# HEAD AND EYE OPERATED COMPUTER INTERFACE FOR A PHYSICALLY DISABLED PERSON


Gunarathna Dilan Tuder

( 149365F )


Dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Science in Industrial Automation


Department of Electrical Engineering

University of Moratuwa
Sri Lanka


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# DECLARATION OF THE CANDIDATE & SUPERVISOR

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Signature: ................................ Date: ...................
G.Dilan Tuder

The above candidate has carried out research for the Masters Dissertation under my supervision.

Signature of the supervisor: ................................ Date: ...................
Dr.A.G.B.P. Jayasekara

# ABSTRACT

Human computer interaction has the physical and theoretical limit among the human being and the input/output devices of a computer. Studies of severely disabled people have shown that most of disable people can be able to direct head and eye motions. This can be applied to build new human computer interface mechanisms, then it helps to communicate between others otherwise control certain specific devices. The proposed and designed system is a head and eye operated mouse which is expected to be used by a disabled person. The system is divided into main two parts, first one is a Wearable glass module with Arduino Nano, Accelerometer sensor, Eye blink sensor, Bluetooth Module, Voltage regulator and Lithium polymer battery (Transmitting part), Second one is Base station with Processor and Bluetooth module (Receiving part).

Developed mouse have accelerometer sensor to identify the head movement of user, to control mouse courser in real time. Infrared sensor to identify the intentional eye blink of the user to activate mouse clicks (single / double) in real time. Developed mouse uses Bluetooth technology to communicate tirelessly with a computer.

A usability testing survey was conducted to validate the product, a group of 20 was volunteered in conducting the survey including a disabled person, among the considered group 90% were strongly agreed to the product as a new concept to be used by disabled person. 65% were satisfied with the functionality when compared to the existing mouse. Further 60% of the users were satisfied with the usability in different environments. Finally, 40% were in the position of not satisfied with the wear ability by a disable person by himself. Survey results validate the product that have smooth control, proper perfect movements and good sensitivity as normal mouse operation. Wireless , portable Head and eye controlled mouse will be an easy input device for paralyzed and hand disabled people. The overall operation of device complied with all of the requirement set out in the original design proposal.

## ACKNOWLEDGEMENT

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I want to express my sincere thanks to all of them.

The special thank goes to my helpful supervisor Dr.A.G.B.P.Jayasekara. The supervision and support that he gave truly help the progression and smoothness of the project. The co-operation is much indeed appreciated. I wish to extend my thanks to supervisor for the valuable guidance and constant encouragement given for the completion of MSc study and this thesis.

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This acknowledgement would be incomplete if I do not mention the emotional support and blessings provided by my friends and colleagues. I had a pleasant enjoyable and fruitful company with them. My greatest thanks are to all who wished me success especially my parents and my brother whose support and care makes me stay on earth. Finally I would like to thank everyone who didn't mention and helped me to successfully complete my project through the guidance encouragement.

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# LIST OF ABBREVIATIONS

HCI - Human Computer Interaction

MEMS - Micro Electro-Mechanical System

HID - Human interface device

EOG-Electro-oculography

EEG - Electroencephalography

# LIST OF APPENDICES

# CHAPTER1

# BACKGROUND OF THE PROJECT

## 1.1 Aim

To Design a wireless, portable, head and eye operated computer mouse for a disabled person.

## 1.2 Objectives

Design and implement a head and eye operated computer mouse for disabled person. Application of embedded systems design, Sensors and electronics engineering knowledge in implementing new design concepts.

## 1.3 Introduction

We all know that computer is very important to all in this century with modern life. In this modern life without a computer man can't achieve best target. Day by day all people interested in computer because of its requirement, benefits and essential are vast. Knowledge is very important to all of us, even a small kid has to use a computer for various purposes. They also need computer and internet knowledge. The computer is must automate a system, monitoring a system, improve our ability, keep records, keep databases and connect to the internet etc.

Computer has made essay to automate a system, monitoring a system than it ever was. It helps a management to save lots of times in their day to day works. It has made searching, processing any kind of computer related work very easy, and it can be processed by a single mouse click in graphical user interface. A standard physical mouse has an object held user’s one of the hands with one left, one right and a middle button. Mouse movement is typically transferred into movement of the mouse cursor in real time on a computer screen. This function allows user to control a running program in an operating system.

## 1.4 Human computer Interaction (HCI)

Human computer interaction involves learning, plan, the arrangement of the interconnection with users and personal computers. The human being computer boundary is the physical and theoretical limit among the human being and the input/output devices of a computer.

With the uses of safety things, productivity and entertainment human computer interaction give full help to complete human computer works and it can be done to several types of computer program systems, such as street colour light control, military function, shops, hotels, office and computer interactive gaming. Human computer interaction systems are very simple, safety, likable and effective.

Studies of severely disabled people have shown that most of disable people can able to direct head and eye motions. It can apply to build new man computer interface mechanisms, then it helps to intercommunicate between others otherwise control certain specific devices.

## 1.5 Problem statement

Brain computer interface (EEG Mouse) [1], Image processing technology-computer interface [2] and Development of a human computer Interface system using EOG [3] are some existing computer interfaces for physically disabled people. Available interfaces not only are very expensive, but also they are difficulties of wearing on the body of the operator, making it uncomfortable for the user.

Some other computer interfaces [4], was a major problem that is, a system using infrared sensor to identify the eye blink of the user to activate the mouse click but they do not differentiate about intentional blinking and unintentional blinking. So the major problem is clicking of the mouse activates the entire time as the user blinks the eye.

Another disadvantage in this project is processed digital information is transmitted to the PC through the PS/2 port [4] or serial port, but I hope to consider the USB connection rather than Ps/2 or serial connection because the modern desktop computer almost all modern laptops do not have Ps/2 or serial port. So we need a converter cable for the connection, this is an additional cost to the system.

Wire connection between the wearable unit and the PC also can be replaced by the wireless connection (wireless computer interface). For the purpose of using as a commercial device, user head movement and eye blink detection units have to be small size. The smaller size device can develop if the product circuit is improved by using a printed circuit (PCB). Install a suitable small battery can also give smaller size device and less the device weight.

## 1.6 Project overview

The human computer interface is the physical and conceptual boundary between the human and the input/output devices of a computer. People with a physical disability can no longer control the computer with their hands, also can't control the computer by patients with paralyzed shoulder downward. Research on a group of severely disabled people have shown that most of disable people can able to direct head and eye motions. It can apply to build new man computer interface mechanisms.

Design and implement a head and eye operated hand free mouse help disable person to communicate with a computer or control some special instruments. Simple head movement and eye blinking do not require too much energy. Therefore, users easily use the build mouse without tired. The implemented new system provides wireless, portable and user friendly human computer interface. This help to overcome the problems faced by a disabled person in operating a PC. Also, it can be easily adapted without any special training, but with some instructional guidance. User can move and selecting the function of text, files, folders and icons in a graphical user interface. In addition to that this system has the capability of adding different extra features with proper interfacing techniques.

Further, this human-machine interface can be extended to the general population in computer games or other entertainment activities. Developed mouse has an accelerometer sensor to identify the head movement of the user, to control the mouse cursor in real time. Infrared sensor to identify the intentional eye blinks of the user to activate mouse clicks (single / double) in real time. Developed mouse uses Bluetooth technology to communicate wirelessly with a computer. The Arduino library allows an Arduino board with USB capabilities to act as a Mouse

The proposed and designed system is a head and eye operated mouse which expected and implemented to a disabled person. The system is divided into main two parts, First one is a wearable glass module with Arduino Nano, Accelerometer sensor, Eye blink sensor, Bluetooth Module, Voltage regulator and Lithium polymer battery (Transmitting part), Second one is Base station with Processor and Bluetooth module (Receiving part).

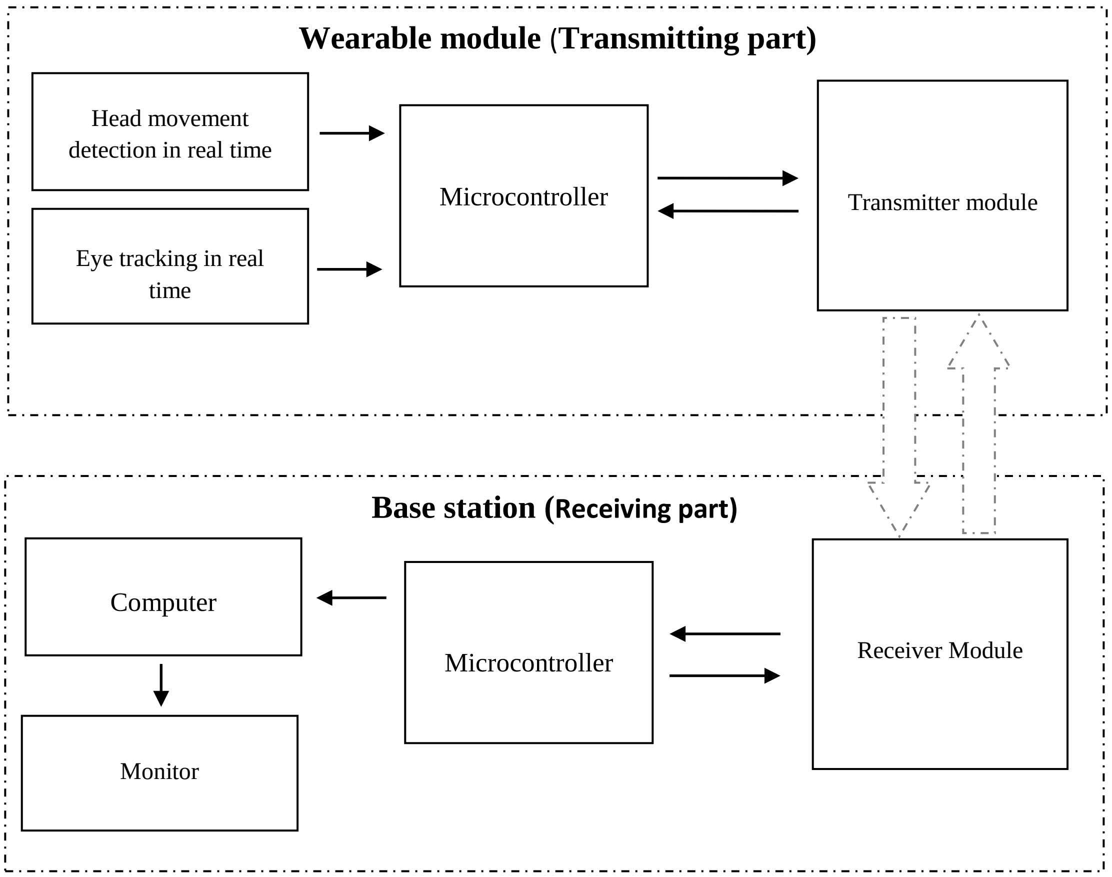



Figure 1.1: Basic Block Diagram of the system

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

To get the clear idea about this project and its drive, the background information is very important. This chapter review about the available technologies and systems designed for existing related computer interfaces, existing computer interfaces for a physically disabled person.

## 2.2 Existing computer input interfaces

An input device is any hardware device that loads data into a PC, permitting you to interconnect with and control it such program. The following figure shows the input devices of a PC.

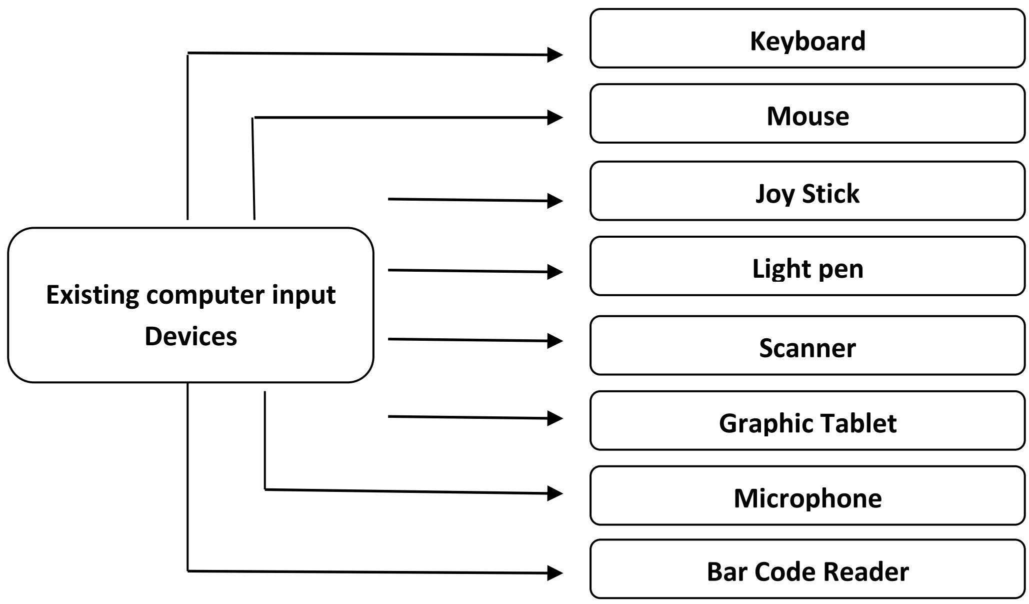



Figure 2.1:Existing computer input Devices

As related to this project mouse background information is very important to develop this product. Generally, it has two buttons called the left and the right button and a wheel is existing among the buttons.

A mouse can be used to control the location of the pointer on the monitor, also it can be used to enter text into the PC through on screen keyboard.

## 2.3 Existing related computer input interfaces

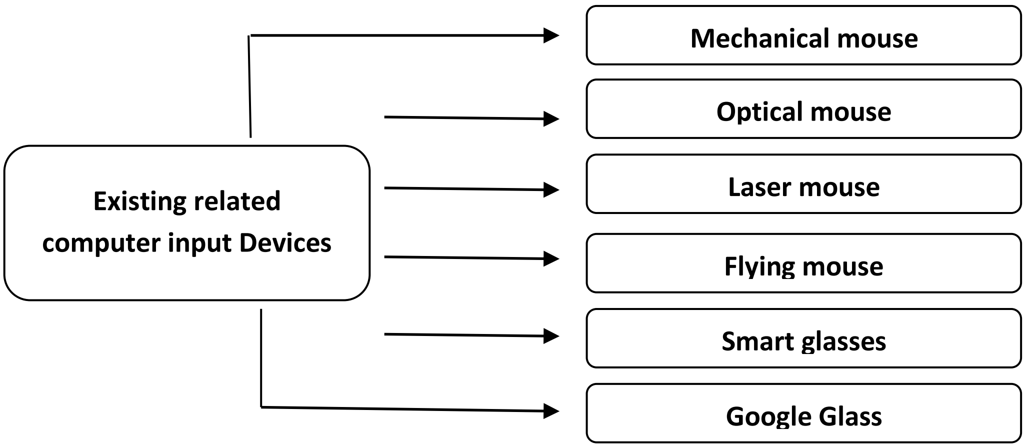



Figure 2.2: Existing related computer input Devices

### 2.3.1 Mechanical mouse

"A mechanical mouse is a PC mouse with a metal or rubber sphere on its bottom [6]. When the sphere rolls in any way, the sensor inside the mouse detects these changes and moves the mouse cursor on the display in the equal way."

