SIGN LANGUAGE TRANSLATOR GLOVE

An interim capstone report submitted in partial fulfilment of the requirement for the award of the degree of

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ABSTRACT

Human beings interact with each other to convey their ideas, thoughts, and experiences to the people around them. Communication is a basic fundamental human right, however those who are speech disabled and hearing impaired communicate differently. They primarily use sign language while the rest of the world communicates verbally. This puts them at a disadvantage as sign language is not commonly known to general people. This proposed system which is sign language translator glove aims to bridge the gap by overcoming the barriers in communication by removing the need of interpreter and being self-sufficient.

The project proposes a glove with flex sensors that translates the gestures and signs from the hand glove and converts it to text. The finger movements actually cause a change in resistance of the flex sensors when any sign is made. The flex sensors on the glove read the finger movements and change in resistance is converted into voltage and then to 12-bit binary value which is given as an input to the already programmed microcontroller (Arduino/Raspberry Pi). The controller processes the input signal from the glove and matches the input signal to the predefined dataset and displays the corresponding alphabet on a wireless LCD display. Therefore, a word/alphabet can be diaplayed on the LCD which can be easily read by the normal person and this makes their work easily done thus saving theirs as well as others time to understand their signs.

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CHAPTER 1

INTRODUCTION

Conferring to the World Federation of the Deaf and Mute, there are about 72 million deaf, mute, or deaf-mute people in the world at the moment and though many of them can intercommunicate with each other by the means of sign language, there is a dialectal barrier between them and individuals who can speak and write but do not recognise signs. Additionally, most people suffering from hearing disability choose sign language. Occasionally some sounds cannot be distinguished from the lip reading for instance “ice cream” and “I scream”, “hear” and “here”, “bo” and “po”, etc. Furthermore, another example is the word “lie”, this word has more than one connotations and could easily be misunderstood. Therefore, the use of sign language in the life of deaf and/or mute people becomes important.The use of electronics and its associated technologies can serve to improve their daily life.

1.1 EXISTING SOLUTION

Mute people hire people to translate their signs so that they can communicate with others. These translators charge high amount of money to the people and are difficult to find. It is also not possible every time that translator travels with the mute person so it becomes difficult for the disabled person.

Different sign language translator gloves are also available in the market similar to our glove. These are Cyber Glove II by Cyber Glove Systems, 5DT Data Glove 14 Ultra and Enable Talk etc. but they are not complete systems for gesture translation into text and speech which do not support the disabled person completely. These gloves are also very much expensive and cannot be afforded by everyone. The gloves are also not known by many people as they do not have a wide outreach.Therefore the proposed project aims to develop a low cost and easily ineffaceable system between the deaf/mute person and a normal human being. This is explained in the next subsection.

1.2 PROPOSED SYSTEM

A system is proposed in which converts Sign Language to Text and Speech convertor. This makes use of a glove with felx sensors attached on it , the input from these sensors is given to the Microcontroller that compares the received signals with adata base and displays the respective character on the LCD screen.The glove can be used by any deaf and/or mute person to communicate with people that do not understand American sign language. the proposed system has 2 microcontrollers one placed on hand and one is connected to a LCD on which the text can be displayed. This system includes a glove section which takes sensor values from the movement of flex sensors (which are on each finger) to the microcontroller placed on hand. It also has an IMU (Inertial Measurement Unit) which also takes in the effects that occurs due to hand movements as it has an accelerometer and gyro sensor included in it. This is done so that the values input from the signs do not get affected by hand movements.

The microcontroller processes the input values of the flex sensor and IMU and transmits the alphabet that corresponds to the sign made using glove through the Bluetooth Module. Output alphabet transmitted from the glove is received using the output section which uses a Bluetooth Module which is interfaced with Arduino, and the letter is displayed on the wireless LCD.

Then the Text to Speech software will be used to convert the displayed text into speech for the ease of usability.

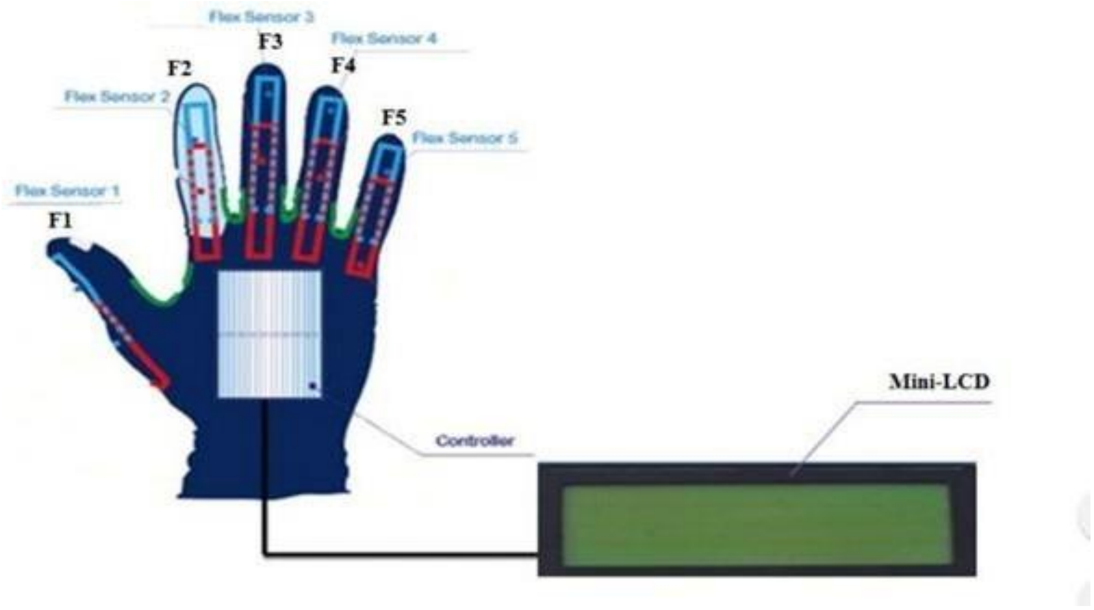


Fig 1.1.1 Proposed System

1.3 BLOCK DIAGRAM OF THE PROPOSED PROJECT

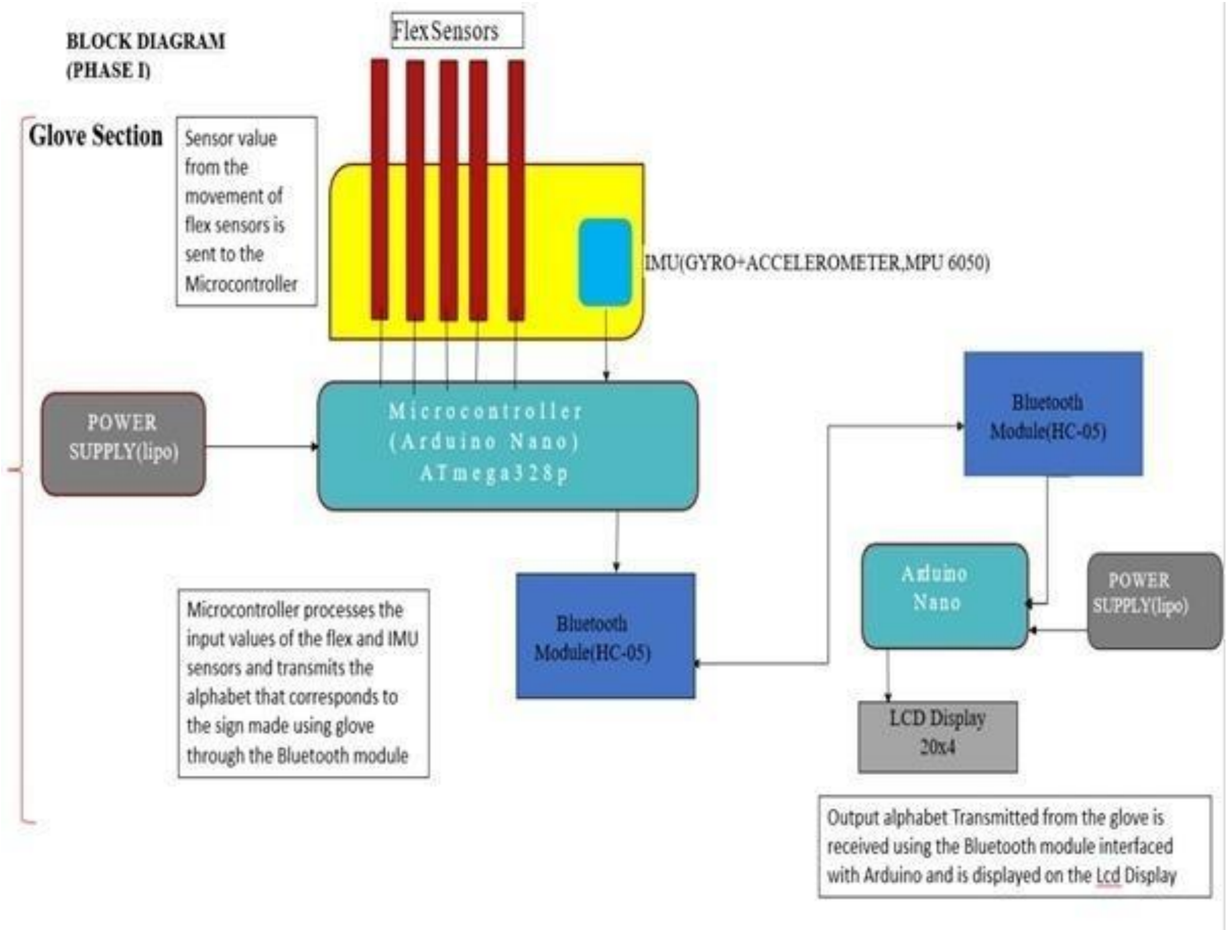


Fig. 1.3.1 Flow of the project (block diagram)

1.4 COMPONENTS

1.4.1 Flex Sensors

A flex sensor or bend sensor is a sensor that measures the amount of deflection or bending. Usually, the sensor is stuck to the surface, and resistance of sensor element is varied by bending the surface. Since the resistance is directly proportional to the amount of bend it is used as goniometer, and often called flexible potentiometer. Flex sensor is used in wide areas of research from computer interfaces, rehabilitation, security systems and even music interfaces.[4] It is also famous among students and Hobbyists.

Fig 1.2.1.1 Flex Sensor 4.5”

1.4.2 LCD Display

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays, as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of very small pixels, while other displays have larger elements. LCDs are used in wide range of applications, including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable devices such as digital cameras, watches, calculators,and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks.

