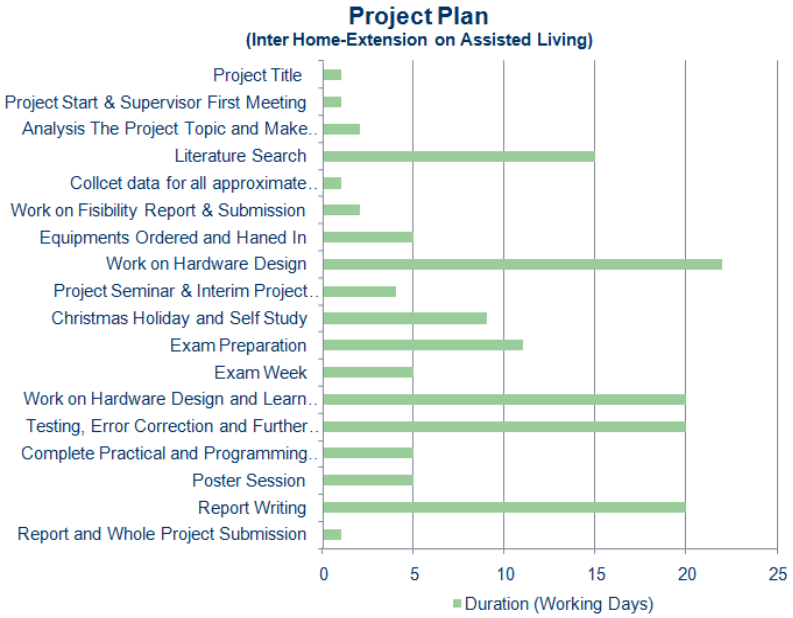


Figure 6-1: Summery of proposed the project plan

6.2 RESOURCE ANALYSIS

This embedded device is designed on then Meridian/P microcontroller. All components are visible in market. Some components require separate adaptor to connect on the breadboard. Here XBee and Charging IC need adaptor to connect on the breadboard. That's why the additional cost in hardware has been increased.

In the software design, Microsoft Visual studio 2008 Professional is provided and PuTTY is downloaded free from online. There is no cost in software development.

6.3 RISK ASSESMENT

This embedded device is wearable so it is designed to consider the human body. So the risks of any danger are considered. This device is powered by Li-Ion battery. The microcontroller requires 5V DC and 80mA current. [28] The whole device need approximate 300mA of current. It operates at very low voltage and current. So there is no risk of electric shock. The proposal PCB is designed on 48mm. So the final product would be very light weight to bind on wrist.

7CONCLUSION

The aim of this project is to design a device for assistive residence which will send data wirelessly to the existing Smart Home system called InterHome. By sending data, the embedded device monitors and updates the health condition of the assistive residence. So a wrist-belt is proposed which is for 24 hours home-based health monitoring system.

The device is designed with the Meridian/P, body sensors and XBee. By using XBee, the device transmits data to the receiver is shown in Section 5.2.3. So the main aim of this project has successfully achieved.

Additionally Power Management Unit is added for charging the battery. This unit is working properly. So the device can work as wireless and portable device.

So the wrist-belt is low-cost and remote monitoring system which has been developed. It enables to provide an assistive person to retain independent lifestyle while he or she still is being monitored. It provides long-term data and continuous monitoring. The device provides more security as well. The designed system has the potential to reduce additional health care service costs by facilitating more efficient use of health care technology. So the commercial aspects and future recommendation are included in this chapter in Section 7.1 and Section 7.2.

7.1 COMMERCIAL AND SOCIAL ASPECTS

This project has many commercial and social aspects. A large amount of world population will be grown older near future. According to Technology Strategy Board UK,more than a third of the world population will be over 65 by 2050. [42]

Different surveys have done to alarm about the increase rate ageing people. The European Commission has predicted that the UK will see about 44% increases in the 60 and over age range between 1995 and 2025. [9] According to Office for National Statistics UK, there were 1.3 million people aged 85 and over in the UK in 2007 that is predicted to be 3.1 million by 2032. [43]

So it will be hard to assure good health service with the growth rate of elder people. Nowadays modern technology is utilised in health sector to provide better service in

home. This project is for providing health monitoring service from home. This device is designed with concept of 24/7 health monitoring for assistive residences. This wrist-belt can be used by old and disable person. By using this, the person gets care in home environment. It provides more independence and flexibility as well.