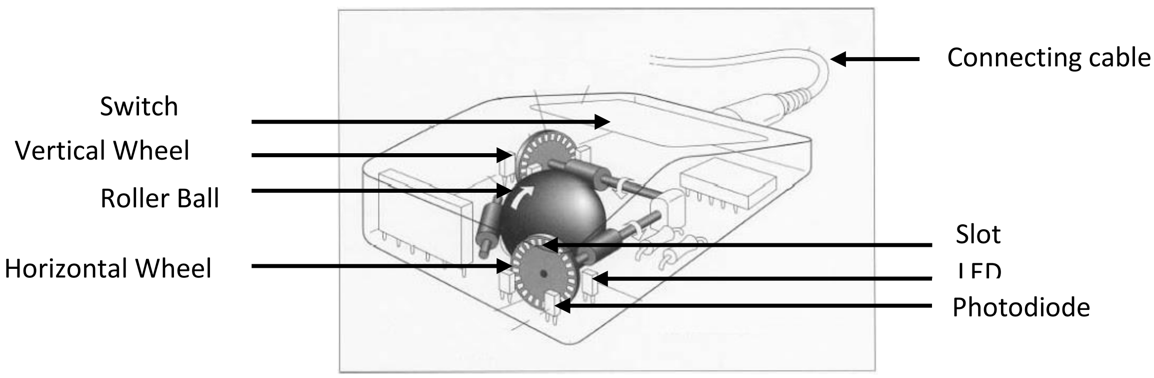



Figure 2.3: Mechanical mouse

**Mechanical mouse mechanism**

Internally, the mechanical mouse is very simple. The sphere usually rests on two rollers, one roller is used to convert the X-axis motion, and the further roller is used to convert the Y-axis motion. These rollers are generally attached to minor plates with closes that consecutively block and allow light to permit through. The minor optical sensor senses the motion of the wheel by detecting the infrared light inside when the close wheel swaps and "cuts light" to sense flicker. These blinks decode into motion along the axis. This kind of arrangement is named an optomechanical device.

The black and light is converted by phototransistors into electrical beats that go to the border integrated circuit (IC) in the mouse. The beats tell the IC that the ball has chased left-right and up-down, transfers the command to the Central Processing Unit (CPU), and instructs the arrow to transfer accordingly on the monitor.

**2.3.2 Optical mouse**

The other main technique of motion detection is optics. The various initial mouse made by mouse systems and other vendors used sensors that essential special grid pattern pads. Even though this mouse is exactly perfect, the need to use them with pads can reason them to drop out of favor.

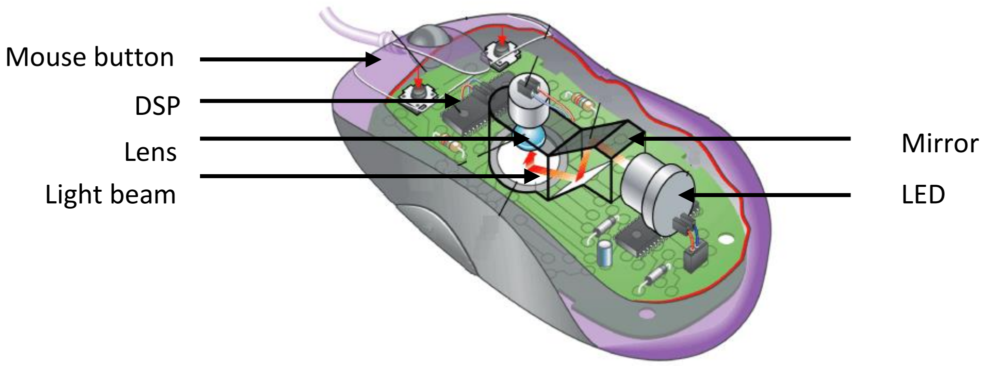



Figure 2.4: Optical mouse

**Optical mouse mechanism**

An optical mouse is a PC mouse that uses a light emitting diode (light source LED) and a photodiode (light detector) to detect motion relative to a surface. LED delivers light to the surface under the mouse. Mirror part is really involved of a lens and a reflecting system the lens here is used to fling light and the combination of reflecting shells focus this light just under the camera and a lend focus the image of surface on camera.

CMOS (Complementary metal oxide semiconductor),now this is the maximum key part of the mouse it takings the images of the surface at a frequency of about 1500 frames per sec. The picture's measurement is 18 x 18 pixels, CMOS directs this data to the DSP. DSP (Digital Signal Processor) receives the pictures and processes them at 18MIPS (million images per second) and thus produces the location of the mouse and sends it back to the computer. Mouse buttons, there are three mouse controls left, right and center clicks the signals through these keys are also sent to the computer.

### 2.3.3 Laser mouse

Optical mice use LEDs to way their movements, although laser mice use lasers. The mouse emits a laser ray, and the mirrored image is received by a CMOS sensor and directed to a DSP (digital signal processor). This sequence happens many times in a second. The DSP senses designs and variations in the picture and tracks the motion of the mouse, then sends the position to the PC.

A classic laser mouse is three times more sensitive than an optical mouse. As the laser mirrors any object, Can use the laser mouse on any surface. Though, cannot use the optical mouse on glossy surfaces such as glass.

### 2.3.4 Flying mouse

Mouse movement control with mouse button click support (also optional joystick emulation). Use angle-based accelerometer (ACC) inputs to simulate precise mouse movements. The slant based method does not need any design equivalent procedures. The angle-based accelerometer in signal is smoothed to prevent any unnecessary motion. The slant based approach was considered intuitive by project developers, which is controversial considering the real use of a only ACC sensor on the wrist or hand. Can simulate left-mouse-button (LMB) click by a hand-snap movement. The ACC input signal is processed by a high pass filter to detect sharp or quick movements which should trigger LMB click.

### 2.3.5 Eye blink detection for smart glasses

Blinking is a fast stroke to close or open your eyelids. Blink recognition has a wide-ranging range of applications in human PC communication and human visual condition research. Present wink detection methods typically do not adapt well to blink detection platforms with limited resources, such as smart glasses, they have limited energy source and often can't provide powerful picture and computing skills.

An effective and strong, smart glasses blink discovery way is proposed. This way first uses the characteristic eye method to detect closed eyes in each video frame. Then, the method learns the blink mode built on the closed eyelid's discovery results, and uses the "gradient enhancement" method to detect blinks.

This method also uses a minimum conquest algorithm to eliminate frequent discovery of the same blinking motion in consecutive video frames. Experimental This prototype smart glasses prepared with a powerful camera and a fixed processor showed correct discovery results on small 16 × 12 video frames at 96 fps (correct ness over 96%), thus achieving many applications in health care, driving security and human computer interaction.

### 2.3.6 Google Glass

They demonstrated how to use information from Google Glass sensors about blink frequency and head movement patterns to differentiate different types of advanced actions. Although it is well recognized that flicker regularity is related to user action, our purpose is to show that flicker regularity data from non-obtrusive marketable platforms are sufficiently useful, and the addition of head movement pattern information greatly increases Recognition level. The way was estimated based on a dataset from a research that included five movement categories of eight participants (reading, talking, watching TV, mathematical problem solving, and sawing), viewing blink-only recognition correctness It is 67%, and the recognition accuracy of extension by head movement is 82% pattern.

Sensors mounted on the user's head have long been considered too clumsy to recognize activity in everyday life (for example, sensors can be easily integrated into helmets in industrial applications). The "Google Glass platform" (and many developing parallel devices) has evidently broken this guess. It is intended for wholly day use in everyday conditions,

Thousands of people have used this method last year. Google Glass has four sensors that might be used for action recognition. "A camera, a microphone, an inertial measurement unit (IMU), and an infrared proximity sensor facing the user's eyes for blink detection". The inertial measurement unit and blink recognition, which consider to be the most distinctive of Google Glass (and similar products) platforms. For the microphone, the location on the head does not change much (probably to recognize the user's speech). There is still a lot of standing work for head motion cameras. On the other hand, to date, there has been no in-depth research on combining blink regularity and head movement shapes for activity recognition in everyday scenes.

## 2.4 Existing computer interfaces for a physically disabled person

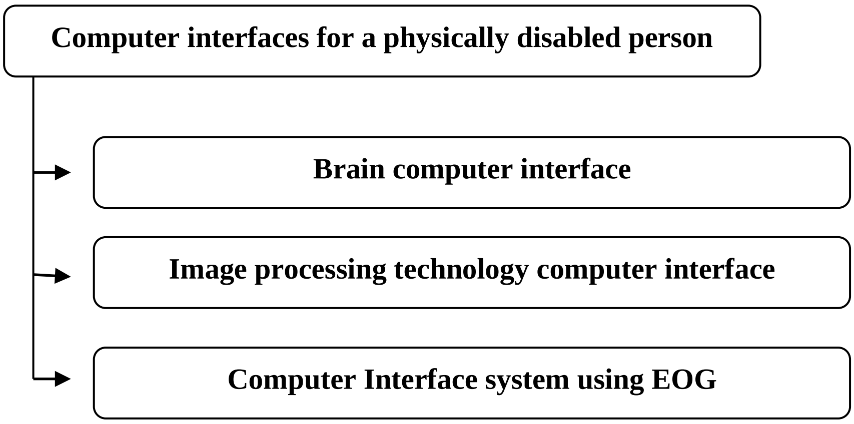



Figure 2.5 : Existing computer interfaces for a physically disabled person

### 2.4.1 Brain computer interface

The smallest invasive method for measuring brain waves is to use an electroencephalogram (EEG) to save  microvolt range potential changes in various positions on the operator's scalp [1]. To do this, a two stage amplification circuit and filtering circuit is erected. In addition, they used a microcontroller's built-in ADC function to digitize the signal. Passive silver covered conductors immersed in saline solution are located on the operator's head and coupled to the amplifier panel.

The optically insulated UART sends the analog to digital converter, digital rate to the computer coupled to the microprocessor via USB. The computerruning software written in MATLAB and C programing to complete the FFT, and runs a device learning algorithm on the follow-on signal [5]. After that, we can switch our own OpenGL application of the classic computer game with brain waves.

### 2.4.2 Image processing technology computer interface

Camera and Visualization technology, such as picture separation, background removal and color tracing, to control mouse pointer tasks and how it can achieve all as present general mouse devices can. A color indicator has been used for the item recognition and tracing, so as to develop the unit without any bodily communication with the system. Help of image processing techniques, the eye recognition and chasing is realized.

The processing techniques involve a picture subtraction procedure to detect colors. The color is detected from the picture pixel and the pixel location is plotted into mouse input location, the root class Java program for mouse movement is called to move the cursor. The setup of IR sensors and camera module is to be used for head movement and eye blink detection and this technique used to control the mouse.

### 2.4.3 Computer Interface system using EOG

Created on electronic eye motion (EOG) technology, signals with various directions in eye motion can be sensed and studied to recognize what they signify (such as horizontal or vertical). Convert analog signals to digital signals and use them as control signals for the display unit.

The classification method used in EOG-based HCI devices are used to detect eye motion in eight orders. The device contains an EOG signal procurement section, a wet electrode and an EOG signal ordering algorithm. The EOG ordering algorithm is based on filtering features of electrical signals equivalent to eight orders of eye motion (up, down, left, right, top, left, bottom left, top right, bottom right) and blinks.

The identification and dispensation of these eight various features are realized under truthful situations, which shows that the device can consistently measure the features of the EOG signal. The system and its classification program deliver an effective way for detecting eye motion. In addition, it can be used to learn eye function in actual life in the nearby coming.

# CHAPTER 3

# HEAD AND EYE OPERATED COMPUTER MOUSE FOR DISABLED PERSON

## 3.1 Introduction

As mention above, the system is divided into main two parts, First one is a Wearable glass module with Processor, accelerometer, Eye blink sensor, Bluetooth module (Transmitting part), Voltage regulator and Lithium polymer battery. Second one is a Base station with Processor and Bluetooth module  (Receiving part).