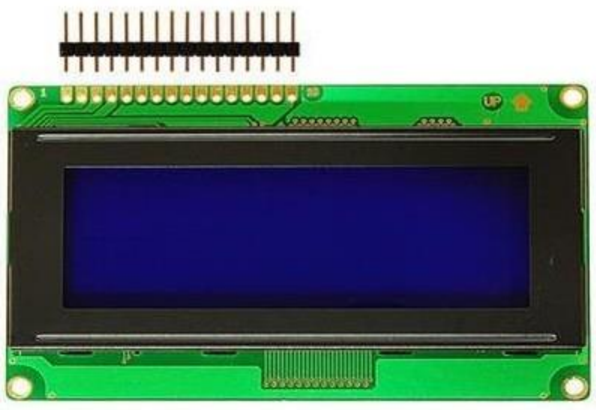


Fig 1.2.5.1 LCD Display

1.4.3 Resistors

A resistor is a passive two-terminal electrical component that implements electrical resistance as circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistor that can dissipate many watts of electrical power as heat, may be used as part of motor controls, in power distribution systems, or as test load for generators. Fixed resistors have resistance that only change slightly with temperature, time or operating voltage.

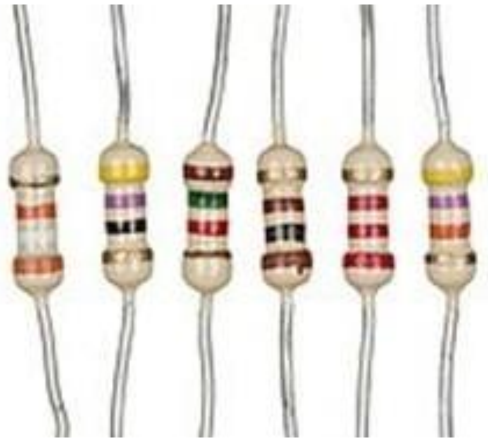


Fig 1.2.6.1 Resistors

1.4.4 Printed Circuit Board

A printed circuit board (PCB) supports and electrically connects electronic components or electrical components using tracks, which are conductive pads and other features done on from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrates. Components are generally soldered onto the PCB to both electrically connect and fasten them mechanically to it. Printed circuit boards are used in all the simplest electronic products. They are also used in electrical products, such as passive switch boxes.

Fig 1.2.7.1 PCB

1.5 PROJECT SCOPE

The solution aims to provide aid to those in need thus ensuring social relevance for the hearing and speaking impaired people in whole world. The people can easily communicate with each other. The user friendly nature of the system ensures that people can use it without any difficulty or complexity. The glove is placed on the hand of the deaf person; the design will fulfill the following requirements:

- The system provides accurate data collection and data output and the system is also portable.
- The system is easy to install and can be used by anyone easily.
- The system is safe to use & does not cause any harm to the user and it is durable enough too.

CHAPTER 2

LITERATURE SURVEY

2.1 BASIC IDEA

The system architecture comprises of two primary sections: Transmitter and Receiver section. The transmitter section is responsible for recognizing the hand gestures of a person. This is done by wearing the gloves which are fitted with flex sensors each of 4.5” on the 5 fingers of the glove. The output of flex sensors is in the form of variation in resistance in accordance to the bend of fingers. Also along with this an accelerometer is mounted on the palm side of the glove to sense the tilts of the hand. The outputs of the flex sensors and the accelerometer are directly given to the ADC channels of the microcontroller. The ADC output of each channel is processed and a specified value is assigned to each gesture. To each specified value of the gesture, a digital value is fed to the encoder which converts the parallel data to serial and transmits it through the Bluetooth transmitter. Once the serial data is received at the Bluetooth receiver this data is converted to parallel form by the decoder and given to the microcontroller. In accordance with the digital value received the microcontroller the text is displayed on the LCD at the receiver end.

2.2 HISTORY AND EVALUATION

Hand gestures, facial expressions and body language together form the sign language, but most of the measureable data about a particular sign is revealed due to the movement of the hand and thus now a days the research involves the study of hand gestures and its detection. the research work On static hand gestures, has been going on but it is still a challenging task because sometimes two hand gesture can represent the same meaning i.e. there is an issue of accuracy. For example, ‘U’, ‘V’ and ‘V’ have the almost similar hand gesture.

Thus, in this literature survey, the related work of the authors and their research papers which contain information of their system design in context to the proposed system was analyzed.

These include the existing understanding, essential findings, as well as theoretical and procedural contributions of each of the authors pertaining to Gesture Detection. Thus, these elaborate the approaches which were used in them along with all their results as well as their downsides, which are focused on each paper.

Priyanka Lokhande et.al. [12] presented a system that consists of 5 Flex sensors and accelerometer to distinguish the hand and palm activities at the input. The accelerometer senses the movement of palm which picks the language of the communication creating the First bit of binary number to be associated in the lookup table. The flex sensor has a Resistive strip which can be bent. The resistance fluctuates as the flex strip is bent to indicate either logical One or logical Zero by giving the inconstant analogue resistive Input to inbuilt ADC of ARM7 microcontroller. In this way, 6 bit binary number was made for each gesticulation. In all circumstances only 32 such signs were conceivable due to 5 flex sensors. These numbers were stored in the external memory of ARM7. The microcontroller then relates these readings to the look up table kept in the internal program memory. The reading which is neighbouring to the lookup table ARM7 was then selected for that expression. After this the ARM7searched the external memory for the audio file for equivalent binary number i.e. the gesture.

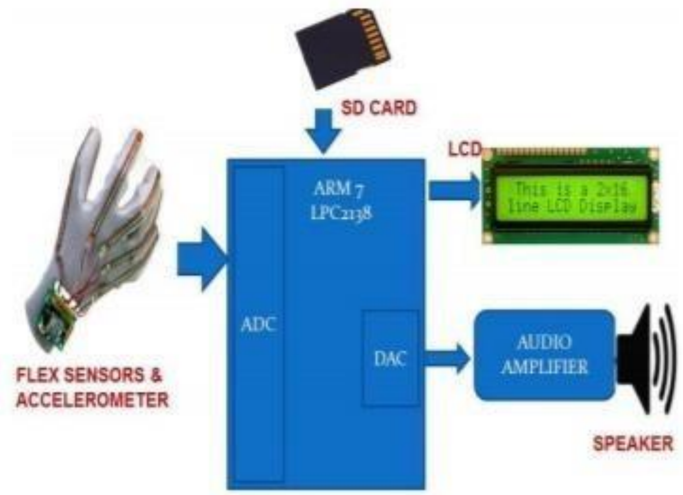


Fig. 2.2.1 Proposed System (Fig. 3 [12])

Yasmeen Raushan et. al. [10] realized a glove that captured the hand gestures of the user. These gloves had flex sensors along the length of each fingers and the thumbs. The flex sensors output had a stream of data that varied with the bend of Flex sensors. The analogue outputs from the sensors were then fed to the microcontroller. It processed the signals and performed ADC i.e. analogue to digital conversion. The gesture was identified and the matching text data was recognized. In this system, the user needed to know the signs of specific alphabets and he needed to stay with the sign for 2 seconds. There were no disadvantages for signs, it was hard to build a standard library of signs. These sensors are attached along the length of fingers and thumb. The extent of bend of fingers and thumb results in the voltage variation, which while translating to analogue form produces desired voice. A set of two gloves along with sensors enables deaf and dumb people to interact with the public in the essential language.

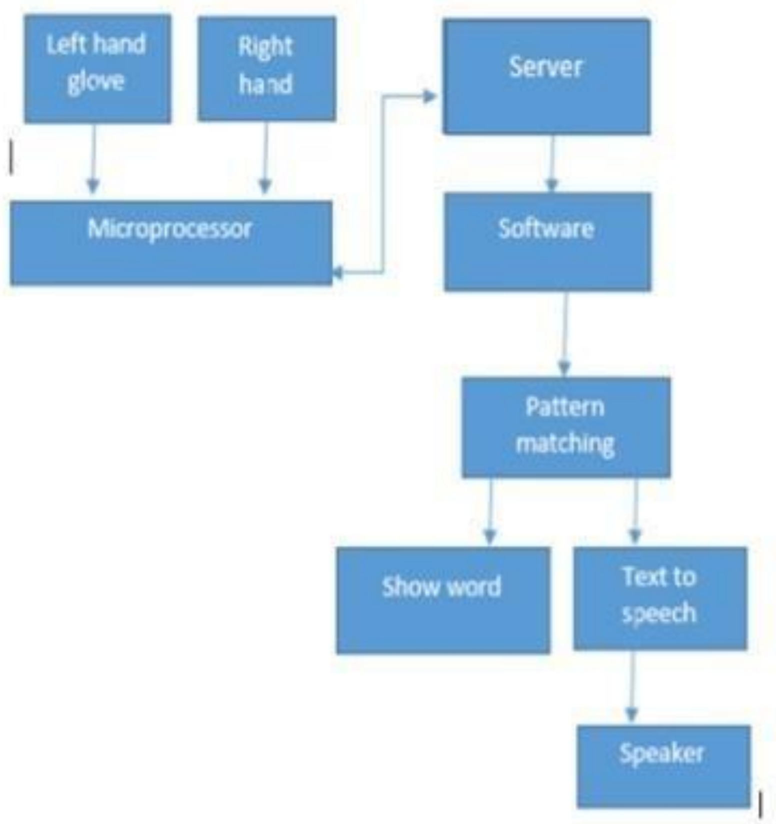


Fig. 2.2.2 Block Diagram (Fig. 7 [10])

JanFizza Bukhari et. al.[11] presented a research article where Flex sensors of 2.2 inches were used for calculating the degree of bend of flex sensors. By noticing the resistance of sensor, measurement of bent was performed. The sensor was used with one more resistance to form a voltage divider, which splits VIN by a ratio that is determined by the 2 resistances. The value of resistance used fluctuates for every single sensor. To identify a contact, a more simple logic of utilizing conductive plates linked to the input voltage through pull-up resistors was used. Whenever any of the conductive plate is linked to zero

Volt or ground was touched to positive plate, a connection was sensed. Hence, whenever one finger was in interaction with the other, value of contact sensor (which was originally 1 due to pull-ups) for that specific finger became 0. To sense and calculate the acceleration of hand ADXL 345 was used in I2C mode. Specifically, ADXL 345 was used to identify the letter Z and to distinguish between character set I and J. By placing all these sensors on a glove at suitable locations, a data glove as an input device to our main controller was made.