There are many patients who are suffering from long-term health condition. They are hospitalised due to 24 hours monitoring. But they can be monitored by using assistive technology. Approximately 30% of assisted living residences suffer from long-term health condition and 72% are inpatient bed days. [44]

This technology is also applicable for the patients who stay in bed for long time. So the doctor can checked update health data of the patient with the help of technology. The assistive technology helps to provide more home based care. So it helps to reduce the cost.

This project has carries a vital role for community. Many old people are lived alone in their home. Their health can be motored continuously by using this assistive technology. According to Age Concern organisation, 11% of aged 65 or over are live always lonely and aged 75 and over living alone will increase by over 40% in UK next 20 years. [45]

This device is also suitable for care home service provider. They can monitor multiple patients by using this technology at the same time. In care home many patients suffer from different motor neuron diseases. So they are immobile and some have problem in speech. Their movement can be monitored by using this device. This is wireless device so they feel more independence and secure.

The market ability of health monitored technology is very high. According to The Wireless Association CITA, the current market for home-based, wireless health care product in USA is $304 million and the market is expected to grow to $4 billion next 3 years. [46]

The future market of this type of product is wide. Different companies and organisations are still working to develop in various products related this area. The home-based health monitor technology type product of would be used widespread near future.

7.2 FUTURE DEVELOPMENT

Here proposed a wrist-belt which monitors only movement and temperature. The designed device has successfully sends data to the receiver. In the market only one product can do only single task. But here this single device is doing multi-tasks. The device is using I2C bus which is multi-master bus. In future more sensors can be added with this I2C bus. Such as blood pressure sensor, pulse-oximeter or heart-beat monitor sensor etc. By doing this, one device can measure different health related data at the same time.

This device can be used in care home service in future. So the same device will be used among many users. The device transmits data through XBee network. So the next step would be worked for multi users. If the device is used in care home basis, then multiple patients send data by using the same network. The challenging part would be identifying the patient through data. So every patient will be carried different identification. All patients data will be come together but the data can be distinguished by using patients ID. So by upgrading this system in future, the care service provider will be able to monitor a number of patients. This application will be help to identify patient's data in emergency situtation.

More works can be done in LIS302DL accelerometer. Only CTRL_REG1 register is used in this project. To get more accurate value of movement, it is requires to work on other registers of LIS302DL. So working on the other registers is helpful for better measurement.

The Charging IC MCP73837 is interface able with the Meridian/P. The charging system can be controlled by interfacing with Meridian /P. The IC has auto shut down mode and low voltage indication system. Both systems would be worked if the IC is interfaced with Meridian/P. So here proposed to connect the charging IC with GPIO pin of Meridian/P and worked on programming with this.

It has already tested that the device works wirelessly. Now the device is transmitting data with XBee. In future the data transmitting range can be high by using XBee-Pro.