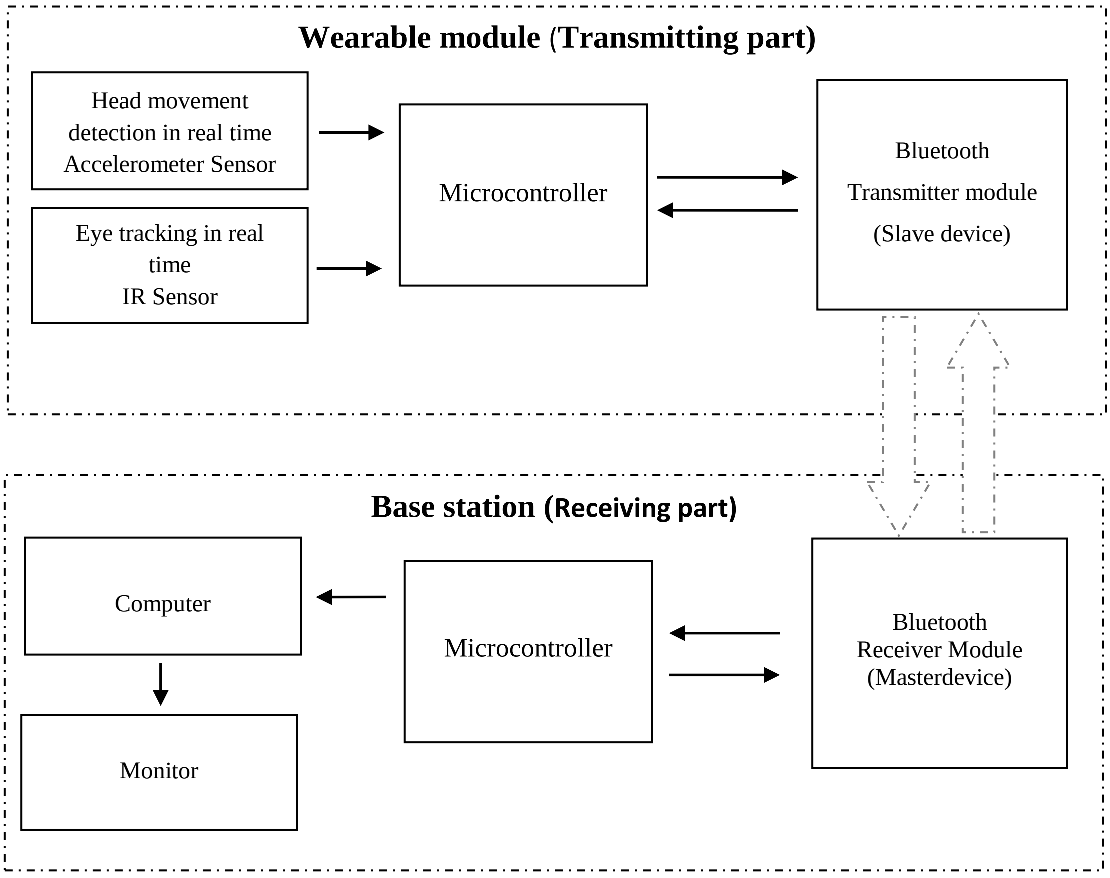



Figure 3.1 : System block diagram

## 3.2 Head movement detection

The system uses head motion as an input method, more precisely the tilt angle of the head. The head tilt angle defines how far the head is swapped along side the axis. The figure shows the place that accelerometer sensor fixed and it’s X and Y axis are parallel to the head mid point X and Y axis therefore head tilt angle accurately sense with this placed accelerometer sensor in There are two possible head tilt movements,

- ‘Pitch’ The vertical head revolution movement (looking up or down, Y axis used)
- ‘Roll’ The head revolution when tilting head towards the shoulders (X axis used)

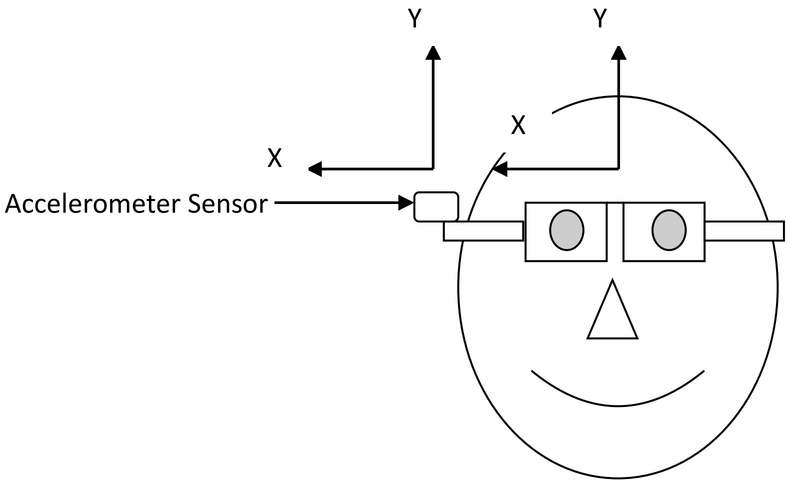



Figure 3.2: Accelerometer Sensor placement

### 3.2.1 Measuring the Tilt angle

To find the tilt slant "θ", the analog to digital rate from the accelerometer sensor is sampled by the analog to digital channel on the microprocessor. Match the tilt angle with zero g offset to get either it is a left or right tilt slant. For a case, if the value is more than the offset value, the tilt angle is a right side tilt angle.

If the tilt slant is left side, then the rate is subtracted from the offset to decide the amount of left tilt slant. One result can measure zero degree angles to a ninety digree angle of slant with a one axis accelerometer sensor.

The following chart displays out-put in g's of the accelerometer sensor as it slants from -90° to +90°. Important that the slant sensitivity reduces within -90° to -45° and within +45° to +90°. This resolution difficult between these values makes this method of manipulating the slant of tilt inaccurate when the accelerometer output is near the +1g or -1g range.

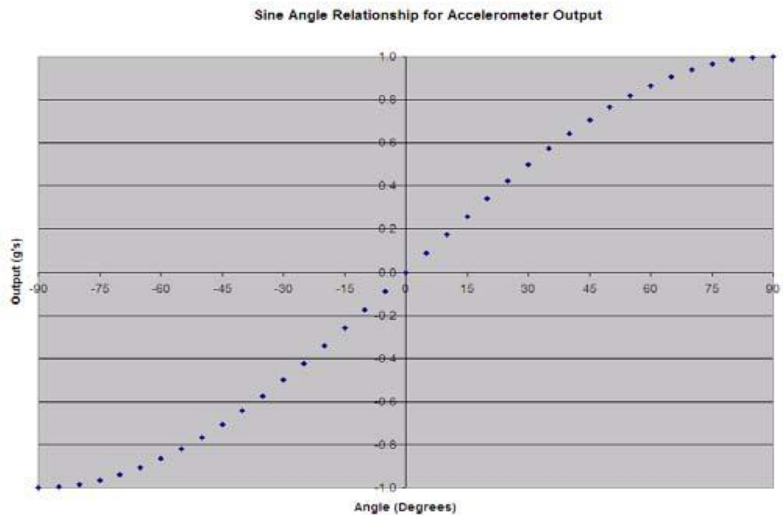



Figure 3.3: Accelerometer Out-put (g's) Tilting from -90° to +90°

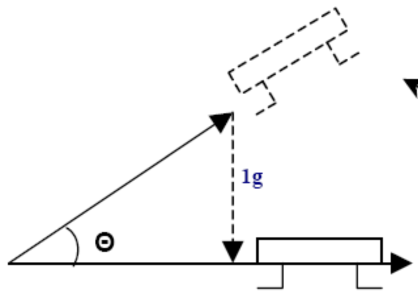



Figure 3.4: Tilt angle along the X-axis

If X axis (only one axis) is used to calculate the slanting angle of the accelerometer the next trigonometry connection is used:

$$V_{out} = V_{offset} + \left( \frac{\Delta V}{\Delta g} \times 1.0g \times \sin\theta \right) \text{..................Equation3.1}$$

Where: $V_{out}$= Accelerometer output volts

$O_{ffset}$= Accelerometer sensor 0g offset

ΔV/Δg= Sensitivity

1g=Earth gravity

θ = Angle of slant

Solving for the angle $\theta = \text{arc}\sin\left(\frac{V_{out} - V_{offseet}}{\Delta V / \Delta g}\right)$……Equation 3.2

This equation can be used with the ADXL335 accelerometer as an example:

$V_{out} = 2048mV + (300mV \times \sin\theta)$……………………..Equation 3.3

Where the angle can be solved by

$\theta = \text{arc}\sin\left(\frac{V_{out} - 2048mV}{300mV / g}\right)$……………………..Equation 3.4

From the above equation, get the result that at $0^0$tilt angle the accelerometer output voltage is 2048mV and at $90^0$tilt angle the accelerometer output voltage is 2348mV. Voltage Vs is 3 V, if the acceleration increase by 1 g, the output voltage will increase 300 mV (typical).

For the movement analysis, it is needed to translate the head tilt angle data from an accelerometer as analog voltage to digital form. Accelerometer ADXL335 x, y pins connected to Arduino A0, A1 pins, The value is in analog (voltage) form which then being converted to digital form in Arduino. This digital signal send to the base station through Bluetooth module. Displacement of mouse cursor that is with this digital signal.

### 3.2.2 Digital value of tilt slant

Head pitch detects with Y axis, The vertical head variation movements when seeing up direction digital value is the nearly 600 range when looking down digital value is the nearly 400 range. Roll, X axis, head rotation when slanting head nearly the shoulders left side digital value is nearly 400 range, when slanting head nearly the shoulders right side digital value is nearly 600 range.

The midpoint coordinate is (500,500), If fixed this coordinates as midpoint that means hard code, then wearable unit have to always placing midpoint on screen. The user has to always sit at a computer as keep straight, level the wearable unit to the map midpoint of the screen. To overcome this issue device should be calibrated before use.

## 3.3 Device calibration technique

### 3.3.1 Find mid-point

To find midpoint when users it at a computer device should be calibrated. Digital value on Arduino A0, A1 pins are Accelerometer X and Y pin output voltage correspond to tilt angle acting on it.

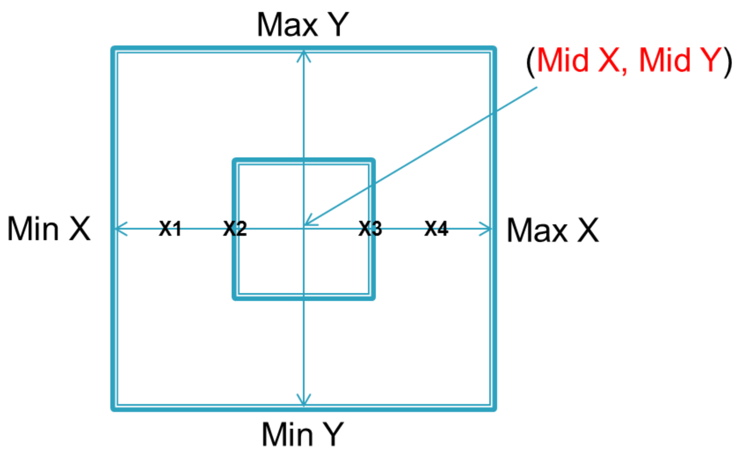



Figure 3.5: Device calibration

Initially set Min X = 600 because this is the maximum digital amount of X axis,

Max X = 0this is minimum digital amount of X axis.

bX=Digital amount of A0 reading the Current value of accelerometer X pin.

If bX>Max X then Max X=bX, to get maximum value in operating range

If bX< Min X then Min X=bX, to get minimum value in operating range

Mid X= (Min X +Min X)/2

Initially set Min Y = 600 because this is the maximum digital amount of Y axis,

Max Y = 0 this is minimum digital amount of Y axis

bY=Digital amount of A1reading the Current value of accelerometer Y pin.

If bY>Max Y then Max Y=bY, to get maximum value in operating range

If bY< Min Y then Min Y=bY, to get minimum value in operating range

Mid Y= (Min Y +Min Y)/2

Therefore mid-point coordinate is **Mid X, Mid Y**

### 3.3.2 Differentiate left and right, up and down values to the mid-point

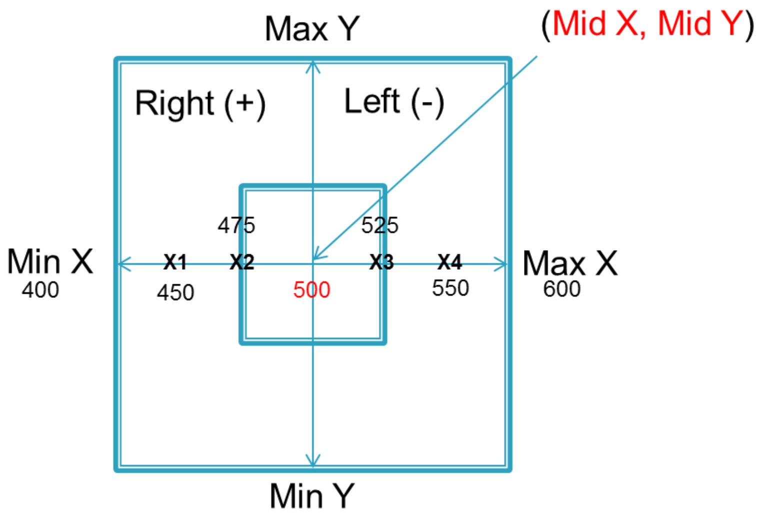



Figure 3.6: Device none operate mid-range

If Mid X current reading value is X1=450 less than mid-point value then,

Val X= Mid X- X1

Val X= 500-450 = 50

If Val X>0 then it can be identified Val X is right side value from mid-point, mouse cursor should be move to right side.

If current reading value is X4=550 greater than mid-point value then,

Val X= Mid X- X4

Val X= 500-550 = -50

If Val X<0 then it can be identified Val X is left side value from mid-point, mouse cursor should be move to left side.

Val X= Val X+255

Val X= 205 Send this value to receiver because negative value can't be send through Bluetooth technology (0 to 255 range value can send at a time)

Check the value at receiver, If Val X<0 then it can be identify Val X is left side value of mid-point; mouse cursor should be move to left side.

If Val X > 160 then (-95 but value is about -30)

Val X= 205-255 = -50

Likewise

If Val Y>0 then it can be identified Val Y is down side value from mid-point, mouse cursor should be move to downward. If Val Y<0 then it can be identified Val Y is up side value from mid-point, mouse cursor should be move to upward.

### 3.3.3 Sets non operate mid-range

Set non operate mid-range, to keep head freely with slight motions (Between X2 to X3)

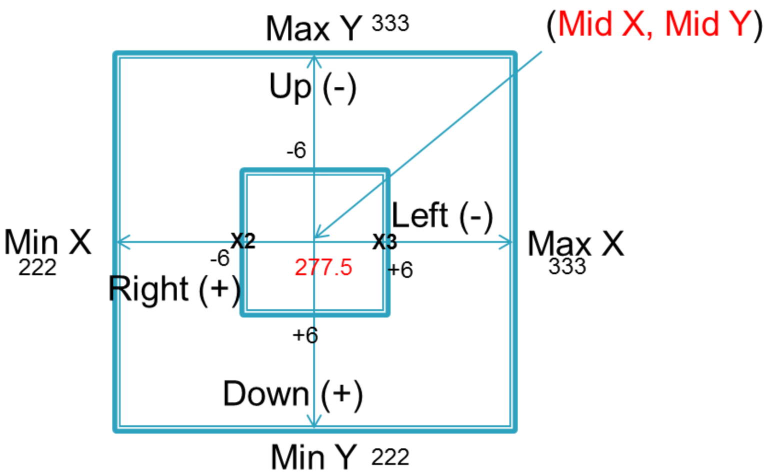



Figure 3.7: Device non operate mid-range

Current reading value is Val X, Val Y to scale down these values,

Val X= Val X * 0.555

Val Y= Val Y * 0.555

Val X <= + 6 and Val X <= - 6 then, Val X = 0

Likewise

Val Y<= + 6 and Val Y<= - 6 then, Val Y = 0

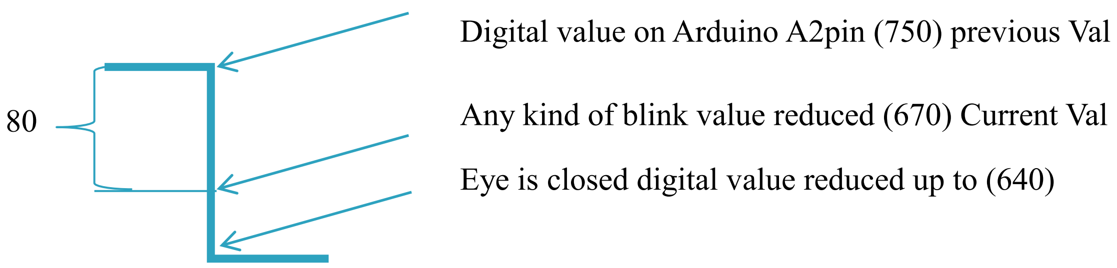
Cursor moves to Val X, Val Y coordinates, but cursor not moves Val X <= + 6,

Val X <= - 6 and Val Y<= + 6, Val Y<= - 6 (range to about +/-$10^0$)

## 3.4 Eye tracking

The clicking of the pointer is initiated by the operator's eye tracking in real time. The algorithm used by the system for detecting and analyzing blinks is initialized automatically depend on eye blinking of the user. Eye blink information is detected by the IR based eye blink sensor (TCRL5000L-LM393) on this unit, which export analog voltages to interface circuit through the microcontroller.

