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PEDOMETER PROPOSAL FOR FOOT MOTION DETECTION BY ARM MOTION DETECTION

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Master`s Thesis

Supervisor

Prof. Dr. Osman UÇAN

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Abdulqader Mohamme AL-KHALIDI

Signature

DEDICATION

To my Parents, the reason of what I become today. To my sister & brothers. A special thanks to Prof. Dr. Osman UÇAN for his support, worth notes and close follow up.

ABSTRACT

PEDOMETER PROPOSAL FOR FOOT MOTION DETECTION BY ARM MOTION DETECTION

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We developed and constructed a pedometer using low-cost components for this research. The proposed pedometer utilized a three-axis MEMS digital accelerometer type (ADXL345) in order to records moving activity, a 8-bit low- power microchip microcontroller pic18F4550 microchip microcontroller to that controls the overall process of pedometer and embedded the step algorithm. This algorithm can estimate the foot motion by detecting arm motion. The movement of the arm is detected by the accelerometer, it can evaluate the position and the dynamic change of the movement. Then, the algorithm calculates the steps taken by the operator and follows it by showing the total distance traveled by the person. The pedometer has also a Bluetooth module type (HC-05) to allow tracks the user activity with a smartphone or tablet communication pedometer.

The system has been tested and compared with real reading and with Smartphone pedometer techniques available with Samsung smartphone. The results appeared that the proposed pedometer has less error in case of walking than jogging, for distance calculation, the error is less than 3% for walking and it less than 7% for jogging. For steps calculation, the error is (2%) for walking and (6%) for jogging. The test results also show that the proposed pedometer has less error than smartphone’s pedometer which is about 3.3% less error than smartphone, this because of high accurate algorithm that used in calculation of steps.

Keywords: Pedometer, Accelerometer, Adxl345, Pic18f4550,

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Figure 4. 2: The final result displayed on the LCD and application. 30

ABREVIATIONS

A	:	Ampere
ADCs	:	Analog-To-Digital
CPU	:	Central processing unit
C	:	Calories
°C	:	Celsius
CCS c	:	CCS, Inc. Compiler
EEPROM	:	Elcentrically erasable programmable read-only memory
EUSART	:	Enhanced/Addressable Universal Asynchronous Receiver
F	:	Force
I2C	:	The Inter-Integrated Circuit
IC	:	Integrated Circuit
INT	:	Interrupt Pins
I/O	:	Input/Output
IOC	:	Interrupt on Change
k	:	Spring of Stiffness
KB	:	Kilobyte
KHz	:	Kilohertz
LCD	:	liquid-crystal display
LSB	:	least significant bit
m	:	Meter
m	:	Mass

mm	:	Millimeter
MCU	:	Microcontroller Unit
MEMS	:	Microelectromechanical System
mg	:	Milli g, where g is acceleration due to gravity,
min	:	Minute
PNS	:	Pedestrian Navigation System
S	:	Second
SDI	:	Silicon Designs
γ	:	Damping Coefficient
Ω	:	Ohm
µ	:	Micro

1. INTRODUCTION

This chapter explains the general introduction for human activity monitoring system and the step counting technologies in addition to review some of modern studies in field of step counting and pedometer that make a base line for this work.

1.1 GENERAL OVERVIEW

Individuals are now very interested in wearable devices because they're the most recent technological innovation for monitoring daily activities. A wearable gadget is a cutting-edge piece of gear that contains an app for monitoring and storing health information including such total calories, training run or strolled, and, in some cases, rest monitoring and heart rate. Smartwatches are ultra-compact, cutting-edge electronics that individuals wear on different parts of their bodies, such as smart watches, glasses, wristbands, and clothing-connected wristbands. Wearable devices have grown in popularity as a result of their ability to provide users with real-time information. Wearable technology has applications in a range of fields, including aging, diet, exercise, and health. Furthermore, daily activity or fitness tracking and monitoring would be automated. It's also possible to pair them with more laid-back attire. The wearable device will need to monitor activities and show information about the user's daily routine on the smartphone or wearable device screen. [1]. A pedometer, often known as a step counter, is a typical wearable gadget that is used to measure physical activity today. The origins of step-per-day ideas may be traced back to the year 2000.

the mid-1960s with a Japanese model of pedometer and walking theory name "Manpo-Keiwhich" which means (10,000 steps meter). As the pedometer and walking recommendation spread out Japan, studies searching for the optimum the proliferated of steps per day, putting the classic step suggestion as a building block that has been optimized to fit the needs of special populations like, older adults, children and some peoples that have chronic disease. Simplest and cheaper pedometer devices are actually obtainable by any person who needs to wear during daily activities and running exercise to recording the number of steps taken. They are more accurate, smarter and doing far more than just compute how far person walks. The advantage of employing such a device is mainly the improvement in motivation to enhance the physical activity. These instruments are additionally utilized in disease management and rehabilitation, as an example, the physical activity analysis is necessary for the treatment or prevention of diabetes. Pedometers are also being used to evaluate the mobility of the elderly [2].

Even though, the recommendations of physical activity in the present day are the intensity based and the predominately time. The developers not only have researchers on designed translations of intensity based physical activity guidelines, but they have also enhanced and updated pedometer technology to record and monitor further physical activity data. As a consequence of the widespread dissemination of knowledge about the value of regular physical exercise, there has been a drive to assess other elements of personal health people require for very high performing activity tracks has affected the technical advancement of pedometers more than basic step count. Pedometers have advanced from simple spring-lever devices capable just to counting steps to tri-axial accelerometers that capable to detect activity in three dimensions, calculating the energy expenditure, and determine the distance traveled while enhancing accuracy for step count [3].

The basic spring-lever pedometer has placed on the waistband, and it calculated the steps once the spring hung horizontal lever arm has displaced from its resting position as a result of the force of the foot of user while it hits the ground. The swings of lever arm in below and above the resting angle which will closes and opens an electronic circuit, as a consequence, counting steps. Since the horizontal lever arm is just responds to the hip's vertical displacement. Therefore, this device is considered to be uni-axial. The uni-axial characteristics of classic pedometers make several limitations. In cases where the pedometer rotationally shifts over and above its vertical placement at the waistband, step count data would be inaccurately recorded due to the device is not able to read motion when in any position. This kind of limitation attracts user error as the pedometer has to be secured vertically to the waistband and positioned on the right area of the hip. As well, it should also be securely fixed to a tight waistband to stop rotation of the device though ambulation. Additionally, a main downfall of spring-lever pedometers is situated in step count inaccuracy in case that walking speeds under 80.47m/min. Slowly walking speeds exhibited through the chronic disease, obese and elderly populations will not make sufficient force on the lever-arm with each step, as a result, the device doesn't display an accurate step count. The make use of piezoelectric accelerometers is recommended to increase accuracy in slow walking peoples because of their heightened sensitivity to motion [4].

Activity monitors like Omron HJ-720ITC, obtain data by using two piezoelectric accelerometers: the first in the vertical and the other in the horizontal plane. This type of accelerometer works when force from foot hit, and the body acceleration makes strain at the piezoelectric crystals which lie inside the accelerometers. The data records from the movement of the crystals are translated to distance traveled, energy expenditure and step count by utilizing algorithms found in the tiny processing unit in the device. Since piezoelectric activity monitors are usually more sensitive to force when compared to spring lever devices, there're capable to much more accurately count steps at and under speeds of 80.47m/min, that in spring lever pedometers has been proven it produce inaccurate readings. At last, the dual-axis accelerometer is able to read motion in two planes providing further options for affixing the unit to the body and will allow for rotation the device with no loss in accuracy [6].

Pedometers, now favorite as a daily basis exercise progress motivator and monitor, can help individuals vie with themselves in terms of getting their feet and reducing weight. One of the popular modern technological advancements in accelerometers is the MEMS accelerometer that is used to analyze movement. MEMS accelerometers have the capability to track acceleration or strain in three dimensions, possibly providing improved sensitivity. Data collected via tri-axial
Fitbit android application is meshed with proprietary algorithms in the small CPU of the devices to make distance traveled, step count, aerobic step count, energy expenditure during exercise and resting energy expenditure [7].

MEMS inertial sensors allow better detection of steps and lesser false positives. Taking MEMS Inertial devices have the benefits of taking up little space, being inexpensive, and using little power. The fitness trackers are connected to a variety of portable electronic devices, including cell phones and music players. The thin, small, low-power 3-axis accelerometers such as ADXL335, ADXL345 are very appropriate for such applications [8].

1.2 THE PEDOMETER BASICS

A pedometer, often known as a step counter, is a small electrical or electromechanical device approximately the size of a pager that records physical activity such as jogging, walking, or running. Some activities, such as upper body exercise, rowing, cycling, and so on, do not count steps. The accuracy of a pedometer varies greatly across devices, and it also relies on the length of the step taken by the user. The most effective pedometers are accurate, with a percentage error of less than 5%. The hardware, which contains the mechanical sensor, and the software, which includes the algorithm for counting steps, are the two primary components of the pedometer technology. To identify steps, today's modern pedometers employ sophisticated algorithms and MEMS inertial sensors. These pedometer MEMS sensors can measure acceleration on 1-axis, 2-axis, or 3-axis. The integration of MEMS inertial sensors in the step counter allows for more precision in step recognition and fewer false positives. Commercially available pedometers generally cost between $10 and $50 depending on their functionality. Figure 1.1 depicts a single commercial digital type [9].

Figure 1. 1: Omron HJ-112 digital pedometer [9]

1.3 LITERATURE REVIEW

Many studies on counting steps from accelerometer have been proposed, which include hardware and software. Summaries for studies are presented below:

Lee and Mase (2002) [10], have used angular velocity and measured acceleration to gather data by using low cost and wearable sensors. Their method are able to determine the location of user, recognize and classify user's behaviors such as standing, walking and sitting. Also, it can detect transitions between preselected locations. This approach got good result; however, it has some limits in case of a long path and it subject to drift- meaning which means if the recognizer determines wrongly the location transition from a starting location, then this method cannot determine the accurate location transition.

Takacs et al (2013) [13] determined the tri-axial accelerometer utilized in the Fitbit One, which is similar product to the Fitibit Zip, to become reliable and valid device for counting steps, however, it is not accurate for evaluation the distance at all walking speeds used in the study which was (90, 112, 133, 154, and 178 m·min-1). The Fitbit algorithm accuracy for energy expenditure is doubtful as recent research has informed that the Fitbit Ultra and Fitbit Tracker underestimation the energy expenditure during physical activity.

1.4 AIM OF THE THESIS

This study is important both in terms of social and engineering design. In social terms, the prototype design of pedometer that we have designed to help to encourage individuals to maintain a higher level of physical activity and exercise on a regular basis. In terms of engineering knowledge and design, we would have knowledge about the microcontroller 3-axis MEMS accelerometer and other hardware components at the end of thesis. This situation leads to the promotion of other theses and projects

2. THEORETICAL BACKGROUND

This chapter presents a theoretical background about human activity monitoring system methods, devices and algorithms that are used.

2.1 THE ACTIVITY MONITORING SYSTEM

Systems that monitor human activity provide a method of monitoring and summarizing a people physical activity. One application of these systems are the pedometer that can count, and in addition to that the modern wearable pedometer is a small lightweight body-worn gadget that consistently monitors physical activity, 24 hours a day and can also effectively summarize the level and type of physical activity for the monitored people on a minute-by-minute basis, these recorded data can sent wirelessly to a storage system and can viewed by the computer. [14]

2.2 THEORY AND DESIGN FOR ACCELEROMETER

The accelerometer sensor can determine the acceleration over three axis x, y, and z axes. The calculated acceleration involves both change of velocity (physical acceleration) and the static gravity functioning on the pedometer at all times. Capacitive, piezo-resistive, and piezoelectric methods are often employed to convert mechanical motion to an electrical signal in these devices. Single crystals or piezoceramics (such as lead zirconate titanate) are used in electromechanical motion sensors (such as quartz, tourmaline). These types are unequaled in terms of high temperature range, low package weight, and greater frequency range. Capacitive accelerometers work well in the low-frequency region and can be operated in servo mode to provide high linearity and reliability [15]. Piezo-resistive accelerometers are preferred in high-shock applications, but capacitive accelerometers work well in the low-frequency region and can be operated in servo mode to provide high linearity and reliability.