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APPENDIX

Programming Code

Program.cs

```
using System;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using System.Threading;
using DeviceSolutions.SPOT.Hardware;

namespace InterHomeMeriP
{
    public class Program
    {
        private static RoomBoard room1;
        private static XBee xbee;
        private static string text;
        private static InterruptPort ipPanic;

        public static void Main()
        {
            Debug.Print("Initialising...");

            room1 = new RoomBoard(0);
            xbee = new XBee("COM1");
            xbee.DataReceived += new
XBee.DataReceivedHandler(xbee_DataReceived);

            ipPanic = new InterruptPort(MeridianP.Pins.GPIO11, true,
Port.ResistorMode.Disabled, Port.InterruptMode.InterruptEdgeHigh);
            ipPanic.OnInterrupt += new
NativeEventHandler(ipPanic_OnInterrupt);

            StartTimer();

            Debug.Print("Initialisation complete");
```

```
        }

        static void ipPanic_OnInterrupt(uint data1, uint data2,
TimeSpan time)
        {
           bool GPIO_Pin11 = true;

        //    while (false)
        //    {
                if (ipPanic.Read() == true)
                {
                    GPIO_Pin11 = !GPIO_Pin11;
                    Thread.Sleep(500); //Thrad used for time. So it
will stop for 500ms.
                    Debug.Print(DateTime.Now.ToString() + "|" +
ipPanic.Read().ToString());
                    text += DateTime.Now.ToString();
                    Debug.Print("Need Assistance");
                    xbee.WriteData("Need Assistance");
                }


       //     }
        }

        static void xbee_DataReceived(object sender,
XBeeDataReceivedEventArgs e)
        {
            Debug.Print("Received something");
        }

        private static void UpdateTick()
        {
            Thread.Sleep(200);
            text = room1.Temperature.ToString() + "|" +
room1.GetAccelerometerValue()[0].ToString() + "|"
                + room1.GetAccelerometerValue()[1].ToString() + "|" +
room1.GetAccelerometerValue()[2].ToString() + "|";

            text += DateTime.Now.ToString();
            Debug.Print(text);
            xbee.WriteData(text);
        }


        #region Main thread
        // Delegate type for the callback
        private delegate void VoidProcDelegate();

        private static Thread TimerThread;
        /// <summary>Starts the timer thread for the
animation</summary>
        static void StartTimer()
        {
            TimerThread = new Thread(new
ThreadStart(TimerThreadProc));
            TimerThread.Start();
        }
```

```
        static void TimerThreadProc()
        {
            while (TimerThread.ThreadState == ThreadState.Running)
            {
                DispatcherOperation op =
Dispatcher.CurrentDispatcher.BeginInvoke(new
VoidProcDelegate(UpdateTick));
                op.Wait();
                Thread.Sleep(100);

            }
        }
        #endregion
    }
}
```