The human unintentional eye blinking is significantly shorter than intentional eye blink. TCRT5000L reflective sensor analog pin connected to Arduino A2 pin, The value is in analog (voltage) form which then being converted to digital form in Arduino. The digital value of Arduino A2 pins is IR sensor analog pin output voltage corresponds to eye blink acting on it.




previous Val =Digital value of A2 (analog Read IR) delay then

difference = current Val – previous Val

If ( difference < -80 ) then eye is closed after keeping opened.

If the eye is kept closed shorter than 150ms then it is considered as an unintentional eye blink and neglected

If (0 < period of closing after keeping opened < 150ms) == unintentional blink

If (150ms < period of closing after keeping opened < 400ms) == single click

If (400ms > period of closing after keeping opened) == double click

Check eye is closing after keeping opened, Wait 150ms time duration, Check eye is still closed position, Wait another 250ms time duration, Check eye is still closed position if eye is still closed after total 400ms time duration then activate double click otherwise activate single click.

## 3.5 Bluetooth Communication

Bluetooth is an identical protocol for the transfer and receipt data over 2.4GHz wireless links. This is a security procedure that is very suitable for small distances, small power consumption, and small cost wireless transmission between electronic devices. Bluetooth is like the radio frequency version of serial communication, and Bluetooth devices have unique addresses, usually expressed as hexadecimal values. (Such as 98d3: 34: 905d3f), the working range is 10 meters (30 feet).

### 3.5.1 How Bluetooth Works

Bluetooth systems (usually known as networks) use a master or slave classic to switch at what time and wherever devices can send data. In Bluetooth HC-05 model, one master device can connect up to 7 various slave devices. Any slaves in a Bluetooth network can only be linked to a lone master device. The host matches communications through the Bluetooth network. A master device can send data to or request data from any of its slaves. A slave station is only allowed to send and receive with its master.

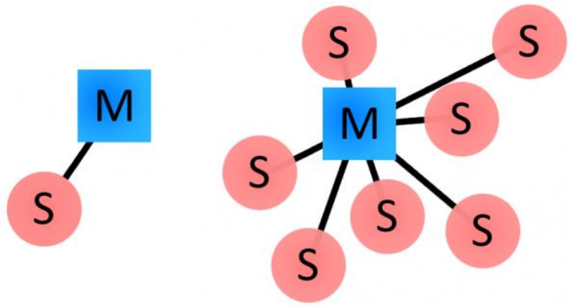



Figure 3.8: Examples of Bluetooth master/slave piconet topologies.

### 3.5.2 Arduino and HC-05 in communication mode

Model HC-05 is built on the Bluetooth module called EGBT-045MS. This can operate either as a slave or master. When function as a slave, it only receives links. As a host, they can start a Bluetooth connection. The HC-05 adapter module has a 3.3 voltage regulator its lets voltage in from 3.6 volts to 6 volts, however the 'TX' and 'RX' pins are always 3.3 volts. This means that 5 volts is out-put from the Arduino board to power the Bluetooth module, but the Arduino can't be connected straightly to the module'RX' pin. Module'RX' pin (data input) needs to change Arduinos output 5 volts to 3.3 volts.

A modest method is to use a voltage divider consisting of several resistors. In my circumstance, I used a 1K ohm resistor and 2K ohm resistor. A fast guide for voltage dividers; 1KΩ + 2KΩ = 3KΩ. 1KΩ is a third of 3KΩ, so it decreases the voltage by a third. One third of 5 volts is 1.66 volts, and 5-1.66 = 3.33 volts. The Arduino accepts a high voltage of 3.3 volts and connects the module'TX' pin (data output) straightly to the Arduino 'RX' pin (5 volts Arduino is 3 volts or upper).

Module standard Settings

The standard settings of new Bluetooth modules,

– "Name = HC-05"

– "Password = 1234"

– "Baud rate in communication mode = 9600*"

– "Baud rate in AT/Command mode = 38400"

Connections

BT module ‘Vcc’ to 5 volts supply from the Arduino board

BT module ‘GND’ to common Ground

BT module‘RX’ to ‘Arduino pin D3 (TX)’through a voltage divider circuit

BT module‘TX’ to ‘Arduino pin D2 (RX)’ connect straight.

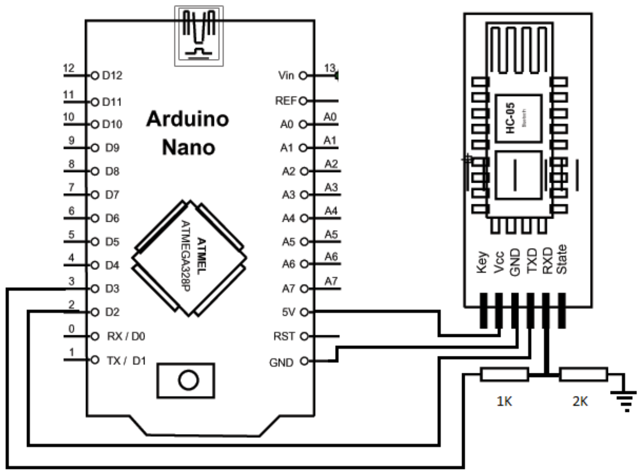



Figure 3.9: HC-05 Basic setup

### 3.5.3 Configuring the HC-05 Bluetooth Module

In order to configure both modules, need to switch to AT Command. First need to connect the Bluetooth module to the Arduino, as shown in the circuit schematic in Figure. The ‘RX’ pin of Arduino wants to be linked to the ‘RX’ pin of the Bluetooth module over a voltage divider, and the ‘TX’ pin of Arduino wants to be linked to the ‘TX’ pin of the Bluetooth module. Currently, while press downs the minor switch on the "EN" pin, you want to power the module, which is in what way it will enter command mode. Now the led Bluetooth module flickers every 2 seconds, it finds that it has effectively entered the AT command mode.

After that, have to upload a blank draft to the Arduino board, but essential remove the ‘RX’ and ‘TX’ links when upload the blank sketch. Then essentially to run the serial monitor and choice "both NL and CR" and "38400 as baud rate", which is the normal baud rate of this Bluetooth module.

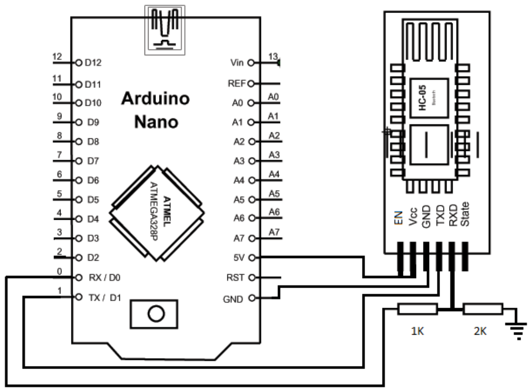



Figure 3.10: Connection of Bluetooth module and Arduino board

Now module complete to send commands, All commands being with “AT”, followed by the “+” sign, then a <Parameter Name> and they end, both with the “?” symbol which revenues the current value of the parameter or the “=” sign after we need to enter a fresh value for that parameter.

<u>HC-05 Bluetooth Module Slave Configuration</u>

So in case, if we type such ‘AT’ which is a check command we must get back the message ‘OK’. Then, if we type ‘AT+UART?’ we must get back the message that displays the default baud rate as‘38400’. Then, if we type ‘AT+ROLE?’ we will get back a message ‘+ROLE=0’ which earn that the Bluetooth device is in slave mode. If we type ‘AT+ADDR?’ then we can get the address of the Bluetooth device and it's something looks similar this kind ‘98d3:34:905d3f’.

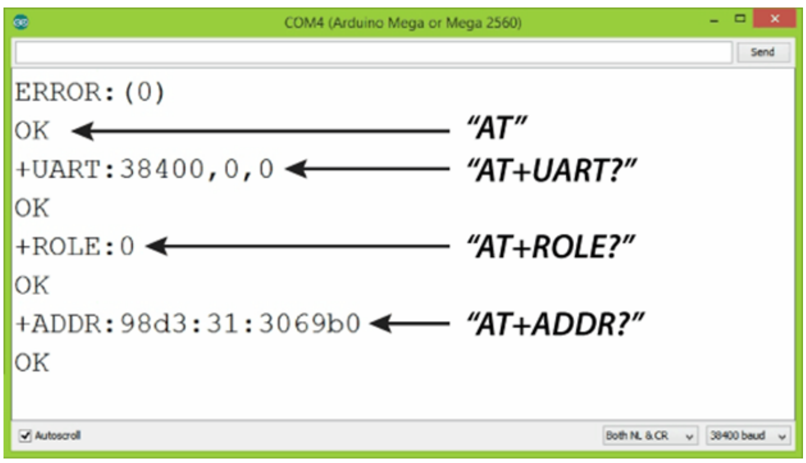



Figure 3.11: Sending AT Commands to Slave

Now essential to write down this address because when configuring as the master device we need that address. Really, that's entirely want when configuring as the slave device, to get its address, though can transform various dissimilar parameters like its name, baud rate, pairing password etc.

HC-05 Bluetooth Module Master Configuration

Organize the further Bluetooth module as a master device. Main check the baud rate to make assured it's the same '38400' as the slave device. At that point, by typing 'AT+ROLE=1'to set the Bluetooth module as a master device. After this using the 'AT+CMODE=0' we will set the attach mode to 'fixed address' and using the 'AT+BIND='command we will fix the address of the slave device that we earlier wrote down.

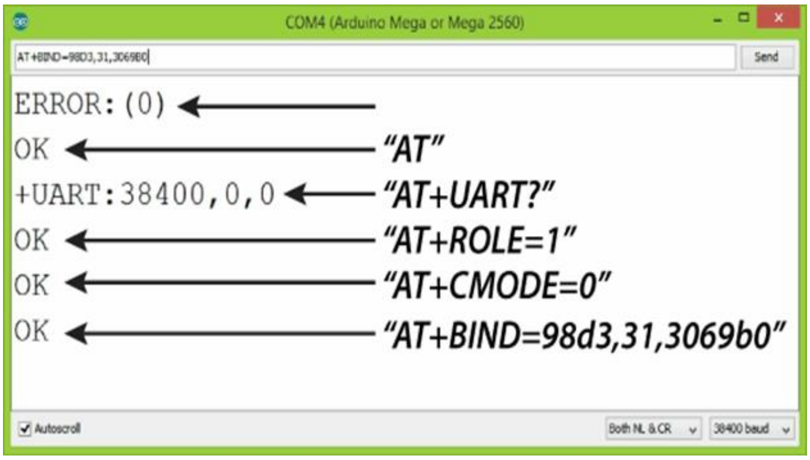



Figure 3.12: Sending AT Commands to Master

## 3.6 Mouse libraries and its functions

The mouse function allows a '32u4 or SAMD' micro based motherboard to regulator cursor movement on a connected PC through its micro's native 'USB' port. When the pointer is updated, it is permanently relative to the earlier location of the pointer. These fundamental libraries permit'32u4 and SAMD' based motherboards ("Leonardo, Esplora, Zero, Due, and MKR series") to seem as natural Mouse on the linked PC.

In the Leonardo surroundings, there are two sequential ports existing. First one is an emulated ‘VCP’ port linked via ‘USB’, and the second one  is hardware ‘UART’ on the microcontroller itself.

When consuming the Mouse library, it is greatest to mainly test the output by ‘Serial.print ()’. This method you can be assured that you identify what value is being testified. Mouse library, Mouse.h file includes the Human interface device library, HID.h file.

The mouse functions

With “Mouse.move()”: “mouseX” and “mouseY” are Left/Right/Up/Down displacements, negative for Up/Left and positive for Down/Right, +/-1 displacement steps give a smooth movement.

### 3.6.1 Human interface device (HID)

A HID is a type of PC equipment commonly used by humans, which get input from humans and provides out-put into humans. In the HID protocol, there are two objects: ‘host’ and ‘device’. Devices are entities that interact directly with humans, such as a Touch pad or mouse. The host interconnects with the device and obtains input data from the device founded on processes achieved by humans. Output data currents from the host to the device and then to the persons. The greatest mutual example of a host is a computer. The term ‘HID’ most usually mentions to the USB-HID description.

The term was invented by Microsoft's ‘Mike Van Flandern’ when he planned that the USB team make a human input device lesson employed group. The ‘HID’ protocol has its restrictions, but all current ordinary operating systems can identify standard USB HID devices, such as a touch pad and mouse, without the need for dedicated drivers. When Arduino Leonardo is connected to a computer, it usually displays a message on the monitor stating "HID-compliant device has been identified" and communicates with our system by using the HID driver.