Micro Electromechanical System is used to make recent accelerometer sensors (MEMS). MEMS (microelectromechanical systems) is an embedded system that integrates electrical and mechanical components on a microscale. It is made up of a cantilever beam with a seismic-mass (also known as proof-mass) produced in single crystal silicon using bulk micromachining or surface micromachining techniques [15].

2.2.1 Working Principle of Accelerometer

The concept of an accelerometer is similar to that of a spring-dampener system. A spring/dampener system connects the frame to a known mass. When force or acceleration is applied on the frame, it can be measured through view the displacement between frame and mass. Figure 2.1 demonstrates the essential structure of an altimeter. The fundamental weight (W) is linked to a stiffness spring (k), which is attached to the case on either end. The example is presented, with a damper factor of (), is frequently linked to the mass in a parallel to the spring configuration. This produces a pleasing low impact. [16]

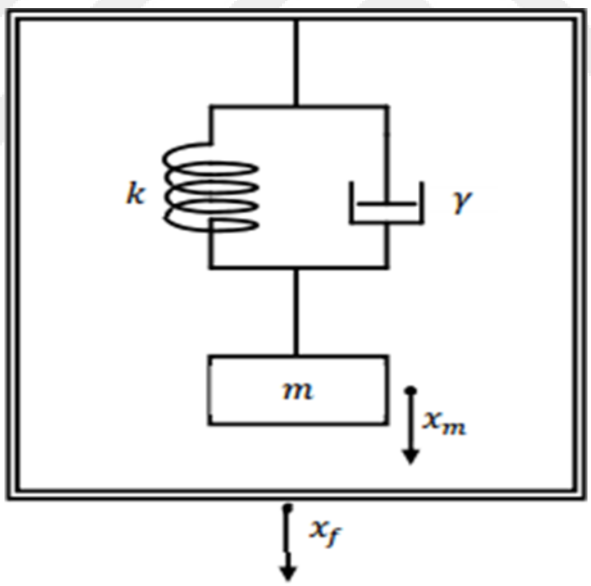


Figure 2. 1: Simple diagram of the accelerometer [16]

Computing the distance between the proof mass and the frame allows for calculate the frame acceleration. A significant consideration is the gravity effect on spring dampener system. This spring dampener system is able to measure force, and not simply the acceleration. This result in a 9.81m.s-2 constant acceleration in direction of the sensor arranged with gravity [16].

2.2.2 How to Use an Accelerometer

The exerted on the solid evidence when an accelerometer is exposed to an accelerometer is equal to mass times acceleration (i.e., F=ma), causing it to deflect. With the proper tools, this may be recognized and transformed into an electrical signal. The amount of deflection is proportional to velocity of the accelerometer. There must be some form of dampening. Otherwise, so when system is accelerated, it will take a long time to settle. The unit mobility formula was created using Newton's second law, which stipulates that any real force acting on the proof-mass is equal to the inertia force on the proof-mass. As a consequence, a fluid issue may be seen as an issue of static balance. The equation of motion is derived from the linear form of the conservation laws. This damped mass-spring system resembles a classical second order mechanical system in terms of force applied [17].

2.3 ACCELEROMETER BASED MEMS

MEMS is a manufacturing technology that combines electrical and mechanical components to create small integrated systems or devices. By combining micromachining with silicon-based microelectronics technology, it has been demonstrated to be one of the most promising technologies of the twenty-first century, having the ability to improve both consumer and industrial goods [18].

MEMS are made utilizing integrated circuit batch manufacturing technologies, and their dimensions vary from a few micrometers to millimeters. MEMS systems or devices have the capacity to regulate, perceive, and actuate on a micro scale while also having macro-scale consequences.While IC are designed to take advantage of the silicon's electrical properties, MEMS take advantage of the mechanical properties of silicon or take advantage of both mechanical and electrical properties of silicon. In most popular form, MEMS involve micro sensors, microelectronics, micro actuators and mechanical microstructures, all combined on to the same silicon chip. Figure 2.2 shows the MEMS schematic [19].

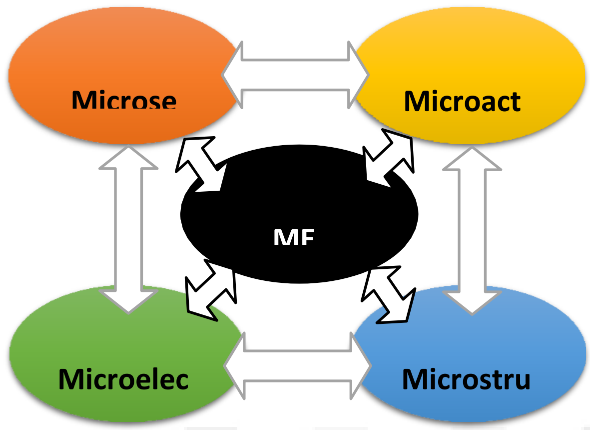


Figure 2. 2: Schematic model of MEMS components [19]

Microsensors discover variations in the system's environment by measuring electromagnetic or chemical information, magnetic thermal, mechanical or phenomena. The microelectronics processes this data and signal. The microactuators respond and make some kind of changes to the environment. The MEMS are very small in size; their elements are mostly microscopic. Pistons gears, levers, and also motors and likewise steam engines have all been manufactured by MEMS. Even soMEMS isn't simply about manufacturing things out of silicon or miniaturizing engine systems; in fact, the word "MEMS" is misleading since many micro -machined devices will not be mechanical in any way. The MEMS is a developing technology; that uses the batch fabrication techniques in order to design and constructing complex mechanical systems and devices along with their integrated electronics [20].

MEMS has many specific positive aspects as a manufacturing technology. First, the interdisciplinary characteristics of MEMS technology and its micromachining methods, and also its range of applications have led to an unprecedented range of synergies and devices along recently unrelated fields (such as microelectronics and biology). Secondly, MEMS as well as its batch fabrication methods allows devices and components to be manufactured with improved reliability and performance, coupled with the obvious advantages of minimized the cost, weight, volume, and physical size. Finally, MEMS offer the basis for the products manufacture that could not be made by other methods. All these factors make MEMS probably a far more pervasive technology than IC microchips. Even so, there are many issues and technological challenges associated with miniaturization that require to be resolved and overcome before MEMS can realize its overwhelming potential [21].

MEMS is found in varying systems across communication, medical, automotive, electronics and defense applications. Recent MEMS devices involve accelerometers, read/write heads of computer disk drive, heads of inkjet printer, blood pressure sensors, biosensors, projection display chips, microvalves, optical switches and several other products that are all fabricated and shipped in large commercial volumes [21].

A common example of MEMS and microelectronics having fabricated is the airbag accelerometer. The monolithic processing of the airbag accelerometer, together with the reduced number of components, allows for the creation of a very tiny device with high dependability at a reasonable cost. The trade-off is found within its complexity, since this method allows for a very rigid and limited process flow, which may be costly and so necessitates extremely large quantities. Figure 2.3 shows the commercial accelerometer from Analog Devices to Modern day MEMS [19].

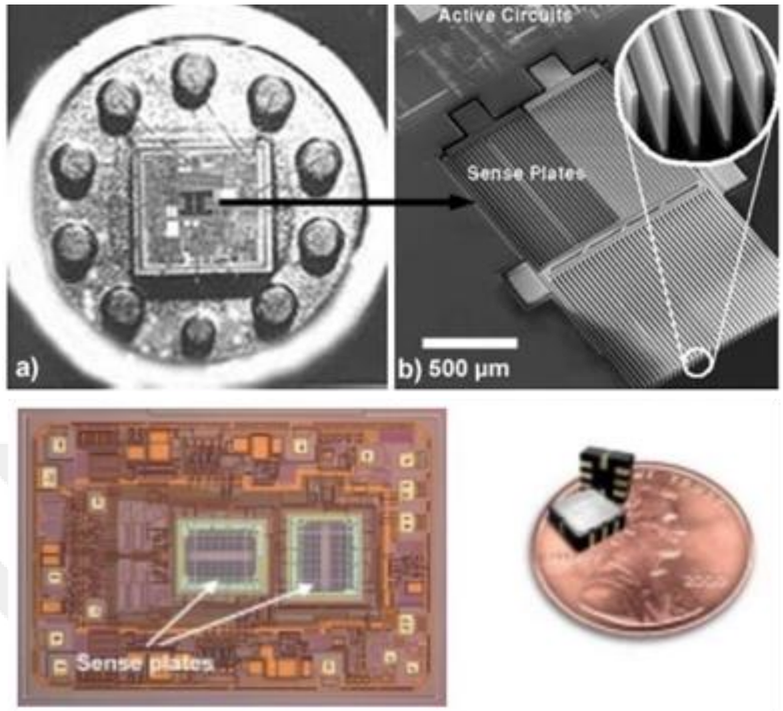


Figure 2. 3: (a) The first industrial accelerometer by Analog Devices (made in 1990), its less than 1cm2 in size, (b) the capacitive sense latest, and (c) the modern MEMS accelerometer (at left), and the fully packaged device (at right). [19]

2.3.1 MEMS Accelerometer Structure

Capacitive sensing is the most popular method of computing displacement in a MEMS accelerometer [16].

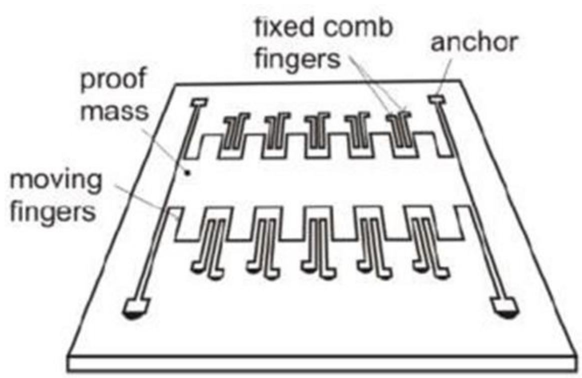


Figure 2. 4: Typical MEMS Capacitive sensing implementation [16]

The anchored comb fingers act as one of the plates in a capacitor, while the proof mass act as the other capacitor plate. The convert in capacitance is calculated and used to evaluate the acceleration [16].

Figure 2.5 depicts the inner workings of a capacitive accelerometer. There are a number of alternative designs and accelerometer kinds available from a range of different manufacturers. The choice is based on the cost, constraints, and intended use, as well as other considerations including sensitivity. Silicon Designs Inc.'s SDI accelerometers, for example, rely on capacitance changes as a function of acceleration force. The sensitive technique has major benefits over the triode sensors used in other gyroscopes [22].