RoomBoard.cs

```
 using System;
using System.IO;
using Microsoft.SPOT;
using Microsoft.SPOT.Hardware;
using System.Threading;

namespace InterHomeMeriP
{
    public class RoomBoard
    {
        #region Drivers for on-board devices

        internal sealed class DS1624
        {
            #region Fields

            private I2CDevice.Configuration config;
            //private I2CSlave _slave;
            //private byte _deviceAddress;
            private byte[] _dataBuffer = new byte[2] { 0x00, 0x00 };

            #endregion

            #region Constants

            const int TIMEOUT = InterHomeConfig.I2C_TIMEOUT;
            const int BUS_SPEED = InterHomeConfig.I2C_BUS_SPEED;
            const byte DEFAULT_Address = 0x48;
            const byte REG_IO = 0x00;
            const byte REG_MEMORY = 0x17;
            const byte REG_CONFIG = 0xAC;
            const byte REG_TEMP = 0xAA;
            const byte REG_START = 0xEE;
            const byte REG_STOP = 0x22;

            #endregion

            #region Constructors

            /// <summary>
            /// DS1624 default address
            /// </summary>
            public DS1624()
                : this(DS1624.DEFAULT_Address)
            {
            }

            public DS1624(int deviceAddress)
            {
                config = new
I2CDevice.Configuration((byte)(DEFAULT_Address + deviceAddress),
BUS_SPEED);
            }

            /// <summary>
            /// DS1624 Temperature Monitoring
            /// </summary>
```

```
            /// <param name="deviceAddress"></param>
            public DS1624(byte deviceAddress)
            {
                config = new I2CDevice.Configuration(deviceAddress,
BUS_SPEED);
                //_deviceAddress = deviceAddress;
                //this._slave = new I2CSlave(deviceAddress);
            }

            #endregion

            #region Members

            public byte StartConversion
            {
                set
                {
                    try
                    {
                        /*
                        using (I2CSlave _slave = new
I2CSlave(_deviceAddress))
                        {
                            _slave.WriteRegister(DS1624.REG_START,
_dataBuffer);
                        }
                        */
                        I2CSlave.WriteRegister(config, REG_START,
_dataBuffer, TIMEOUT);
                    }
                    catch (System.IO.IOException e)
                    {
                        Debug.Print(e.Message);
                    }
                }
            }

            public byte StopConversion
            {
                set
                {
                    try
                    {
                        /*
                        using (I2CSlave _slave = new
I2CSlave(_deviceAddress))
                        {
                            _slave.WriteRegister(DS1624.REG_STOP,
_dataBuffer);
                        }
                        */
                        I2CSlave.WriteRegister(config, REG_STOP,
_dataBuffer, TIMEOUT);
                    }
                    catch (System.IO.IOException e)
                    {
                        Debug.Print(e.Message);
                    }
                }
```

```
            }
            /// <summary>
            /// Temperature Reading
            /// </summary>
            public byte Temp
            {
                get
                {
                    try
                    {
                        /*
                        using (I2CSlave _slave = new
I2CSlave(_deviceAddress))
                        {
                            _slave.ReadRegister(DS1624.REG_TEMP,
_dataBuffer);
                        }
                        */
                        I2CSlave.ReadRegister(config, REG_TEMP,
_dataBuffer, TIMEOUT);
                    }
                    catch (System.IO.IOException e)
                    {
                        Debug.Print(e.Message);
                    }
                    return _dataBuffer[0];
                }
            }

            /// <summary>
            /// Memory
            /// </summary>
            public byte Memory
            {
                get
                {
                    try
                    {
                        /*
                        using (I2CSlave _slave = new
I2CSlave(_deviceAddress))
                        {
                            _slave.ReadRegister(DS1624.REG_MEMORY,
_dataBuffer);
                        }
                        */
                        I2CSlave.ReadRegister(config, REG_MEMORY,
_dataBuffer, TIMEOUT);
                    }
                    catch (System.IO.IOException e)
                    {
                        Debug.Print(e.Message);
                    }
                    return _dataBuffer[0];
                }
            }
            #endregion

            /// <summary>
```

```
            /// Config
            /// </summary>
            public byte Config
            {
                get
                {
                    try
                    {
                        /*
                        using (I2CSlave _slave = new
I2CSlave(_deviceAddress))
                        {
                            _slave.ReadRegister(DS1624.REG_CONFIG,
_dataBuffer);
                        }
                        */
                        I2CSlave.ReadRegister(config, REG_CONFIG,
_dataBuffer, TIMEOUT);
                    }
                    catch (System.IO.IOException e)
                    {
                        Debug.Print(e.Message);
                    }
                    return _dataBuffer[0];
                }
            }

            #region IDisposable Members
            /// <summary>
            /// Dispose object
            /// </summary>
            public void Dispose()
            {
                /*
                using (I2CSlave _slave = new I2CSlave(_deviceAddress))
                {
                    _slave.Dispose();
                }
                */
            }
            #endregion
        }
    #endregion

       internal sealed class LIS302DL
         {
             #region Fields

         private I2CDevice.Configuration _deviceConfig;
         private int _timeOut = 50;
         private byte[] _dataBuffer = new byte[2] { 0x00, 0x00 };

             #endregion
```

```
#region Constants

        const int CLOCK_Rate = 100;
        const byte DEFAULT_Address = 0x1C;
        const byte REG_WHO_AM_I = 0x0F;
        const byte REG_CTRL_REG1 = 0x20;
        const byte REG_CTRL_REG2 = 0x21;
        const byte REG_CTRL_REG3 = 0x22;
        const byte REG_HP_FILTER_RESET = 0x23;
        const byte REG_STATUS_REG = 0x27;
        const byte REG_OUTX = 0x29;
        const byte REG_OUTY = 0x2B;
        const byte REG_OUTZ = 0x2D;
        const byte REG_FF_WU_CFG_1 = 0x30;
        const byte REG_FF_WU_SRC_1 = 0x31;
        const byte REG_FF_WU_THS_1 = 0x32;
        const byte REG_FF_WU_DURATION_1 = 0x33;
        const byte REG_FF_WU_CFG_2 = 0x34;
        const byte REG_FF_WU_SRC_2 = 0x35;
        const byte REG_FF_WU_THS_2 = 0x36;
        const byte REG_FF_WU_DURATION_2 = 0x37;