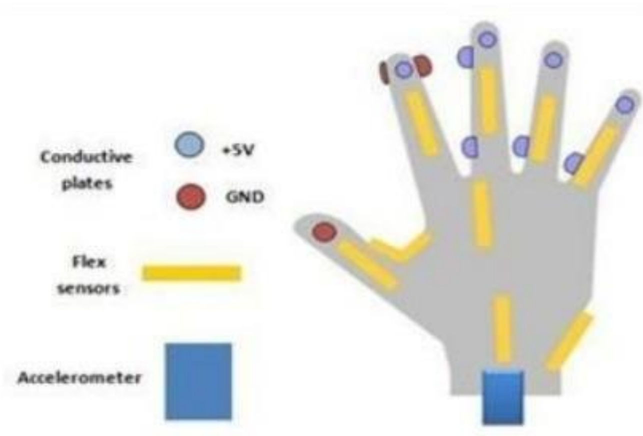


Fig. 2.2.3 Location of Sensors (Fig. 1 [11])

M. Borghetti et al [6] showed a scheme that depicts the fingers' positions of one hand in order to observe the rehabilitation actions of the hand. This device included a glove that had a flex sensory device on the limbs linked to an electronic unit. However, to perform the bending tests of the limbs, only 1 flex resistor was calculated at a time that there are 10 flex sensory device, two on each and every limb of the glove leading to an extended operating time that led to a low power consumption as a requirement. The system needed a massive hardware, in addition to the instrumented glove holding the ten sensors and the circuit unit that contained the microcontroller, the battery, the communicating antenna, the connectors, the transceiver, a CPU, a receiver circuit, a DAQ card, and an optical arrangement were needed to perform the experimentation. Arabic sign language recognition technique using glove and provide vector machines is shown in [7]. This system still necessitates a CPU to evaluate the limbs' positions and to show the Script. A noteworthy paper presented a new system proposed to allow speechless people to converse with the realm using an electronic glove and a LCD Screen [8]. It displayed a system that allows symbols input matrix system, detonating a faster letter keying built on photodiodes and photo-detectors in addition to the study of the space between links. A predetermined chip is used for following digital signal processing; the meaningful data will show up on a screen for new responses. The logic of the system lies on the bend position of the limb; it used the intensity of the LEDs that is analysed in order to display the “alphabet required "the voltage can be used to represent the amount of “finger bending". The detected light was added to digitized into 8-bit signals via using the 0-255 grey scale. The letters were selected from a virtual keyboard and the thumb is used to approve the letter. This implied the need of a large LCD screen that displayed a full keyboard and a typescript input row. The tests were made on photo-detectors of 4.5 and 6 cm of diameter. This meant that this scheme needed a large amount of photo detectors which might not be practical in real environment. Additionally the system had to re-programmed (the software has to be altered) for each case in order to meet the user necessities. Other techniques used for the recognition and translation of the letters particularly in the Arabic sign linguistic were established using five stages; Pre-processing phase, Best frame Detection phase, Category Detection phase, Feature Extraction phase, and finally Classification phase. This technique used the images of bare hands that could convert the movement to Arabic Alphabets using minimum distance classifier (MDC) and multilayer perception (MLP) neural networks [9]. This system required an enormous software program, preparation, and a computer including a camera with high resolution.

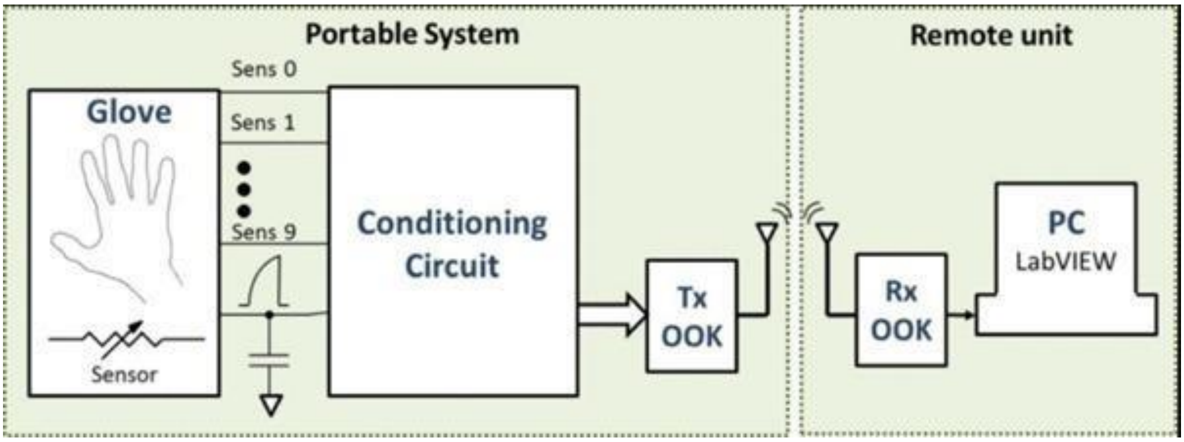


Fig. 2.2.4 Block diagram of the proposed system (Fig. 1 [6])

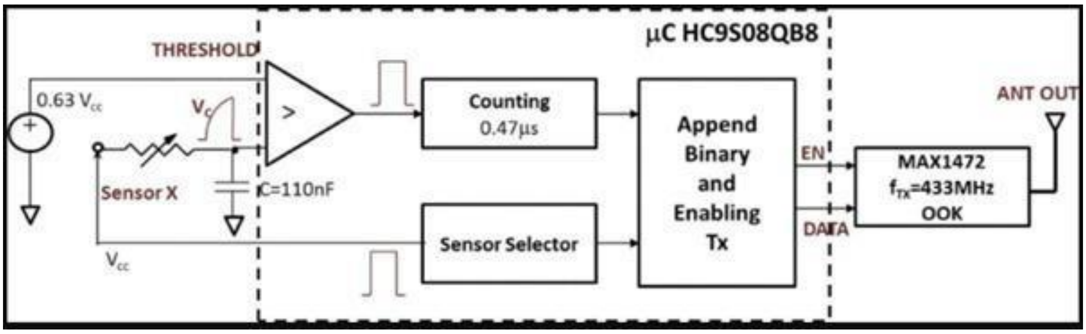


Fig. 2.2.5 Block diagram of the conditioning and transmitting electronics (Fig. 2 [6])

Shahrukh Javed [13] realised a sensor established system envisioned for using four 4.5 inch and two 2.2 inch flex sensory device on the glove which were used to determine the extent to which the limbs are bent. These were sensed in terms of resistance bend values which is maximum for lowermost bend radius. The flex sensory device on glove included a potential separator (divider) network which was used to line the output voltage across 2 resistors connected. The outer resistor and flex sensors formed a potential separator (divider) that separated the input voltage by a measureable relation calculated by the modifiable and attached resistors. For precise gestures the current will modify, as a result of the varying resistance of the flex sensor which is utilized as analogue information. One terminal of flex sensor was linked to the 3.3Volts and another terminal to the ground to close the circuit. A Inertial Measurement Unit (IMU) is important for accelerometer and gyroscope to read values which is positioned on the top of the hand to determine hand location. The co-related 3D coordinates were collected by the inertial measurement unit as input data [14]. The impedance values from flex sensors and IMU coordinates for distinct gesture were recorded to enumerate the database. The database contains values allotted for different finger actions. When the data is fed from both flex sensors and IMU to Arduino Nano it was computed and compared with the predefined dataset to spot the specific gesture and transmitted wirelessly to the central processor i.e. raspberry pi by means of Bluetooth module. Raspberry Pi 3 is programed to demonstrate text output on GLCD. Graphic LCD is interfaced with the Raspberry pi3 using 20-bit universal serial bus in order to evade bread board link between processor and the display, and a 10 K ohm trim potentiometer is used to regulate the intensity of display unit. Additionally to provide an auditory speech, pre-embedded local language voice is allotted

for each circumstances as similar to the text database which is mapped with the impedance values. Two speakers are used with single jack of 3.5mm for association and a

USB to power-up the speakers [15]. When text is displayed, the processor will hunt for the voice signal which will be spread through speakers. Figure 2.2.6 shows the block diagram of the implemented system[16]

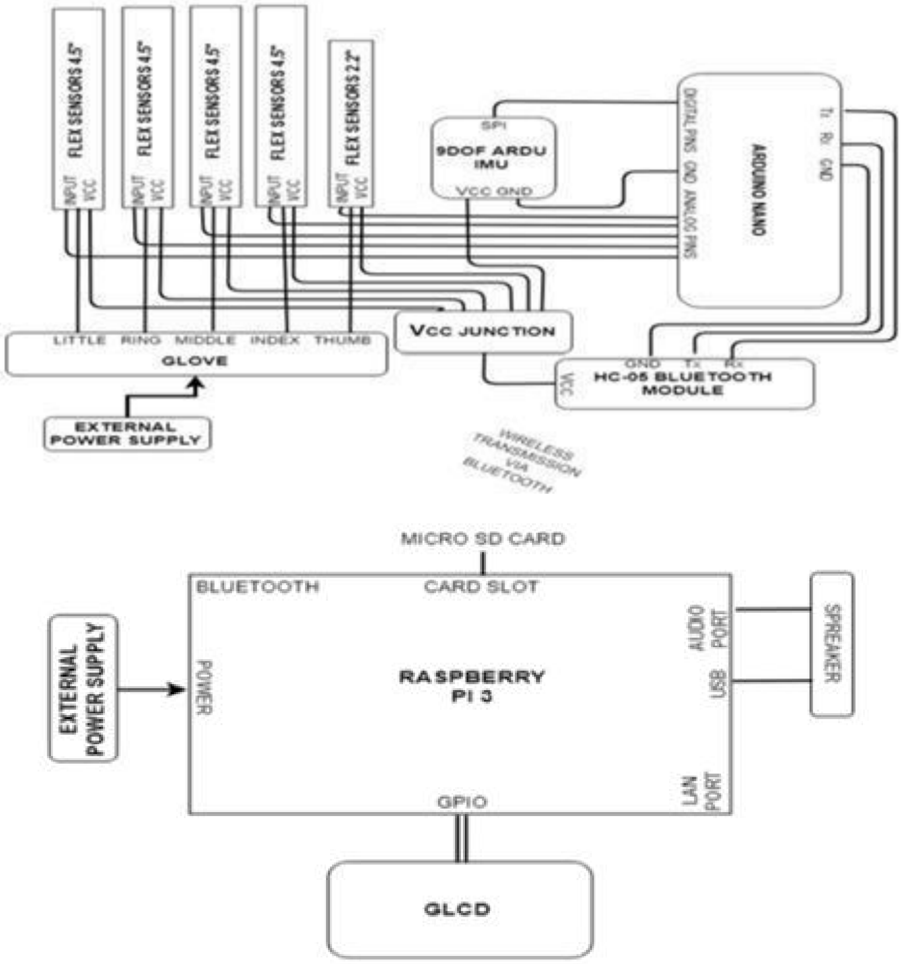


Fig. 2.2.6 System Block Diagram (Fig. 1 [13])

Hanine El Hayek and Jessica Nacouzi [16] system is mostly made of the flex sensory device, a 9V power supply, and an electronic hardware circuit. The inputs are the symbols from the flex sensors that are linked to the electronic hardware circuit and the power supply. The mentioned hardware circuit contains a microcontroller, discrete components, and a LCD Screen. The flex sensory device are important elements that play the role of receiving the symbols which are the inputs from the user while detecting the modification in the amount of bend applied on the flex [17, 18]. They translate the alteration in bend to electrical resistance - the more the bend, the additional is the resistance value. They are used in a voltage divider circuit to supply the information (analogue signal) to the microcontroller after digitized into ten bits of accuracy to get processed. The ranges taken were roughly close for the different fingers and same location. The different varieties were entitled as follows: OPEN, MID1, MID2 and CLOSE. Looking inside the Sign to Letter Converter hardware system, the microcontroller is the central unit. It is activated with a clock of 4MHz to deliver enough data to its associated components and in the meantime to obtain accurate data. It has many distinct eatures from which are a Central Processing Unit and a 10-bit, 8-channel A/D Converter. In addition to the microcontroller, the PCB contains discrete components, an oscillator, and a voltage regulator that alters the 9 Volts supplied by the battery to 5 Volts required to work the microcontroller circuit.