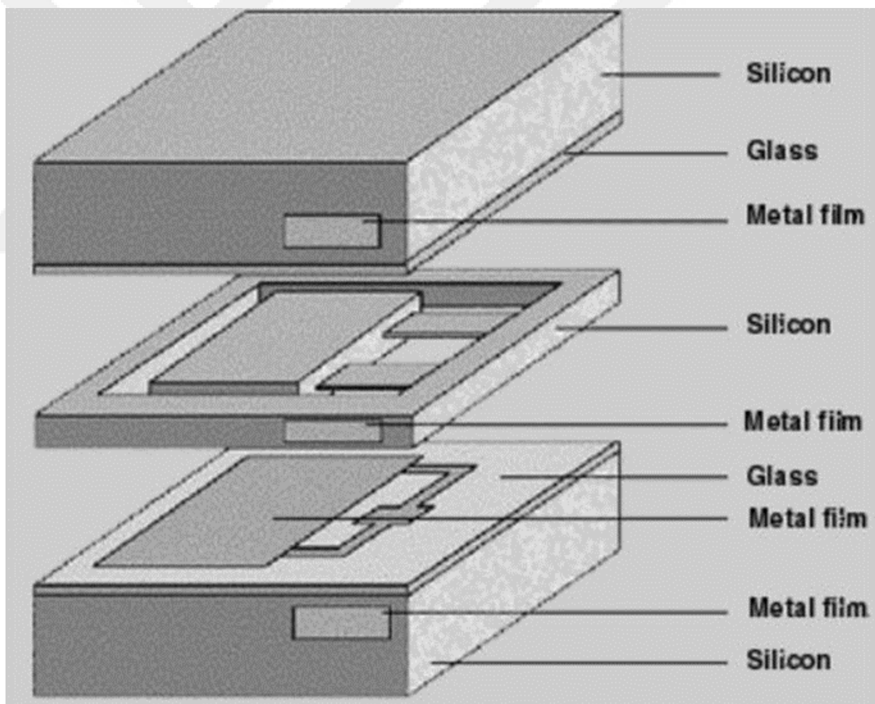


Figure 2. 5: Construction of silicon based capacitive accelerometers [22]

Figure 2.6 depicts the SDI's basic principle. The SDI detector facility is formed of a metal single sheet suspended above the substrate surface by two tension bar connected to the main plinth.

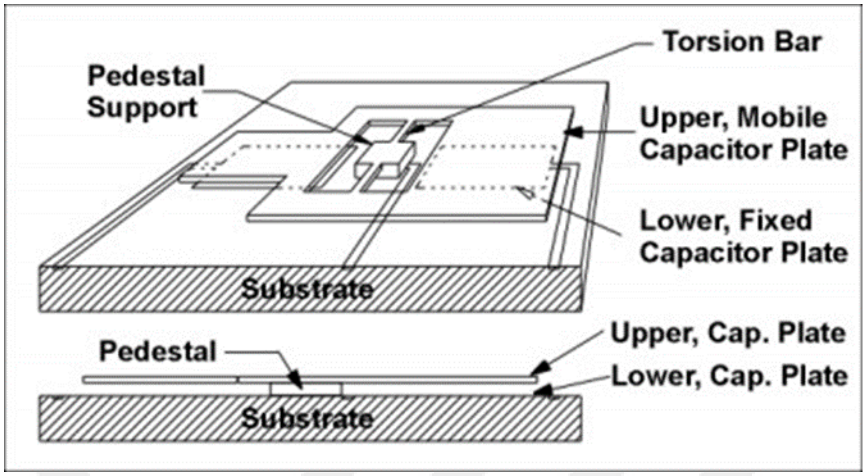


Figure 2. 6: SDI basic structure [22]

2.3.2 Material Used in Fabrication of the Accelerometers

Silicon was chosen as the material for the accelerometer construction because to its exceptional characteristics. Silicon is a good structural material and is widely utilized in MEM fabrication. It has a modulus similar to steel yet is lighter than aluminum. Silicon has a higher melting point of about 1400 degrees Celsius. Its specific heat is smaller than steel's, making it more dimensionally stable at extremely high temperatures. Another advantage of silicon is that its wafers are relatively flat, using them to to cover and add additional thin coating to create nanostructures. It also lacks mechanical hysteresis and possesses geometrical features which can be created utilizing common etched and stereolithography techniques. Because of its qualities, silicon is electrically conductive and has a 0.1-cm resistance, making it ideal for making accelerometer proof-mass. For top/bottom wafers, Pyrex 7740 glass is recommended because it reduces stray capacitance and provides desired sealing. Anodic bonding is used to join the glass wafers to the silicon wafer. Using the E-beam evaporation technique, sub-micron thickness aluminum coating is applied to the electrical contact pads and electrodes. Table 2.1 [20] shows the material parameters of pyrex glass and silicon.

Table 2. 1: Semiconductor and Borosilicate crystal have different physical aspects. [20]

Material Property	Silicon	Pyrex
σ_y (yield strength) 10^9N/m^2	7	0.5-0.7
E (Young Modulus) 10^{11}N/m^2	1.69	400
V(Poisson's ratio)	0.28	0.17
α Thermal expansion coefficient 10^{-6}mt/mt^{0}c	2.5	0.5
ρ (Density) g/cm^2	2.3	2.225

2.3.3 Accelerometer Configuration

Before completing the accelerometer setup, a number of criteria are considered. Existing manufacturing procedures, material selection, electrical routing, packaging, and the signal conditioning electronic circuit are all given special attention. The arrangement of the accelerometer is depicted in fig. 2.7.

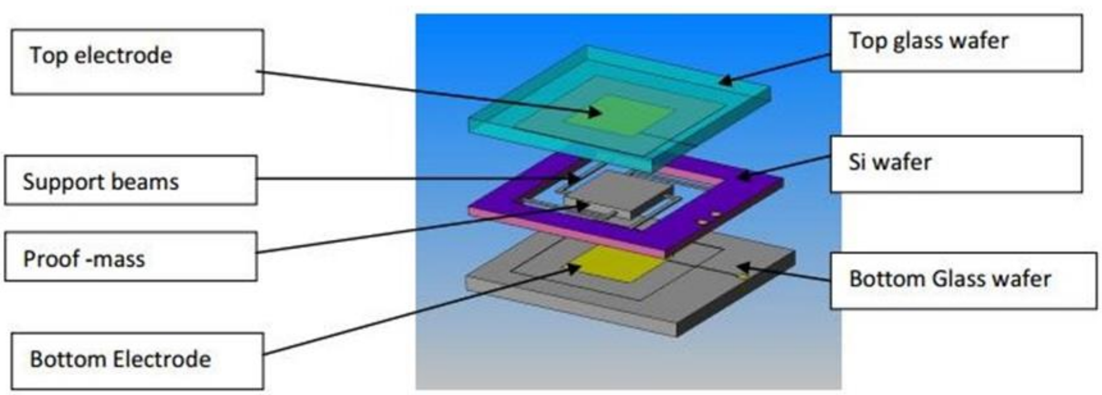


Figure 2. 7: Configuration of the Accelerometer [20]

2.4 BONUS FEATURES

Accelerometers that have recently been designed may have a few other characteristics in addition to collecting acceleration data. Tap sensing, sleep control, 0-g detection, and customizable measurement ranges are all possible features of current accelerometers.

2.5 TYPES OF ACCELEROMETERS ACCORDING TO THE NUMBER OF AXES.

2.5.1-Axis Digital Accelerometer (Pedometer)

Digital pedometer is the portable activity monitor device which can count every step that person takes via detecting the person's body motion with accelerometer. The simple pedometer design is shown in Figure 2.8. It involves a sensor feeding to the amplifier circuit which outputs the signal to the analog-digital converter through microcontroller. As the microcontroller converted data, they could be processed and locally saved in the microcontroller memory or can wirelessly transmit output to a remote location. [24]

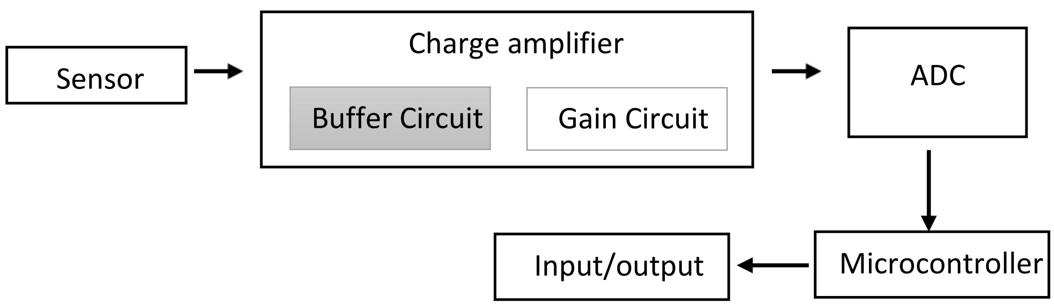


Figure 2. 8: Accelerometer configuration [24]

In the present day, advanced pedometers are based on MEMS, sophisticated software and inertial sensors. The MEMS inertial sensors that include minimal space, low cost as well as low power requirements. The pedometers are becoming included in a raising number of portable devices like as mobile phones and music players.

2.5.2 Operation of Three Axis Digital Accelerometer

The acceleration might be chosen as the most relevant metric among the elements that can be used to study walking or running. For a person, Figure 2.9 depicts the 3 parts of vibration: forward (roll), side (pitch), and vertical (yaw) [8].

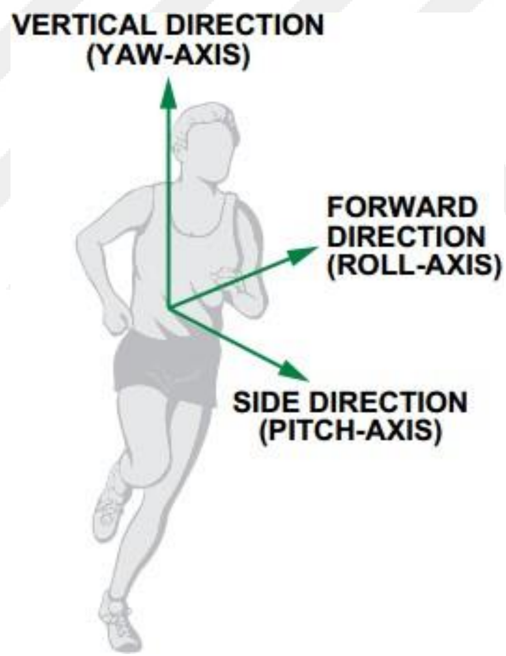


Figure 2. 9: Definition of the components of motion for a human [8]

The measuring and velocity axes of the altimeter A small action is shown in Figs 2.10, which represents a single walking cycle [8].

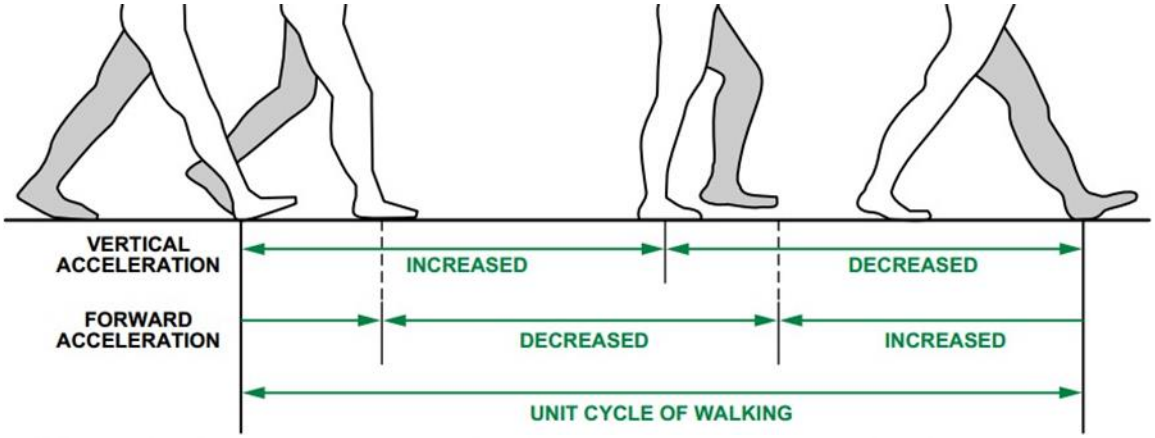


Figure 2. 10: The phases of running and the structure of speed [8]

The usual pattern measurements of x, y, and z are connected to vertical, side, and forward acceleration of the running individual, as illustrated in figure 2.10. Regardless of how the pedometer is worn, one axis may have comparatively bigger fluctuations in periodic acceleration. For determining a unit cycle of running or walking, the method of dynamic threshold choice and peak detection for acceleration on all three axes is crucial [8].