        const byte REG_CLICK_CFG = 0x38;
        const byte REG_CLICK_SRC = 0x39;
        const byte REG_CLICK_THSY_X = 0x3B;
        const byte REG_CLICK_THSZ = 0x3C;
        const byte REG_CLICK_TimeLimit = 0x3D;
        const byte REG_CLICK_Latency = 0x3E;
        const byte REG_CLICK_Window = 0x3F;


            #endregion

            #region Constructors

        /// <summary>
        /// LIS302DL default address 0x1c
        /// </summary>
        public LIS302DL()
            : this(LIS302DL.DEFAULT_Address)
        {
        }

        /// <summary>
        /// LIS302DL Triple Axis Accelerometer
        /// </summary>
        /// <param name="deviceAddress"></param>
        public LIS302DL(byte deviceAddress)
            : this(deviceAddress, CLOCK_Rate)
        {
        }

        /// <summary>
        /// LIS302DL Triple Axis Accelerometer
        /// </summary>
        /// <param name="deviceAddress"></param>
        /// <param name="clockRate"></param>
        public LIS302DL(byte deviceAddress, int clockRate)
        {
```

```
            _deviceConfig = new I2CDevice.Configuration(deviceAddress,
clockRate);
        }


             #endregion

            #region Members

        /// <summary>
        /// Device identification register. This register contains the
device identifier for LIS302DL (set to 3Bh)
        /// </summary>
        public byte Who_Am_I
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_WHO_AM_I, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }


        public byte Ctrl_Reg1
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG1, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG1, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }


        public byte Ctrl_Reg2
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG2, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG2, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte Ctrl_Reg3
        {
            set
            {
```

```
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG3, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CTRL_REG3, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte HP_Filter_Reset
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_HP_FILTER_RESET, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte Status_Reg
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_STATUS_REG, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte OutX
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_OUTX, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte OutY
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_OUTY, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte OutZ
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_OUTZ, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
```

```
        }

        public byte FF_WU_CFG_1
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_CFG_1, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_CFG_1, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_CFG_2
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_CFG_2, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_CFG_2, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_SRC_1
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_SRC_1, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_SRC_2
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_SRC_2, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_THS_1
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_THS_1, value, _timeOut);
            }
```

```
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_THS_1, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_THS_2
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_THS_2, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_THS_2, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_DURATION_1
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_DURATION_1, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_DURATION_1, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte FF_WU_DURATION_2
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_FF_WU_DURATION_2, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_FF_WU_DURATION_2, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_CFG
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_CFG, value, _timeOut);
```

```
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_CFG, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_SRC
        {
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_SRC, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_THSY_X
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_THSY_X, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_THSY_X, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_THSZ
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_THSZ, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_THSZ, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_TimeLimit
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_TimeLimit, value, _timeOut);
            }
            get
            {
```

```
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_TimeLimit, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_Latency
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_Latency, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_Latency, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        public byte CLICK_Window
        {
            set
            {
                I2CSlave.WriteRegister(_deviceConfig,
LIS302DL.REG_CLICK_Window, value, _timeOut);
            }
            get
            {
                I2CSlave.ReadRegister(_deviceConfig,
LIS302DL.REG_CLICK_Window, _dataBuffer, _timeOut);
                return _dataBuffer[0];
            }
        }

        #endregion

            #region IDisposable Members
           /// <summary>
        /// Dispose object
        /// </summary>
        public void Dispose()
        {
        }
            #endregion
         }

        private int _address;
        private DS1624 _temp;
        private LIS302DL _accelometer;
        private bool[] _outputs;
        private bool[] _inputs;

        public int Address { get { return _address; } }
        public int Temperature { get { return (int)_temp.Temp; } }


        public bool[] Outputs { get { return _outputs; } }
```

```
        public  RoomBoard(int address)
        {
            _address = address;
            _temp = new DS1624(_address);
           _accelometer = new LIS302DL ();

            _outputs = new bool[8];
            _inputs = new bool[8];

            for (int i = 0; i < _outputs.Length; i++)
                _outputs[i] = false;

               _temp.StartConversion = 0xEE;

               _accelometer.Ctrl_Reg1 = 0x67;

        }

        public int[] GetAccelerometerValue()
        {
              int[] xyz = new int[3];

              xyz[0] = _accelometer.OutX;    //The output value for x-
axis.
              xyz[1] = _accelometer.OutY;    //The output value for y-
axis.
              xyz[2] = _accelometer.OutZ;  //The output value for z-
axis.


              //Debug.Print(_accelometer.ToString());

           return xyz;

        }


    }
    }
```