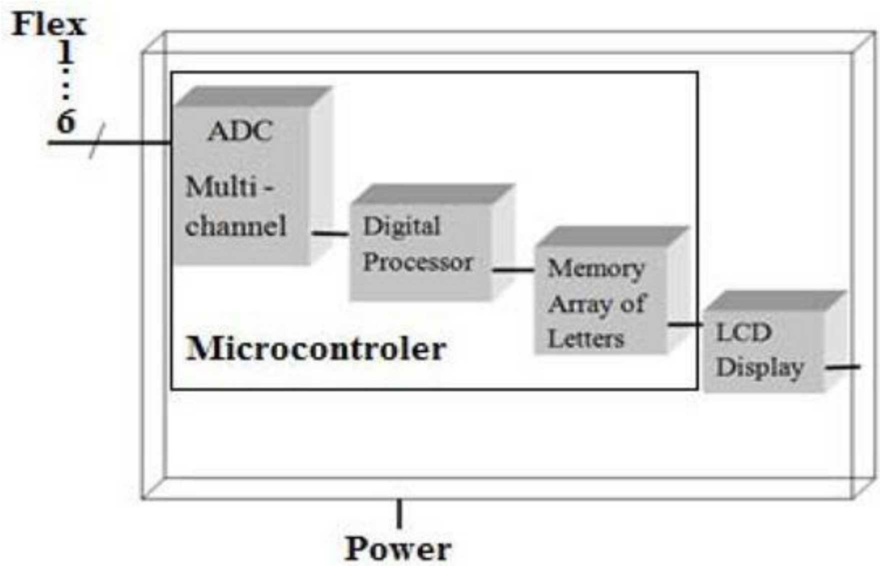


Fig. 2.2.7 Block diagram of the proposed S2L (Fig. 2 [16])

K Abhijith Bhaskaran [19] presented his research that concentrated on exploiting flex sensory device to track the orientation of limbs and IMU (Inertial Measurement Unit) to track the movement (motion) of hand in 3-D space. Hand-talk Gloves planned by Ambika Gujrati et.al, familiarizes the idea of using flex sensors (variable resistance) embedded on a glove to track the positioning of fingers. Flex sensors are resistance varying devices, whose resistance depends on its radius of curvature. The output of the sensory device can be digitalized and processed by a microcontroller to convert it into the speech corresponding to the gesture of the hand [20].

To track the movement of hand in 3-D space an Inertial Measurement Unit (IMU)was used. Attaching an IMU on the human finger allows us to track its movement in any direction. The location could be found by two times integrating the acceleration values attained from the accelerometer [21]. However, they add noise and induce drift errors. Due to the drift, positional values move away within the small intervals of time. Hence, it had to be compensated and precision of positional values had to be upgraded. Another method to track the movement of hand, using the IMU, is to find the angular coordinates (pitch, roll and yaw). Pitch and roll could be determined using the accelerometer data and was vulnerable to noise. Pitch and roll could also be calculated by integrating the gyroscope values. To decrease the error induced due to integration and to complement each other's weaknesses, an appropriate sensor fusion algorithm could be used. Kalman Filter could be designed to acquire stable values of pitch and roll by combining the accelerometer and gyroscope data. A magnetometer could be used to find the yaw (or heading). When a magnetometer was tilted it presented errors in the reading. A tilt compensation technique could be realized to avoid the errors in heading due to the tilt [22].

The union of sensor and gyroscope data could be attained by using filters Pitch and roll could be found out from accelerometer data using inverse trigonometric functions. To remove the effect of external noise in accelerometer readings, the values were passed through a low pass filter. To reject the drift error in integration of gyroscope readings, the integrated values were passed through a high pass filter. A steady output can be found by combining the output of both low pass and high pass filters [23].

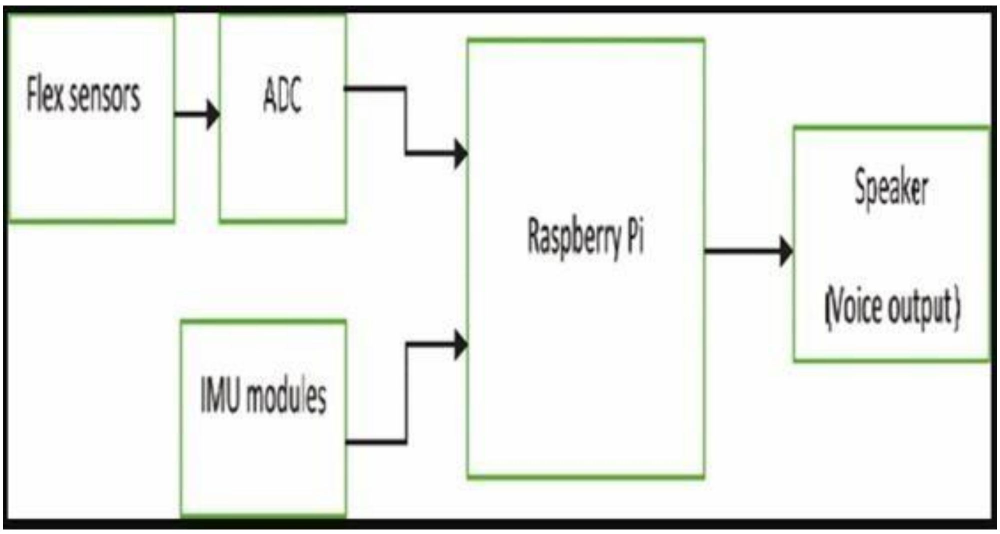


Fig 2.2.8. Hardware block diagram (Fig.1 [19])

Kunal Purohit [24] system 2 hand gloves is employed to capture the hand gestures of a operator. The data glove is built-in with flex sensors along the length of each limb. The flex sensory device output a stream of data that differs with amount of bend. The analogue outputs from the sensory devices are then fed to microcontroller. It processes the signals and perform analogue to digital signal translation. The gesture is identified and the equivalent text information is recognized. The operator need to know the signs of specific alphabets and he need to keep the position of fingers depicting a sign for 2 seconds. There are no restrictions for signs it is hard to build a standard library of signs. The new sign presented should be supported by the software used in the system. These sensory device are attached along the fingers. The amount of bending of 5 fingers produceed the output voltage variation which in turn on converting to analogue form produced essential voice. A duo of gloves along with sensors allowed mute people or old people to communicate with the people in the required sentence which was very much helpful for them. Flex sensor and microcontroller are mounted on the gloves. These flex sensors are linked with micro controller via jumping cables and data send to android phone via a Bluetooth module.

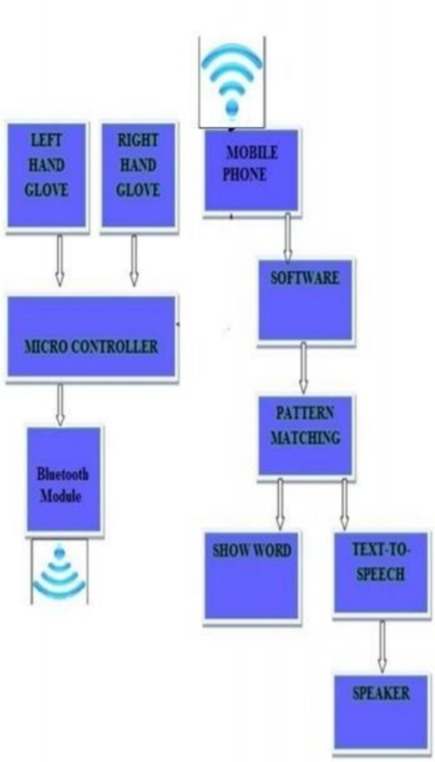


Fig. 2.2.9 System Architecture (Fig. 1 [24]

CHAPTER 3

THE PROJECT DESIGN AND IMPLEMENTATION

3.1 DESIGN IDEOLOGY

In this project we are designing a sign language translator which converts sign language into text as well as speech. The system uses gloves mounted with flex sensors which will detect the bend and corresponding alphabet will be printed on the screen of the LCD. The user can then show this to the people around so that they can see what he/she wants to say and they will be easily able to understand.

3.1.1 Circuit Diagram

Flex is connected to the Arduino Nano V_{cc} (Supply) and Ground for powering the flex. The user uses 5 fingers therefore, use of 5 flex sensors. 2 Bluetooth modules HC-05 are used which work in Master and Slave configuration respectively. Since the data is transmitted serially into slave HC-05, connected to LCD display 20X4 where the output or alphabets are displayed conveying the message sent by the user. The baud rate of each HC-05 in these respective modes is set at 38400. LCD displays the output received by 2^{nd} HC-05 serially, showing the data transmission is sent wirelessly and efficiently.

The flex sensors are designed to change their electrical resistance when they're bent or stretched, so when a finger is straight, the device registers a 0 input, while a bent finger sends a signal of 1. The system combines these signals from all 5 sensors to generate a 5-digit code, which corresponds with particular letter. For example, in sign language the letter A is made by keeping the thumb straight while bending all fingers, so the code is 01111. To differentiate between similar gestures, the glove is also equipped with an accelerometer. These values generated by the flex sensors are sent to Arduino using Bluetooth module HC-05.