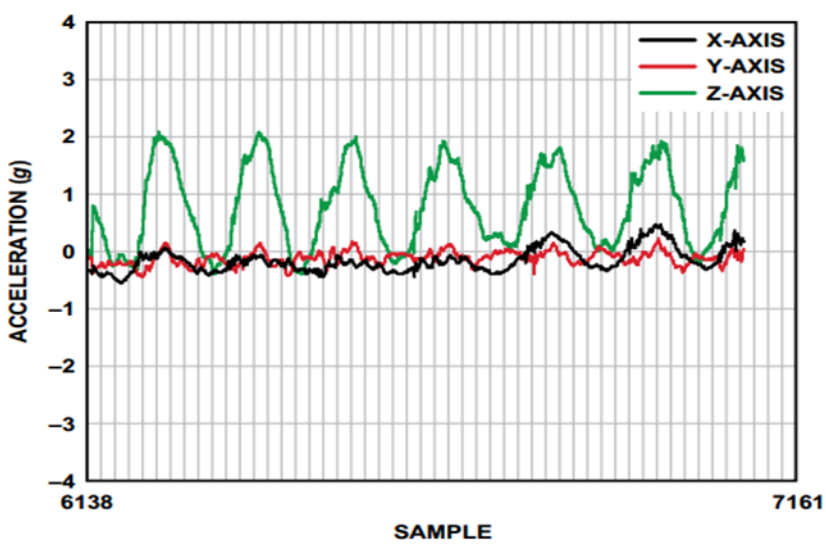


Figure 2. 11: Illustrate the normal x, y, and z speed patterns recorded by a runner [8]

2.5.3 ADXL345 iMEMS Accelerometer

iMEMS accelerometers can sense acceleration on 1, 2, or even 3-axes, and give digital or analog outputs. The accelerometer might have multiple detection ranges, ranging from a few g to tens of g, depending on the application. Multiple interrupt modes might be included in the digital versions of iMEMS accelerometers. These features provide the user with flexible and easy options. The ADXL345 is a three-axis accelerometer that was just launched. which has digital output. Its technical specifications are in follows: [25]

(i) Has a selectable measurement range of ±2g, ±4g, ±8g, or ±16g; 2- Has a resolution of up to 13 bits.

(ii) The sensitivity is fixed which is 4mg/LSB.

(iii) It has tiny package size of (3mm × 5mm × 1mm).

(iv) Ultralow power consumption in range from 25µA to 130µA.

(v) Standard SPI and I2C® digital and serial interfacing; in addition to 32level of FIFO storage.

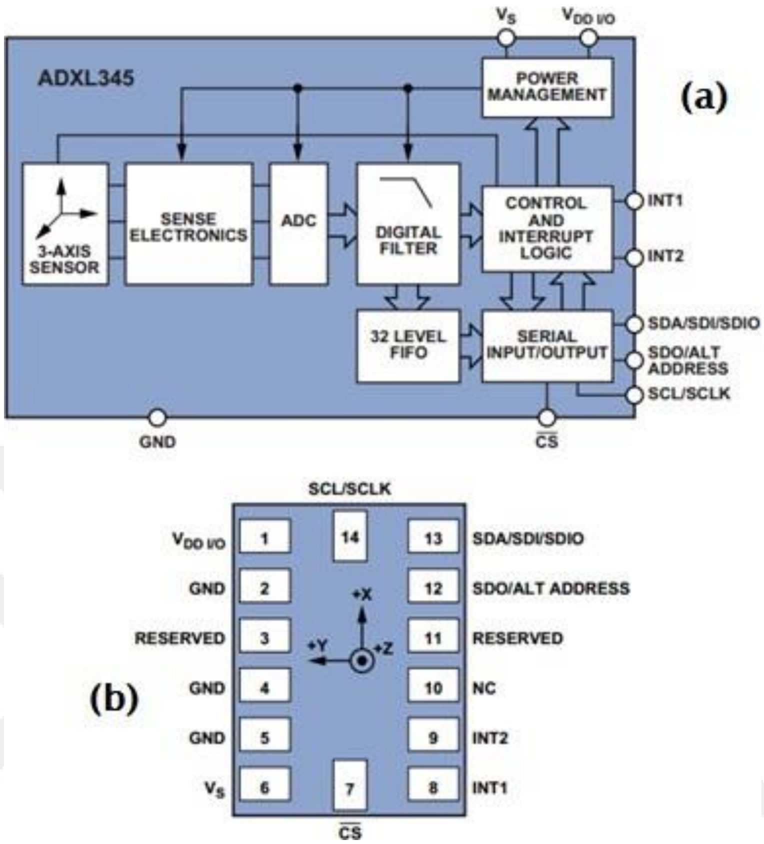


Figure 2. 12: Block diagram of ADXL345 system with pin designations, (a) ADXL345 structure, (b) be pin connections of ADXL345

3. PROPOSED PEDOMETER DESIGN

This chapter presents an experimental setup to 3-axis pedometer which includes system hardware and software design in addition to specify the hardware component used and the program operation and its algorithm.

3.1 PROPOSED PEDOMETER DESIGN

The proposed pedometer device consists of three main components, hardware, interrupt on change button and software. Hardware is consisted of 8-bit microcontroller type PIC18F4550, accelerometer type ADXL345, UART peripheral sampling data, HC05 Bluetooth radio module and 16x2 LCD; The software is user interface application that host and display the collected data on an Android phone with BT functionality. Figure 2 illustrated the Digital pedometer block diagram.

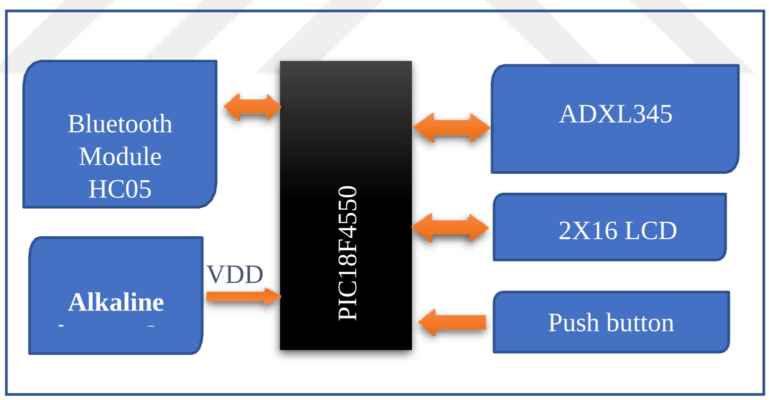


Figure 3. 1: Digital pedometer block diagram

3.1.1 Hardware Design

The proposed pedometer hardware parts include a Microcontrollers type PIC18F4550 which is Low-Cost Low-Power 8-Bit Microcontrollers that controlled the functionality of the pedometer and operated it. The output data is digitally formatted as 16bit twos complement, accessible via SPI (3 or 4 lines) or (I2C) digital interface. The HC-(05) Bluetooth module is used as a radio wireless communication unit with a TTL serial protocol interface to send step data from the pic16f4550 platform to a smartphone device. Figure 3.2 shows the PCB and proteus design of proposed pedometer.

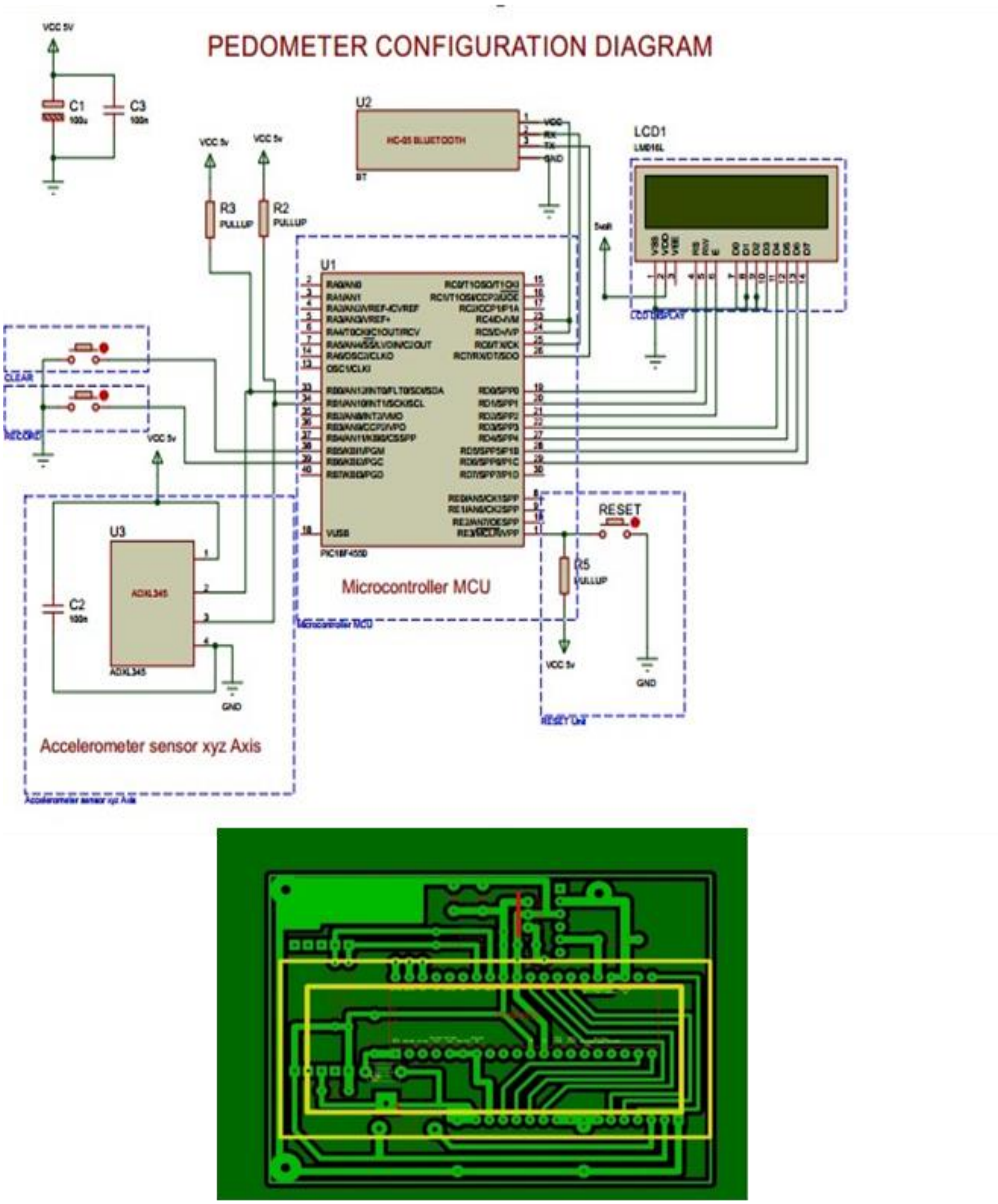


Figure 3. 2: PCB and proteus design

The PIC18F4550 given in Figure 3.3 is an 8bit microcontroller which is a part of PIC18 family that based on the architecture of 16bit instruction set. The PIC18F45502KB SRAM, 32KB flash memory, and 256Bytes EEPROM make up the microcontroller. The PIC18F4550 features 40 pins and 5 I/O ports (ports A, B, C, D, and E, with ports B and D having 8 pins that can send and receive 8bit I/O data). In terms of I/O data transmission, the additional ports have varying amounts of pins.

