

MINIATURIZATION OF COMPUTER MOUSE AS A WEARABLE DEVICE

by

Ooha Reddy Manda, B.S.

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Committee Members:

Qingkay Yu, Chair

Yihong Maggie Chen

Ravi Droopad

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DEDICATION

I would like to dedicate this dissertation to my family for all the guidance, encouragement and support throughout my life. I also dedicate this report to my friends for their constant help and support.

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LIST OF ABBREVIATIONS

Abbreviation	Description
GUI	Graphical User Interface
WMSD	Work-related Musculoskeletal Disorders
RA	Remembrance Agent
GPS	Global Positioning System
ITO	Indium Tin Oxide
LED	Light Emitting Diode
SAW	Surface Acoustic Wave
LCD	Liquid Crystal Display
UART	Universal Asynchronous Receiver Transmitter
SPI	Serial Peripheral Interface

ABSTRACT

Wearable computing is one of the fastest growing technologies today. Smartwatches are poised that it can take over more than half of the wearable devices market in the near future. Smartwatch screen size is a limiting factor for its growth, as it restricts incorporating special touch features. On the other hand, wearable devices have some unique features, like reliable user interaction and hands-free operations. This thesis proposes a new computer mouse for smart watches or for hand pad which utilizes touchscreen sensor and microcontroller to detect and operate the stylus movement. The communication between the smart watch and the computer is done by using Bluetooth technology. This device is computationally intensive and inexpensive when compared to other existing mouse designs. It is compatible with android phones, laptops, and computers.

1. INTRODUCTION

1.1 Background

Since the 1970s, computers have rapidly shaped personal and business life. Factories and industries often use computer-controlled machinery. Occupations like law, engineering, medicine, and finance use computers almost universally. Many workers who once had little use for technology, now interact with computers nearly every minute of the workday. People use computers to read the news, play games, watch live videos, and keep in touch with family and friends.

Computers are used in a constantly growing number of jobs as an aid and tool to facilitate various tasks for workers. It has changed the way of life. Computers perform many tasks quickly and easily. It also saves time, cost and effort to complete a particular task. It is a machine that accepts input, performs calculations or operations according to a set of instructions, and returns the output of its calculations. All computers, regardless of their size, purpose, or type, follow this definition. A personal computer accepts input from a person via the keyboard or mouse, runs programs like word processors or games, and displays the results on the screen. Computers are essential because the information available is much more than the stuff that is seen or heard on television.

The computer has evolved into a smaller and much more powerful machine from a large-sized simple calculating device. The current state computer has evolved generations by generations. Each generation of computer is based on a new technological advancement, that results in better, cheaper and smaller computers. These are faster, more powerful and more efficient than their predecessors. It consists of Hardware and Software components. A computer would be useless if you cannot interact with it because the machine could not receive instructions or deliver the results of its work. The input and

output devices are the hardware components that are used to interact with the computer. The computer accepts data or instructions from Input devices like mouse, keyboard, etc. Output devices like the monitor, etc. are used to return the processed data to the user. The computer displays output to the monitor when the user needs to see the output.

The primary input devices are the keyboard and the mouse. The keyboard allows the user to input symbols, letters, and input into a computer. A mouse allows the user to move the cursor smoothly and intuitively over a 2-D plane. It is used for clicking, selecting, and dragging. The mouse enables users to switch between different applications, select options, and links. It moves around the screen with a significant degree of accuracy and smoothness. The mouse can perform many tasks that are very difficult to function with just a keyboard. There are different kinds of mice: mechanical, optical, trackball, touchpad which are both available wireless and wired.

As discussed above, the mouse is an essential component of the computer, but the usage of this leads to musculoskeletal disorders, called repetitive strain injuries, in the shoulder, arm, and hand region. These are difficult to rehabilitate, and sometimes they require surgery, which is both advanced and costly. Work-related musculoskeletal disorders (WMSDs) are degenerative conditions caused by repetitive motion that result in injury to muscles, nerves, joints, cartilage, and spinal discs. WMSDs most often occur in the forearm, upper arm, shoulder, neck, and back. Mouse tasks such as pointing-and-clicking, dragging and dropping involve repetitive motions of the forearm and fingers that are correlated with WMSDs. To address this problem, many researchers have attempted to design ergonomic computer mice to decrease the risk factors that lead to WMSDs. Many technologies have been emerged to make this mouse portable, user-

friendly, wearable and satisfy ergonomic benefits.

Some of these mice are designed to satisfy ergonomics are available in the market but are very expensive and also have some disadvantages. Below are some of the examples:

Table 1 Examples of Ergonomic Mouse with its Disadvantages

TYPES	DISADVANTAGES
Evoluent Vertical Mouse	Gripping and clicking force Finger grime accumulation
Pad N' Click Gel Pads	The usage of this ergonomic mouse doesn't reduce the Musculoskeletal Disorders, Carpal tunnel syndrome, and Repetitive Stress Injuries completely.
3M Ergonomic Mouse	The thumb to left-click action can be disorienting. It will take some time getting used to this device. The only way to use the scroll functionality is to press the middle button first and then scroll.
Logitech Trackball Mouse	Scroll wheel and browser buttons are a little too far for tiny hands. The scroll wheel is too resistant. The usage of this mouse does not completely resolve the ergonomic problem.

Although there are many mouse designs available in the market in the form of wired and wireless, but due to the advancements in technology people prefer wearable devices.

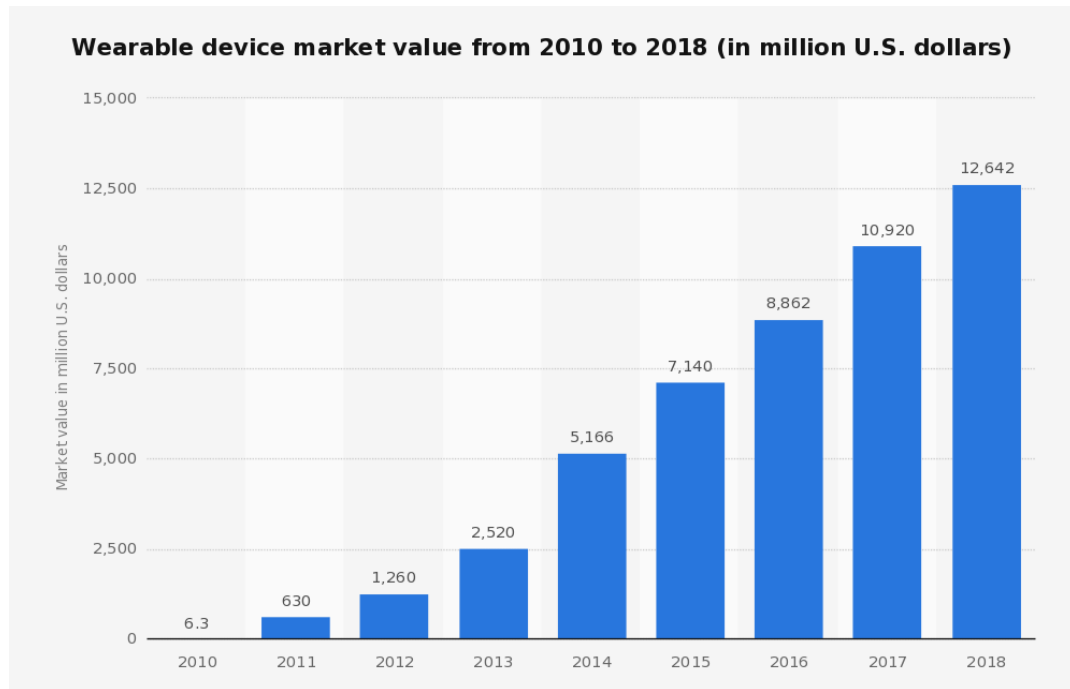


Figure 1 Wearable Device Market Value from 2010 to 2018 [1]

Wearable technology is evolving, and people are interested to see how the future generation of devices evolves. Wearables refer to the technologies or computers incorporated into clothing, watches, jewelry, eyewear, etc. Advantages of using these devices are ease of use, connectivity, and productivity. Now that consumers are becoming familiar with fitness trackers, smartwatches, smart glasses, and smart clothing, developers are interested in introducing wearable devices to keep the consumers involved.

Researchers with the help of wearable technology, started modernizing the devices by maintaining the functionalities of the existing devices like a computer mouse. There are many wearable mice in the market like the mycestro, glove mouse, thumbtrack, etc. which are expensive and also have some disadvantages.

1.2 Previous Wearable Computer Mouse

1.2.1 Mycestro

Mycestro Mouse is a 3D wearable device that is worn on the index finger. The finger movement controls the cursor movement. It does not interfere with the keyboarding because of its light-weight., It also has three buttons just like a regular mouse and thumb is used for scrolling option on the thumbpad [2].



Figure 2 Mycestro Mouse [3]

1.2.2 Maestro Gesture Glove

Maestro Gesture Glove Mouse is used to control the electronic devices like laptops/computers and gaming consoles with hand/arm gestures and gives electronic power. It requires a development software kit in order to work on the laptop [4].



Figure 3 Maestro Gesture Glove [5]

USA today has performed a survey on the wearable technologies, the poll shows that people are more interested in wearable watches. So, our research focus is on designing a wearable smartwatch mouse or a hand pad mouse.

Which of the following wearable technologies are you most excited about?

Response	%
Watches	30%*
Clothing	22%
Glasses	19%
Shoes	9%
Jewelry	9%
Other	1%
None/nothing	8%
Don't know/refused	1%

Figure 4 USA Today Poll on Wearable Devices [6]

1.3 Thesis Focus

The main thesis focus is to design a wearable watch mouse or a hand pad mouse by maintaining the ergonomic benefits and be optimized for using it with smartphones,

desktops, and laptops via Bluetooth technology. Simultaneously improving the mouse design by considering its dimensions to be 1.5inch*1.5inch, and making it wearable, flexible, ergonomic, inexpensive and small. This device will meet the current computer mouse user needs and preferences by maintaining its original functions of left, right clicks. The goal is to present a smartwatch mouse or a hand pad mouse design that satisfies wearability principles and can be used as a foundation to construct additional functionalities for manufacturing purposes.

1.4 Research Contribution

The main contribution of this research is to design a wearable mouse which has a function of a computer mouse. Based on the extensive literature review, we understand this to be the first step to develop a wearable mouse that attracts the customers.

1.5 Organization of Thesis Report

This report is organized into five sections. Following the introduction in Section1, Section 2 provides the literature review of relevant background, fundamental definitions and previous designs of a wearable computer mouse. Chapter 3 includes methodology describing the hardware and software design with the algorithm. Results, Applications, and Advantages over the existing models are discussed in Chapter 4. Section 5 concludes the dissertation with its future scope.

2. LITERATURE REVIEW

2.1 Mouse

The computer mouse is the earliest PC hardware device. A mouse is a handheld device used to position a cursor on the monitor. This device allows the user to select files and perform different actions on the selected items. The mouse is used for performing pointing, clicking and moving operation on a GUI (Windows or the Mac OS) [7].

2.1.1 Main Functions

A computer mouse allows the user to move the cursor across a two-dimensional plane, i.e., computer screen. It is an essential input device used for selecting, clicking, dragging/dropping, and hovering. Mouse is also used to switch between applications and select the options with a high degree of accuracy. It is used to scroll up/down on a website/application, and many more functions that would be impossible with the keyboard alone [8].

2.1.2 Advantages

- Easy to use.
- Cheap.
- Can place the cursor anywhere on the monitor.
- Helps to quickly and easily draw figures.
- Point and click capabilities.
- Works well together with a keyboard.

2.1.3 Disadvantages

- Needs space on the desk
- Excessive use of the mouse can lead to health problems
- If the battery wears out, it cannot be used until the battery is replaced especially in the wireless mouse.

2.1.4 Uses

It allows the user to navigate to different locations on-screen. A user can move the cursor around and can press the buttons for accessing or opening folders, drivers, etc. Once the items are selected, it can be opened, moved, deleted or copied. It can also be used to manipulate information in a selected file [7].

2.2 Ergonomics

Ergonomics is the study of designing a job in a way that fits the worker instead of forcing the worker to fit the job. The physical stress of the worker can be reduced by adapting tasks, tools, equipment and workstations that fit the worker. It helps to reduce many Work-related Musculoskeletal Disorders (WMSDs) [9]. Ergonomics makes use of several disciplines such as biomechanics, anthropology, industrial hygiene, and kinesiology [10-11].

2.2.1 Importance of Ergonomics

To sustain their position in the market, industries must implement technological advancements and increase production rates. As a result, jobs today can involve:

- Frequent lifting, and pushing/pulling loads without the help of other workers or devices [9]

- Increasing specialization that requires the worker to perform only one function or movement for an extended period or day after day [9]
- Working more than 8 hours/day [9]
- Working at a quicker pace of work [9] and
- Having tighter grips when using tools [9]

2.3 Guidelines for Designing the Workplace

Injuries and disorders may be avoided by setting up the workplace in an ergonomic correct way. Below is a list of guidelines to help prevent musculoskeletal disorders while using a mouse and keyboard.

- Breaks are helpful – Taking a break now and then, to let the muscles relax for a couple of minutes is good.
- Keep the hand away from the mouse – Removing the hand from the mouse when it's not being used is very helpful, a mouse that vibrates when it's not been moved for some time can be used as a reminder to remove the hand.
- Maintain a neutral wrist position – The wrist should be held in a neutral position with some space underneath. The forearm should float along with the mouse which allows the larger muscles to contribute to the task [12]. The workplace should be designed so that it facilitates the hand and joints to be held in a natural posture [13]. If a conventional mouse is used, it is advisable to use a keyboard without a numerical pad so that the mouse can be placed closer to the center line. It has also been proven that a mouse that keeps the wrist in a neutral position can reduce musculoskeletal disorders [14].