## 3.7 Functional block diagram of the system

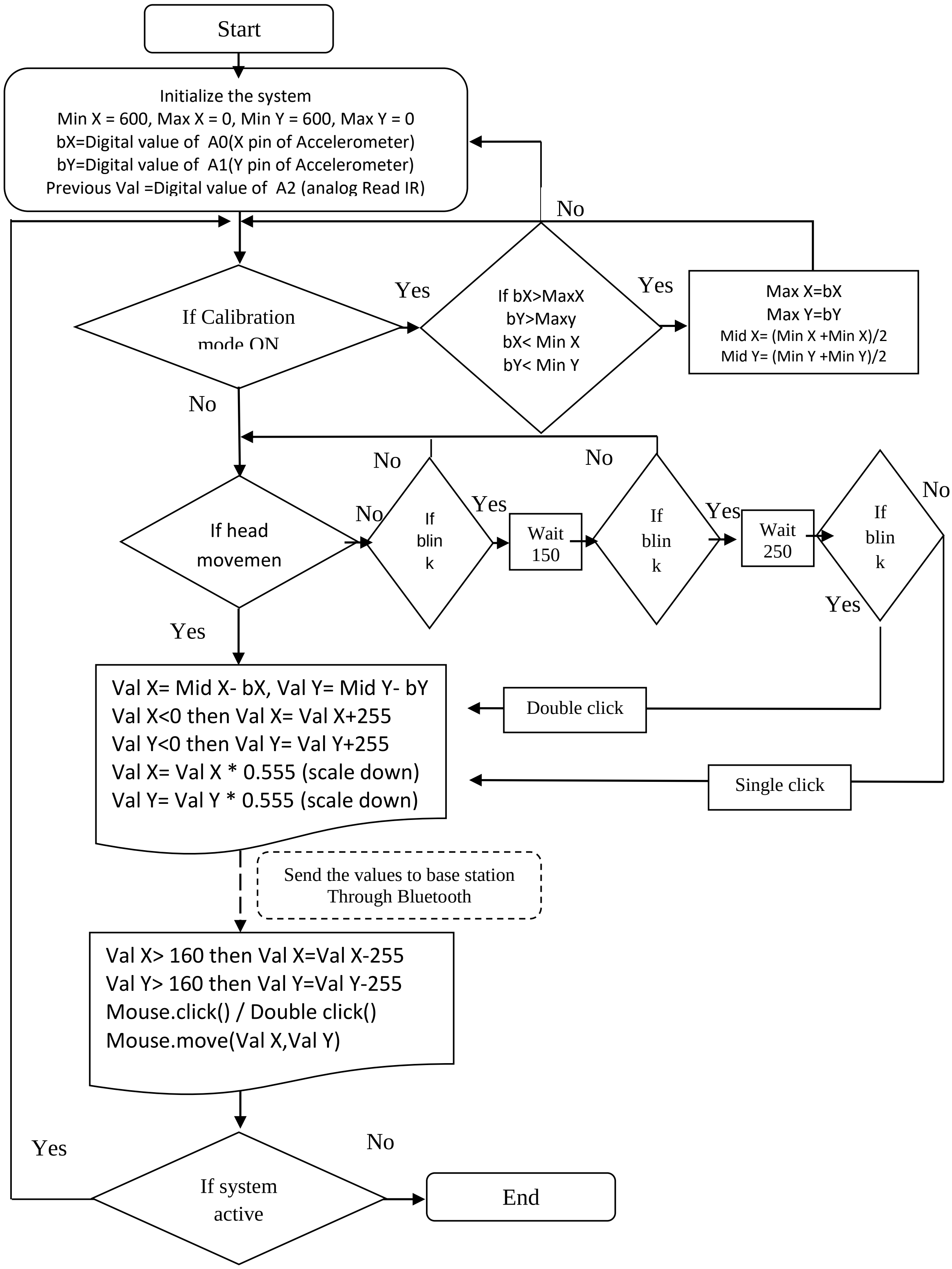



Figure 3.13: Functional block diagram of the system

# CHAPTER 4

# SYSTEM DEVELOPMENT

## 4.1 Introduction

In this chapter explains about the fabrication of all hardware units of the system. The system is divided into main two parts, First one is Transmitting part, Second one is Receiving part. I developed the Wearable glass module power supply circuit, microcontroller unit, Head movement detection with Eye tracking unit and Bluetooth module circuit. Each sub-component and how they work, including the circuit structure all this information have documented with this chapter. Major advantages of this system are wireless, low cost implementation, overcome problem in existing systems and portable, easy to use by physically hand disabled person.

## 4.2 Transmitting part

Wearable glass module with Arduino Nano, Accelerometer sensor, Eye blink sensor, Bluetooth Module, Voltage regulator and Lithium polymer battery.

### 4.2.1 Accelerometer sensor

The implementation of the head and eye operated hand free mouse system is centered on the analog device ADXL335 triple axis accelerometer. The accelerometer is giving an analog signal according to the tilt angle of it, mechanical movement is converted in to analog output from the sensor. On power up, Arduino Nano Analog zeroes pin read the x direction amount of the accelerometer, Analog one pin read the y axis amount of the accelerometer.

### 4.2.2 Eye blink sensor

The clicking of the mouse is activated by the user's eye tracking in real time. The algorithm used by the system for detecting and analyzing blinks is initialized automatically depend on eye blinking of the user.

Eye blink information is detected by the IR based eye blink sensor (TCRL5000L-LM393) on this unit, which exports the analog voltages to Arduino NanoA2 pin., with proper check (Eye tracking 4.4) weather it is a click or not then clicks command send to base station.

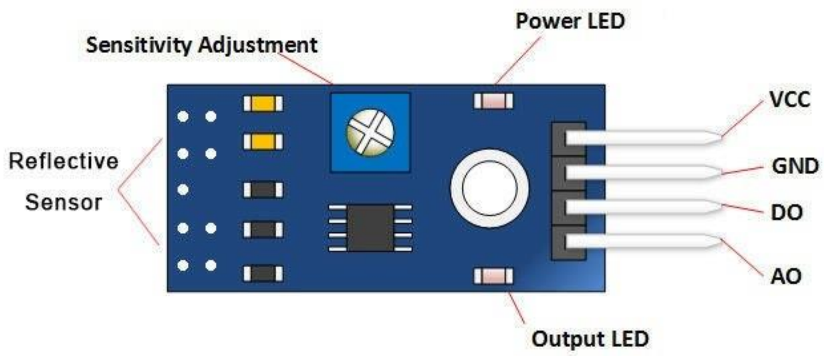



Figure 4.1: IR TCRT5000L Sensor terminal connection

The TCRT5000L infrared reflective sensors it contain an infrared emitter and photo-transistor in a leaded container it avoid visible lighting. The container contains two mounting clips. TCRT5000L is one of the long lead product versions. An infrared emitter is an LED that emits infrared light and is often called an IR emitter. Similarly, an infrared receiver has helped to get IR radiation emitted by an infrared transmitter. It is essential that infrared transmitter and receiver are placed in a straight line.

Whenever the signal is high, the transmitted signal will be sent to the IR transmitter, the IR transmitter LED is on, and it transmits infrared radiation to the infrared receiver. The infrared receiver interconnects with the comparator. Comparator have an LM 324N (OP-Amp) operational amplifier. Comparator circuit has a reference voltage is supplied to an inverting input point. The non-inverting input point is connected to the infrared receiver. The situation of infrared radiation among with infrared TX and the RX is interrupted, infrared RX is not turned on.

Therefore, the voltage at the non-inverting input of the comparator if bigger than the inverting input. This circuit output of comparator out is connected to Arduino A2 pin, the value is in analog (voltage) form which then being converted to digital form in Arduino.

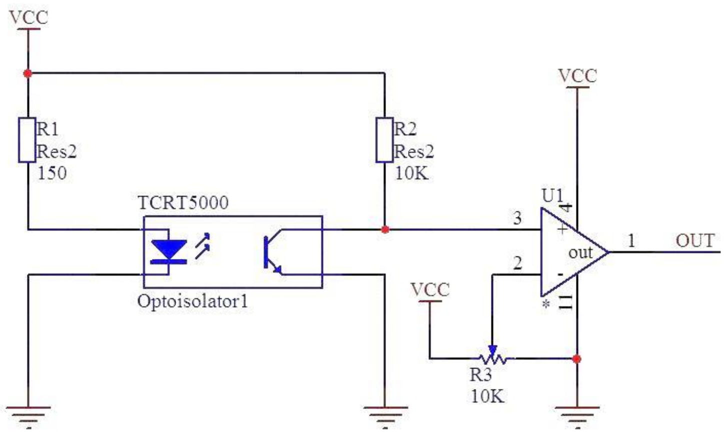



Figure 4.2: Schematic diagram of the eye blink sensor

**4.2.3 HC-05 Bluetooth Module**

HC05 Bluetooth module output data TX pin straightly connected with Arduino nano digital 2nd pin as serial RX, Arduino Nano digital 3rd pin as serial TX connected to HC 05 Bluetooth module input data RX pin through a voltage divider circuit, because HC 05 Bluetooth module gets only 3.3 volts input as HIGH. Arduino Nano gets 5V and 3.3V input as HIGH.

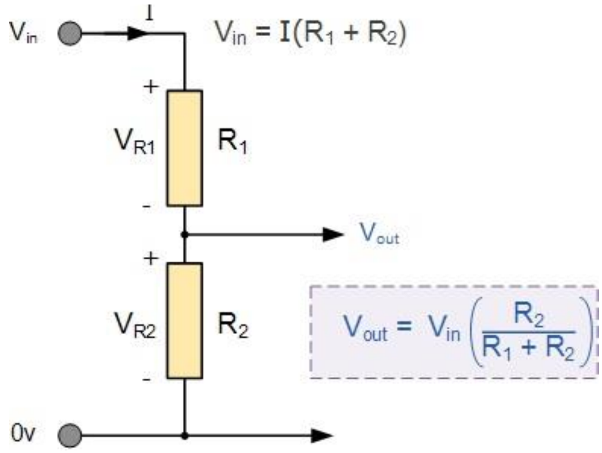



Figure 4.3: voltage divider circuit

Resister one  is 1KΩ and Resister two is 2KΩ, according to voltage divider rule 1KΩ + 2KΩ = 3KΩ. 1KΩ is a third of 3KΩ therefore it reduces the voltage with a third. 1/3 of 5V is 1.66V and 5.00V-1.66V = 3.33V, Vout=3.33V. Base station Bluetooth module HC-05 set as Master.

### 4.2.4 Lithium polymer battery

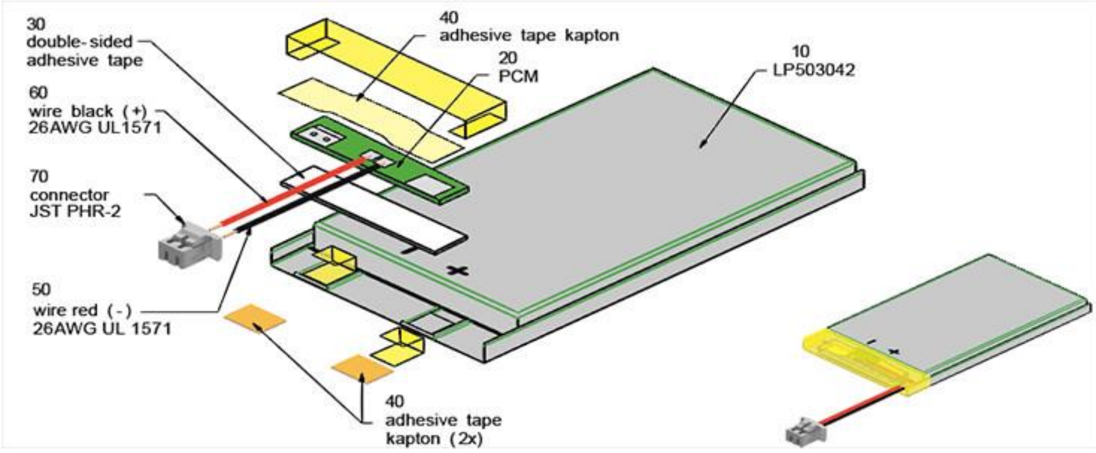
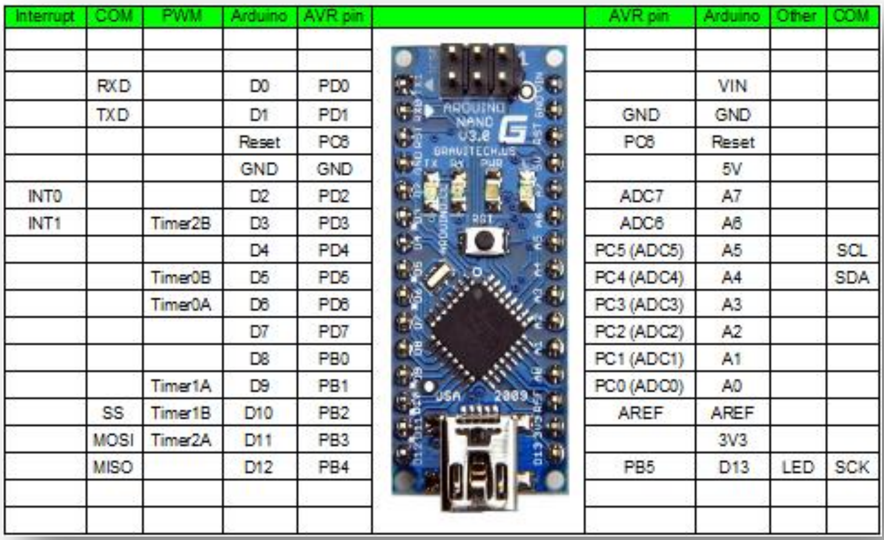



Figure 4.4:Lithium polymer battery layout

Wearable glass module with Arduino Nano, Accelerometer sensor, Eye blink sensor and Bluetooth Module are powered up with two 3.7V 20C 180mAh Lipo lithium polymer rechargeable Battery. Total output voltage is 7.4V, Capacity is 360mAh. The processor will draw around 2.4 mA at 5 volts, The USB chip draws around 15 mA depending on several things, Bluetooth HC-05 power consumption at 3.3v 50mA.

TCRT5000L reflective sensor’s typical output current under test: IC = 1 mA, ADXL 335 accelerometer typical current consumption at VS = 3.6 V is 375 μA.
Total power consumption = 2.4+15+50+1+1=69.4mA, I would also add a 20% safety margin (around 13.88 mA), So need83.28 mA supply, Battery Life equal to battery capacity divided by load current of the circuit, Battery Life=360/83.28= 4.3Hrs. In practically it’s worked more than 6Hrs.