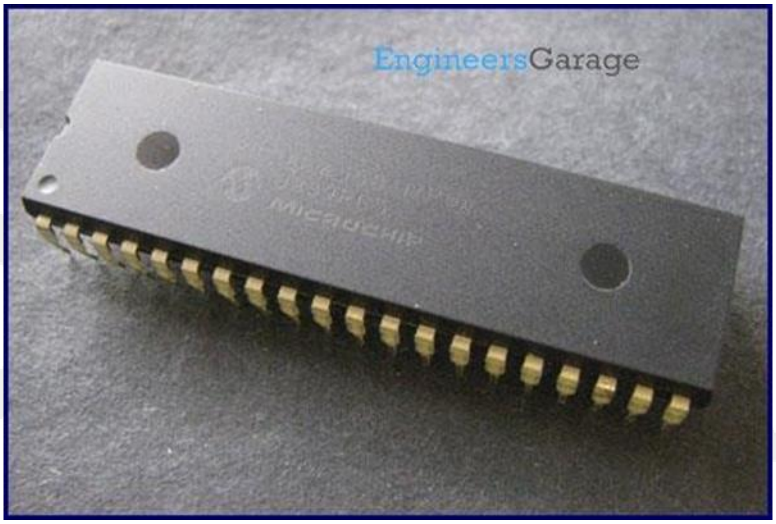
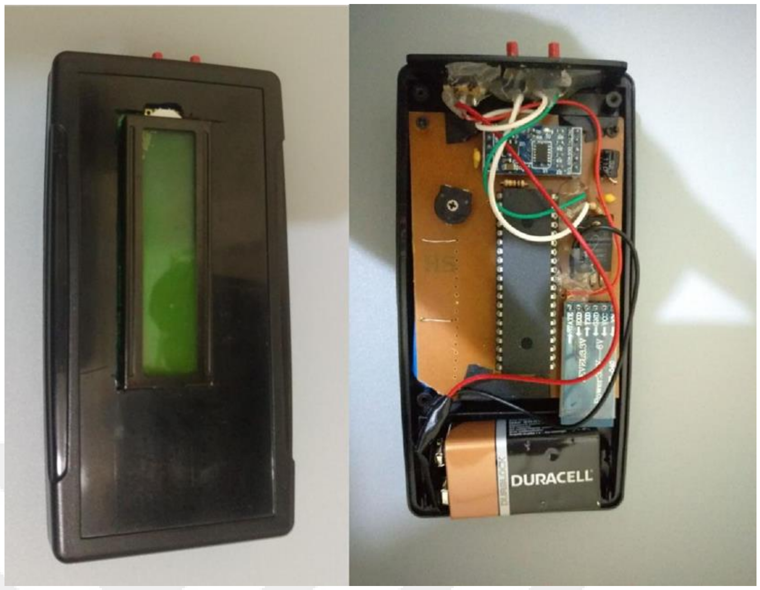


Figure 3. 3: PIC18F4550 microcontroller

The PIC18F4550 may use both external and internal clock sources. It can operate over a wide range of frequencies, from 31 kHz to 48 MHz. There are four timers on the PIC18F4550. This controller also has a number of built-in peripherals, such as comparators and an ADC. The PIC18F4550 is a high-performance microcontroller with enhanced communication protocols such I2C, SPI, EUSART, and USB. Figure 3.4 depicts the suggested pedometer gadget.



(a) **(b)**

Figure 3. 4: Proposed pedometer, (a) External shape, (b) internal structure.

3.1.2 The Interrupt on Change Button (IOC) (ON/OFF)

The quick function control is provided by the button of the pedometer via the change Interrupt (IOC) interface. To turn the pedometer on/off, press and release the button quickly within 1 second. To reset the number of steps, press and hold the button for more than 3 seconds and release it.

3.1.3 Software Design

In order to programing microchip microcontrollers, we used software name Code Optimizing C Compilers for Microchip PIC which provides by custom computer services company (it also called CCS C), this compiler is used for development of embedded software for Microchip microcontrollers that supports standard (C++) constructs of input/output streams to minimize development time. The pedometer programs include the ADXL345 driver (adxl345.h), the 2x16 LCD driver (LCD.h), and the main program (main c), as illustrated in Figure 3.5.

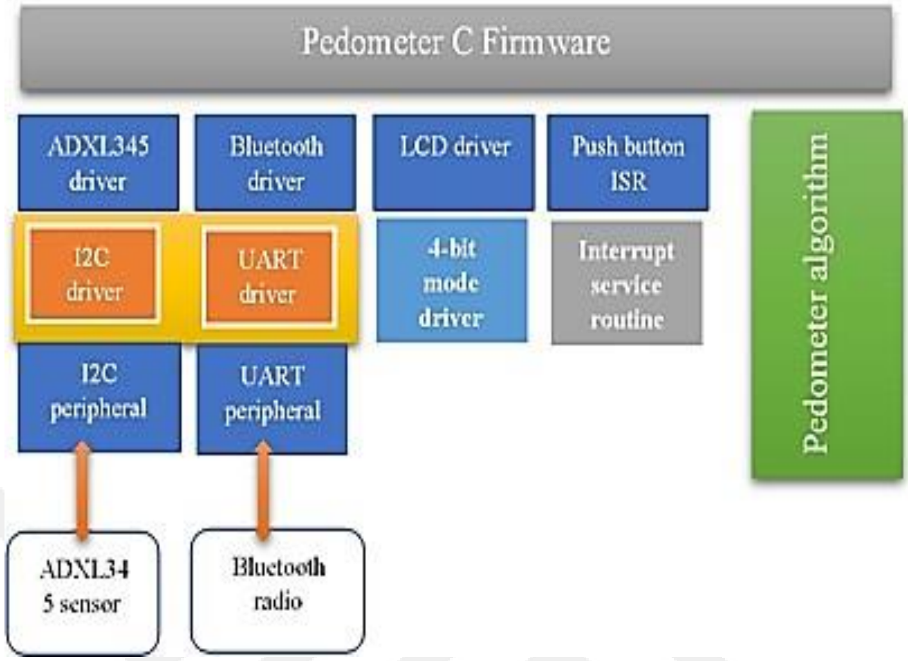


Figure 3. 5: Software Design.

The proposed pedometer uses a 16-bit triaxial digital accelerometer (ADXL345) to detect the user's motion. In every 20 milliseconds, sampling has been generated via accelerometer. The pedometer firmware that runs within the microcontroller contains algorithms for step detection. When user pressed the start/stop button, the microcontroller will wake up from the low power mode and operate the accelerometer. The microcontroller read both pedometer algorithm data and the accelerometer data. When the counting step is in progress, the updated step counter data has sent to the radio module via the UART interface. LCD displays the number of steps coming from micro controller, and the MEM button is saved in the EEPROM.

Once the motion has been detected, the pedometer algorithm starts calculates the step. After about ten steps have been detected the steps, count is updated with last count. The algorithms track the motion and continue counting the steps until the motion stop and then the algorithm reset and waits until detect next ten valid steps.

The main firmware of pedometer inside PIC18F4550 microcontroller has step detection algorithm. When motion detects, this algorithm has called periodically. At first, the microcontroller makes ADXL345 acceleration sensor initialization and if it detects output data from Y-axis of ADXL345 it will read it and push it to the digital filter that has four or more registers, then detect maximum and minimum value for acceleration, the algorithm now put this vale as threshold reference for next step after compare between these two values (max, min) with threshold value. Then, the steps algorithm decides if step detect or not. The step time has been calculated from average of acceleration that change from initial step time to final step time where the difference between the period gives us the step time then correct step during (0.2-2 seconds)). Figure 3.6 shows the pedometer algorithm procedure.

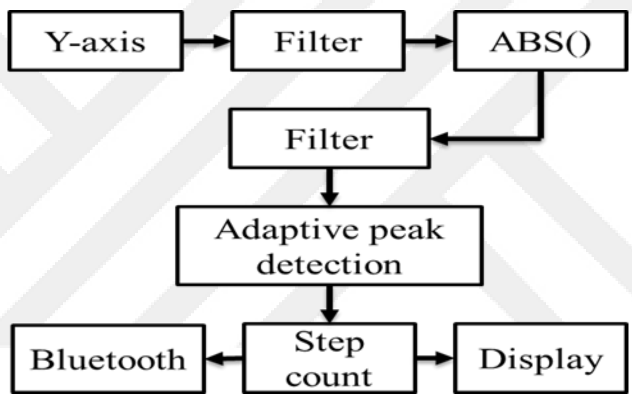


Figure 3. 6: pedometer algorithm

The steps for the algorithm are passes throw following stages:

(i) Pedometer FIRMW Digital Filter: The digital filter is required to smooth the signals; it can be using four summing and registers unit. By used more registers Although the acceleration data will be smoother, the reaction time will be longer. Figure 3.7 shows the Digital Filter scheme.

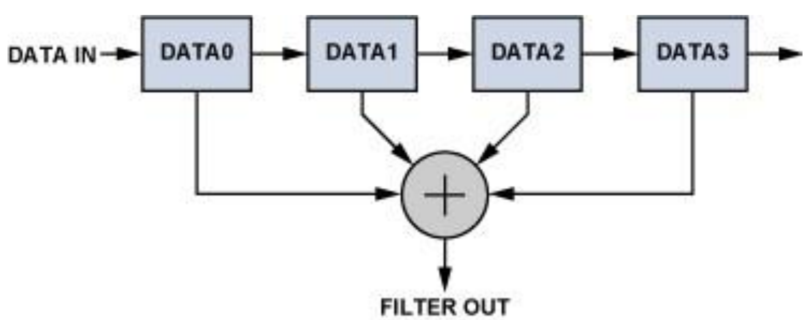


Figure 3. 7: The digital filter.

(ii) Dynamic Precision and Dynamic Threshold: After 50 samples, the updating the three-axis acceleration's highest and lowest estimates. The dynamic threshold level is defined as the average of (Min+Max)/2. This dynamic level is used for the following 50 samples to assess whether measures have been taken. The threshold is dynamic since it is adjusted every 50 samples. The options are customizable and quick. There is also dynamic precision, which may be utilized for additional filtering, in addition to the dynamic threshold. The dynamic threshold and precision b block diagram shown in figure 3.8.

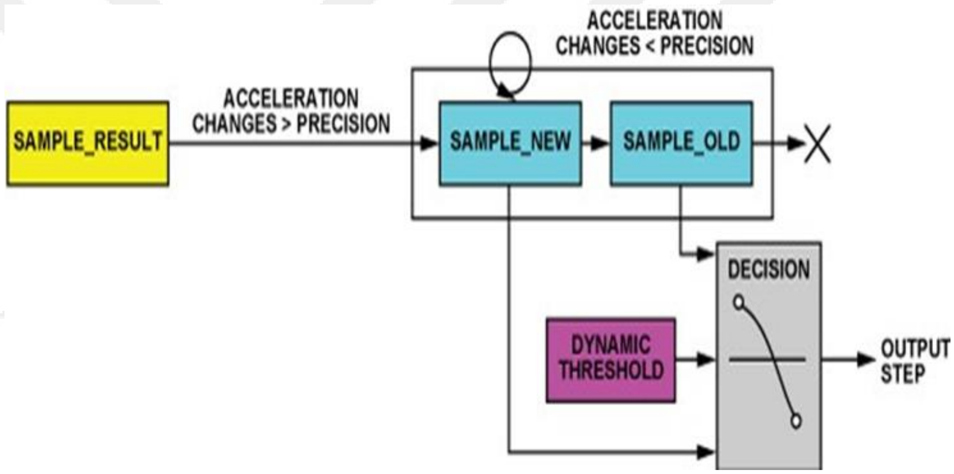


Figure 3. 8: Dynamic threshold and precision.