The MPU6050 are being used as motion tracking devices for low power, low cost and high performance for wearable sensors. It's a combination of 3-axis gyroscope and 3-axis Accelerometer embedded on Digital Motion Processor which processes complex 6-axis motion fusion algorithms. The device can access external magnetometers or other sensors through an auxiliary master i^2c bus, allowing the devices to gather a full set of sensor data without intervention from system processor. The devices are offered in a 4mm x 4 mm x 0.9 mm QFN package.

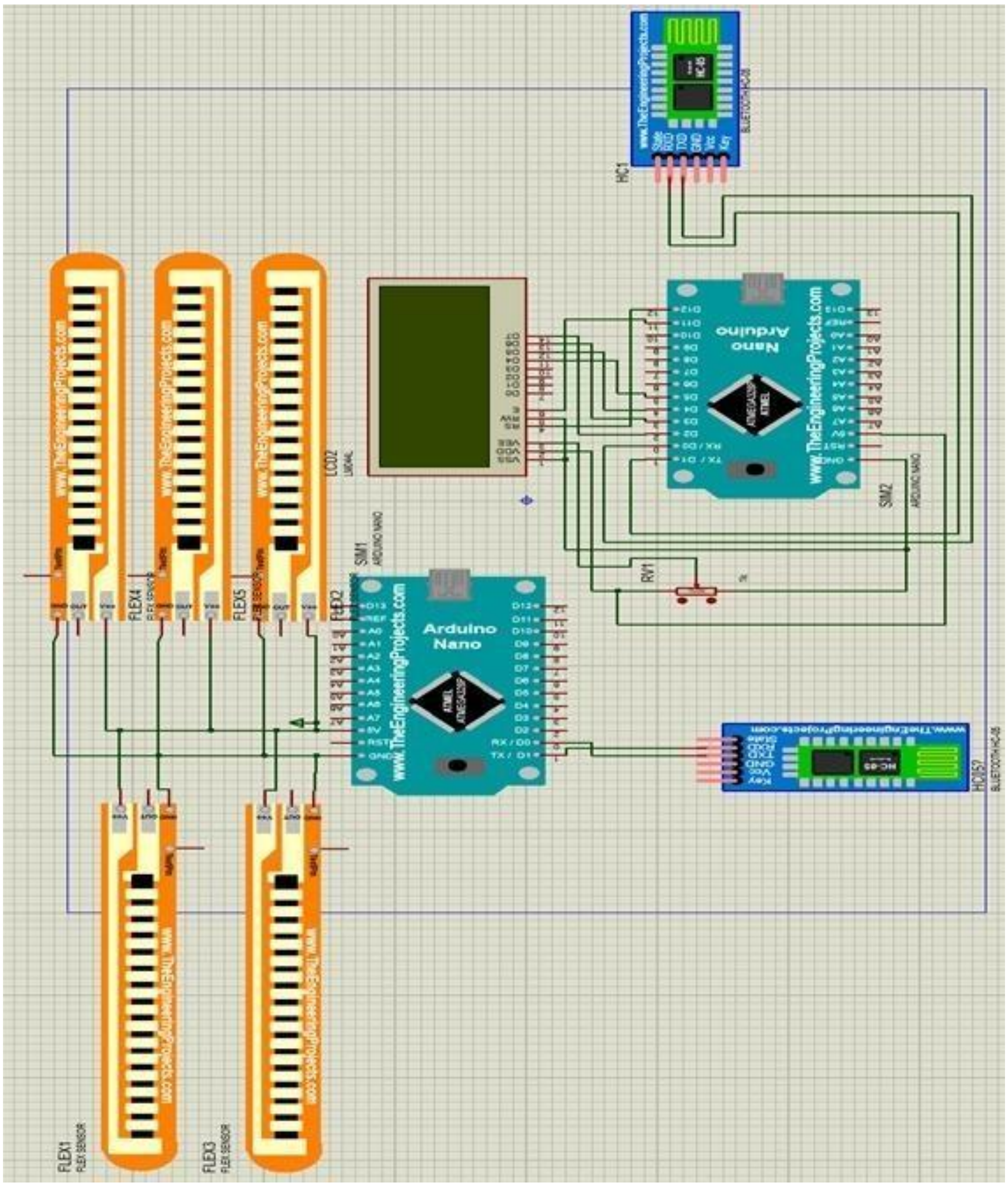


Fig 3.1.1.1 Schematic Diagram of Hand Sign Translator (PHASE-I)

Fig 3.1.1.2 Block diagram of MPU 6050

3.2 FLOW CHART

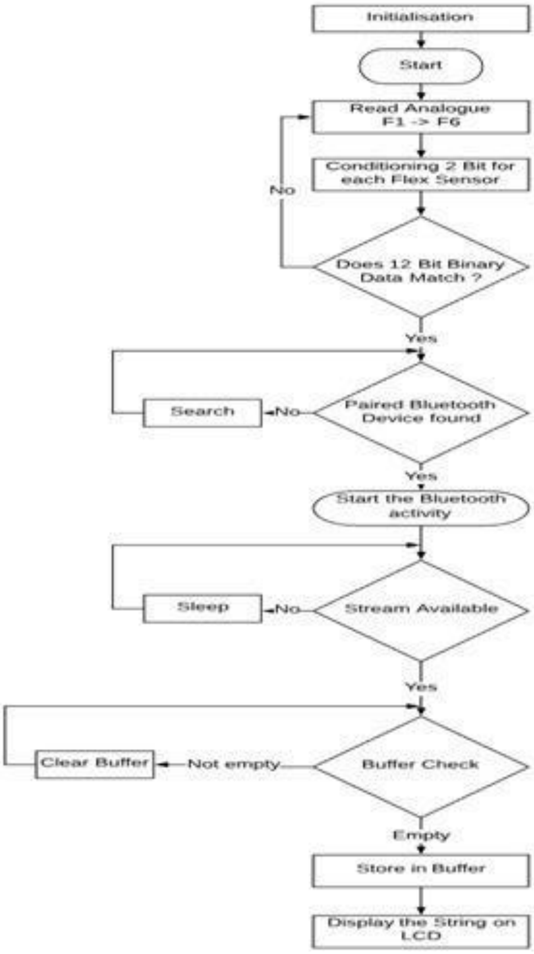


Fig. 3.2.1 Flowchart of the Project

The flowchart presented in figure shows the steps in the program. In the initialization stage, the code tables were well-defined. The program starts by understanding the analogue inputs of origin the flex sensors (F1 -> F6) and storing two bit positions for every one flex value at specific position.

The code is made by concatenating the binary symbols of each and every flex sensors (F1 till F2). Next, the code undertakes some if conditions then it calls a function in order to reach the final output, which is the adequate letter. After this few last steps will be repeated through a loop to get the new data. The user wearing the glove can use sign language merely by moving the suitable fingers of their hand. Since each flex sensor has a variety of resistances, each sensor was tested individually and its voltage values were taken for the 26 Alphabets. While testing, the values are altered, so the problem was resolved by taking different ranges for every flex position.

Then the character i.e. the alphabet which is determined by the code in the microprocessor (Arduino Nano) is sent to the LCD via two Bluetooth Module operating in Master Slave Configuration. The Slave Bluetooth Module is searched by the Master Bluetooth for pairing between the two to occur. When the Slave Bluetooth module is found the Bluetooth Activity begins. Then the Slave Bluetooth Module checks whether the stream is available or not. When the data is sent by the Master Bluetooth Module, the other Bluetooth Module (Slave) checks whether its buffer is empty or not. Whenever it is empty the data Transfer between the two occurs. The Data in the Slave Bluetooth Module is stored in the Microcontroller (Arduino) and then it is given to the LCD which then displays the Alphabet.

3.3 HARDWARE COMPONENTS

3.3.1 Arduino Nano

The Arduino Nano [26] is a small, complete, and breadboard-friendly board based on the ATmega328P (Arduino Nano 3.x). It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. There are totally 14 digital Pins and 8 Analogue pins on your Nano board. The digital pins can be used to interface sensors by using them as input pins or drive loads by using them as output pins. A simple function like pin Mode () and digital Write () can be used to control their operation. The operating voltage is 0V and 5V for digital pins. The analogue pins can measure analogue voltage from 0V to 5V using any of the 8 Analogue pins using a simple function liken analog Read()

These pins apart from serving their purpose can also be used for special purposes which are discussed below:

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.
- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off.
- **I2C A4 (SDA) and A5 (SCA):** Used for IIC communication using Wire library.
- **AREF:** Used to provide reference voltage for analog inputs with analogReference() function.

Fig. 3.3.1.1 Arduino Nano

3.3.2 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode. Revision 3 of the board has the following new features:

- Pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.

- Stronger RESET circuit.
- ATMega 16U2 replace the 8U2.

Fig. 3.3.2.1 Arduino Uno

3.3.3 Bluetooth Module HC - 05

The HC-05 modems work as serial (RX/TX) pipe. Any serial stream from 9600 to 115200bps can be passed seamlessly from your computer to your computer to your target. The remote unit can be powered from 3.3V up to 6V for easy battery attachment. All signal pins on the remote unit are 3V-6V tolerant. No level shifting is required. Do not attach this device directly to a serial port. You will RS232 to TTL converter circuit or Arduino XBee USB Adapter if you need to attach this to a computer. You can either solder a 6-pin header or individual wires. Unit comes without a connector.

3.3.3.1 Usage

- Coupled Mode: Two modules will establish communication automatically when powered. PC hosted mode: Pair the module with Bluetooth dongle directly as virtual serial.

- Bluetooth protocol: Bluetooth specification v2.0+EDR Frequency: 2.4GHz ISM band Modulation: GFSK (Gaussian Frequency Shift Keying) Emission power: <=4dBm, Class 2 Sensitivity: <=-84dBm at 0.1% Authentication and encryption Profiles: Bluetooth serial port.
- CSR chip: Bluetooth v2.0 Wave band: 2.4GHz-2.8GHz, ISM Band Protocol: Bluetooth v2.0 Power Class: Paring – 35mA, Connected – 8mA Temperature: -40 ~ +150 Degrees Celsius User defined Baud rate: 4800, 9600, 19200, 38400, 57600, 115200, 230400, 460800, 921600, 1382400.

Fig 3.3.3.1.1 Bluetooth Module HC - 05

3.3.4 IMU (Inertial Measurement Unit)

An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surroundings the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. IMUs are typically used to maneuver aircraft, including unmanned aerial vehicles (UAVs), among many others, and spacecraft, including satellites and landers. Recent developments allow for the production of IMU-enabled GPS devices. An IMU allows a GPS receiver to work when GPS- signals are unavailable, such as in tunnels, inside buildings, or when electronic interference is present. A wireless IMU is known as a WIMU.