- Working posture – No fixed position should be held, variations in working posture are desirable. Twisted and asymmetrical postures should be avoided, and no upper limbs should be kept in a raised position. Static loading on arm, shoulder and neck regions should be minimized, and therefore the arm and hand should be supported to relieve the upper arm, shoulder and back muscles [14-15].
- Avoid prolonged static muscle loading – Static load may lead to fatigue, reduced work capacity, and soreness. Furthermore, constantly holding a button or switch also triggers fatigue and reduced flexibility [13].
- Avoid repetitive motions – The joints should not be used in a repetitive way for long periods of time, particularly important for the forearm, hand, and wrist [14]. Repetitive finger action should also be avoided to minimize the risk of trigger finger [13].
- Design for both hands – Handheld tools should be designed to be used with either hand because 10% of the population is left-handed but also to allow users to temporarily reduce the load of the primary hand if they wish [13].
- Use keyboard shortcuts – A variety of keystrokes can be used to relieve some mouse work [12].
- Keyboard work – When typing on a keyboard wrist should stay in a neutral position. The keyboard should be as thin as possible to minimize the angle of attack [14].

2.4 Ergonomic Mouse

Ergonomic Mouse is designed to reduce muscle strain and to provide comfort to the user while using this mouse. It reduces strains associated with an injury such as carpal

tunnel syndrome, arthritis, and tendonitis. An ergonomic mouse is designed to fit a natural hand position while it is being used.

2.4.1 Previous Designs

There are very few competing products in the markets that try solving the ergonomics issue but they do not satisfy the ergonomic benefits, or they are too highly priced which makes it inaccessible to most users.

- **Evoluent Vertical Mouse**

One competing mouse that satisfies few ergonomic benefits is the Evoluent Vertical Mouse. It is a vertical mouse that has the buttons and the scroll wheel on the right side of the mouse. The user positions his/her hand on the mouse like he/she is shaking their hands. This mouse is more ergonomic than a normal mouse because the user's arm does not have to twist to use the mouse. This mouse is good for those who use the mouse for a long-time period because the user's arm is in a comfortable position. Evoluent Vertical Mouse costs \$100 in the market. Since this mouse is too costly, less number of users prefer it [11].



Figure 5 Evoluent Vertical Mouse [16]

- **Disadvantages**

- Gripping and clicking force
- Finger grime accumulation

- **3M Ergonomic Mouse**

Another competing product is the 3M Ergonomic Mouse. This mouse has a joystick that is stationary, and at the top of the joystick, it has the left click and right click buttons. The user positions his/her hand in the vertical position so that it is comfortable to use for a long-time period. This mouse is highly recommended by the Arthritis Foundation as it reduces carpal and wrist tunnel injuries. The 3M Ergonomic Mouse costs \$52, which is costly for the casual users.



Figure 6 3M Ergonomic Mouse [17]

- **Disadvantages**

- The thumb to left-click action can be disorienting.
- It will take some time getting used to this device. The only way to use the scroll functionality is to press the middle button first and then scroll.

- **Logitech Trackball Mouse**

The most competing product in the market is the Logitech Trackball mouse. This trackball mouse is a stationary mouse. It has the buttons as a normal regular mouse has, it has a trackball that the user moves with the thumb to control the cursor. One of the main advantages of this mouse is that the user doesn't have to move the arm to move the cursor. The mouse can be used on surfaces that are not flat. The Logitech Trackball costs \$50 which may be expensive for normal mouse users [18].



Figure 7 Logitech Trackball Mouse [19]

- **Disadvantages**

- Scroll wheel and browser buttons are a little far for small hands. The scroll wheel is too resistant.
- The usage of this mouse does not completely resolve the ergonomic problem.

- **Pad N' Click Gel Pads**

Another product that is in the market is a set of Pad N' Click gel pads. The set of these silicone gel pads are placed on the palm and on the buttons of a regular mouse to make clicking of the buttons more comfortable. The shape of these gel pads on the

fingertips cause the finger to bend while clicking that mouse rather than being extended like a regular mouse. The cost of the gel pads is very less and are affordable, which is an advantage. It costs only \$5.



Figure 8 Pad N' Click Gel Pads [20]

- **Disadvantages**

- The usage of this ergonomic mouse doesn't reduce the Musculoskeletal Disorders, Carpal tunnel syndrome, and Repetitive Stress Injuries completely.

- **Trackbar Emotion**

Daniel Amosy and Jonatan Hedin Persson proposed a methodical development and re-design version of the existing Trackbar Emotion. A design that meets both existing and new reactive users, with already developed disorders, and also attract people to use it with proactive care. The slim design with a low profile, a roll bar that is large and easy to reach makes it fit in most of the workstations [21].

- **Disadvantages**

- It is very big in size.
- It is not portable.



Figure 9 Trackbar Emotion [22]

- **Goldtouch Ergonomic Mouse**

The Goldtouch Ergonomic Mouse is another mouse that is designed to reduce the Repetitive Stress Injury and satisfy the ergonomic benefits. The Goldtouch mouse is a right solution for workers in the corporate places. The right tools protect the employer and improve their performance.



Figure 10 Goldtouch Ergonomic Mouse [23]

2.5 Wearable Technology

Wearable technologies are evolved from the invention of electronic chips, internet, wireless technology like Bluetooth, Wi-Fi, etc. It can be defined as the device that can be worn on the users' body. These devices became popular and famous recently even though they existed for decades or even centuries. The scope of wearable technology is very broad and vague. To understand the classification of wearable

technologies based on the basic characteristics and specifications is very delicate but beneficial. These technologies can be worn on the body in the form of jewelry, eyewear, shoes, clothing, etc. The researchers are working hard to develop more comfortable, reliable, integrated, smaller, aesthetic and lighter products to increase the usage and adoption of these technologies.

Wearable devices refer to electronic devices or computers. There are few terms that have a closer meaning of a wearable device, like ‘wearable computers’, and ‘wearable electronics.’ Normally this device is a fashion accessory. The device can work independently or be connected to a smartphone allowing significant interface with the user. The wearable device can be worn on the body, in the body or around the body [24].

2.5.1 Basic Design of Wearable Devices

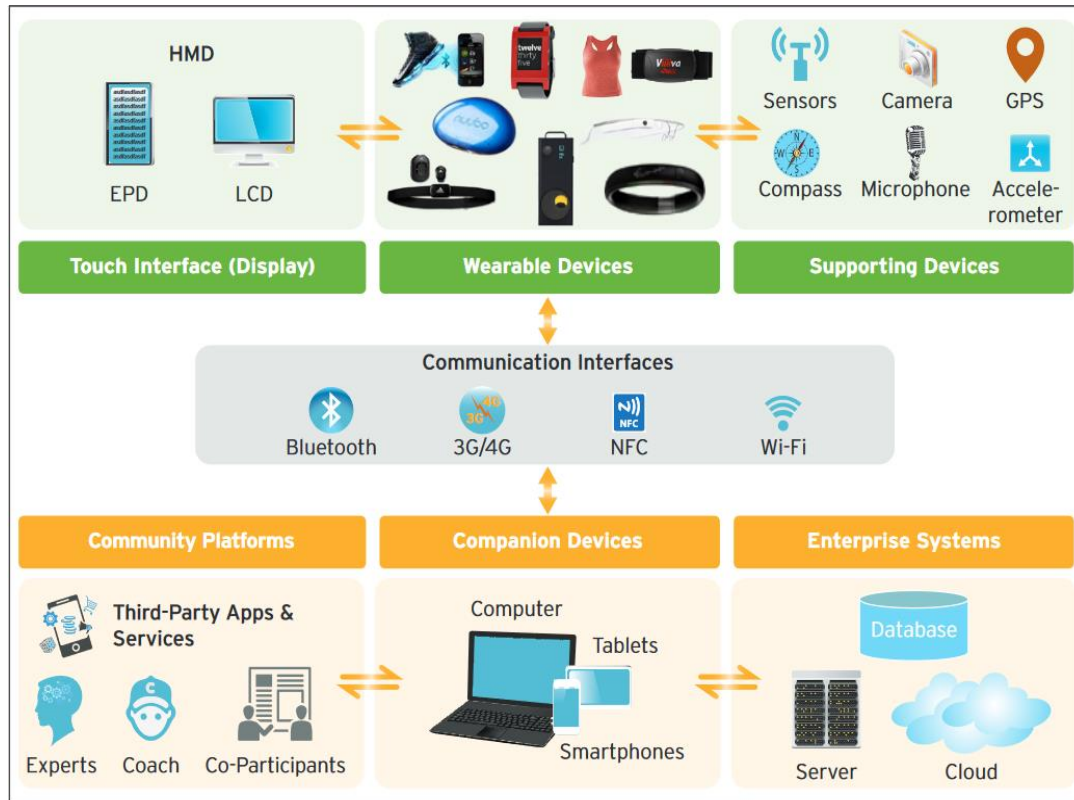


Figure 11 Basic Design of Wearable Device (Business Insider, 2014)

2.5.2 Challenges to Wearable Technology

There are many challenges in designing and marketing the wearable devices. Many users see the disadvantages or obstructions to purchase wearable devices. The price of the product, privacy and security of data are primary concerns, other concerns are the comfort and look. According to the recent report, below are the challenges to the wearable technology.

- Easy to lose
- Break
- Not waterproof
- A pain to sync with the smartphone
- Battery doesn't last for long
- Ugly
- Uncomfortable to wear
- Provide no material benefit

2.5.3 Advantages of the Wearable Devices

- **Consistent:**

There is a constant interaction between the computer and the user.

- **Multi-Tasking:**

Even though the user is engaged with the physical environment, the wearable device can still provide computational support.

- **Mobile:**

Wearable computers can be taken from one place to another without any inconvenience. They can use this device anywhere.

- **Unrestrictive:**

The user can do other things while using this device.

- **Communicative:**

Any person in possession of these devices can communicate with their systems without suspending their normal routine work.

- **Can't be lost easily:**

A wearable device is worn on the body so it can't be lost.

- No distraction

2.5.4 Disadvantages of Wearable Devices

- **Expensive:**

Wearable computers are sometimes of high costs of setting up LANs and hardware components.

- **Heavy:**

Wearable computers are sometimes very heavy as it is made of many components. These components are sometimes very difficult to wear.

- **Discomfort:**

Wearable computers irritate the user because the wearable components emit heat during the hot and humid weather conditions even though the cooling technology is built in them.

- **Security:**

Wearable technology can be hacked easily.

2.5.5 Applications of Wearable Devices

It is used in various fields like medical, fitness, disabilities, education, enterprise, gaming and music. The main objective of these fields is to efficiently incorporate portable electronics and computers into one's daily lives. Before their introduction in the consumer market, these were used in the field of military and health care.

- **Augmented Memory:**

Wearables having augmented memory such as Remembrance Agents (Ras), persistently reminds the wearer of potentially appropriate information in accordance with the wearer's ongoing physical and virtual context. These Ras are always on, it implies that they are always up, active and working rather than being 'worker up' when required.

- **Finger Tracking:**

Finger Tracking is one among the basic applications of camera based upon wearable computing in which computer can visually track the user's finger, such that the user can then control the computer with his fingers and mouse as well.

- **Face Recognition:**

In combination with relevant face identification software, face recognition system can be inculcated for use in wearable computing. This customized feature can be used by the market users such as police, politicians, teachers, the visually challenged and those with bad memories.

- **Visual Filter:**

Visual Filter is basically designed for the visually impaired. This wearable computer is capable of digitally magnifying an image or a prose using a virtual

fish eye lens to assist in reading. This can be accomplished by using a digital visual filter.

- **Navigation:**

Wearable constituting Navigation & Global Positioning System (GPS) with a proper mapping software allows users to keep a track of their desired or the current location while travelling or exploring a new city or place. It helps visually disabled persons by alarming them of an approaching object with the warnings and hence promote safety in their daily lives.

- **Repair Instruction:**

To advise on the next step it spots 3 exclusive marks at fixed distances from each other, such that a wearable camera with a determined focal length can recover the 3-D location of an object based on these three marks. Now the wearable is capable of automatically determining the hazard, locates the object's 3D position and proposes suitable 3D real time step by step guidelines to be followed by the technician about the object.

- **Communication Management:**

To manage personal communications naturally one can make use of WAC with much mobility. Speech recognition technique can be used to convert the user's responses (with constraints on vocabulary and grammar) into text for email responses. It combines speech recognition, synthesis and digital audio recording that acts as virtual secretary which manages mobile communications.

- **Remote Sensing and Maintenance:**

Wearable can also render field workers with remote assistance and expertise

through digital data, audio and image, such that even a non- expert would be able to maintain and accomplish simple repairing tasks with aid of remote experts at the help desk.

- **Industrial:**

Rapid and precise availability of complex information to the workers in the field, office place or at a non-office workplace has been crucial to many organizations since 1950's when computerized records were established. Workers have to perform tasks that requires the usage of one or both hands, and those for which there is a need to maintain eye contact considering the protection aspect. Wearable computers have various advantages based upon the type of industry. Because of their flexibility, portability and hands-free use, wearable computers are being used by workers in many types of industries. For example, a wearable computer with a hands-free interface such as speech, and a head-mounted display can give a solution for these workers.