To check whether an appropriate move can be made, the dynamic threshold and the linear-shift-register were utilized. The sample new and sample old registers are two of the linear-shift-registers, registers and the data in these registers is referred to as sample new and sample old. The sample new register is automatically transferred to the pattern old region when a new data sample is obtained. Even yet, if the following condition is satisfied, the sample result will be moved to the test new registration: The specimen outcome but the most recent specimen outcome is shifted to the sample new register if the velocity adjustments exceed the predefined precision; if the sample new register remains intact, the shift register group can clear away the high-frequency noise, making the decision more precise. If the new sample is smaller than the previous sample, a step is designated to take place.

The step counter will operate in found-out regulation mode. The step counter will be updated only after each legitimate step in this mode. However, if even one invalid step is discovered, the step counter will revert to finding mode and look for four consecutive legitimate stages.
The method is passed via the basic sequence:

(i) lcd_init () This function, and subroutine initialize the 2x16 LCD display, which should be called first.
(ii) Enable_sample () This function returns the Y-axis acceleration sensor data samples.
(iii) Enable_step_detect () This function is the detection step and the number of updates.
(iv) Pedo_bluetooth () This function pushes the number of steps, speed, distance to the Bluetooth module port.
(v) ADXl345_init () This function, and subroutine initialize the ADXL345 acceleration sensor, which should be called before the step calculation.
(vi) ISR_RB () This function, and subroutine execute the statement when the interrupt is changed.

The flowchart that illustrated the operation process of the proposed pedometer and the step count algorithm procedure are described in figure 3.9 and 3.10

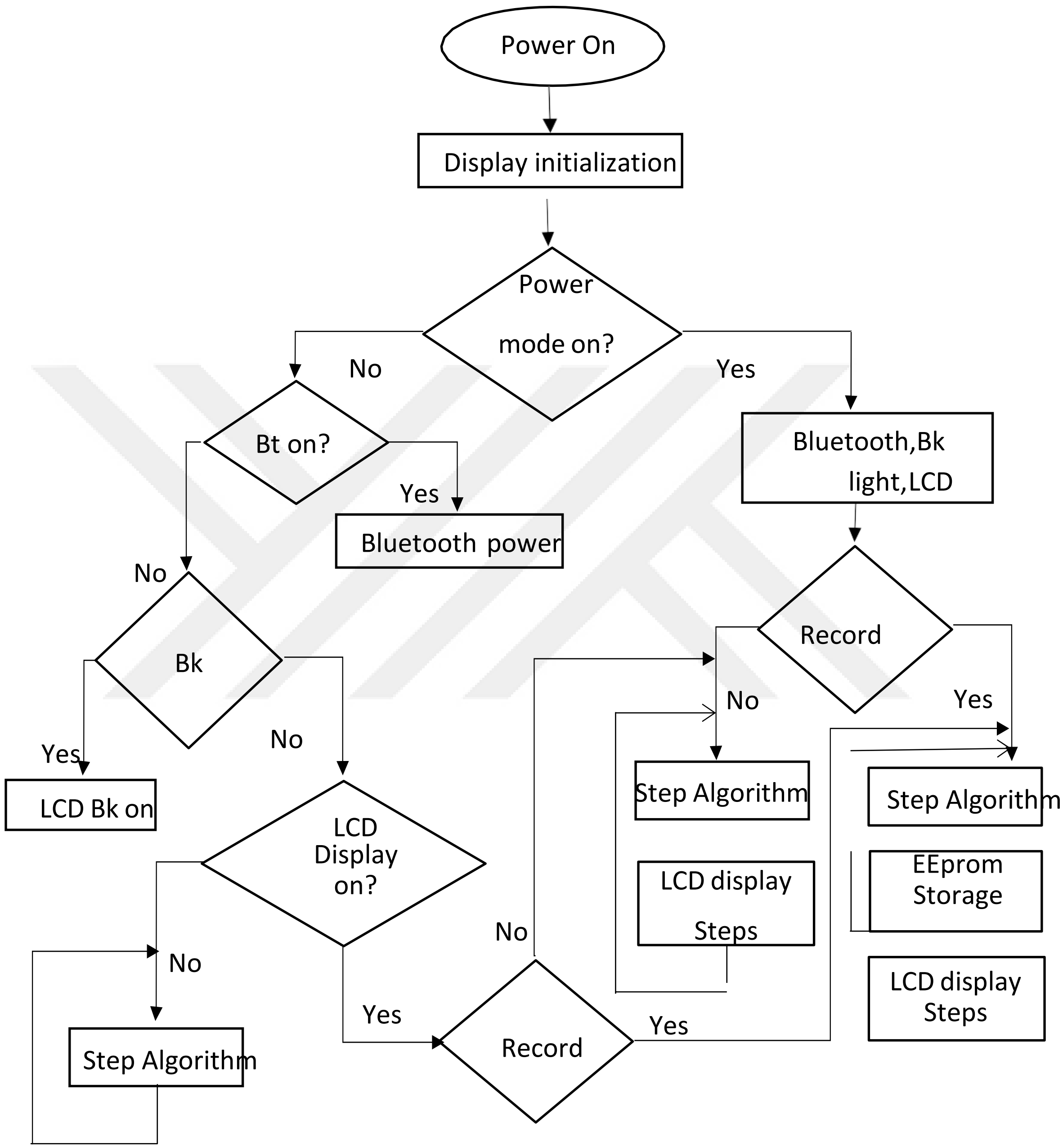


Figure 3. 9: Flowchart illustrates the operation process of proposed pedometer.

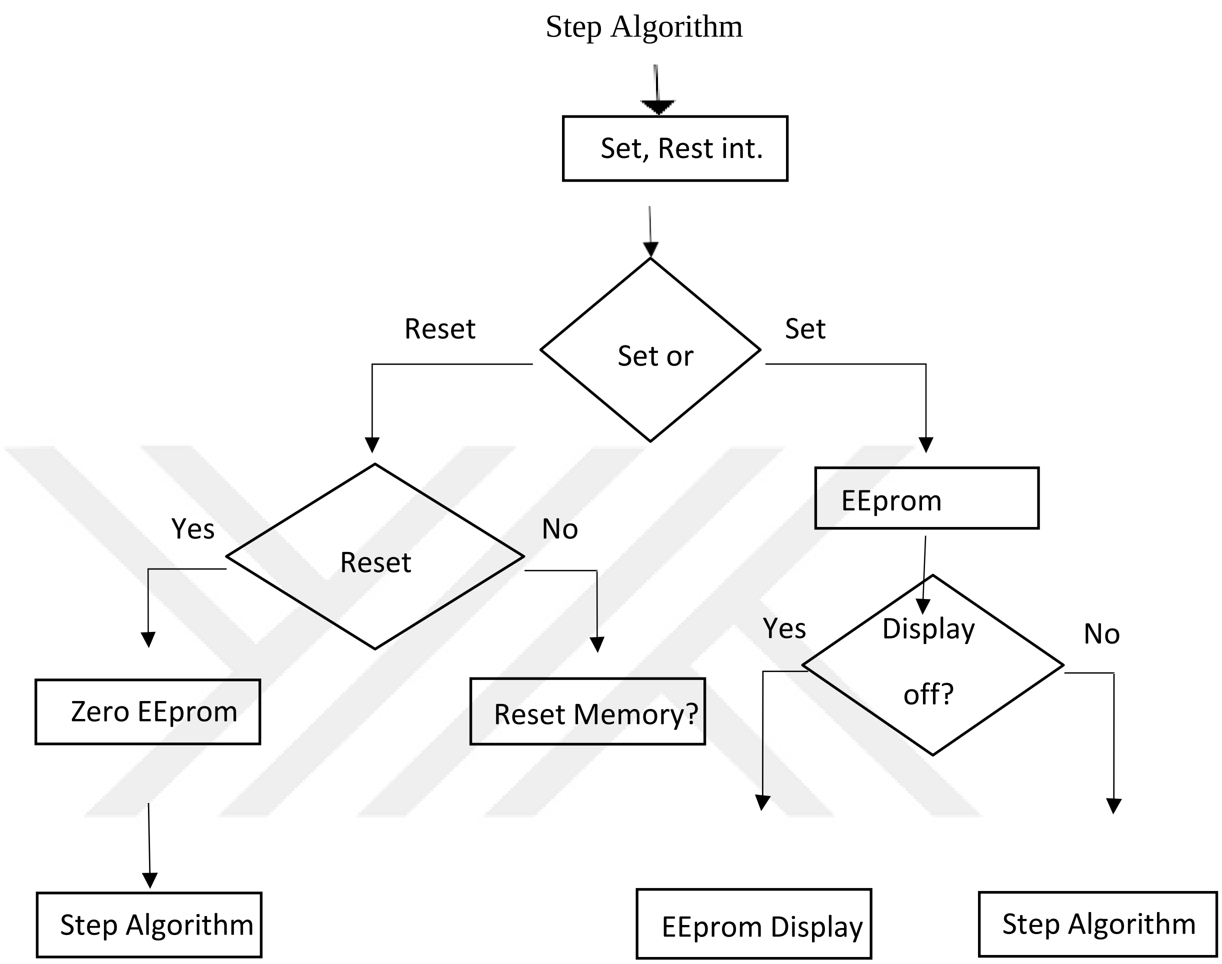


Figure 3.10: Flowchart of the Steps count algorithm

4. SYSTEM TEST AND RESULTS

As illustrated in Figure 4, the pedometer board with 13-bit MEMS acceleration sensors ADXL345 and HC-05. Bluetooth modules and (2x16) liquid crystal displays. It also shows us the final results of the speed, distance, steps and calories. As shown and the similarity of the values found in the application and LCD.

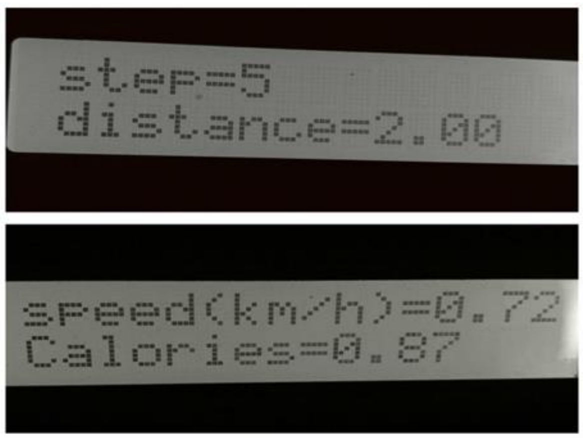


Figure 4. 1: The final result displayed on the LCD and application.

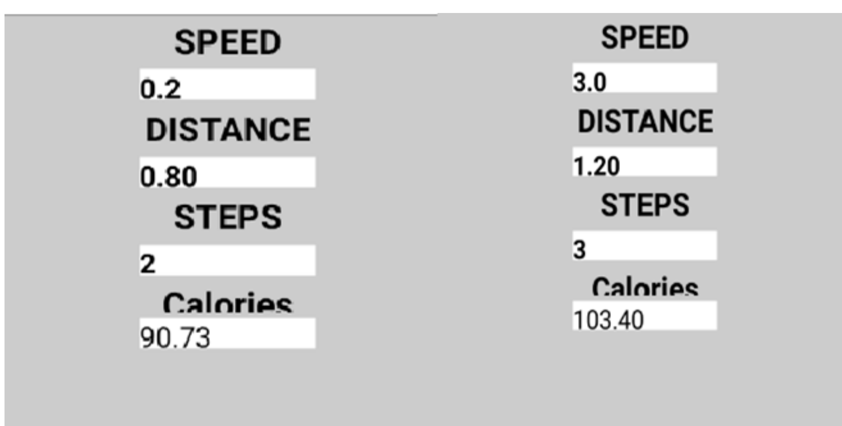


Figure 4. 2: The final result displayed on the LCD and application.