### 4.2.5 Arduino nano board v3.0



| Interrupt | COM | PWM | Arduino | AVR pin | | AVR pin | Arduino | Other | COM |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | RXD | | D0 | PD0 | | | VIN | | |
| | TXD | | D1 | PD1 | | GND | GND | | |
| | | | Reset | PC6 | | PC6 | Reset | | |
| | | | GND | GND | | | 5V | | |
| INT0 | | | D2 | PD2 | | ADC7 | A7 | | |
| INT1 | | Timer2B | D3 | PD3 | | ADC6 | A6 | | |
| | | | D4 | PD4 | | PC5 (ADC5) | A5 | | SCL |
| | | Timer0B | D5 | PD5 | | PC4 (ADC4) | A4 | | SDA |
| | | Timer0A | D6 | PD6 | | PC3 (ADC3) | A3 | | |
| | | | D7 | PD7 | | PC2 (ADC2) | A2 | | |
| | | | D8 | PB0 | | PC1 (ADC1) | A1 | | |
| | | Timer1A | D9 | PB1 | | PC0 (ADC0) | A0 | | |
| | SS | Timer1B | D10 | PB2 | | AREF | AREF | | |
| | MOSI | Timer2A | D11 | PB3 | | | 3V3 | | |
| | MISO | | D12 | PB4 | | PB5 | D13 | LED | SCK |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 4.5: Arduino nano board pin description

The power switch is getting from 5V terminal on Arduino nano board. Lithium polymer battery connected with VIN and GND terminals. On power up, Including software serial library to customize the user defined serial ports, Digital 2 pin as serial RX and digital 3 pin as TX of user defined Serial port 'BTserial', A0 pin assign as get x direction angle amount in accelerometer.

A1 pin assigns as get y direction angle amount in accelerometer, digital 7 pin get state of mode selection switch for calibrate or running mode, A2 pin to get eye blink through IR sensor.  Accelerometer sensor, IR sensor, Bluetooth module are powered up with one power switch get from 5V terminal.

Analog into digital converter (ADC)

The Analog into Digital Convertor takes the signal current and converts it to a binary code. This way a computer can recognize the signal in a digital format. Mouse status information from the measured accelerations and IR based eye blink sensor are export analog voltages. These voltages are transfer of digital value by the analog into digital Converter (ADC) of a microcontroller.

## 4.3 Wearable glass module

Wearable glass module with Arduino Nano, Accelerometer sensor, Eye blink sensor, Bluetooth Module, Voltage regulator and Lithium polymer battery. On power up, Including software serial library to customize the user defined serial ports, Digital 2 pin as serial RX and digital 3 pin as TX of user defined Serial port 'BTserial', A0 pin assign as get x direction angle amount in accelerometer, A1 pin assigns as get y direction angle amount in accelerometer, digital 7 pin get state of mode selection switch for calibrate or running mode, A2 pin to get eye blink through IR sensor.

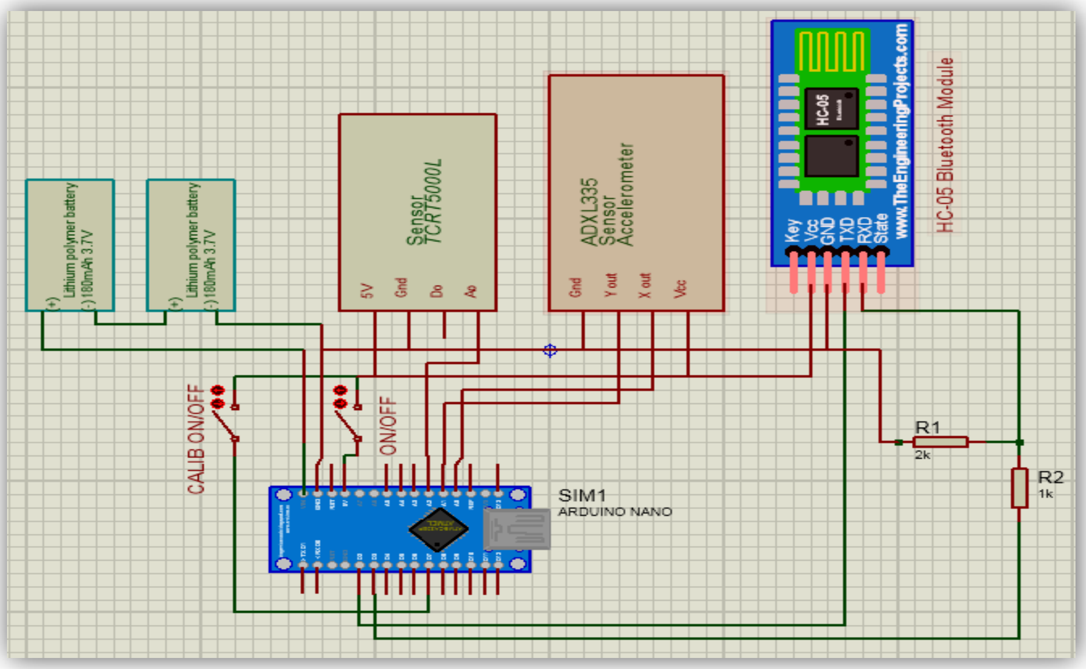



Figure 4.6: Connection diagram of wearable glass module

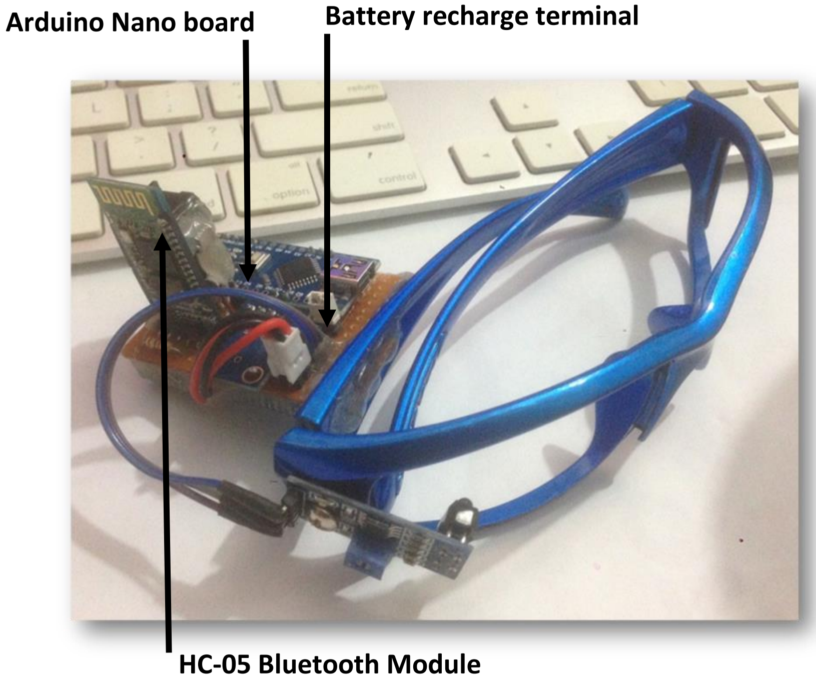
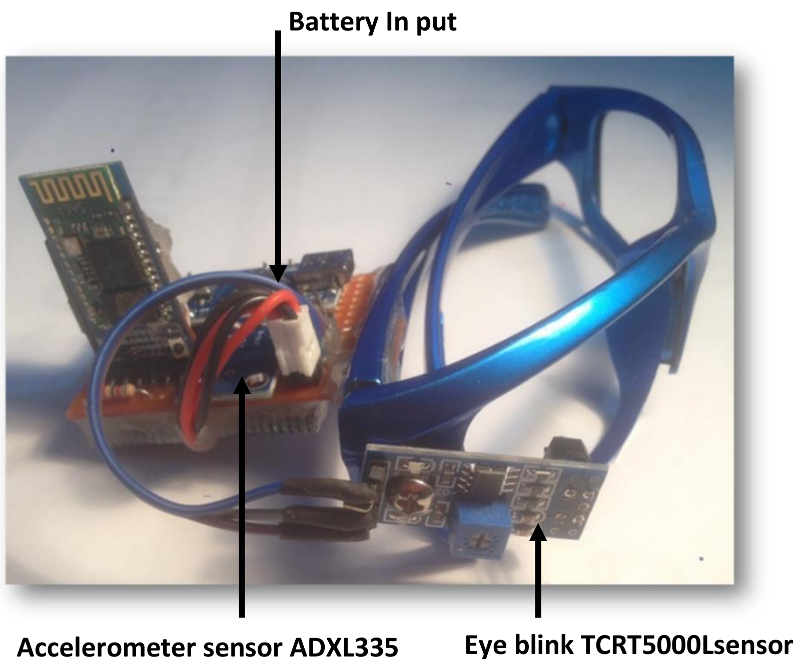



Figure 4.7: Wearable glass module




When the switch for calibrate off it returns the Mid X and Mid Y values (Discussed in 4.3) and device changes to running mode. In running mode Differentiate left and right, up and down values to the midpoint ( 4.3.2 ), Sets non operates a mid - range (4.3.3), Eye tracking (4.4), Bluetooth Communication (4.5) all process done on Arduino nano board. Bluetooth module is configured as master described in 3.5.3.

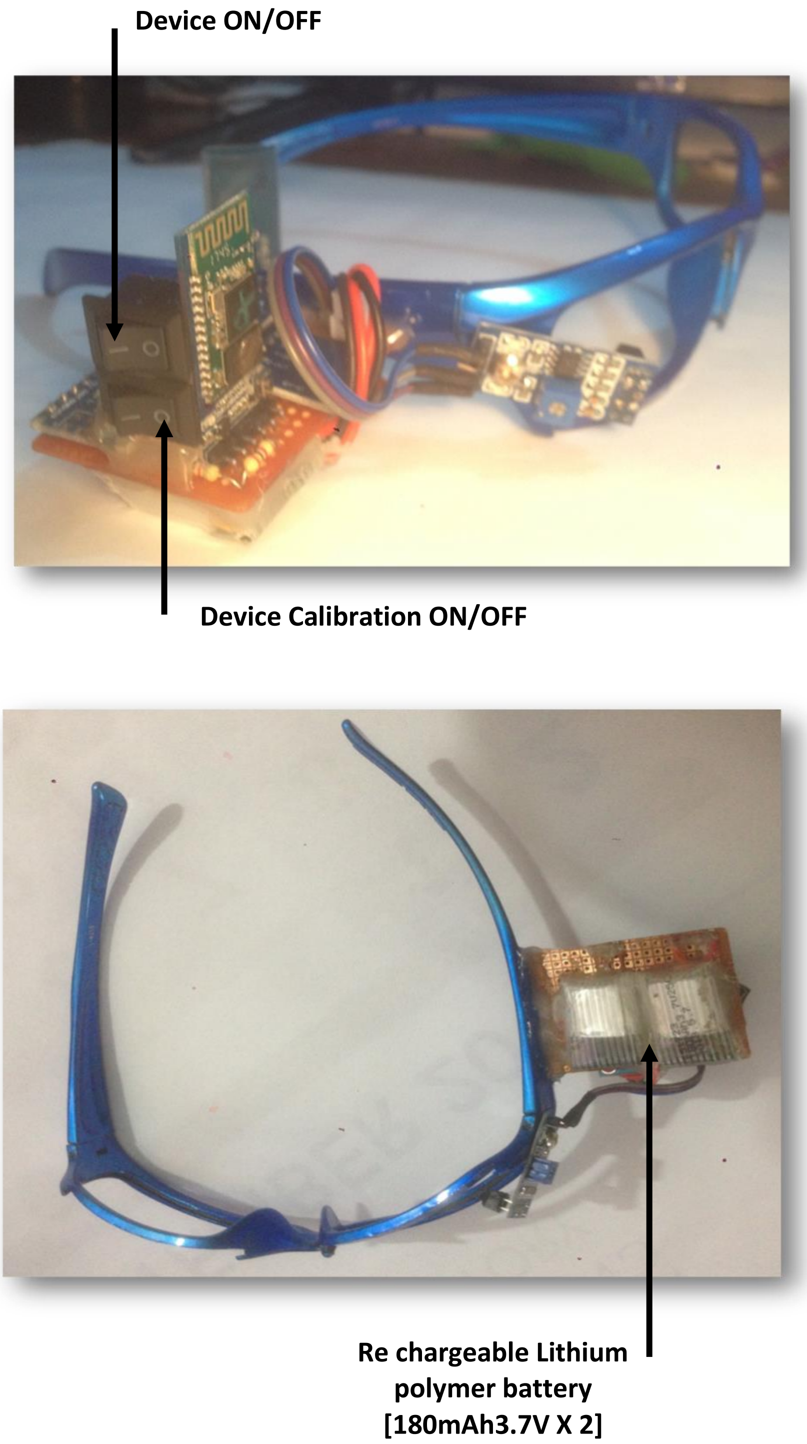



Figure 4.7: Wearable glass module

## 4.4 Receiving part Base Station

Base station with Arduino Pro Micro, Bluetooth module, Voltage regulator and USB male to Micro-B male adapter. Bluetooth module with Voltage regulator is same setup described in 4.2.3 but this Bluetooth module is slave configured.