- **Military:**

Potential applications of wearable computers for infantryman were quickly identified by organizations and other law agencies. Apart from providing command/control communication and navigation functions, it is also capable of providing access to tactical information that helps to distinguish between friendly and hostile forces, and potentially offering strategies for dealing with dangerous scenarios. Miniature cameras integrated with lightweight wearable computers, ultimately allows soldiers to share video of what they experience and see, with each other. Wearables designed for military purposes should be more rugged and

robust to withstand knocks and shocks. Many of these are designed with the total integration of man and system in mind. Much of the research of wearable in military has been kept confidential however examples of collaboration with non-military researchers can be found in the United States, United Kingdom, Australia and Singapore.

- **Medical:**

The basis for many wearable designs come from the awareness of where the user is located. To monitor well-being and activity -the how and what of the user, these wearable computers can be designed and used.

- **Sports and Fitness:**

Interest in wearables for sports and fitness has been largely driven consumers. The typical functions of such wearables are performance monitoring, goal monitoring and management, activity tracking, direction data and location share and optimum performance management.

- **Tourism:**

A few wearable computers which are reassuring for tourists and might prove to be a big slam for the tourism industry are given below.

- Narrative Clip
- Tourist diary
- Triposo travel belt [25]

2.6 Touchscreen

A touch screen is an input display screen device that allows the user to communicate with a computer by using their finger or stylus. Some of the screens are

pressure sensitive. User communicates with the computer by touching pictures or words on the screen. As an alternative to a computer mouse or keyboard, these screens can be used. Touchscreens are used on many devices such as computer/laptop monitors, cash registers, smartphones, ATMs, tablets, etc. [26].

2.6.1 Types of Touchscreen

- **Resistive Touchscreen**

The Resistive touchscreen is made of two electrically conductive layers which is composed of a flexible top layer and a rigid bottom layer separated by insulating dots, attached to a touchscreen controller [26]. The inside surface is coated with Indium Tin Oxide (a transparent metal oxide), when voltage is applied, it produces a gradient across each layer. When the top layer is touched with a stylus, electrical contact is made between the layers, closing the circuit. The resulting X-Y coordinates are determined from voltage drop and are sent to the microcontroller. The touchscreen controller then passes on to the computer for processing.

- **Working**

Resistive touch screen can be used with finger or stylus. It consists of two conductive layers with horizontal and vertical lines. When finger or stylus touches the touch screen, these lines help to calculate the x and y position with the precise location of the touch [26].

It is advantageous for the users who wear gloves to interact with the computer in cold environment. It consists of two layers that are transparent and flexible. These layers are electrically resistive and are separated from each other by a thin space. These layers are scratch resistant. When the device is on, there is a continuous flow of electric current

through the thin space between the top and bottom layer. If the top layer contacts the bottom layer, a location is registered which is then given as an input to the microcontroller via software.

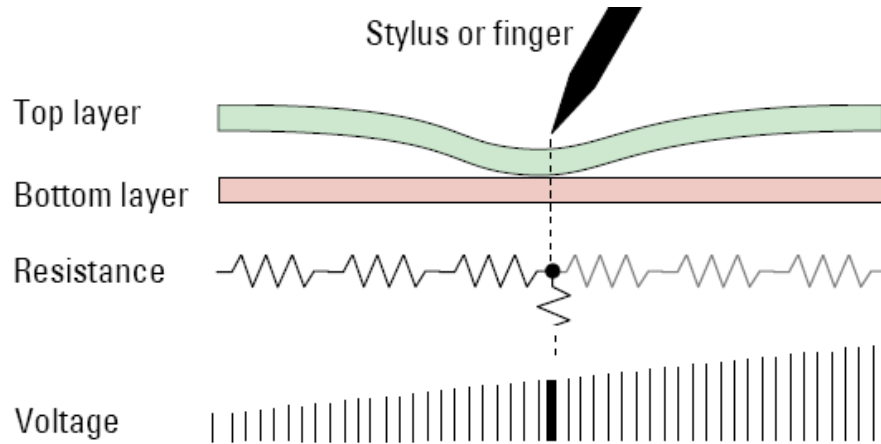


Figure 12 Working of Resistive Touchscreen [27]

The horizontal and vertical lines, that run through these layers are used to get the precise value of the exact location (like coordinates). When the two layers are in contact (finger/stylus), it acts as a voltage divider on each layer at a time. The voltage gradient is applied to the top layer; the bottom layer measures the distance along the top layer which is X-axis distance. The voltage gradient is applied to the bottom layer to measure the Y-axis distance [27].

- **Advantages**

- It is durable and reliable.
- They are not expensive.
- It has a longer life.
- It can be operated by a fingernail, gloved hand, and stylus.
- Stylus versatility since it is based on pressure.

- Higher sensor resolution
- Will register fewer inadvertent touches
- High resistance to dust and water.
- Best suited for handwriting recognition.
- **Disadvantages**
 - Plastic surface can be scratched if it is improperly used.
 - Not too sensitive, you must put some pressure
 - Poor contrast
 - Multi-touch is not supported.

Resistive Technology is divided into two broad categories:

- **4-Wire Resistive Touchscreen Technology**

Four-wire resistive technology is very simple to understand and very easy to manufacture. It uses both layers in the touchscreen to calculate the X and Y coordinates. It is constructed with uniform resistive coatings of ITO on the inner sides of the layers and silver buss bars along the edges; the combination sets up lines of equal potential in both X and Y [26].

- **5-Wire Resistive Touchscreen Technology**

In the five-wire designing, the first wire is connected to the voltage probe of both X and Y. The remaining four wires are connected to corners of the back-glass layer. The two corners (A, B) are applied with 5v by the controller, and the remaining two corners (C, D) are grounded due to which there is a voltage flow across the screen, this gives us the reading of the Y voltage. The two corners (A, C) are then applied with 5v by the controller, and the remaining two corners (B, D) are grounded and gives the reading of X

voltage.

- **Capacitive Touchscreen**

The panel of the capacitive touch screen is coated with a material which stores electrical charges, a small amount of charge is drawn to the point of contact on touching the panel. The capacitance is measured by the circuits which are located at the corners of the screen; the information is then sent to the controller. This technology is divided into two broad categories:

- **Surface Capacitive Technology**

In this technology, one side of the insulator is coated with a conductive layer and a small voltage is applied to the layer that results in uniform electrostatic field [26]. When the finger touches the uncoated surface, a capacitor is formed. The sensor calculates the location of the touch from the change in the capacitance.

- **Projected Capacitive Technology**

This technology utilizes etched conductive layer. This conductive layer allows more accurate and flexible operation. The X-Y grid is formed by etching single or multiple layers to form electrodes. These gridlines are placed perpendicular [26]. This technology is clear, durable, and scratch resistant. Because of these features, it can be used in harsh, industrial, or outdoor applications.

- **Working Principle**

The electrodes located on the four corners are applied with a small amount of voltage. As human body acts as an electric conductor, a small amount of current is drawn creating a voltage drop when the finger touches the screen. The amount of current that drifts through the four electrodes should be proportional to the distance from the touch

position to the four corners [26]. The ratio of the current passed through the four electrodes, and X and Y coordinates of the touch position are calculated by the controller.

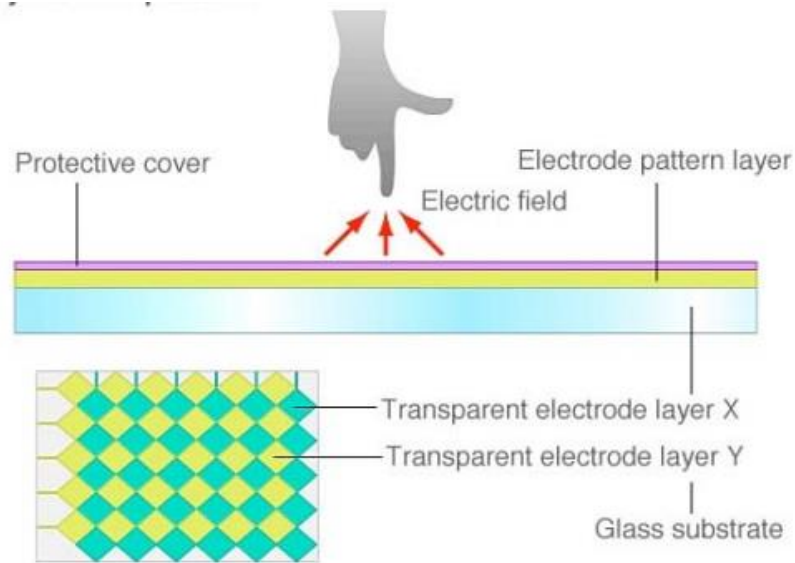


Figure 13 Working of Capacitive Touchscreen [28]

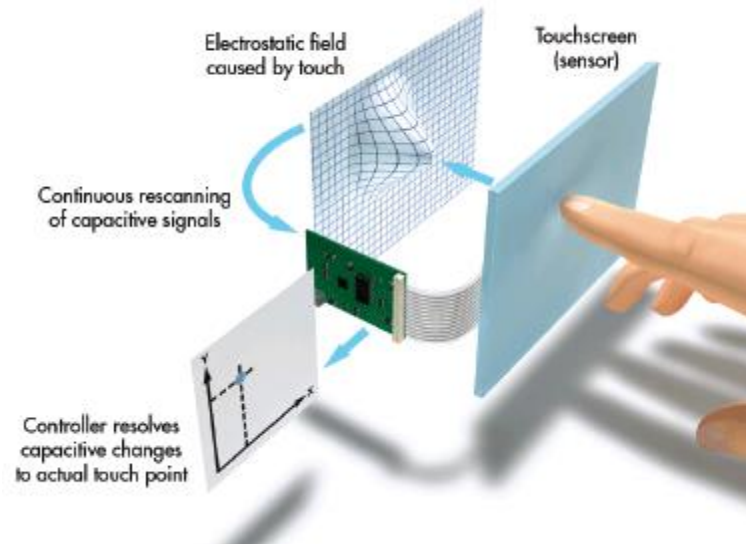


Figure 14 Working of Projected Capacitive Touchscreen [27]

- **Advantages of Capacitive Touchscreen**

- Capacitive touchscreen looks brighter
- Highly touch sensitive
- Great durability
- Reliability
- Future-proofed
- Multi-touch capability

- **Advantages over Resistive Touchscreen**

Capacitive touchscreens are more durable than resistive touchscreens in some ways.

- If a capacitive touchscreen is cracked, it will continue to work but resistive touchscreen stops working.
- It is visible even in the sunlight.
- Resistive touchscreens are less responsive than Capacitive touchscreens.

- **Disadvantages**

- Doesn't work with a glove.
- Due to their complex structure, they are expensive.
- Since it is made of Glass, it can be broken easily.
- Accuracy is up to a few pixels.
- Power supplies with electronic noise reduce the accuracy.

- **Applications**

- Tourism displays
- Store and Restaurant Systems

- Control and Automation Systems
- Computer Based Training
- Assistive Technology
- **Infrared**

An infrared touchscreen uses an array of X-Y infrared LED and photodetector pairs to detect a disruption in the LED beams placed around the edges of the screen [26]. This system can detect any input including a finger, stylus or pen, gloved finger. This technology is used in many outdoor applications.

- **Working**

This technology is based on the light-beam interruption. The display consisting of the light sources or the Light Emitting Diodes (LED's) on one side and light detectors on the other side and is surrounded by a frame that creates an optical grid. The invisible light beam is interrupted upon touching the screen with a finger; this causes a drop in the signal received by light detectors. It works with human touch or stylus. They are more receptive to dirt, flying insects, etc. These provide huge clarity and are durable.

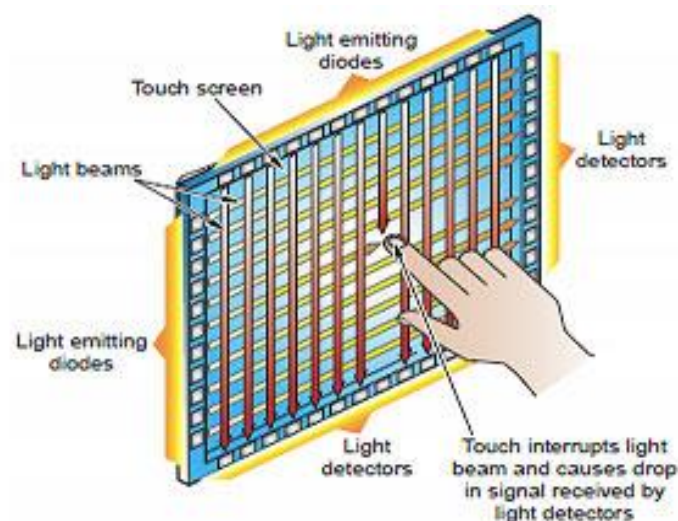


Figure 15 Working of Infrared Touchscreen [26]

- **Surface Acoustic Wave**

The Surface Acoustic Wave technology is the latest and most advanced touchscreen technology types. There are two transducers placed for both X and Y axis on the touchscreen (transmitting and receiving transducer). The other important element of the SAW is the reflector which is placed on the glass. The controller transmits an electrical signal to the transmitting transducer where the electrical signal is converted into ultrasonic waves [26]. The transducer emits these waves to reflectors that are edged up along the corners of the screen. The reflectors refract the ultrasonic waves to the receiving transducers. These transducers convert it back to an electrical signal, which is then sent back to the controller. Compared to other technologies, it produces high image resolution with clarity and higher light transmission. Since this is made of glass, so it is very durable. Disadvantages of this technology include the fact that the touch screen should be touched by the finger, soft tip stylus, or gloved hand. The pen that is hard cannot be used. This technology is recommended for ATMs, Banking, and Financial Applications, or other high traffic indoor environments. The SAW allows gloved hand use. It is very expensive and is difficult to seal from the environment. Another major disadvantage is that it can be activated by dirt, grease, or liquids and can also be damaged by outside elements.