Fig 3.3.4.1 IMU Unit

3.4 SOFTWARE COMPONENTS

3.4.1 Arduino IDE:

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards.

The source code for the IDE is released under the GNU General Public License, version 2.[3] The Arduino IDE supports the languages C and C++ using special rules of code structuring.[4] The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution.[5] The Arduino IDE employs the program *avrdude* to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP).

Fig 3.4.1.1 Arduino Integrated Development Platform

3.4.2 Proteus Professional Suite 8

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards.

The Proteus Design Suite is a Windows application for schematic capture, simulation, and PCB (Printed Circuit Board) layout design. It can be purchased in many configurations, depending on the size of designs being produced and the requirements for microcontroller simulation. All PCB Design products include an auto-router and basic mixed mode SPICE simulation capabilities.

Fig. 3.4.2.1 Proteus Professional design suite 8.7

3.4.2.1 Schematic Capture

Schematic capture in the Proteus Design Suite is used for both the simulation of designs and as the design phase of a PCB layout project. It is therefore a core component and is included with all product configurations.

Microcontroller Simulation

The micro-controller simulation in Proteus works by applying either a hex file or a debug file to the microcontroller part on the schematic. It is then co-simulated along with any analog and digital electronics connected to it. This enables its use in a broad spectrum of project prototyping in areas such as motor control, temperature control and user interface design. It also finds use in the general hobbyist community and, since no hardware is required, is convenient to use as a training or teaching tool. Support is available for co-simulation of:

- Microchip Technologies PIC10, PIC12, PIC16, PIC18, PIC24, dsPIC33 Microcontrollers.
- Atmel AVR (and Arduino), 8051 and ARM Cortex-M3 Microcontrollers
- NXP 8051, ARM7, ARM Cortex-M0 and ARM Cortex-M3 Microcontrollers.
- Texas Instruments MSP430, PICCOLO DSP and ARM Cortex-M3 Microcontrollers.
- Parallax Basic Stamp, Freescale HC11, 8086 Microcontrollers.

3.4.2.2 PCB Design

The PCB Layout module is automatically given connectivity information in the form of a netlist from the schematic capture module. It applies this information, together with the user specified design rules and various design automation tools, to assist with error free board design. PCB's of up to 16 copper layers can be produced with design size limited by product configuration.

3.4.2.3 3D Verification

The 3D Viewer module allows the board under development to be viewed in 3D together with a semi-transparent height plane that represents the boards enclosure. STEP output can then be used to transfer to mechanical CAD software such as Solidworks or Autodesk for accurate mounting and positioning of the board.

3.5 FINAL WORKING MODEL

Our prototype is able to display the alphabets from the English language from the American Sign Language (ASL) rules. Also, it can display words using the alphabets which will initiate better communication.