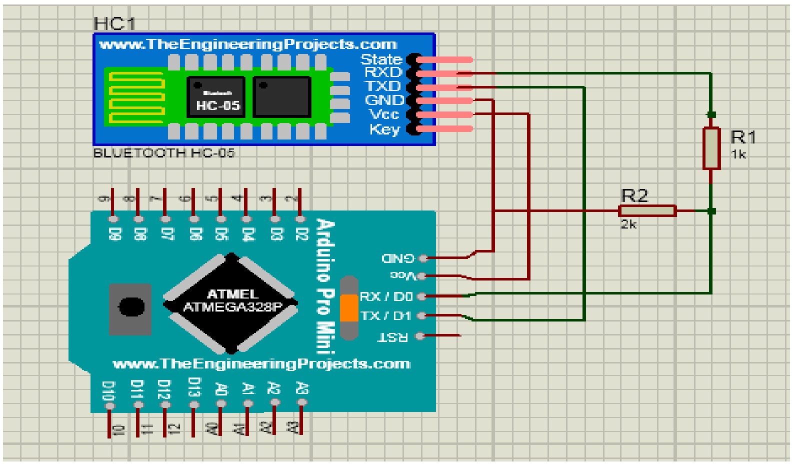



Figure 4.8: Connection diagram of receiving part Base Station

### 4.4.1 Arduino Leonardo Pro Micro - mega32u4

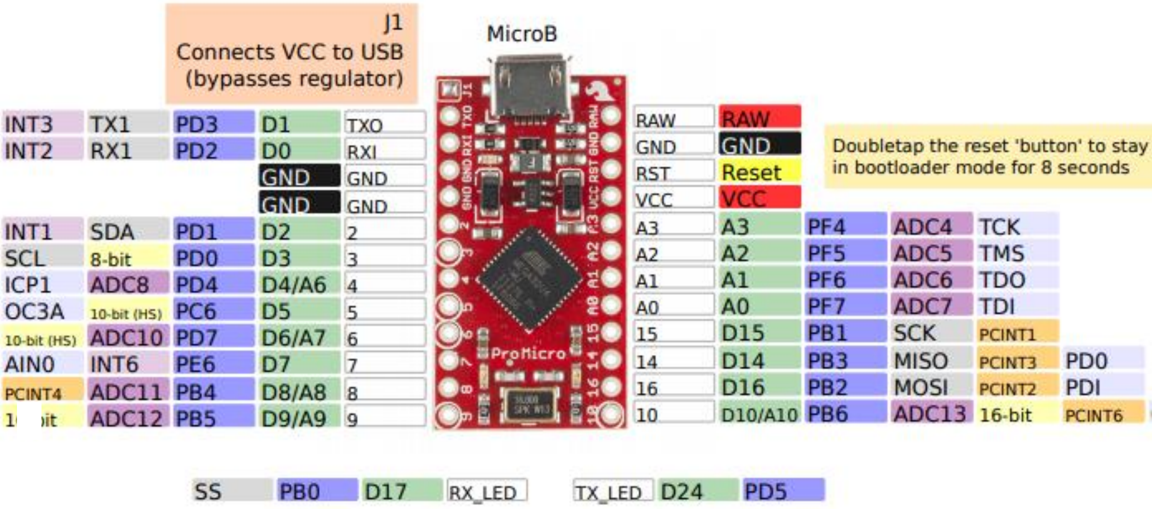



Figure 4.9: Arduino Leonardo Pro micro

Arduino Leonardo Pro Micro builds with a ATmega32U4 microprocessor is a very small board in Arduino family. It can connect with other devices and sensors quickly due to its development in Arduino family. Leonardo D1 and D0 pins are support of serial communication, in order to transfer data with wireless communication. With this mouse its support Bluetooth wireless communication between wearable glass module and base station. Base station Bluetooth module TX and RX pins connected to Arduino Leonardo Pro Micro RX and TX pin.

### 4.4.2 Base station interface

The Arduino Pro micro has Universal Serial Bus (USB) Micro B female port as input, output communication, this can plug to computer Universal Serial Bus (USB) use of male to male adapter. The latest version of the Arduino software contains the mouse library and its detect base station as a mouse with currently loaded program.

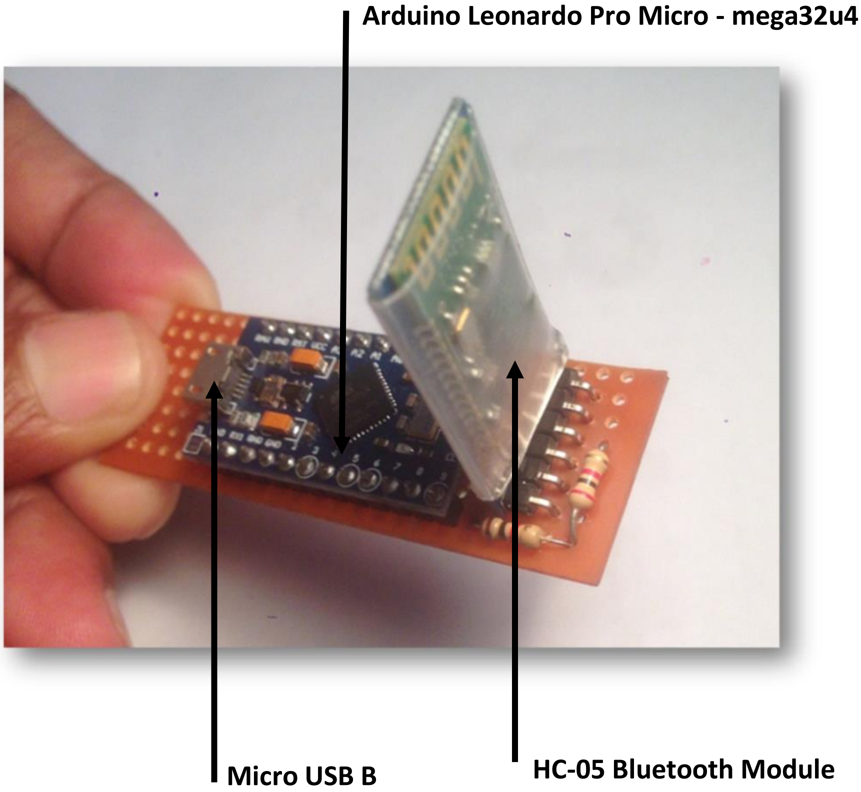



Figure 4.9: Base station - Receiving part

After the Arduino Leonardo is connected to computer, a box message displayed as ‘A HID compliant device has been recognized’ on a computer display, it communicates with our system through the use of HID driver. Computer mouse functions, activate microcontrol to manage mouse motion with interconnect computer (USB interface). When applying a change on cursor position in screen, it will change according to last position of cursor’s. This library allows an Arduino board with USB capabilities to act as a Mouse.

# CHAPTER 5

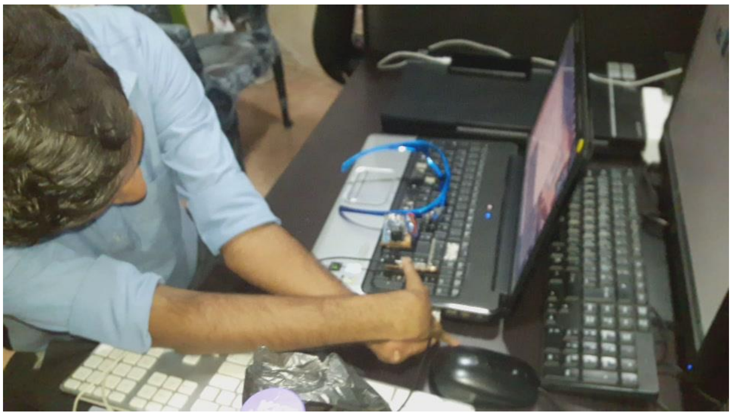
# RESULTS AND ANALYSIS

## 5.1 Introduction

The mouse can be powered by 5.0V of supply voltage from the battery power supply or USB power. The main component of this system is the Arduino board along with the other essential components for its normal operation. This unit can communicate with the sensors and obtaining the values for head movement and eye blink status.

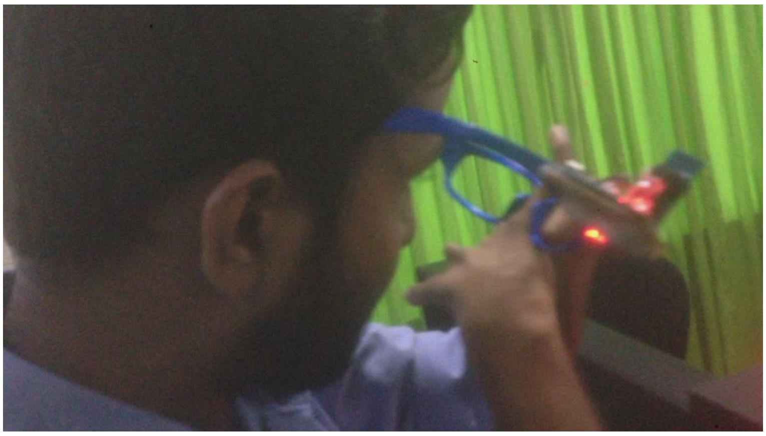
**<u>Operational details</u>**

# Plug base station (Receiving part) into Laptop USB port, now the led in receiver, Bluetooth module flickers repeatedly mean it is waiting for connection in Data Mode.



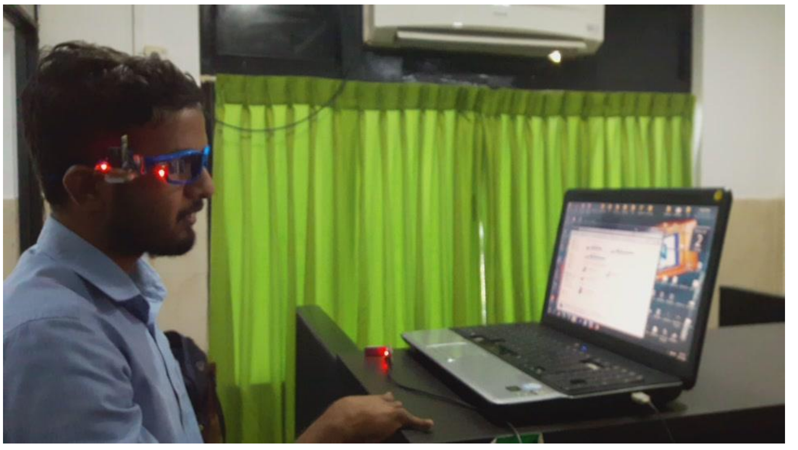
# Turn ON wearable module (Transmitting part) and Device Calibration switches, then wait a few seconds, now the led in transmitter, Bluetooth module flickers synchronously wit led in receiver Bluetooth module that mean both modules are connected successfully.

# After pairing successfully wear the glass, then calibrate the module by tilting the head looking up and down, towards the shoulders, now the module calibrated to current head passion with screen position.



# Turn OFF Device Calibration switch, now the module ready for mouse operation. By tilting the head looking up and down, towards the shoulders can move the mouser pointer up. Down and left, right. The combination of this module works as an actual mouse movement.

# By eye is kept closed more than 150ms and less than 400ms can activate the left single click. The eye is kept closed more than 400ms can activate the left double click.



A usability testing survey was conducted to validate the product, A group of 20 was volunteered in conducting the survey including a disabled person.

Figure 5.1: Usability testing survey

Among the considered group, 90% were strongly agreed with the product as a new concept to be used by disabled people. 65% were satisfied with the functionality when compared to the existing mouse. Further, 60% of the users were satisfied with the usability in different environments. Finally, 40% were in the position of not satisfied with the wear ability by a disable person by himself.

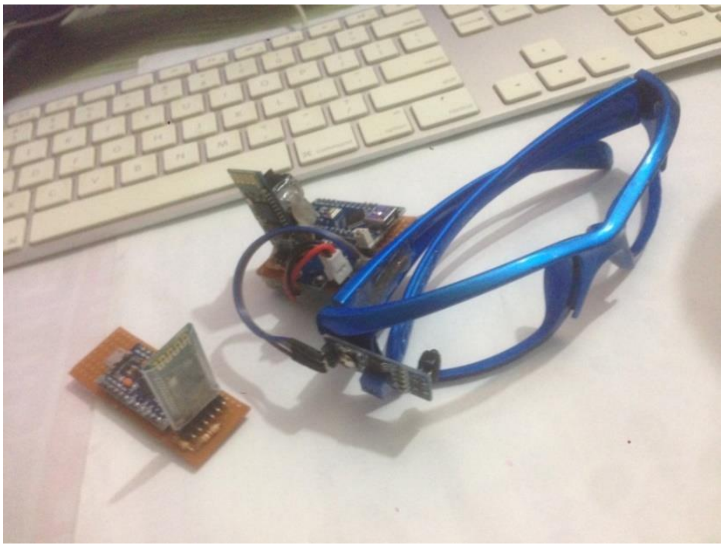


Figure 5.2: Final product

This head and eye operate mouse control cursor left and right, up and down motion, mouse left click can activate single/double click through intentional eye blinking. Microcontroller uses to communicate with the eye blink sensor (TCRL5000L-LM393) which used to user's eye tracking in real time. Mouse status information from the accelerometer and IR based eye blink sensor are export analog voltages. These voltages are transferred to the digital value of the analog to digital converter (ADC) of the microcontroller.

The head and eye operate the mouse accelerometer sensor (ADXL335) identify the operator head motion and control cursor movement on the computer screen in real time. To find the tilt angle of the head "θ", the analog to digital converter (ADC) gets the analog signal and converts it to digital. This way a computer can recognize the signal in a digital format, then calculate the tilt angle. The angle of tilt X, Y directions are tallied with calibrated midpoints to decide positive or negative tilt angle, then move the mouse up, down, left and right. The combination of this mouse works same as actual mouse. Total power consumption of wearable glass module is a 80.28 mA supply, Battery Life is 4 hours and 20 minutes, In practically it's worked more than 6 hours.

# DISCUSSION

The design and the implementation of this head and eye operated computer interface for a physically disabled person is at the focus of this research. The intention of the project was to build ahead and eye operated hand free mouse for a hand disable person. I had a problem that when a disabled person uses this mouse, monitor should be placed properly, aiming the mid of the screen at the operator's eye level. To overcome from this problem, midpoint should not hard code so include the calibration mode to find the midpoint of the current monitor place. Wearable module also should be adjusted from some person to person, because of their different body measurements.

I had another problem that finds out a method to detect this device as a mouse on the Microsoft Windows operating system, after finding out the Arduino Leonardo board communicates with my system through the use of HID driver. Another problem is that how I can get the required components over the internet with a proper trust for the bulk of money that spend. So then my brother had experiences that how to pay money for buying over the internet with trust of feedback services from the supplier. So I have worked on his guidelines with opening a Web card in the Sampath Bank, ordered and got the project components.

# CONCLUSION

The proposed and implemented system which provides wireless, economical, portable and user friendly new human computer interface system. It overcomes the problems that face by a disabled person in operating a PC. In addition to that this system has the capability of adding different extra features with proper interfacing techniques. Further, this human computer interface can be modified to use for normal people for easy operation in computer games and entertainment. Head and eye operated computer mouse for a disabled person has been developed and validated successfully. Using this mouse, we can control computer with Microsoft operating system by using the tilt angle of the head. In addition to that mouse sensitivity and speed are adequate for convenient use.

Mouse speed can be adjusted in the operating system control panel. This product circuit can be improved to printed circuit board to reduce the size of wearable module. Total power consumption is 83.28 mA and battery life is 4hours. In practically it’s worked more than 6 hours. Appendix A lists the detailed cost during the research and development of the head and eye operated computer interface for a physically disabled person, total cost is Rs.4600.00. We have conducted the usability testing survey to validate the product that has smooth control, proper perfect movements and good sensitivity as normal mouse operation.