- **Working**

Surface Acoustic Wave is a new technology, also known as SAW. It operates with ultrasonic waves that move over the screen. When the screen is touched, frequency changes and the receiver notes the change in frequency. Since it is made of glass, there is no additional coating required.

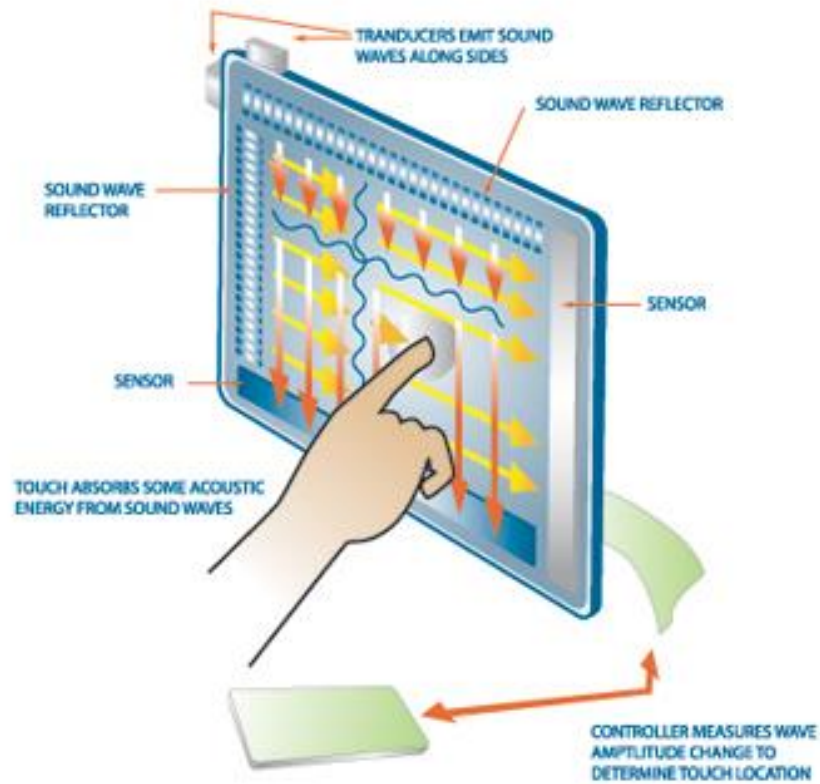


Figure 16 Working of Surface Acoustic Waves (SAW) Technology [29]

- **Advantages of Surface Acoustic Waves Technology**

This technology is an advanced technology which provides high clarity and more durability. It works well by human touch or a mechanical stylus. This technology is expensive than the other technologies, and it is not well supported.

3. METHODOLOGY

3.1 Introduction

The proposed system of wearable wireless mouse consists of the hand pad, which includes a sensor module, data acquisition module, and transmission module. The acquired signal is then transmitted to the receiver end through Bluetooth. The receiver end (laptop or PC) that contains the Bluetooth and the software module receives the signal and displays the data on the screen. The hardware and the software implementation are explained below.

3.2 Initial Approach

Initially, a capacitive touchpad with a touch sensor and the Bluetooth is used. The touchpad raw data is received by the touch sensor; the data is processed by the microcontroller incorporated on the IC. This data is transmitted to the computer by using Bluetooth technology.

3.2.1 Block Diagram

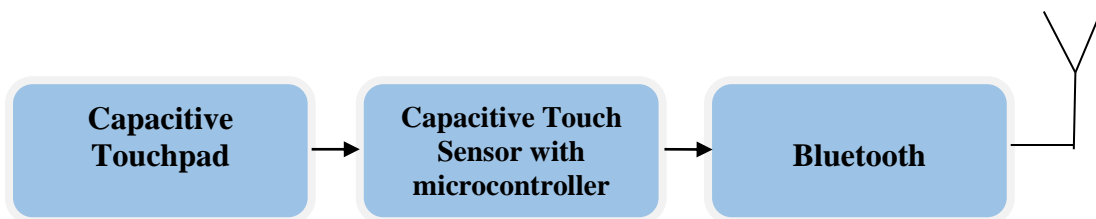


Figure 17 Block Diagram of the Transmitter

3.2.2 Hardware Design

It is easy to design the touchpad by using PCB software. The capacitive touchpad is designed in the ExpressPCB software. The touchpad has two layers, one with X-axis gridlines and other with Y-axis gridlines. These X and Y gridlines are perpendicular to each other. The touchpad is designed with a dimension of 1inch x 1inch, with 8 X-

gridlines x 8 Y-gridlines. The sensor is interfaced with the 16 touchpad terminals. The microcontroller is then connected to the Bluetooth via SPI protocol.

- **Components Used**

Capacitive Touchpad

AT42QT2640

ATBTLC1000

- **Working**

The QT2640 employs Qmatrix transverse charge-transfer sensing; a technology that senses changes in electrical charge forced across two electrode elements by a pulse edge. The QT2640 allows a wide range of key sizes and shapes to be mixed together in a single touch panel, and is designed for use with up to 64 keys, and up to eight sliders and wheels, or a mixture of keys, sliders and wheels.

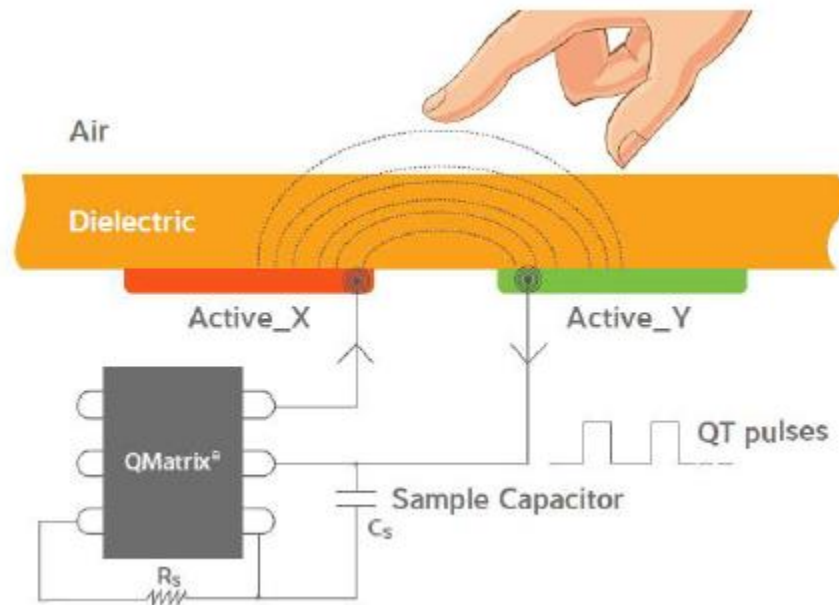


Figure 18 Field Flow X and Y Elements [30]

Table 2 Key Numbers

	X7	X6	X5	X4	X3	X2	X1	X0	Key Numbers
Y0	7	6	5	4	3	2	1	0	
Y1	15	14	13	12	11	10	9	8	
Y2	23	22	21	20	19	18	17	16	
Y3	31	30	29	28	27	26	25	24	
Y4	39	38	37	36	35	34	33	32	
Y5	47	46	45	44	43	42	41	40	
Y6	55	54	53	52	51	50	49	48	
Y7	63	62	61	60	59	58	57	56	

The QT2640 uses an SPI interface for communications with a host. The QT2640 always operates as a slave and must be driven from the host acting as SPI master. The SPI host device initiates communication sequences.

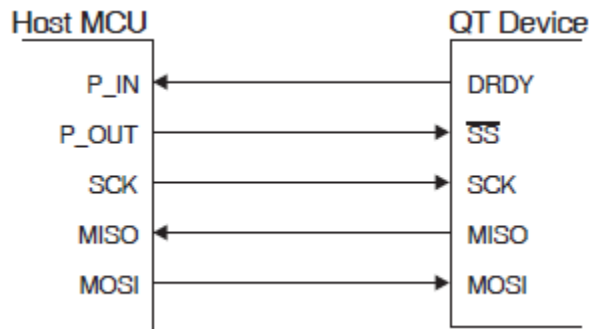


Figure 19 Communication Signals – SPI [30]

The code is written in such a way that the touch pad is interfaced with the touch sensor. When the user is moving the finger on the touch pad the key numbers position data is sent to the touch pad. When a finger is placed over these sensor nodes, it changes the effective capacitance of the sensor nodes [31]. This change in capacitance is used to

detect the touch [31]. The position key number cannot be obtained as a touch pad design in ExpressPCB, the X and Y gridlines does not satisfy capacitive touch design criteria:

1. Size of each sensor node should be between 5mm to 7mm [31]
2. Y-electrode thickness must be 0.2mm and 0.5mm [31]
3. An X-flood can be used for sensors along each column, since they use the same X-line [31]
4. Separation between X-flood columns should be 0.5mm [31]

- **Circuit Diagram**

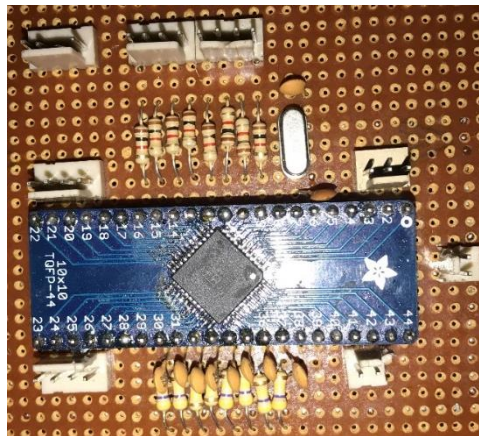


Figure 20 Capacitive Touchpad Circuit Diagram

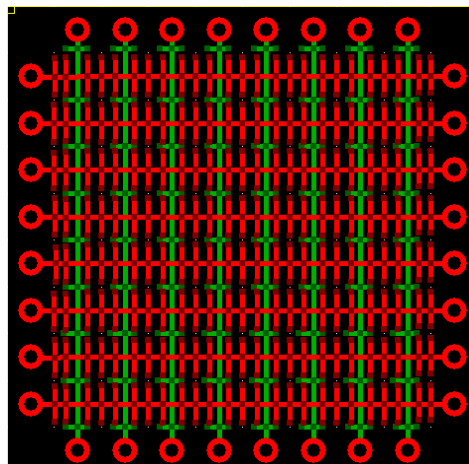


Figure 21 Capacitive Touchpad Design

Since the designed touchpad does not satisfy the design criteria, it is then changed to ATQT6.

ATQT6 Xplained Pro is designed for Xplained Pro MCU boards featuring a microcontroller unit with a built-in peripheral touch controller [31]. This touchpad has 10x10 Mutual Capacitance matrix with 'Z' pattern.

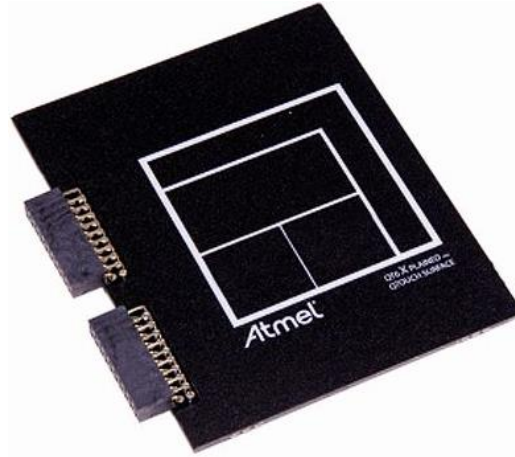


Figure 22 ATQT6 Xplained Pro [32]

8 – X grid lines and 8 – Y gridlines are connected to the AT42QT2640 to detect the touch. The code is programmed on the microcontroller and the device shows some wrong position data. It is observed that this device is very sensitive. Sensitivity depends on the geometry of the sensor pattern and gain setting used [31]. When the touch is made at a particular point, the touch analyzer displays original value with a variation in the reported touch position value. Figure 23 shows the incorrect data obtained from the movement of the finger.

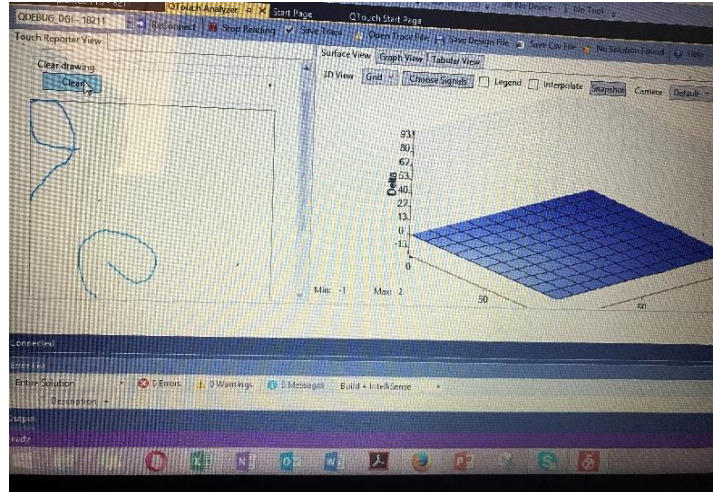


Figure 23 Atmel Studio Touch Analyzer for ATQT6

3.3 Proposed Approach

The above problem in hardware, resulted in change of the Touchpad. The hardware used here is a resistive touchscreen with the necessary microcontroller and the Bluetooth. The touchscreen terminals are connected to the microcontroller, the data is processed and then sent to the computer, laptop or smartphone via the Bluetooth.