Here is the final prototype: -

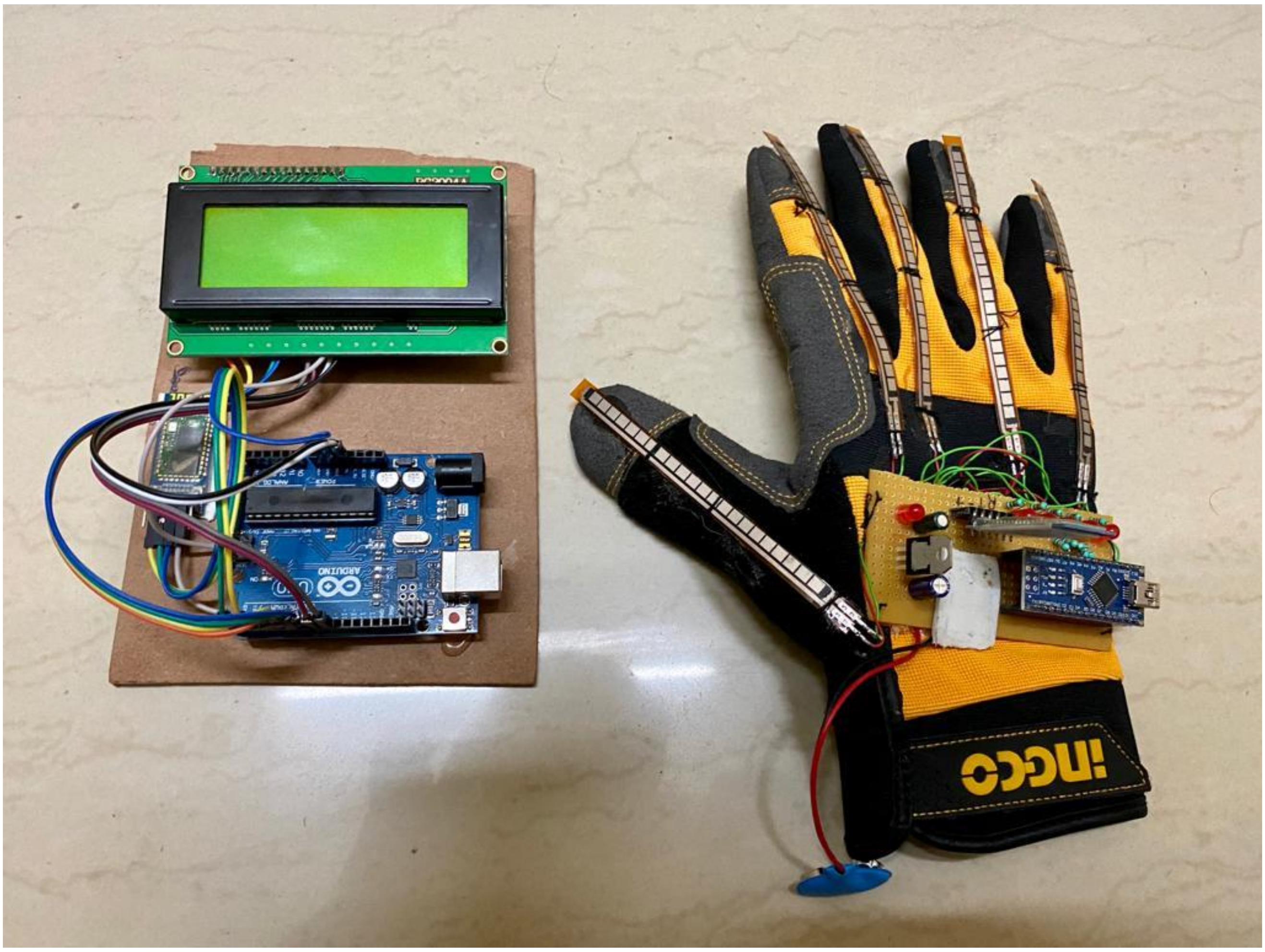


Fig. 3.5.1 Final Prototype

3.5.1 Some examples from prototype's working

3.5.2.1 Alphabet A

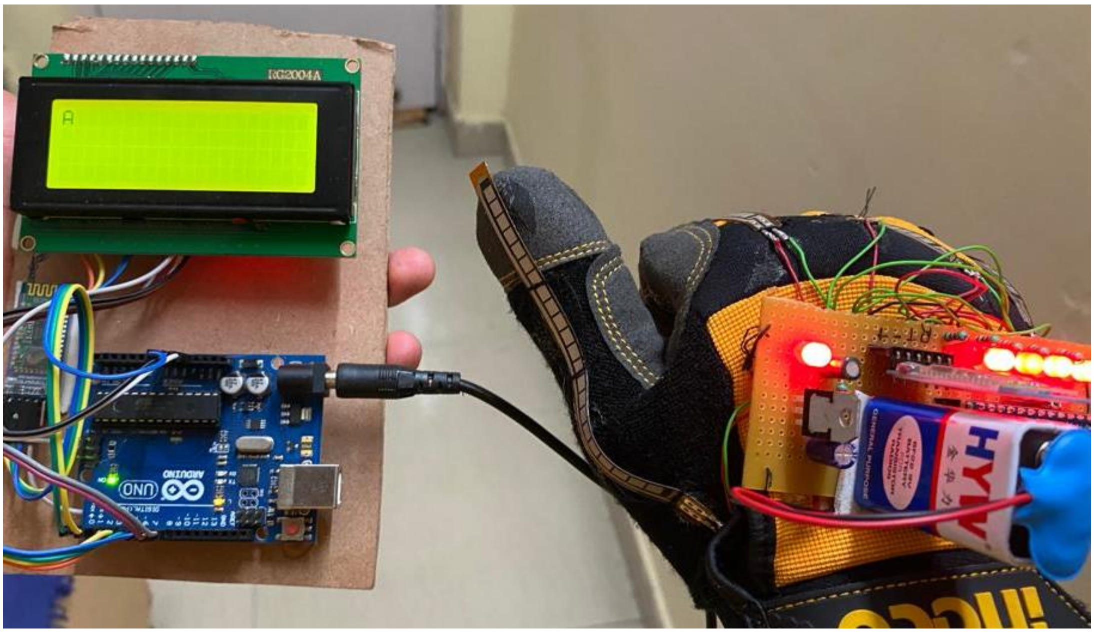


Fig. 3.5.2.1.1 Alphabet A

3.5.2.2 Alphabet 'W'

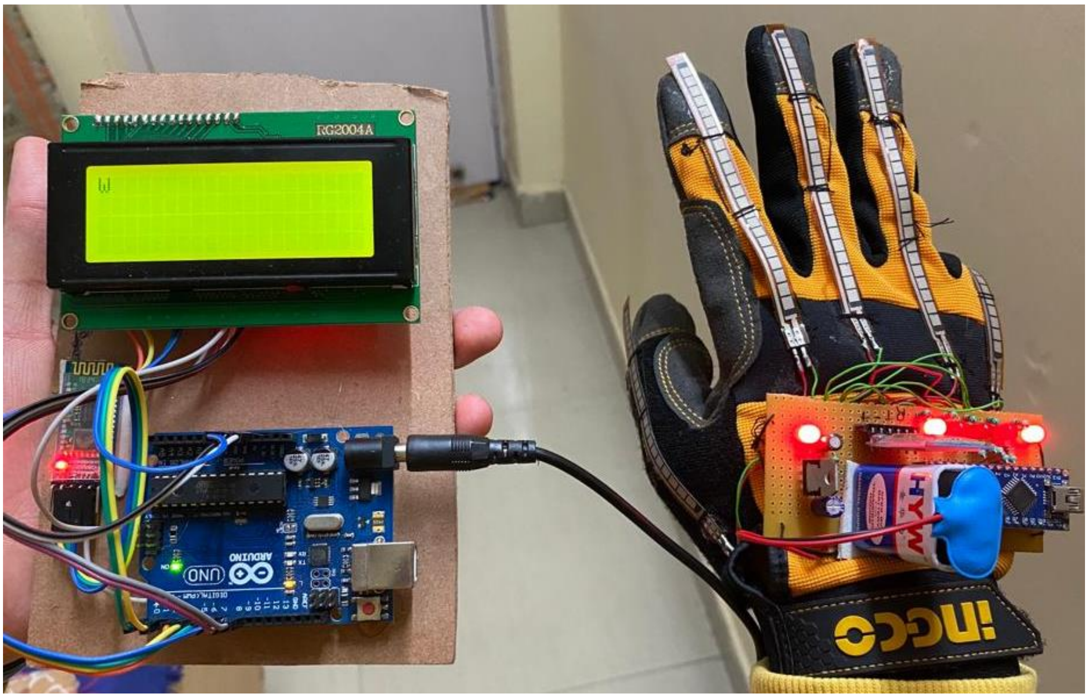


Fig. 3.5.2.2.1 Alphabet W

3.5.2.3 Alphabet 'I'

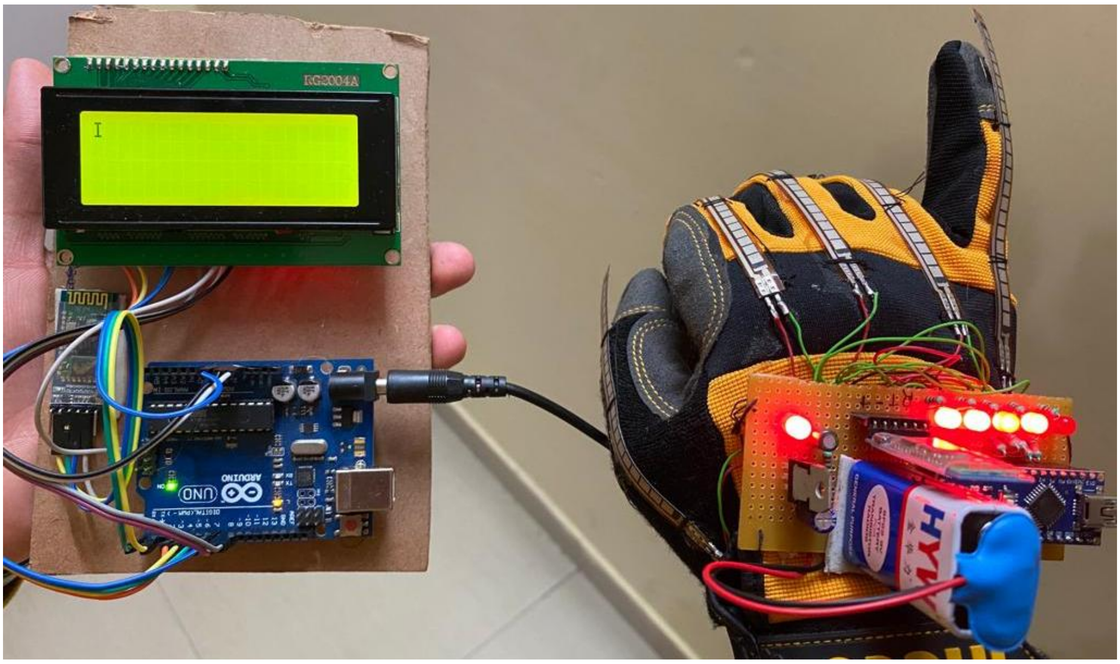


Fig. 3.5.2.3.1 Alphabet I

3.5.2.4 Three letter word 'WAS'

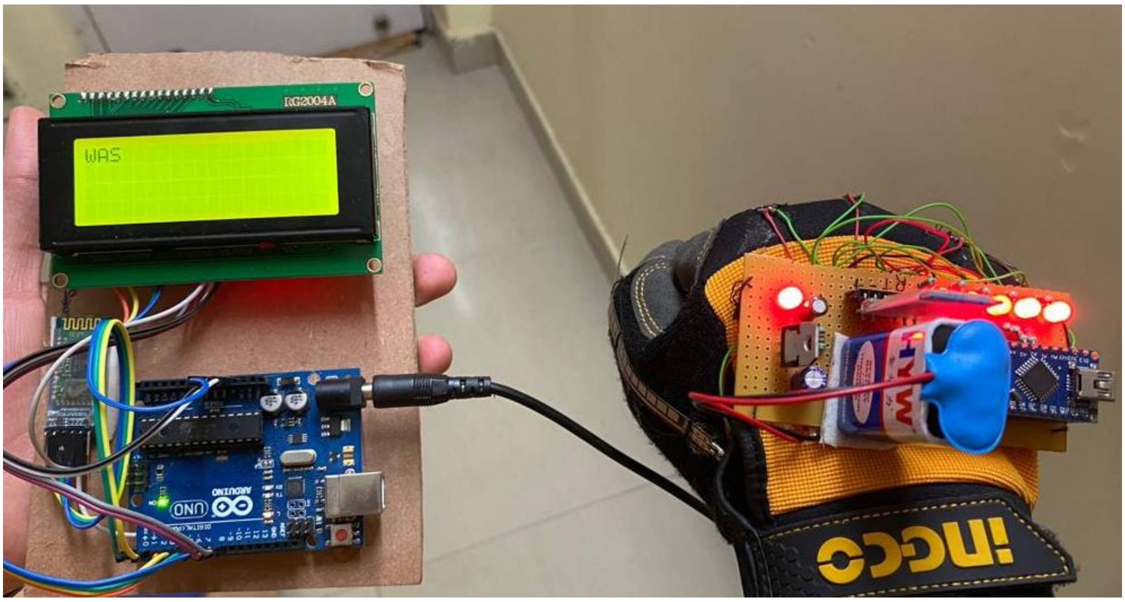


Fig. 3.5.2.4.1 Three letter word 'WAS'

3.5.2.5 Four letter Word 'WALK'

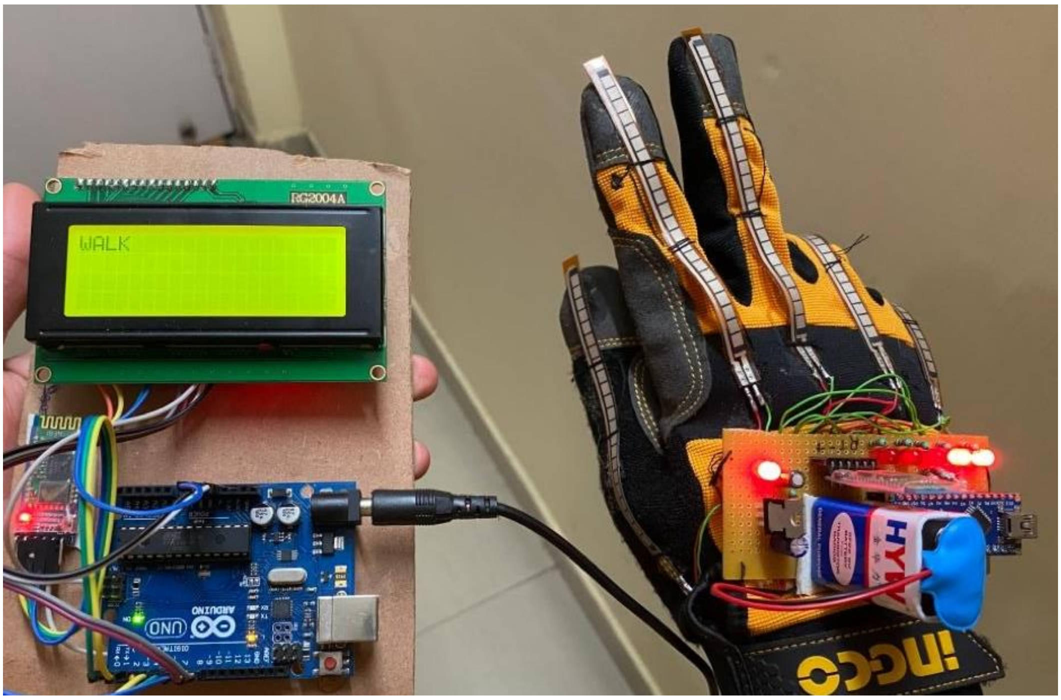


Fig. 3.5.2.5.1 Word 'WALK'

3.5.2.6 Three letter word 'ASK'

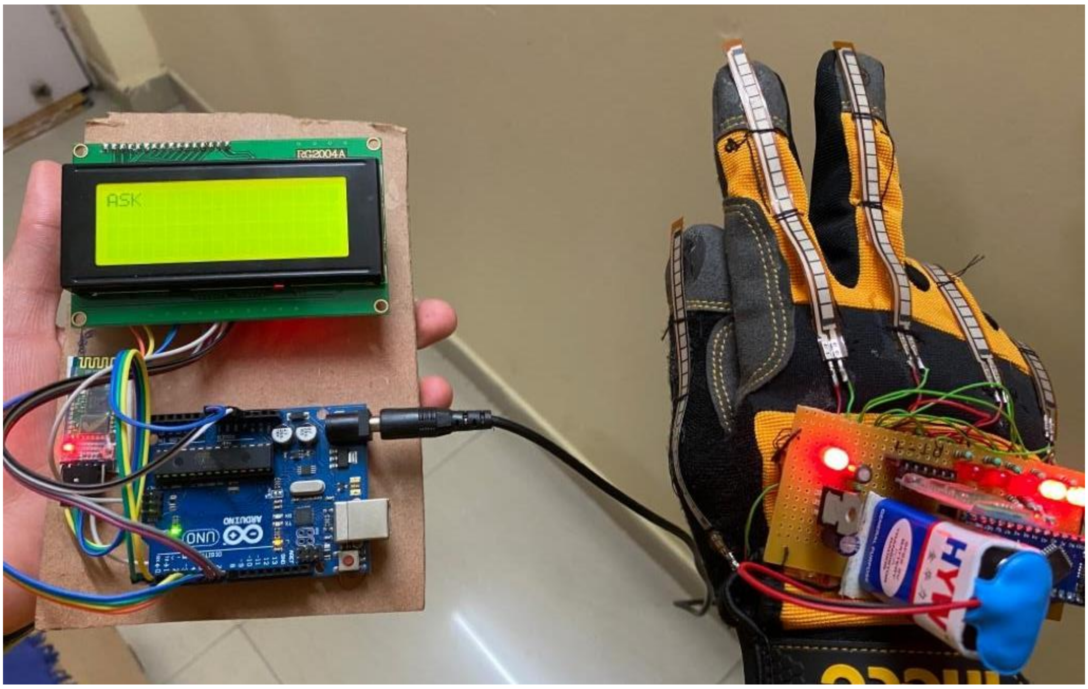


Fig. 3.5.2.6.1 Three letter word 'ASK'

3.6 PROJECT PERFORMANCE EVALUATION

- The Project had better accuracy than "Sign to Letter Translator System using a Hand Glove" [16] Project. Our Accuracy is 93%
- The number of Flex Sensor used by us are five which are less than what is used in "American Sign Language Translation through Sensory Glove"; SignSpeak [11]
- Due to less Flex Sensors than "American Sign Language Translation through Sensory Glove"; SignSpeak [11] the cost of our project is very low and affordable.