The system has been tested in terms of distance parameter, speed parameter and Calories Parameter, then the system has been compared with an authorized pedometer technique based mobile phone to record the steps and distance calculated then compared with actual distance and steps to determine the accuracy of proposed system. The experimental results that got are in follows:

(i) Distance Parameter

After computing the movements parameter using the technique given, Equation 4.1 may be used to calculate the length parameter:

$$\text{Total Distance} = \text{distance per step} \times \text{number of steps} \qquad (4.1)$$

The area covered each step is determined by the user's height and pace. If the user is taller or moving faster, the maximum number of generations may be increased. Every two seconds, the reference design will update the speed, distance, and calories metrics. As a result, it can calculate the current stride length based on the steps collected every two seconds.

(ii) Speed Parameter:

From general speed equation which in following:

$$\text{Speed} = \text{distance/time} \qquad (4.2)$$

As steps are per 2 second, and by applying Equation 4.1 on 4.2, the speed parameter will be calculating from following equation.

$$\text{Speed} = \text{number of steps per 2s} \times \text{stride/2s} \qquad (4.3)$$

(iii) Calories:

The number of calories burned can't be calculated precisely since there isn't one. The majority of elements that influence it include metabolism, body weight, fitness level, and exercise intensity. It might be calculated using a traditional estimate. A typical link between running pace and calorie consumption is shown in Table 4.1.

Table 4. 1: Running Speed vs. Calories Expended

Running Speed (km/h)	Calories Expended (C/kg/h)
8	10
12	15
16	20
20	25

The Calories Expended can be calculated using following equation:

$$\text{Calories} = 1.25 \times \text{running speed} \qquad (4.4)$$

Where, calories unit in (C/kg/h) and the speed unit in (km/h) The Calories expended speed unit for speed in (m/s) will be:

$\text{Calories} = 1.25 \times \text{speed} \times 3600/1000$

$$\text{Calories} = 4.5 \times \text{speed (m/s)} \quad (4.5)$$

Along with the speed and distance data, will be changed every 2 seconds. As a result, the Equation 4.5 to Equation 4.6 can be used to deposit funds for calories expended weight. The user must provide his weight (in kilograms) and 1 hour (3600 seconds), which is equivalent to (1800 2second intervals).

$$\text{Calories (C/2s) } 4.5 \times \text{speed} \times \text{weight}/1800 = \text{speed} \times \text{weight}/400 \quad (4.6)$$

Since there are no changes in distance or steps and the speed is zero because whenever person uses a rest in situ immediately after jogging or walking, Equation 4.7 can be used to determine calories expended.

During repose, caloric intake is typically approximately 1 C/kg/hour.

$$\text{Calories (C/2 s)} = 1 \times \text{weight}/1800 \quad (4.7)$$

Ultimately, the cumulative calories burnt may be calculated by adding the energy from all two-second intervals, reading Test:

In this part, the system has been tested to verify the accuracy of system. To get a real depending on result, the three records (actual readings, system readings and smartphone pedometer readings) have been taken place in same time for human activity in both (walking and Jogging). The distance has been selected to be 36m and 40m and the actual steps have been calculated which is (55 steps) for 36m distance and (69 steps) for (40m). The person handled both pedometer system and phone and start both at same time from starting point and stop them at the end of distance. The reading results are shown in table 4.2.

Table 4. 2: Calories Expended vs. Running Speed

Trials	Actual Readings		Proposed System Readings		Smartphone Readings	
	Distance/ meter	Steps	Distance/ meter	Steps	Distance/ meter	Steps
Walking	36	55	34.8	54	33.6	53
Jogging	36	55	32.8	52	31.8	51
Walking	40	69	39.2	67	38	66
Jogging	40	69	37.2	65	36	64

From Table 4.2 it is clear that the proposed pedometer has a high accuracy result that is very close to real readings.

For distance calculation, the records show that the system records for 36m distance are: (34.8m and 32.8) respectively for walking and jogging, while the smartphone device records are (33.6

and 31.8) respectively for walking and jogging, that mean the percentage of error of proposed system are (3.3%) for walking and (6.67%) for jogging, while the percentage of error smart phone pedometer are: (8.87%) for walking and (11.67%) for jogging. For 40m distance, the records show that the system records are (39.2m and 37.2) respectively for walking and jogging, while the smartphone device records are (38 and 36) respectively for walking and jogging, that mean the percentage of error of proposed system are (2%) for walking and (7%) for jogging, while the percentage of error smart phone pedometer are: (5%) for walking and (10%) for jogging.

For Steps calculation, the records show that the system records for 36m (55 steps) are: (54 and 52) steps respectively for walking and jogging, while the smartphone device records are (53 and 51) steps for walking and jogging respectively, that mean the percentage of error of proposed system are (2%) for walking and (6%) for jogging, while the percentage of error smart phone pedometer are: (4%) for walking and (8%) for jogging. For 40m distance (69 Steps), the records show that the system records are (67 and 65) steps for walking and jogging respectively, while the smartphone device records are (66 and 64) steps for walking and jogging respectively, that mean the percentage of error of proposed system are (2.9%) for walking and (5.8%) for jogging, while the percentage of error smart phone pedometer are: (4.3%) for walking and (7.24%) for jogging.

From results it appears that the proposed system readings are close to actual reading with low error and it more accurate than smartphone pedometer readings this due to high accuracy algorithm that used in proposed system.

5. CONCLUSION AND FUTURE WORK

5.1 CONCLUSIONS

In this research, the 8-bit midrange (18F) series microcontrollers (PIC18F4550) were used to implement a precision, low-cost, low-cost pedometer with 8MHZ internal oscillator speed and low power, high-precision MEMS acceleration sensor. The (ADXL345) uses HC-05 Bluetooth radio monitor in order to share recoded data such as steps, speed, and distance with devises like smartphone. The test findings reveal that the suggested system has a high precision error rate. From results, it appeared that the pedometer (for both smartphone and proposed pedometer) has less error in case of walking than jogging, for walking it be less than 3%, and less than 7% jogging. The test results show that the proposed pedometer has less error than smartphone’s pedometer this because of high accurate algorithm that used in calculation of steps.

Finally, the overall tests have proven that the proposed pedometer has high accuracy with low readings error beside it low in cos, that will make it dependable in step counting and can be used as dependable device for field of fitness application.

5.2 SUGESTION FOR FUTURE WORKS

Even this steady got a high accuracy in detection steps, but it needs more improving by side of hardware and software.

(i) For hardware suggestion, the proposed pedometer needs to investigate the improvement in step counting when using another type of MCU and accelerometer. In addition, there is need design compact wearable pedometer to be more user friendly.

(ii) For software, there is a need to improving step counting algorithms in order to reduce error to minimum as can.

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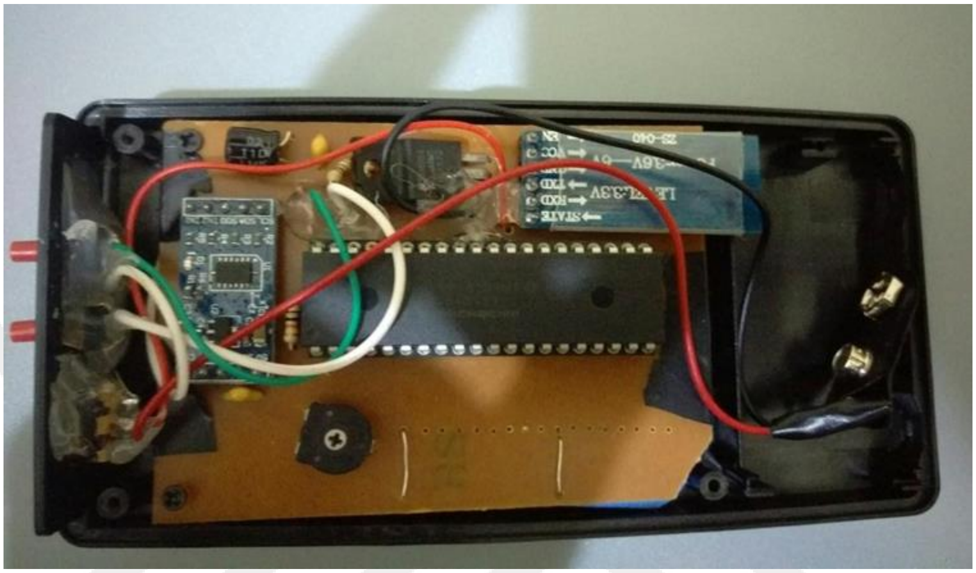
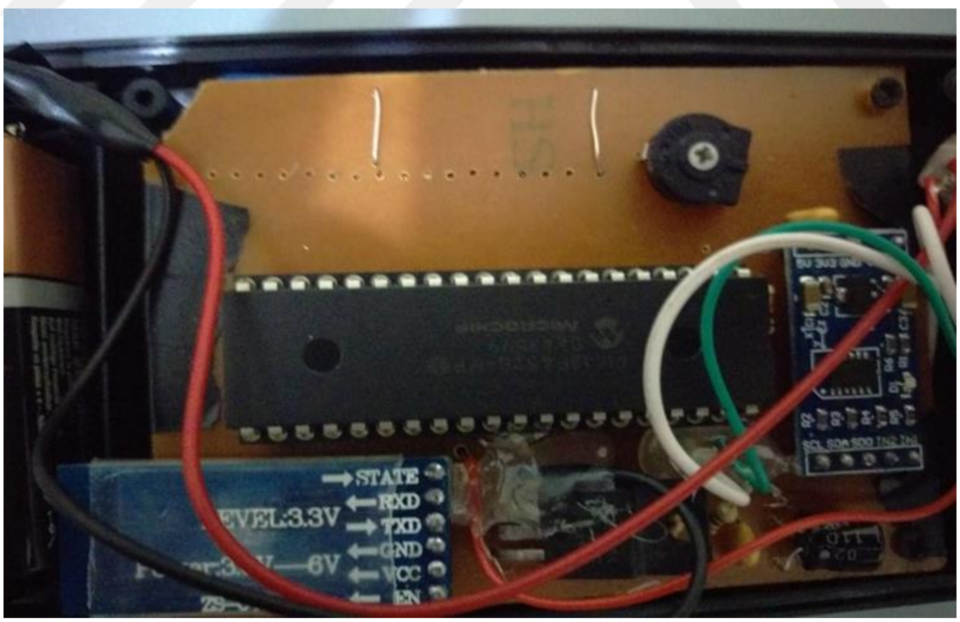
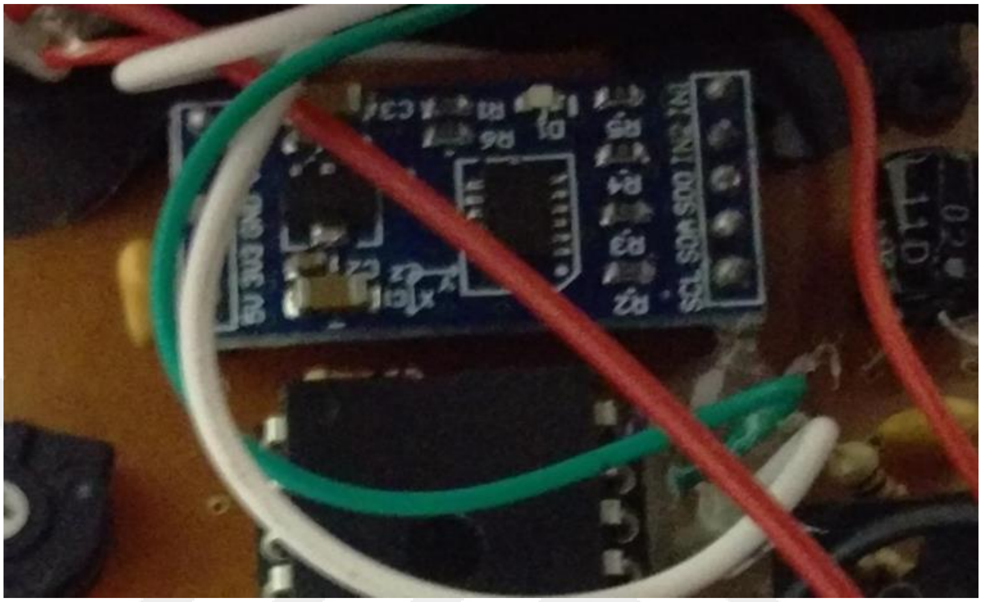
APPENDIX A