3.3.1 Block Diagram

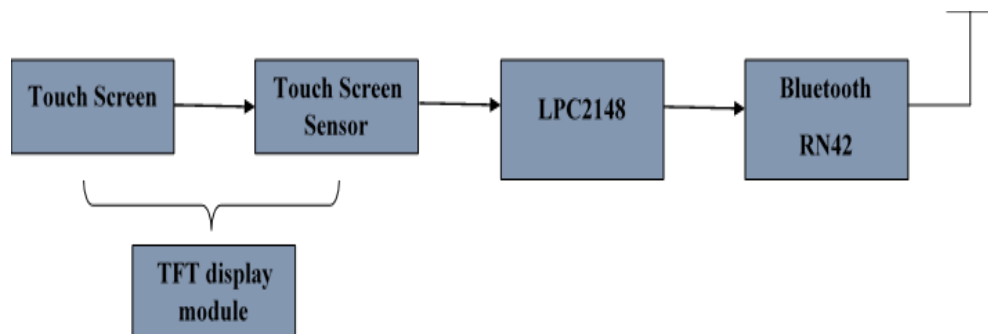


Figure 24 Block Diagram of Transmitter

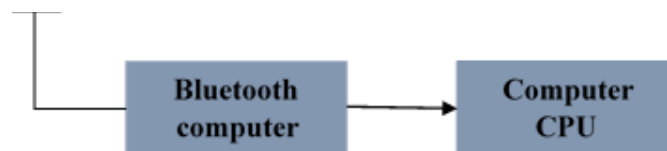


Figure 25 Block Diagram of Receiver

3.3.2 Hardware Design

After explaining the block diagram of the design procedure, the next step is to simulate the hardware using the Proteus software. Then the hardware components are designed on the PCB with the help of ORCAD software.

- **Components Used**

- LPC2148
- RN42
- TFT LCD display screen

- **Components Description**

- **LPC2148**

LPC2148 is invented by NXP Semiconductor (Phillips), and it is loaded with many inbuilt features and peripherals. This is more efficient and reliable choice for a high-end application developer [33] .

The LPC2148 is a 32/16 bit ARM7 CPU microcontrollers with real-time emulation. It is incorporated with high-speed flash memory that ranges from 32kB to 512kB. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at the maximum clock rate [33]. If miniaturization is a key requirement, LPC2148 is ideal because of its small size and very low power consumption.

- **Features**

- 8 to 40kB of on-chip static RAM and 32 to 512kB of on-chip flash program memory. 128-bit wide interface/accelerator enables high speed 60MHz operation [33].

- In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software. Single flash sector or full chip erase in 400 ms and programming of 256bytes in 1ms [33]
- Single 10-bit D/A converter provides variable analog output [33].
- Low power real-time clock with independent power [33].
- Multiple serial interfaces including two UARTs, two Fast I2C-bus, SPI and SSP with variable data length and buffering capabilities [33].
- Up to nine edge or level sensitive external interrupt pins available [33].
- 60MHz maximum CPU clock available from programmable on-chip PLL with settling time of 100 μ s [33]
- On-chip integrated oscillator operates with an external crystal in range from 1MHz to 30MHz and with an external oscillator up to 50MHz [33].
- Power saving modes [33].
- **Applications**
 - Industrial control
 - Medical systems
 - Access control
 - Point-of-sale
 - Communication gateway
 - Embedded soft modem
 - General purpose applications

- **Block Diagram**

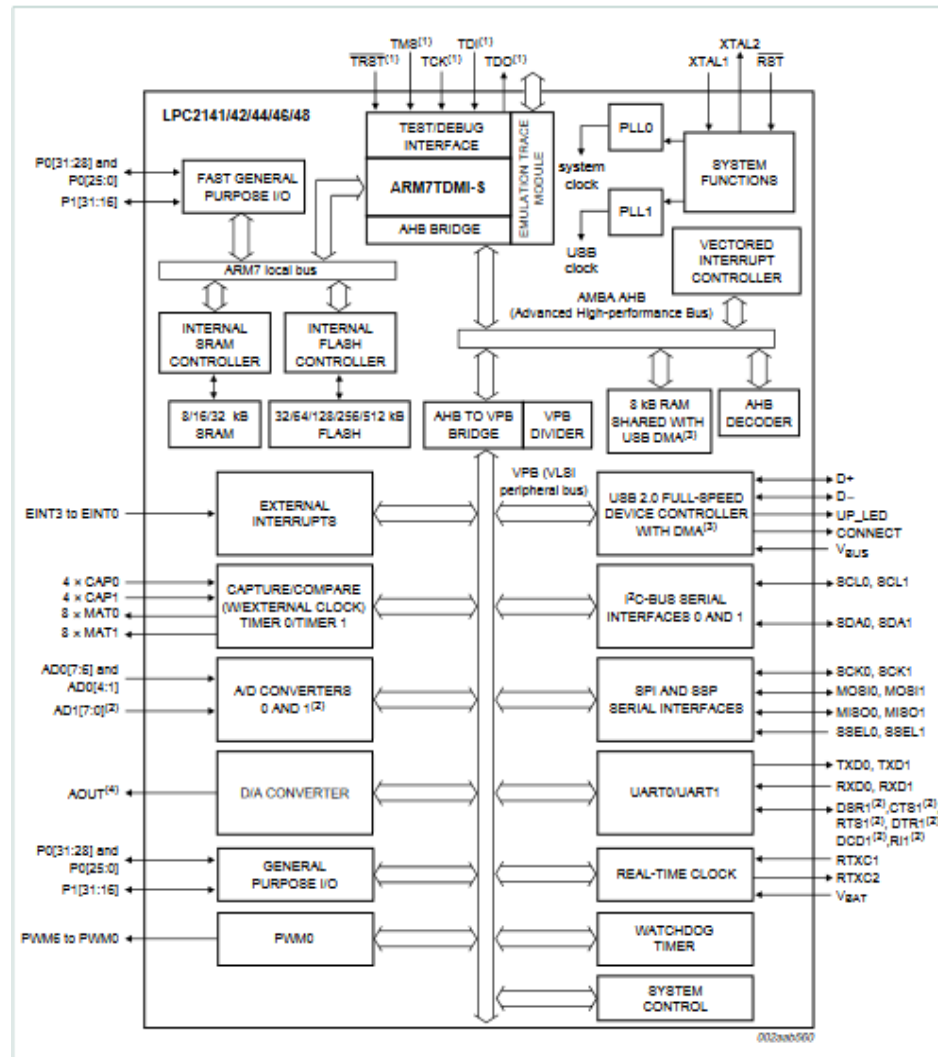


Figure 26 Block Diagram of LPC2148 [33]

- On-chip SRAM 32kB+8kB
- Number of pins 64
- Endpoint USB RAM 2kB
- On-chip FLASH 512kB
- Number of 10-bit ADC channels 14
- Number of 10-bit DAC channels 1

- Note UART1 with full modem interface
- **Pin Configuration**

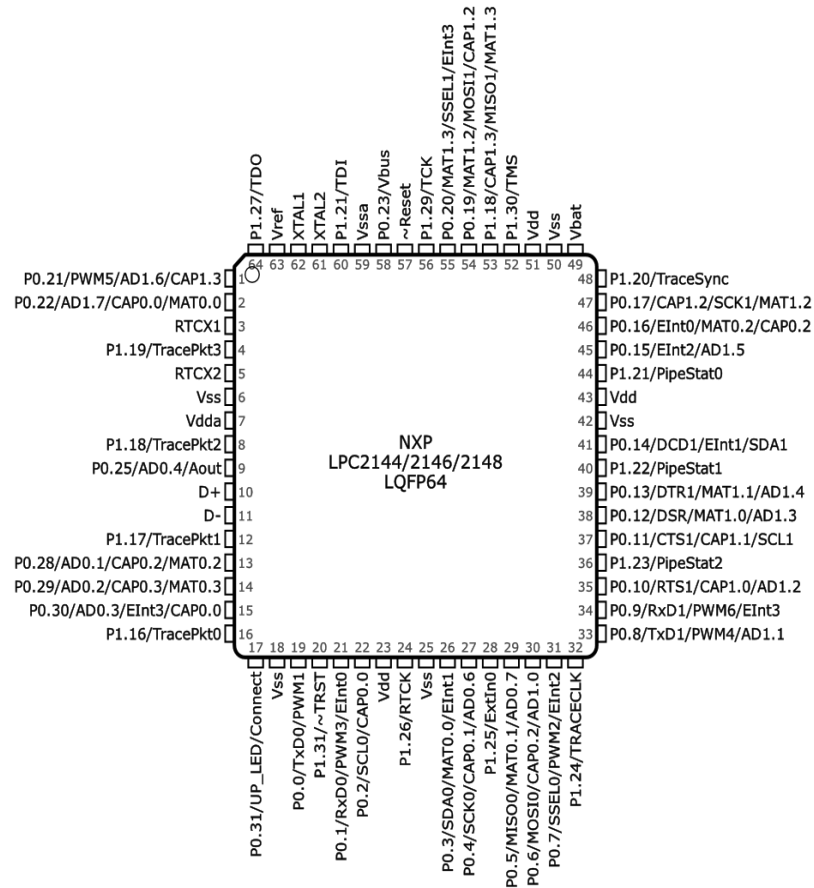


Figure 27 Pin Diagram of LPC2148 [33]

- **RN42**

The RN42 module is a class 2 Bluetooth radio with low power and small form factor. It is ideal and simple to design for designers who like to add wireless capability to their products. RN42 supports multiple interface protocols [34]. The PCB antenna (RN42) transmits up to 3-Mbps data rate for up to 10-meter distance [34].

- **Device**



Figure 28 Device RN42 [34]

- **Pin Diagram**

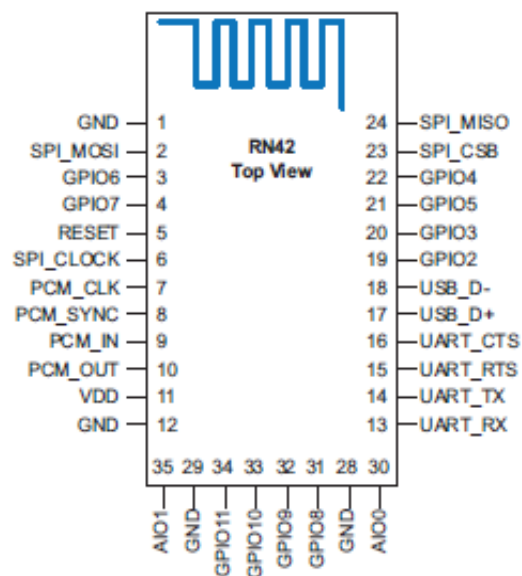


Figure 29 Pin Diagram of RN42 [34]

- **MCU Interface**

The RN42 module can be controlled by ASCII commands via the UART communication. A microcontroller unit sends commands to read status, configure module features, and manage Bluetooth data connections [34]. To communicate with the module and to transfer data across the Bluetooth, UART TX and RX are required. The module can be configured via the UART or over-the-air. It does not require any software for

discovering and pairing with the device. This module supports auto-connect with a passcode, I/O pin, and character-based trigger modes.

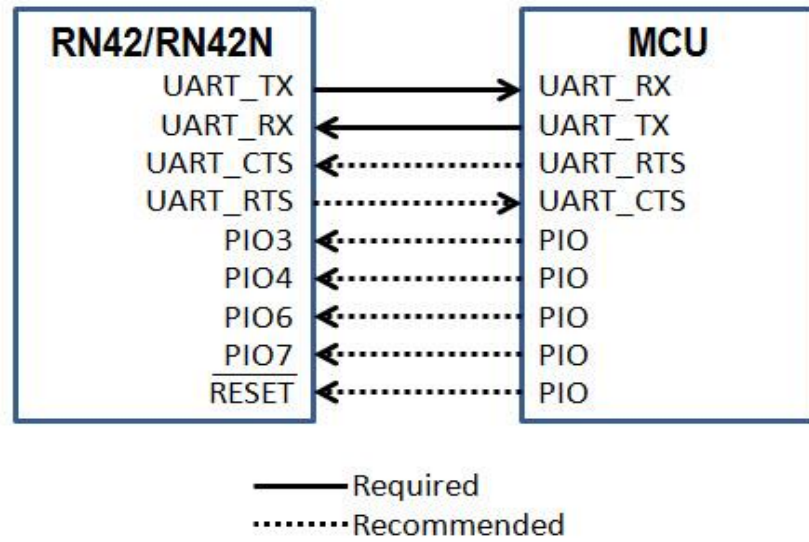


Figure 30 RN42 Communication [34]

- **Electrical Parameters**

Table 3 Electrical Parameters of RN42

Parameters	min	type	max	units
Supply Voltage (DC)	3.0	3.3	3.6	V
Average Power Consumption	—			
Radio On	—	40	—	mA
Connected Idle (No Sniff)	—	25	—	mA
Connected Idle (Sniff 100 ms)	—	12	—	mA
Connected with Data Transfer	40	45	50	mA
Deep Sleep Idle Mode	—	26	—	μA

- **Features**

- ASCII command interface over UART
- Size 13.4 x 25.8 x 2.4 mm
- Low power
- UART and USB data connection interfaces [34]
- Sustained SPP data rates: 300 Kbps – Master mode, 240 Kbps – Slave mode
- HCI data rates: 3.0 Mbps burst, 1.5 Mbps sustained in HCI mode
- SMT pads for easy and reliable PCB mounting [34]
- Class 2 power amplifier with on-board PCB antenna (RN42) [34]
- Integrated Crystal, Matching Circuitry, Low Noise, Internal Voltage Regulator, Memory Amplifier, Power Amplifier, and PCB Antenna
- Compatible with Microchip Microcontroller Families
- 10-meter range

- **Applications**

- Cable replacement
- Barcode scanners
- Monitoring systems
- Industrial sensors and controls
- Medical devices

- **TFT**

TFT LCD Screen Module is an LCD that includes the Touch, SD card, and Flash design. It consists of 16-bit data interface controller SSD1289. Operating this device with many MCUs like AVR, and 8051 is easy. HY-TFT320 contains a touch controller in it.