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# Appendix A

## ADXL335 Triple Axis Accelerometer

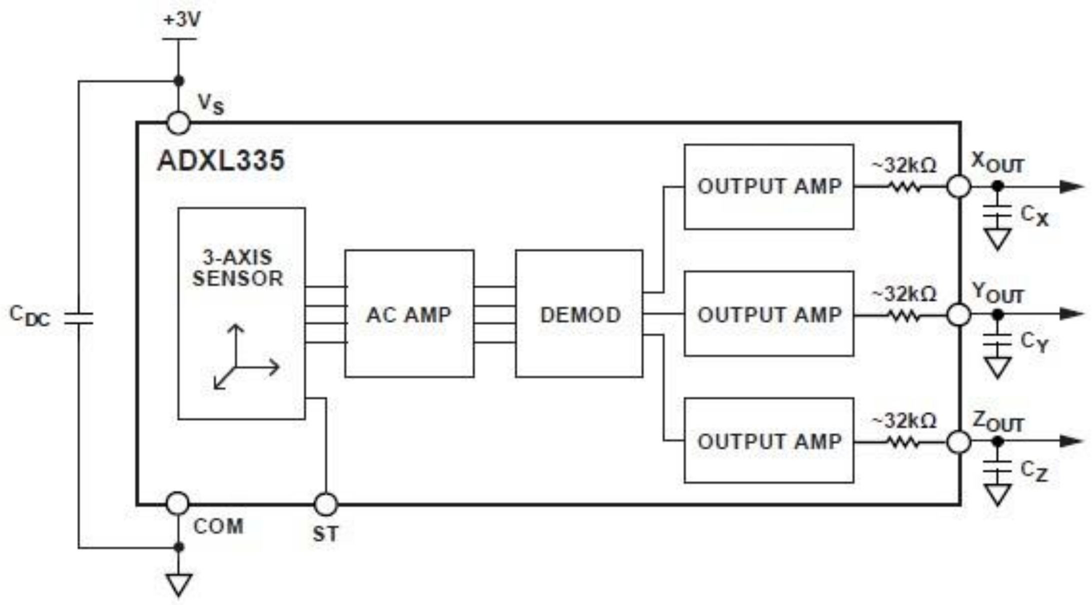



Figure A1: Simple accelerometer block diagram

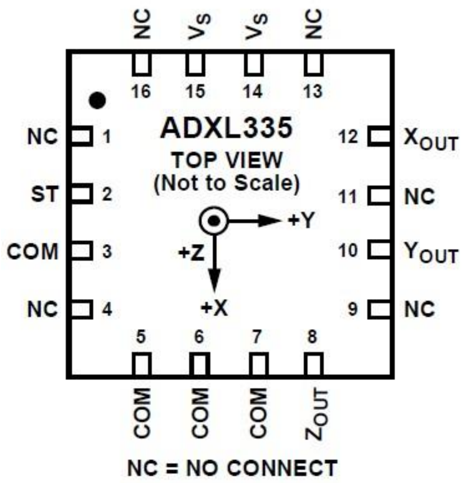



Figure A2: ADXL335 accelerometer Pins Configuration

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | NC | No Connect.[1] |
| 2 | ST | Self-Test. |
| 3 | COM | Common. |
| 4 | NC | No Connect.[1] |
| 5 | COM | Common. |
| 6 | COM | Common. |
| 7 | COM | Common. |
| 8 | $Z_{OUT}$ | Z Channel Output. |
| 9 | NC | No Connect.[1] |
| 10 | $Y_{OUT}$ | Y Channel Output. |
| 11 | NC | No Connect. [1] |
| 12 | $X_{OUT}$ | X Channel Output. |
| 13 | NC | No Connect. [1] |
| 14 | $V_S$ | Supply Voltage (1.8 V to 3.6 V). |
| 15 | $V_S$ | Supply Voltage (1.8 V to 3.6 V). |
| 16 | NC | No Connect. [1] |
| EP | Exposed Pad | Not internally connected. Solder for mechanical integrity. |

Table 1: ADXL335Pin description

## ADXL335 Specification

| Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| SENSOR INPUT | Each axis | | | | |
| Measurement Range | | ±3 | ±3.6 | | *g* |
| Nonlinearity | % of full scale | | ±0.3 | | % |
| Package Alignment Error | | | ±1 | | Degrees |
| Interaxis Alignment Error | | | ±0.1 | | Degrees |
| Cross-Axis Sensitivity[1] | | | ±1 | | % |
| SENSITIVITY (RATIOMETRIC)[2] | Each axis | | | | |
| Sensitivity at $X_{OUT}$, $Y_{OUT}$, $Z_{OUT}$ | $V_S$ = 3 V | 270 | 300 | 330 | mV/*g* |
| Sensitivity Change Due to Temperature[3] | $V_S$ = 3 V | | ±0.01 | | %/°C |
| ZERO *g* BIAS LEVEL (RATIOMETRIC) | | | | | |
| 0 *g* Voltage at $X_{OUT}$, $Y_{OUT}$ | $V_S$ = 3 V | 1.35 | 1.5 | 1.65 | V |
| 0 *g* Voltage at $Z_{OUT}$ | $V_S$ = 3 V | 1.2 | 1.5 | 1.8 | V |
| 0 *g* Offset vs. Temperature | | | ±1 | | m*g*/°C |
| NOISE PERFORMANCE | | | | | |
| Noise Density $X_{OUT}$, $Y_{OUT}$ | | | 150 | | μ*g*/√Hz rms |
| Noise Density $Z_{OUT}$ | | | 300 | | μ*g*/√Hz rms |
| FREQUENCY RESPONSE[4] | | | | | |
| Bandwidth $X_{OUT}$, $Y_{OUT}$[5] | No external filter | | 1600 | | Hz |
| Bandwidth $Z_{OUT}$[5] | No external filter | | 550 | | Hz |
| $R_{FILT}$ Tolerance | | | 32 ± 15% | | kΩ |
| Sensor Resonant Frequency | | | 5.5 | | kHz |
| SELF-TEST[6] | | | | | |
| Logic Input Low | | | +0.6 | | V |
| Logic Input High | | | +2.4 | | V |
| ST Actuation Current | | | +60 | | μA |
| Output Change at $X_{OUT}$ | Self-Test 0 to Self-Test 1 | −150 | −325 | −600 | mV |
| Output Change at $Y_{OUT}$ | Self-Test 0 to Self-Test 1 | +150 | +325 | +600 | mV |
| Output Change at $Z_{OUT}$ | Self-Test 0 to Self-Test 1 | +150 | +550 | +1000 | mV |
| OUTPUT AMPLIFIER | | | | | |
| Output Swing Low | No load | | 0.1 | | V |
| Output Swing High | No load | | 2.8 | | V |
| POWER SUPPLY | | | | | |
| Operating Voltage Range | | 1.8 | | 3.6 | V |
| Supply Current | $V_S$ = 3 V | | 350 | | μA |
| Turn-On Time[7] | No external filter | | 1 | | ms |
| TEMPERATURE | | | | | |
| Operating Temperature Range | | −40 | | +85 | °C |

Table 2: ADXL335 Specification

# Appendix B

## Arduino Nano Pin Layout

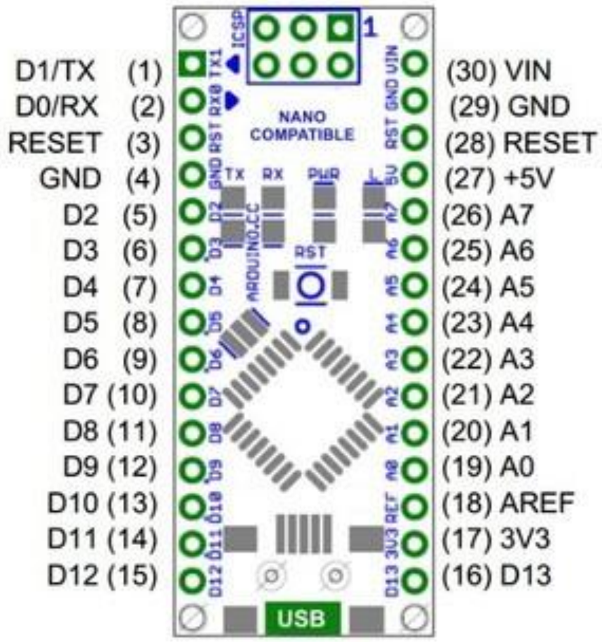



Figure B1: Arduino Nano Pin Layout

| Pin No. | Name | Type | Description |
|---|---|---|---|
| 1-2, 5-16 | D0-D13 | I/O | Digital input/output port 0 to 13 |
| 3, 28 | RESET | Input | Reset (active low) |
| 4, 29 | GND | PWR | Supply ground |
| 17 | 3V3 | Output | +3.3V output (from FTDI) |
| 18 | AREF | Input | ADC reference |
| 19-26 | A7-A0 | Input | Analog input channel 0 to 7 |
| 27 | +5V | Output or Input | +5V output (from on-board regulator) or +5V (input from external power supply) |
| 30 | VIN | PWR | Supply voltage |

Table 3: Arduino Nano Pin configuration

# Appendix C

## Arduino Pro microLayout

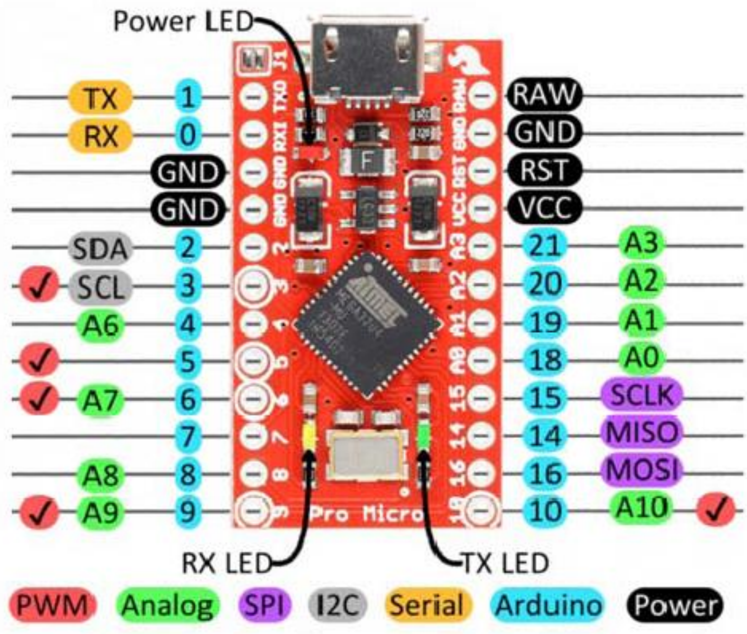



Figure C1: Arduino Pro micro Pin Layout

| | |
|---|---|
| Microcontroller | ATmega32u4 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 20 |
| PWM Channels | 7 |
| Analog Input Channels | 12 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB (ATmega32u4) of which 4 KB used by bootloader |
| SRAM | 2.5 KB (ATmega32u4) |
| EEPROM | 1 KB (ATmega32u4) |
| Clock Speed | 16 MHz |

# Appendix D

### HC-05 Bluetooth Module

Specific:

- Type: HC-05
- V In : DC 5V
- Communication: Serial Communication
- Master/slave mode operation

Pin Description:

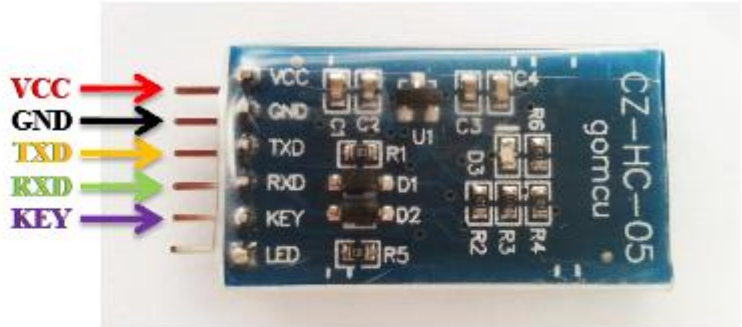



Figure D1: Pins Definition of  HC-05 Bluetooth Module

| Pin | Description | Function |
|---|---|---|
| VCC | +5V | Connect to +5V |
| GND | Ground | Connect to Ground |
| TXD | UART_TXD, Bluetooth serial signal sending PIN | Connect with the MCU's (Microcontroller and etc) RXD PIN. |
| RXD | UART_RXD, Bluetooth serial signal receiving PIN | Connect with the MCU's (Microcontroller and etc) TXD PIN. |
| KEY | Mode switch input | If it is input low level or connect to the air, the module is at paired or communication mode. If it's input high level, the module will enter to AT mode. |

Table 4: HC-05 Bluetooth Module pin description and function

# Appendix E

## TCRT5000L Sensor

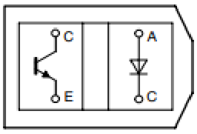
VISHAY

**TCRT5000, TCRT5000L**

Vishay Semiconductors

### Reflective Optical Sensor with Transistor Output

19156_2




Top view 19156_1

**FEATURES**

- Package type: leaded
- Detector type: phototransistor
- Dimensions (L x W x H in mm): 10.2 x 5.8 x 7
- Peak operating distance: 2.5 mm
- Operating range within > 20 % relative collector current: 0.2 mm to 15 mm
- Typical output current under test: $I_C$ = 1 mA
- Daylight blocking filter
- Emitter wavelength: 950 nm
- Lead (Pb)-free soldering released
- Compliant to RoHS directive 2002/95/EC and in accordance to WEEE 2002/96/EC

Pb Pb-free

e2 RoHS COMPLIANT

**DESCRIPTION**

The TCRT5000 and TCRT5000L are reflective sensors which include an infrared emitter and phototransistor in a leaded package which blocks visible light. The package includes two mounting clips. TCRT5000L is the long lead version.

**APPLICATIONS**

- Position sensor for shaft encoder
- Detection of reflective material such as paper, IBM cards, magnetic tapes etc.
- Limit switch for mechanical motions in VCR
- General purpose - wherever the space is limited

| TCRT5000 / TCRT5000L | Infrared Photoelectric Switch |
|---|---|
| Operating Voltage | 5V |
| Sensing Distance | 12mm |
| Operating Wavelength | 950 mm |
| Sensing Method | Reflective |
| Forward Current | 60mA |
| Forward Surge Current | 3A (approximation) |
| Emitter Power Dissipation | 100mW |
| Detector Power Dissipation | 100mW |
| Operating Temperature | -25°C ~ +85°C |
| Dimensions | 30mm x 10mm x 6mm |
| Weight | Approx. 5g |

Table 5 : TCRT5000L Sensor configuration