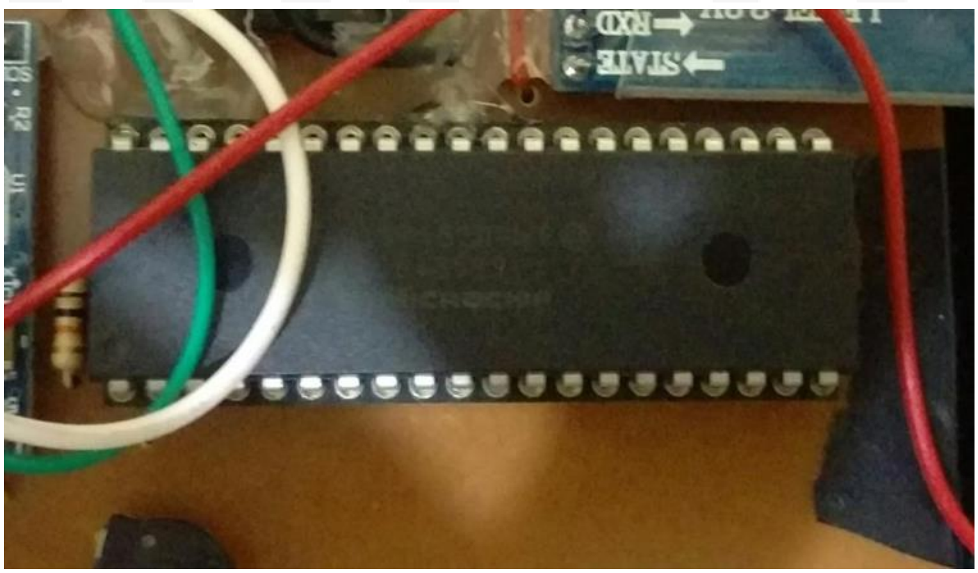
Pedometer components



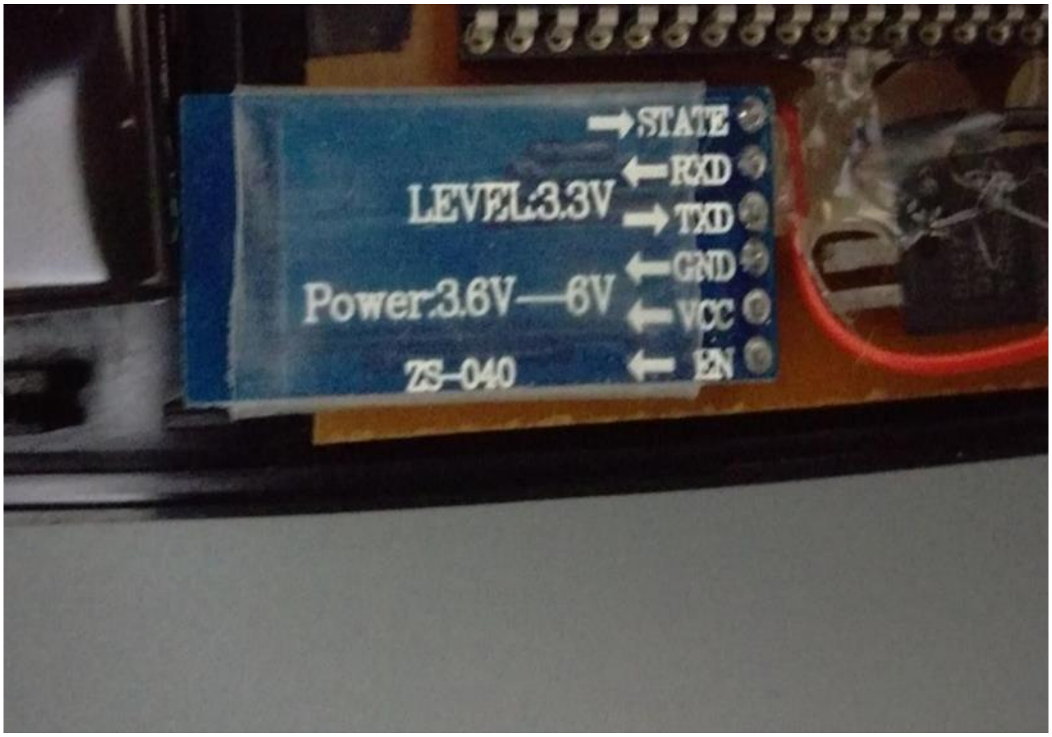




Sensor adxl345



Microcontroller pic18f4550

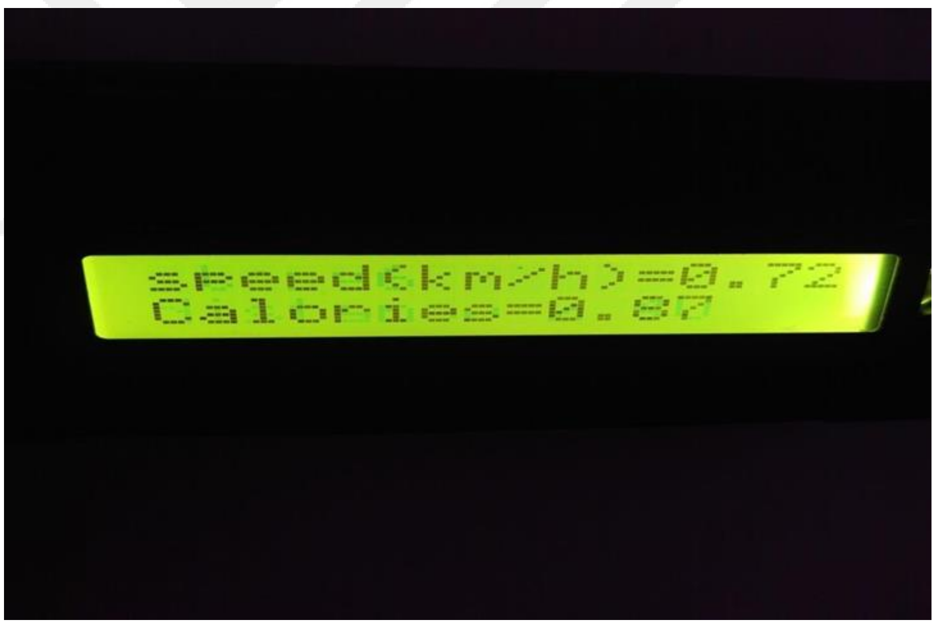


Bluetooth module

APPENDIX B

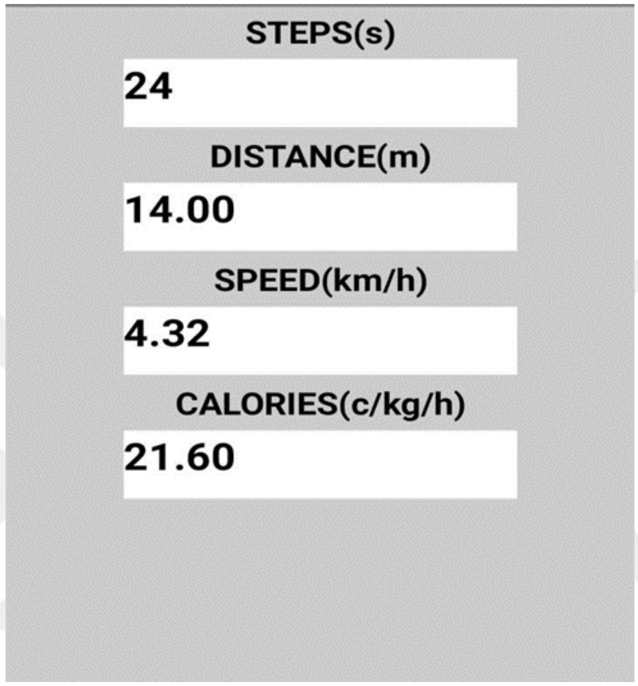
The readings of pedometer on LCD

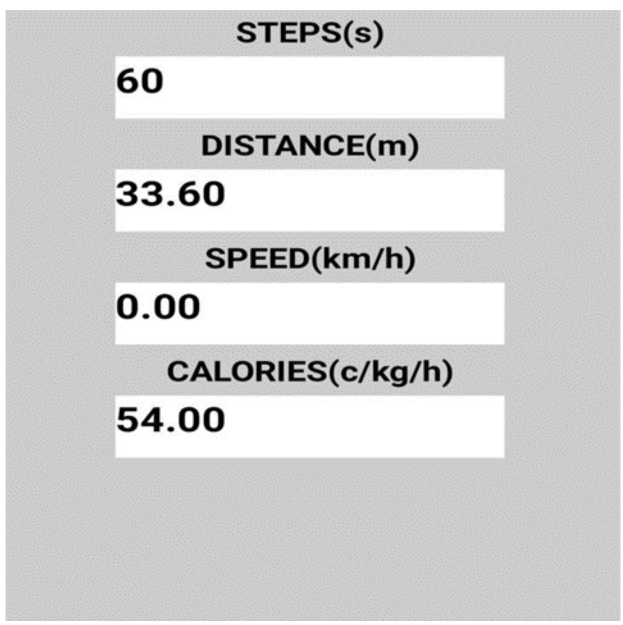

speed(km/h)=0.00
Calories=0.00


speed(km/h)=0.72
Calories=0.87

APPENDIX C

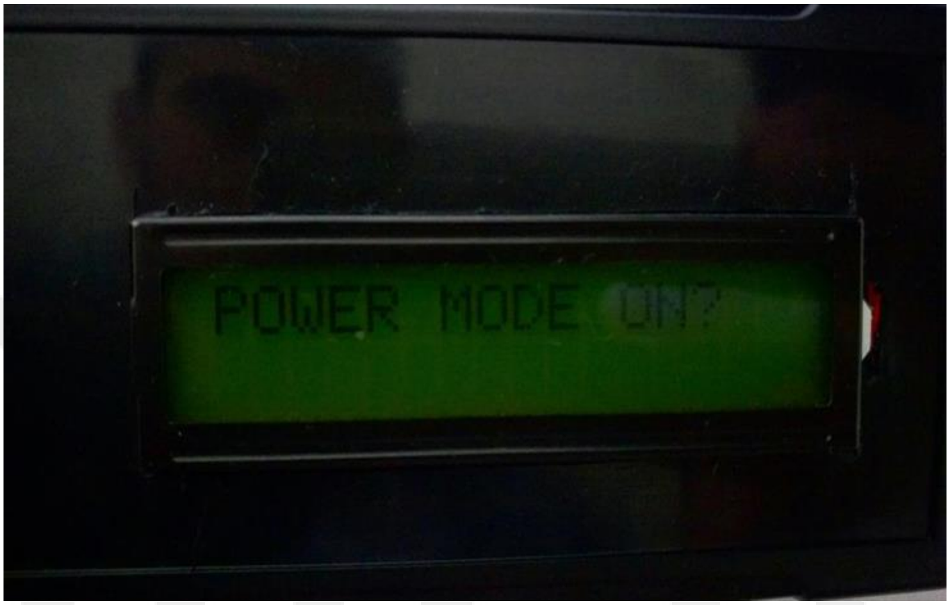
Smartphone application GUI





APPENDIX D

Power mode



APPENDIX E

Wearable