The 34 pins breakout comprises of the touch IC XPT2046 and the touch interface. The SD Card socket is another useful extension. It uses the SPI mode to operate the SD card; the SPI interface includes in the 40pins breakout. (SLA384A).

- **Features**

- Extensive bus interface
- 240RGBx320-dot resolution
- wide view display
- hardware reset and Internal oscillator
- Partial drive function
- Modes:
 - 8-color mode
 - standby mode
 - sleep mode
 - Power saving mode
- Low-power consumption architecture

- **Application Ideas**

- Digital Photo Frame (DPF)
- Video terminals
- Instrumentation
- GPS
- Game consoles
- Video phones and Portable VCD, DVD



Figure 31 TFT Screen- Top View



Figure 32 TFT Screen- Bottom View

3.4 Design Procedure

- **Interfacing the TFT Touchscreen with LPC2148**

A circuit is designed to connect a touchscreen with the microcontroller. The X and Y coordinates of the touchscreen are determined by connecting the pins of the touch panel to the power supply and the ground. The left of the X surface and bottom of the Y surface are connected to the A/D converter of the microcontroller, the voltage at these coordinates is converted into digital data which is used to calculate the X-Y coordinates.

The software design consists of turning the circuit for touchscreen control on/off and reading the voltage values of A/D converter which gives the X and Y coordinates of the touch. Coordinates determined are processed by the microcontroller and then sent to the Bluetooth device.

- **Interfacing Bluetooth with LPC2148**

To connect the Bluetooth to the microcontroller, the RX and TX pins on the microcontroller are considered. The wires are cross-connected, i.e., the RX pin from Bluetooth is connected to the TX pin of the microcontroller, and the TX pin from the Bluetooth device is connected to the RX pin of the microcontroller.

3.5 Software Implementation

The software is designed to detect the movement of the stylus and send the data to the host Bluetooth for moving the mouse pointer. A code is written to simulate mouse clicks with tap. On the transmitter side, the LPC2148 continuously gets the data from the resistive touchscreen. If it detects a stylus, location data is sent to the microcontroller, and it is transmitted to the computer via RN42 through UART communication. On the receiver side, the Bluetooth present in the computer/laptop/mobile receive the data, converts it into USB HID protocol, and displays it to the user.

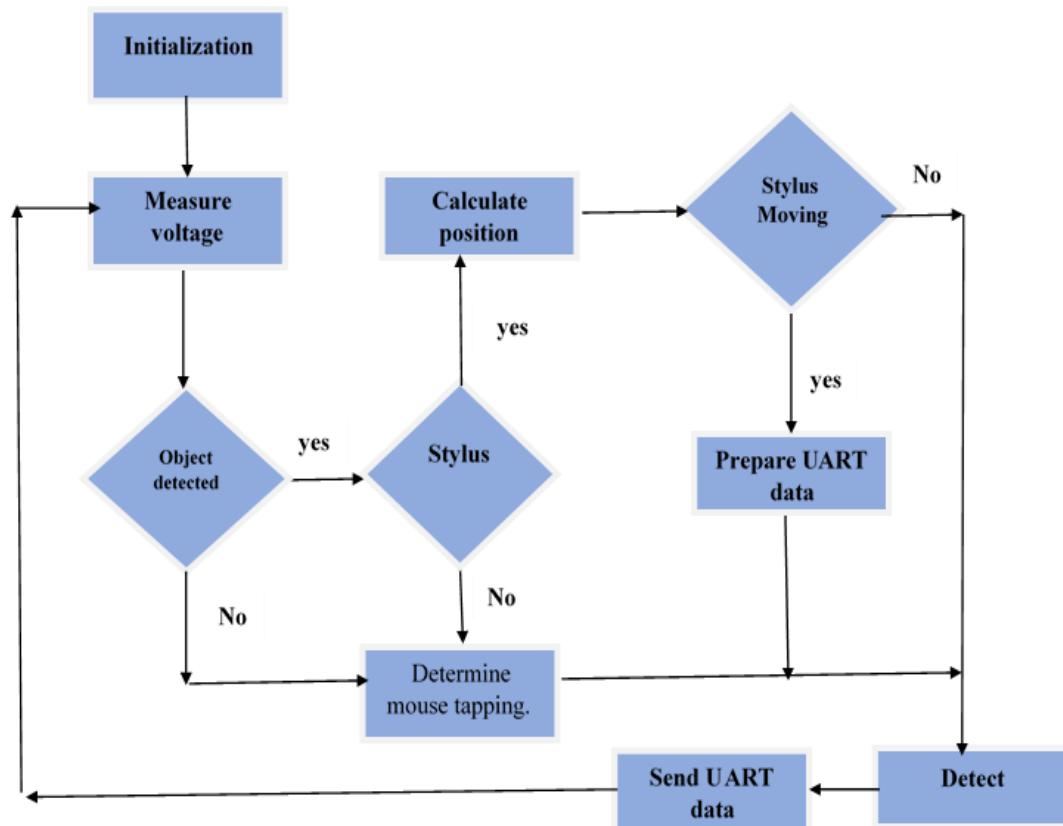


Figure 33 Software Flowchart

• Software Requirements

Software used for programming lpc2148 microcontroller and burning in the microcontroller:

1. Keil μ Vision4: Keil is based on Integrated Development Environment (IDE). It consists of a code editor, a compiler, a debugger used for programming in embedded c and generate Hex code for burning in the microcontroller.
2. Flash Magic: This software is used for burning the generated Hex file into the microcontroller.

• Starting of Keil and Creating a Project

6. Open the Keil IDE. The main window is divided into three parts.

- Editor: Here .c file and .h files are written and edited.

- Project explorer: It shows the project chart.
 - Output window: Shows messages related with project building, compiling and debugging.
2. Click on the project and then ‘new uvision project.’
 3. Follow these steps now
 - Choose the file name, and its saving location
 - Select the device for target ‘target1’, i.e., NXP, lpc2148 and press ok.
 - Now select yes to copy startup.s file, this is for initial configuration and right click the target option in the project window, and select output.
 - select create hex file option.
 4. Click on New and save the file with the project name (main.c). Write the program.
 5. Save the program.
 6. Right click source group and add files to source group and select saved files to add to the program.
 7. Click on Build for compiling the program and see for errors in the output window, if any to correct it. After clicking the Build option, it will create hex file with the same name as project name with an extension of .hex and this is used for burning program in flash memory of microcontroller using flash magic. This is done by serial communication using UART by connecting PC with UART0 of a microcontroller using RS232 (DB 9 cable).
 - **Steps Involved in Burning**
 - Hex file is created
 - Pc is connected to the lpc2148 microcontroller using DB-9 and UART.

- Open Flash magic and select lpc2148 microcontroller, select assigned COM port.
- Set the Baud Rate to 9600 and crystal frequency to 12 MHZ.
- Select erase blocks and verify after programming
- Load the hex file and click on start to burn the hex file.

3.6 PCB Circuit



Figure 34 Top Layer of the PCB Circuit



Figure 35 Bottom Layer of the PCB Circuit

4. RESULTS

This chapter discusses the results by analyzing few design criteria of wearable devices which are satisfied and working of the device.

4.1 Performance Characteristics

4.1.1 Discharge Profile

For the normal operations of a mouse, i.e. movement and clicking, below is the discharge characteristics of this mouse. The graph indicates that at 11.5 hours, battery discharges once it reaches 3V.

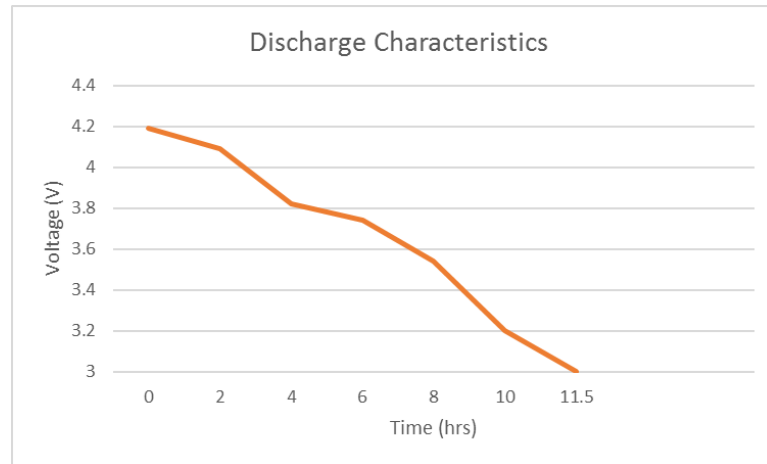


Figure 36 Discharge Characteristics of the Lithium Ion Battery

4.2 Design Criteria of a Wearable Devices

As mentioned before integrating new technology into everyday life is always challenging especially in the case of a wearable device that has to be worn on the hand. This gives rise to issues related to social acceptability and ergonomics of the device. Also for a design to be successful, it should follow some criteria to hit the market like physical and aesthetical issues of wearable devices will be explained briefly with this device performance as follow:

- **Speed of Execution**

The device responds to the user input very quickly. There is no delay in clicking operation. During the development phase of this device, the primary functions of the mouse are tested by simulation. Because of the space criteria, it is designed in a way that for a small change there is an adequate movement of the cursor on the screen.

- **Accuracy**

The accuracy of this device is very good. The basic functionality of this device such as cursor movement and mouse clicks are successfully achieved. Touch sensor which is the base of the mouse works well in detecting the movement, and thus allow the microcontroller-LPC2148 to adjust the cursor speed based on the stylus movement. The data is sent with high degree of accuracy to the receiver Bluetooth (i.e., computer, laptops or smartphones) via RN42.

- **Usability**

The device is very easy to use and usable in laptops, computers, and smartphones. More notably, users can use any sized stylus. It can be used very well on Android smartphones, laptops, computers, etc. For prototyping purposes, the bottom left is used for left click, and the bottom right is used for right click operations. This area cannot be used for moving a mouse.

- **Safety**

This product is designed by taking safety into consideration. It does not contain any wires except the battery terminals. All wires are fabricated on the PCB; additional wires are not required. Like the armband like bracelets, watches or a

remote, the mouse's construction avoids direct contact of the electrical circuit with the user. It uses 3.7V battery which does not cause any harm to the user. The device will be in touch with the skin, the materials used in the device does not cause problems such as sweating caused due to heat and allergies for the skin.

- **Comfortability**

Physical comfort is one of the important rules that should be considered while designing a wearable device. A comfortable product does not disturb the user or brings physical burden such as difficulty in the movement to its user. Size and weight of the device are two important elements that play an important role in the comfort of a wearable device. Many people prefer a portable device with minimal bulk and weight [35]. This product is of very less weight.

- **Aesthetic**

Aesthetic and appearance of a wearable device is an essential part of a design process and has a significant impact on user's acceptance. As a wearable device has a vital effect on people's identity; it is a part of the style and appearance of the user, and its effects on their self-image [36]. A successful design of a wearable device should appeal the user's taste of beauty and fulfill the need of the wide range of customers. It consists of a screen below which the electronic circuit is designed with battery.

- **Mobility**

One of the advantages of wearable computers is that it is always with the user, which means it is moving with the user all the time both in inside and outside

environments. Users might do many different activities while using the device [35]. They should be able to do activities such as running, climbing or jumping without having the fear that their wearable device might be damaged [37]. Different parameters such as size, weight and the way it is attached to the body can affect the mobility of the device [35]. This device can be taken from one place to another. It is weightless and portable. It can connect to any device that has Bluetooth built in it.

4.3 Design Specifications

Compared to other wearable mouse devices this device is different from the appearance and the hardware used. The specifications of this device are:

Battery- 3.7V 380mAh

Resistive touchscreen- TFT 240*320

Bluetooth- RN42

LPC2148

4.4 Design Drawings

Below is the PCB layout of the device.

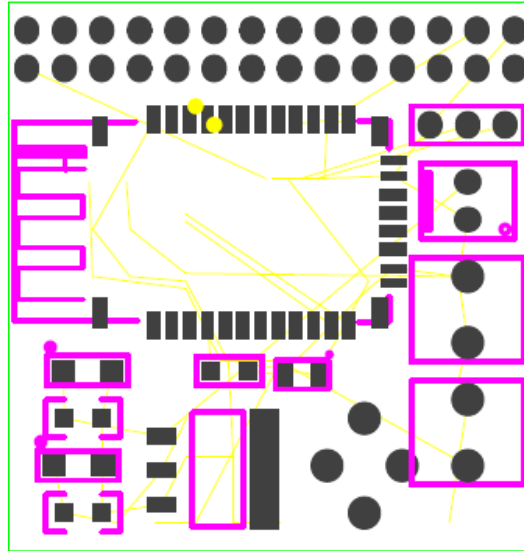


Figure 37 PCB Layout- Bottom

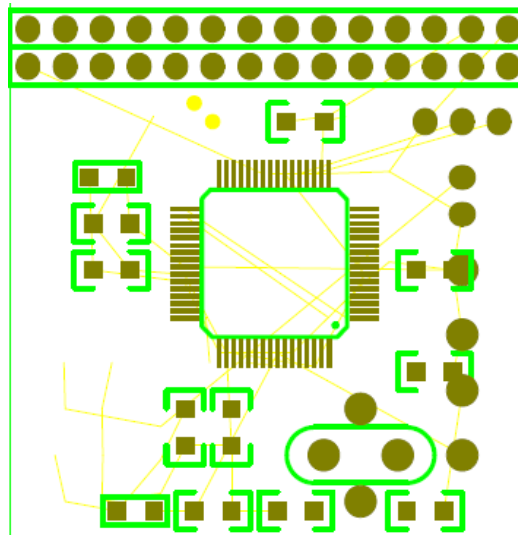


Figure 38 PCB Layout- Top

4.5 Design Output

This device is connected to a laptop by matching the passcode. Once connected, operations are done, i.e., movement and clicks. Below are the images of the operations.

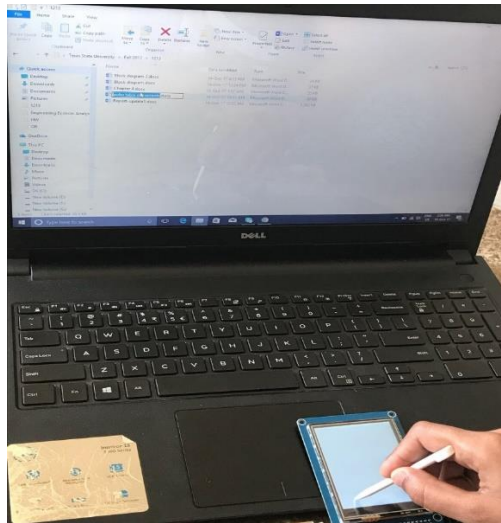


Figure 39 Left Click

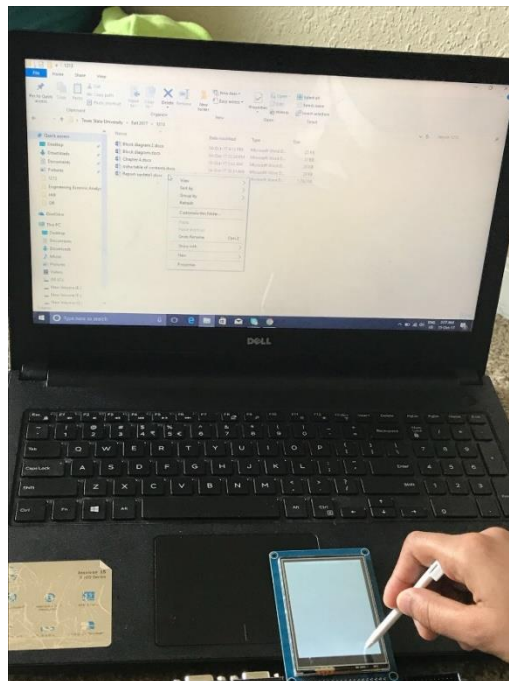


Figure 40 Right Click

4.6 Comparison over the Existing Wearable Mouse Designs

4.6.1 Maestro Gesture Glove Mouse

Table 4 Comparison over Maestro Gesture Glove Mouse

Specification	Maestro Gesture Glove Mouse	Wearable Mouse-Smartwatch
Installation of the Software for the device to work	Required	Not required
Cost	Very high-\$147	Very low
Wi-fi connectivity	Yes	No
Size	Available in different sizes	Small

4.6.2 Mycestro Mouse

Table 5 Comparison over Mycestro Mouse

Specifications	Mycestro Mouse	Wearable Mouse-Smartwatch
Cost	Very high-\$137	Low
USB Dongle	Required	Not required
Size	Very small	Small

4.7 Final Design



Figure 41 Internal Circuit- Bottom



Figure 42 Internal Circuit- Top

5. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

Wearable Technology is thriving in the consumer segment and is starting to gain momentum also in the business segment. Enterprises anticipate that big opportunities exist with deploying the technology within industrial environments. Utilizing Wearable Technology imposes several advantages over conventional technologies and methods. It can improve efficiency in the workplace by providing access to real-time data while freeing the hands to hold tools and equipment. It could also collect data and provide the user with information that previously has not been possible.

Since Wearable Technology is a wide concept with a diverse set of products and application areas, it is somewhat troublesome to uniformly analyze the development of the technology. This thesis' analysis of the market has therefore considered each segment separately, but at the same time taken the common characteristics of each segment into account. Considering the market of smartwatches and fitness trackers, this thesis argues that many of the characteristics of a mature industry can be identified. This thesis proposed another method of using a smartwatch for computing application, i.e., mouse. The proposed design uses the stylus movement data from the touchscreen and accordingly operations are produced on the display screen. This smartwatch is connected to a handheld device with the help of Bluetooth. This device satisfies the ergonomic benefits and principles/characteristics of the wearable devices with very less manufacturing cost.

5.2 Power Consumption of each Component

RN42 consumes 40mA of power

LPC2148 consumes 350mA of power

Resistors are 1/4W power resistors

5.3 Future Work

This section presents ideas and possibilities to improve the Touch Mouse; they were generated by the work during this research, as well as suggestions received during the usability study.

- By changing the code, Keyboard can also be interfaced using the same circuit.

Many users expect a device to have diverse features so that they don't have to buy/use multiple devices to perform various operations. So, by implementing a keyboard on this device, users don't have to buy wearable keyboard.

- This design is a square design. Mostly users prefer a circular design.

Customers get attracted to the gadgets that are good looking and fashionable. This device is in a square shape, so a new hardware should be designed by the manufacturer to make it circular.

- Making it compatible with MAC and apple devices.

Customers worldwide use android, apple phones and Windows, Mac laptops. This device is only compatible with android smartphones and Windows/Linux computers/laptops. So additional coding needs to be done in order to work on MAC and apple phones.

APPENDIX

APPENDIX 1: Source code

Main.c

```
#include <lpc214x.h>

// #include "uart0.h"

#include "uart1.h"


volatile char first=1;

char vf;

/* touch panel interface define */

#define DCLK      0x00000010      //p27 p0.4
#define DOUT      0x00000020      //p29 p0.5
#define DIN       0x00000040      //p30 p0.6      //in
#define CS        0x00000080      //p31 p0.7
#define Penirq    0x00000008      //(in) p41 p0.15 Touch screen response signal detection

void delaysms(int count) // /* X1ms */
{
    int i,j;

    for(i=0;i<count;i++)

        for(j=0;j<1000;j++);

}

struct pix_
```

```

{

unsigned int x;

unsigned int y;

};

struct pix_ Tp_pix;    //Sampling the current touch coordinate value

//*****

void spistar()          //SPI Start

{

IOSET0 |=0x00000080;    //cs set

IOSET0|=DCLK;

IOSET0|=DIN;

}

//*****

void WriteCharTo7843(unsigned char num)    //SPI Write data

{

unsigned char count=0;

IOCLR0 |=DCLK;

for(count=0;count<8;count++)

{

if(num&0x80)

IOSET0|=DIN;

else

```

```

IOCLR0|=DIN;

/*DIN=(num&0x80)  //DIN=CY; */

num<<=1;

IOCLR0 |=DCLK; //_nop_();_nop_();_nop_();          //Rising edge

vf=0;

vf=0;

vf=0;

IOSET0 |=DCLK; //_nop_();_nop_();_nop_();

vf=0;

vf=0;

vf=0;

}

}

//*****

unsigned int ReadFromCharFrom7843()          //SPI Read data

{

    unsigned char count=0;

    unsigned int Num=0;

    for(count=0;count<12;count++)

    {

```

```

Num<=1;

IOSET0|=DCLK;

vf=0;

vf=0;

vf=0;

IOCLR0|=DCLK; //_nop();_nop();_nop();

vf=0;

vf=0;

vf=0;

if(!((IOPIN0&DOUT)==0))

Num++;

}

return(Num);

}

unsigned char Makpix(struct pix_ pix1,struct pix_ pix2)

{

unsigned char l=0;

int x=pix1.x>pix2.x?pix1.x-pix2.x:pix2.x-pix1.x;

int y=pix1.y>pix2.y?pix1.y-pix2.y:pix2.y-pix1.y;

if(x<14&&y<11)

{

l=1;

```



```

    Tp_pix.x=pix1.x;

    Tp_pix.y=pix1.y;

}

return l;

}

```

```

struct pix_ AD7843()

{

    struct pix_ pix;

    IOCLR0 |=CS;

    WriteCharTo7843(0x90);

    IOSET0|=DCLK; //_nop_();_nop_();_nop_();_nop_();

    vf=0;

    vf=0;

    vf=0;

    IOCLR0|=DCLK; //_nop_();_nop_();_nop_();_nop_();

    vf=0;

    vf=0;

    vf=0;

    pix.y=ReadFromCharFrom7843();

```

```

WriteCharTo7843(0xD0);

IOSET0|=DCLK; //_nop_();_nop_();_nop_();_nop_();

vf=0;

vf=0;

vf=0;

IOCLR0|=DCLK; //_nop_();_nop_();_nop_();_nop_();

vf=0;

vf=0;

vf=0;

pix.x=ReadFromCharFrom7843();

IOSET0 |=CS;

return pix;

}

```

```

unsigned char Getpix()

{

    struct pix_ pix1;

    struct pix_ pix2;

    pix1=AD7843();

    pix2=AD7843();

    return Makpix(pix1,pix2);

}

```

```

void TIMER0_ISR (void) __irq //timer interrupt 0      TIMER0
{
    VICIntEnClr |=0x00000010; //timer0

    T0TCR = 0x00; //Disable timer

    first=1;

    T0IR = 0x01;

    VICVectAddr = 0x00000000;
}

void TIMER0_init()
{
    T0TC = 0; // clear the timer count

    T0CTCR = 0x0;

    T0PR = 15000-1; // prescale divide by

    T0MR0 = 200-1; // divide by ? to get approx ? ints per second

    T0MCR = 0x03; // interrupt on match, reset on match

    VICVectAddr0 = (unsigned)TIMER0_ISR;

    VICVectCntl0 = 0x00000024;

```

```
T0TCR = 0x02; // reset the timer
```

```
T0TCR = 0x01; // start the timer
```

```
VICIntEnable |= 0x00000010;
```

```
}
```

```
int main()
```

```
{
```

```
    unsigned int lx,ly;
```

```
    signed char xv=0,yv=0;
```

```
    int xs=0,ys=0,xr=0,yr=0,xrp=0,yrp=0;
```

```
    spistar(); //spi initialization
```

```
    IODIR0 |= 0x0000ffff;
```

```
    IODIR0 &= 0x000000d0;
```

```
    //uart0_init(); uart0_puts("WELCOME");  uart0_enter();
```

```
    uart1_baudrate(115200);
```

```
start:
```

```

while(1)

{

if ((IOPIN0&Penirq)==0)

{

if(Getpix()==1)

{

lx=((Tp_pix.x-340)*10/144);

    if(lx>237)

    {

        lx=0;

    }

    lx=(237-lx);

        ly=320-((Tp_pix.y-320)/11);

if(ly>320 || ly<0)

    ly=0;

        if(ly>250)

        {

            if(lx<115)

            {

```

```
    while(!(U1LSR & 0x20));  
    U1THR =0xfd;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x05;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x02;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x01;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x00;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x00;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x00;
```

```
    delayms(20);
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0xfd;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x05;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x02;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```

        //uart0_puts("LEFT CLICK"); uart0_enter();

    }

    else

    {

        while(!(U1LSR & 0x20));

        U1THR =0xfd;

        while(!(U1LSR & 0x20));

        U1THR =0x05;

        while(!(U1LSR & 0x20));

        U1THR =0x02;

        while(!(U1LSR & 0x20));

        U1THR =0x02;

        while(!(U1LSR & 0x20));

        U1THR =0x00;

        while(!(U1LSR & 0x20));

        U1THR =0x00;

```



```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
delayms(20);
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0xfd;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x05;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x02;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
    //uart0_puts("RIGHT CLICK"); uart0_enter();
```

```
}
```

```
while((IOPIN0&Penirq)==0);
```

```
delayms(200);
```

```
goto start;
```

```
}
```

```
xr=(lx/2);
```

```
yr=(ly/2);
```

```
if(xr==xrp && yr==yrp)
```

```
goto start;
```

```
xrp=xr;
```

```
yyp=yr;
```

```
TIMER0_init();
```

```
//uart0_puts("X:"); uart0_int(xr); uart0_puts(" ");
```

```
//uart0_puts("Y:"); uart0_int(yr); uart0_enter();
```

```
        if(first==1)
    {
        first=0;

        xs=xr;

        ys=yr;
    }
```

```
xv=xr-xs;
```

```
yv=yr-ys;
```

```
        if((xv>126))
    {
        xv=127;
    }
```

```
if(xv<-126)
```

```
{
    xv=-127;
}
```

```
if((yv>126))
```

```
{
    yv=127;
}
```

```
if(yv<-126)
```

```
{  
    yv=-127;  
}
```

```
while(!(U1LSR & 0x20));  
    U1THR =0xfd;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x05;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x02;
```

```
while(!(U1LSR & 0x20));  
    U1THR =0x00;
```

```
while(!(U1LSR & 0x20));  
    U1THR =xv;
```

```
while(!(U1LSR & 0x20));  
    U1THR =yv;
```

```
while(!(U1LSR & 0x20));
```

```
U1THR =0x00;
```

```
delayms(200);
```

```
/*
```

```
uart0_puts("X:");
```

```
if(xv&0x80)
```

```
{
```

```
uart0_putch('-');
```

```
lx=(xv*(-1));
```

```
}
```

```
else
```

```
{
```

```
uart0_putch('+');
```

```
lx=xv;
```

```
}
```

```
uart0_int(lx); uart0_puts(" ");
```

```
uart0_puts("Y:");
```

```
if(yv&0x80)
```

```
{
```

```
uart0_putch('-');
```

```

        ly=(yv*(-1));

    }

    else

    {

        uart0_putchar('+');

        ly=yv;

    }

    uart0_int(ly); uart0_enter();    */

}

}

}

}

```

Uart0.c

```

#include<lpc214x.h>

#include"uart0.h"

void uart0_init()

{

    PINSEL0 |=0x00000005;

    U0LCR =0X80;

    U0DLL =97;

```

```

    U0LCR = 0x03;

}

void uart0_baudrate (unsigned int baudrate)
{
    unsigned long DLreload;

    PINSEL0 |= 0x00000005;

    DLreload = (15000000UL / baudrate) / 16UL;

    U0LCR = 0x80;      /* Set DLAB */

    U0DLL = DLreload;

    U0DLM = (DLreload >> 8);

    U0LCR = 0x03;      /* Clear DLAB */

}

void uart0_putch(unsigned char val)
{
    while(!(U0LSR & 0x20));

    U0THR = val;

}

unsigned char uart0_getch()

```



```

{
    while(!(U0LSR & 0x01));

    return(U0RBR);
}

void uart0_puts(unsigned char *stringptr)
{
    while (*stringptr)
        uart0_putchar(*stringptr++);
}

void uart0_enter()
{
    uart0_putchar(13);
    uart0_putchar(10);
}

void uart0_int(unsigned long value)
{
    unsigned char arr[10];
    unsigned char val=0;
    if(value==0)
        uart0_putchar(0+48);

```

```

while(value!=0)
{
    arr[val] = value%10;
    value = value/10;
    val++;
}

```

```

while(val!=0)
{
    val--;
    uart0_putchar(arr[val]+48);
}
}

```

```

void uart0_intL(unsigned int uart_value,char count)
{
    unsigned int uart_arr[5];
    char uart_val;

    for(uart_val=0;uart_val<count;uart_val++)
    {
        uart_arr[uart_val] = uart_value%10;
    }
}

```

```

    uart_value = uart_value/10;

}

for(uart_val=count-1; uart_val!=0 ; uart_val--)

    //sending data to UART1

{

    uart0_putch(uart_arr[uart_val]+48);

}

uart0_putch(uart_arr[uart_val]+48);

}

```

Uart1.c

```

#include<lpc214x.h>

#include"uart1.h"

//#include"delay.h"

void uart1_init(void)

{

    PINSEL0 |=0x00050000;

    U1LCR =0X80;

    U1DLL =97;

```

```

    U1LCR = 0x03;

}

void uart1_baudrate (unsigned int baudrate)

{
    unsigned long DLreload;

    PINSEL0 |= 0x00050000;

    DLreload = (15000000UL / baudrate) / 16UL;

    U1LCR = 0x80;      /* Set DLAB */

    U1DLL = DLreload;

    U1DLM = (DLreload >> 8);

    U1LCR = 0x03;      /* Clear DLAB */

}


void uart1_putch(unsigned char val)

{
    while(!(U1LSR & 0x20));

    U1THR = val;

}


unsigned char uart1_getch()

{

```

```
while(!(U1LSR & 0x01));
```

```
return(U1RBR);
```

```
}
```

```
void uart1_puts( unsigned char *stringptr)
```

```
{
```

```
while (*stringptr)
```

```
{
```

```
    uart1_putchar(*stringptr++);
```

```
    //delay_ms(2);
```

```
}
```

```
}
```

```
void uart1_enter()
```

```
{
```

```
    uart1_putchar(13);
```

```
    uart1_putchar(10);
```

```
}
```

```
void uart1_int(unsigned int uart_value, char count)
```

```
{
```

```
    unsigned int uart_arr[5];
```

```

char uart_val;

for(uart_val=0;uart_val<count;uart_val++)
{

uart_arr[uart_val] = uart_value%10;

uart_value = uart_value/10;

}

for(uart_val=count-1; uart_val!=0 ; uart_val--)

    //sending data to UART1

{

uart1_putchar(uart_arr[uart_val]+48);

}

uart1_putchar(uart_arr[uart_val]+48);

}

```

APPENDIX 2: SIMULATION CIRCUIT

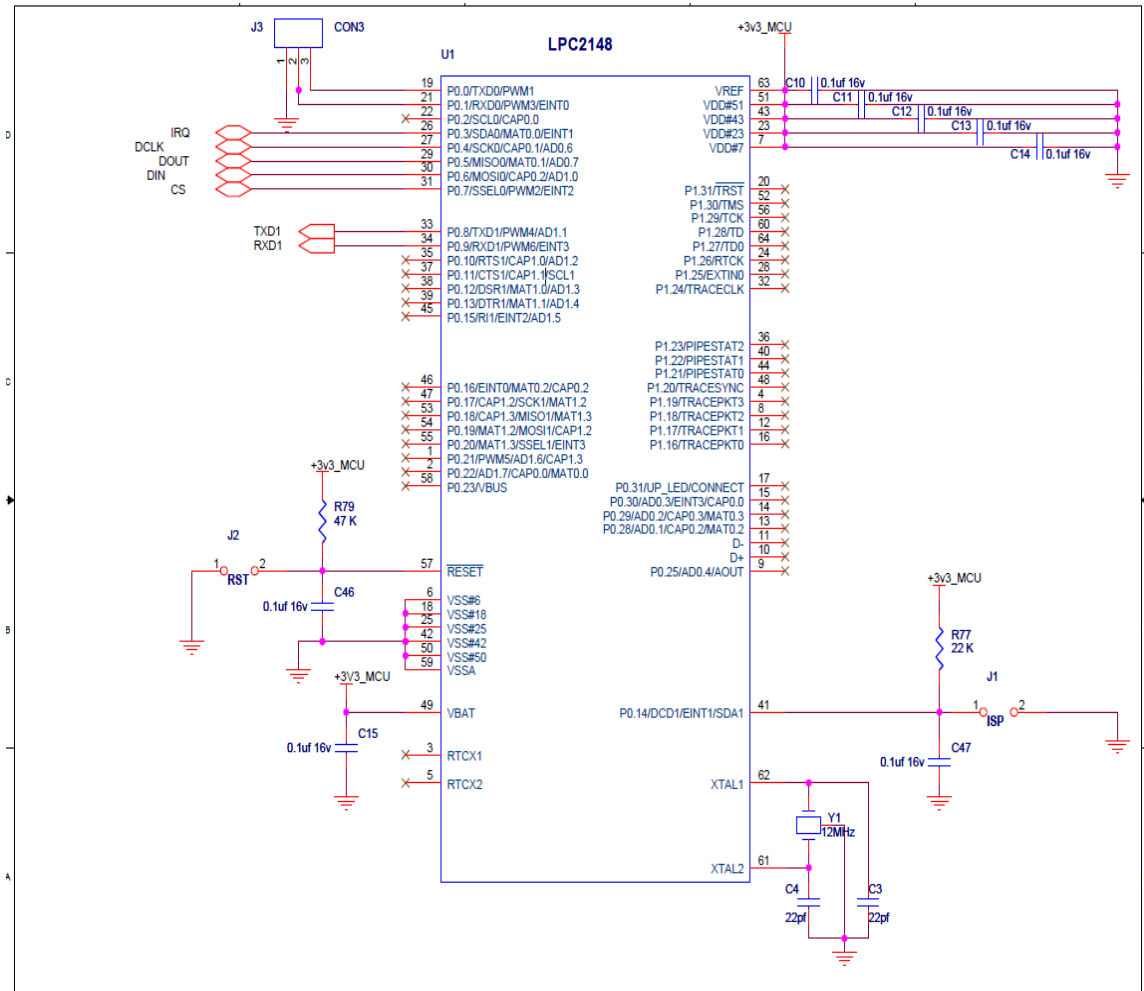


Figure 43 LPC2148 Schematic

APPENDIX 3- PCB DESIGN

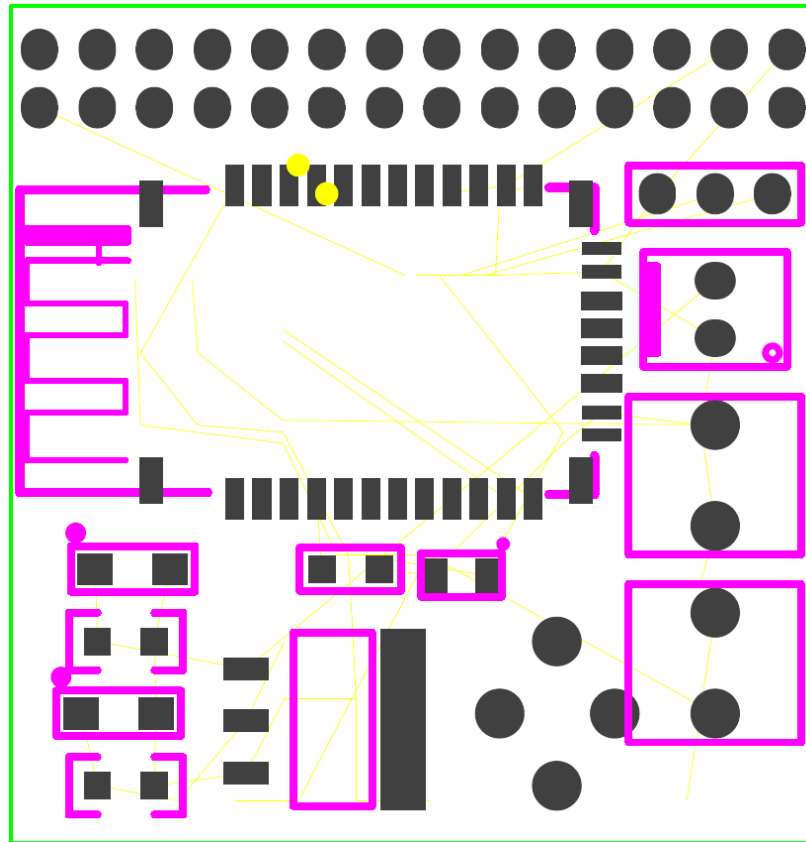


Figure 45 Bottom Layer of PCB Layout

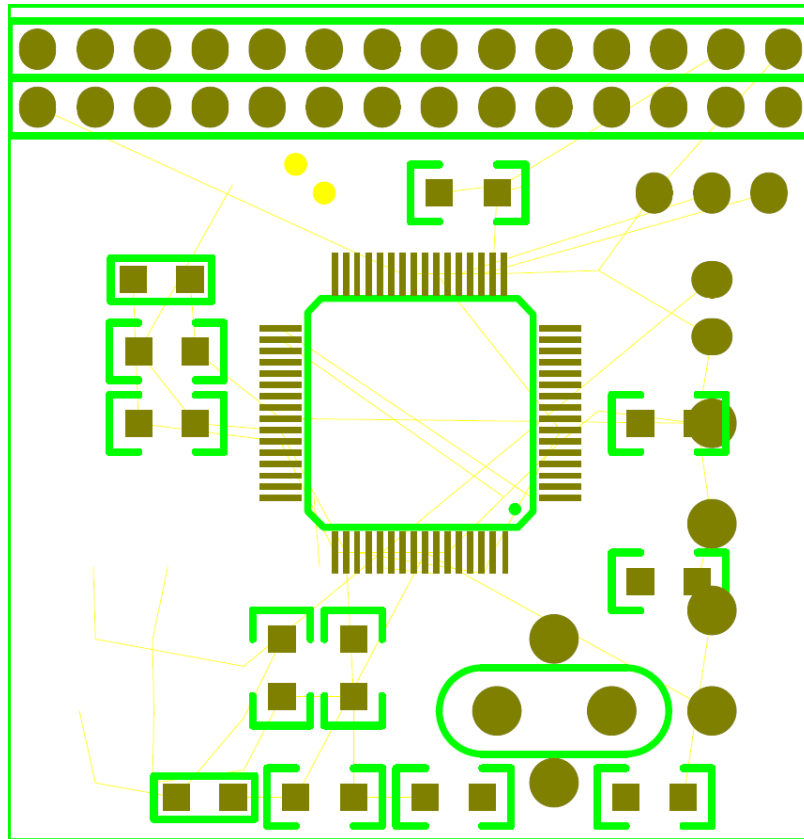


Figure 46 Top Layer of PCB Layout

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