CHAPTER 4

OUTCOMES AND PROSPECTIVE LEARNING

4.1 PROSPECTIVE LEARNING

During the course of the proposed project, we learned about flex sensors, the basic working and calibration of the flex sensors. We also learned about the interfacing of the flex sensors with the Arduino Microcontroller for reading input and interpreting a collective input of the flex sensors and generating desired output sign. We learned about the Arduino Uno(328p) and Arduino Nano microcontrollers and their interfacing with flex sensors and LCD display(20x4) respectively. We also used our knowledge of our UG-course Engineering Design-III to develop schematics and flow charts of the projector the Simulation of the project and proper circuit designing we also learned about the “Proteus Professional software” in which we simulated our basic circuit before moving on to the hardware section. We learned about serial communication using Bluetooth module (HC-05) and the different modes it works, which helped us choose a specific baud rate for our purpose. With the help of serial communication using Bluetooth we were able to implement a wireless LCD display which was crucial for our project. We used previously gained knowledge from the subject Circuit Analysis and Synthesis to properly connect the flex sensors to the Arduino Board. The most Sign Language translators are generally wired or are software based so our attempt was to develop a user-friendly device.

4.2 OUTCOMES

We were able to develop the “Sign Language Translator Glove”, which successfully translated the sign made by hand of a person to a particular alphabet and also display it on the wireless LCD display simultaneously. Our prototype supports 26 alphabets (a-z). we are working on to convert these single units of alphabets to collective words and form sentences. The glove developed is user friendly and easy to carry and has its own power supply.

4.3 SCALABILITY AND FUTURE SCOPE

Our prototype is able to display alphabets when the user uses the predefined sign language and is also able to make words out of those alphabets. Different words such as walk, will, was etc. are displayed onto the 20X4 display. It is evident from the experimental results that the prototype has the potential to help targeted individuals and communities.

Further the project can be improved by using higher quality of flex sensors or gyroscopes and/or accelerometers which will be implemented in this system in order to improve its performance and reduce errors. The system can also be modified to transmit information to a smart phone, this should eliminate the use of an LCD, and will take advantage of the text-to-voice applications available in smart phones. Also, slimmer battery supplies which may provide the required voltage and hopefully enough power to last for at least 5 hours would also be a valued improvement to the prototype.

This all can be done after the prototype is decided to be made for the general public and is produced on a large scale.

For Capstone project the students of undergraduate program in Electronics and Communication Engineering/Electronics and Computer Engineering will have	
C. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	
	Yes/No
C1. Analyze needs to produce problem definition for electronics and communication systems.	Yes
C2. Carries out design process to satisfy project requirement for electronics and communication systems	Yes
C3. Can work within realistic constraints in realizing systems.	Yes
C4. Can build prototypes that meet design specifications.	Yes
D. an ability to function on multidisciplinary teams.	
D1. Shares responsibility and information schedule with others in team	Yes
D2. Participates in the development and selection of ideas.	Yes
G. an ability to communicate effectively.	

G1. Produce a variety of documents such as laboratory or project reports using appropriate formats and grammar with discipline specific conventions including citations.	Yes
G2. Deliver well organized, logical oral presentation, including good explanations when questioned.	Yes
H. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.	
H1. Aware of societal and global changes that engineering innovations may cause.	Yes
H2. Examines economics tradeoffs in engineering systems.	Yes
H3. Evaluates engineering solutions that consider environmental factors.	Yes
I. a recognition of the need for, and an ability to engage in life-long learning.	
I1. Able to use resources to learn new devices and systems, not taught in class.	Yes
I2. Ability to list sources for continuing education opportunities.	Yes
I3. Recognizes the need to accept personal responsibility for learning and of the importance of lifelong learning.	Yes
K. an ability to use the techniques, skills, and modern engineering tools necessary for	

engineering practice.	
K1. Able to operate engineering equipment	Yes
K2. Able to program engineering devices.	Yes
K3. Able to use electronic devices, circuits and systems modeling software for engineering applications	Yes
K4. Able to analyze engineering problems using software tools	Yes

The Learning Outcomes for Capstone project are following-:

Course Learning Outcomes	Rate between 1-5 (5: achieved, 1: not achieved)
Developing new/multidisciplinary technical skills.	4
Using professional and technical terminology appropriately.	5
Effectively utilizing and troubleshooting a tool for development of a technical solution.	5
Analyzing or visualizing data to create information.	5
Creating technical report with usage of international standards.	5
Acquiring and evaluating information.	5

COURSES REFERRED AND IEEE STANDARDS REFERRED

Standards Referred-:

IEEE STANDARD USED	PURPOSE
IEEE 802.11	Wireless Networking
IEEE 2700-2014	Standard for Sensor performance and parameter definitions
IEEE 802.15.1-2002	Standard for Telecommunications and Information exchange between systems
IEEE 1559-2009	Standard for Inertial System Technology (used for IMU)
IEEE 1101-1987	Standard for Inertial System Technology (used for IMU)
IEEE P802-REV/D1.6	Draft Standard for Local Area Networks: Overview & Architecture

Table 4.1 Standards Used

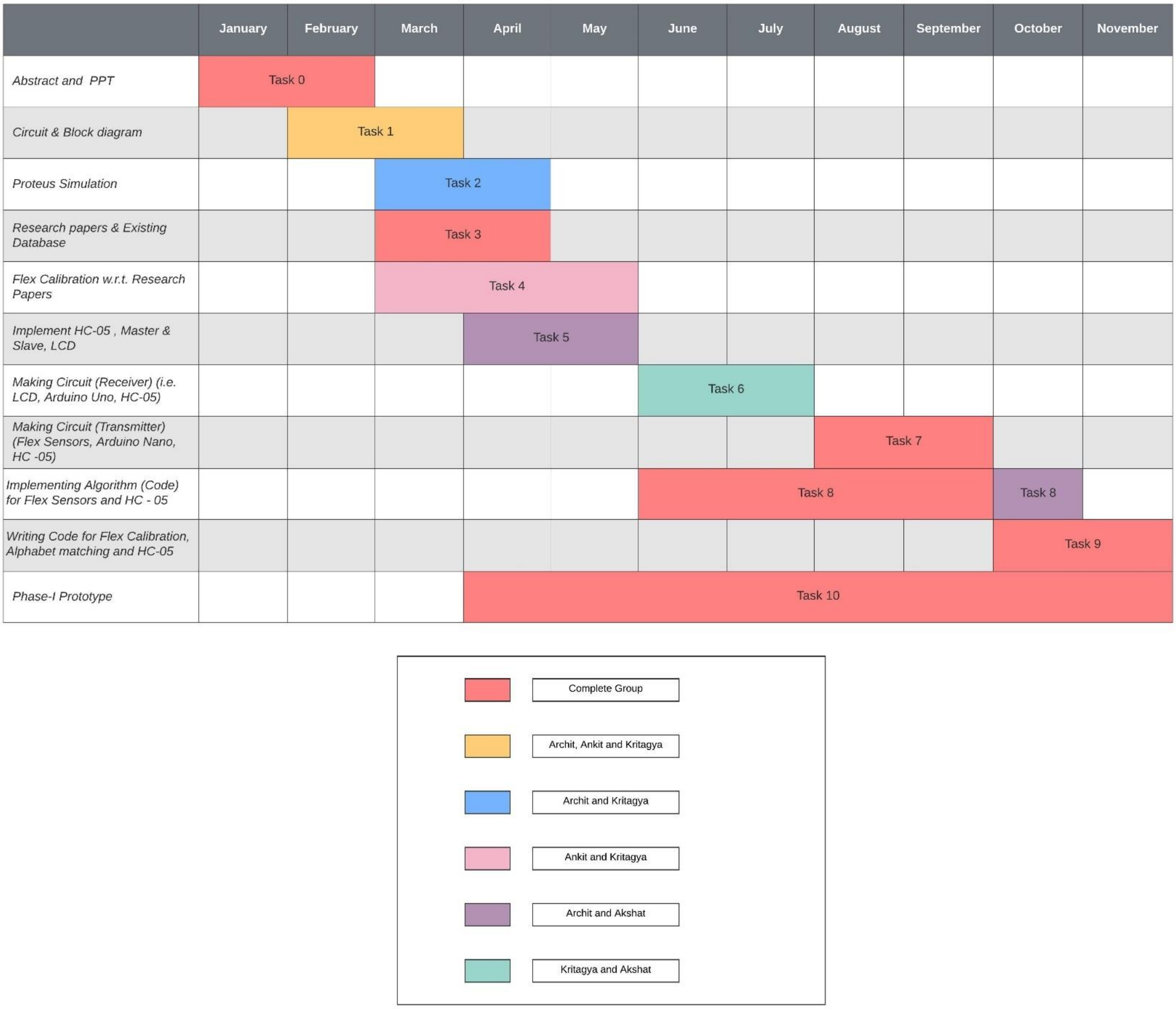
Courses Referred

- Machine Learning
- Embedded Systems
- Circuit Analysis and Synthesis
- Wireless Sensor Networks
- Signals & Systems
- Data Communication & Protocols

CHAPTER 5

PROJECT TIMELINE

PROJECT GANTT CHART



INDIVIDUAL GANTT CHART

Akshat's Contribution

Akshat Sharma (101606020)

<table>
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<tr><td>Abstract and PPT</td><td colspan="2">Task 0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Research papers and Existing Database</td><td></td><td></td><td colspan="2">Task 3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Impleament HC-05, Master & Slave, LCD</td><td></td><td></td><td></td><td colspan="2">Task 5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Making Circuit (Receiver) (i.e. LCD, Arduino Uno, HC-05)</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Task 6</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Making Circuit (Transmitter) (i.e. Flex Sensors , Arduino Nano, HC-05)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Task 7</td><td></td><td></td></tr>
<tr><td>Implementing Algorithm (Code) for Flex Sensors and HC-05</td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Task 8</td><td></td></tr>
<tr><td>Writing Code for Flex Calibration, Alphabet Matching and HC-05</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Task 9</td></tr>
<tr><td>Phase-I Prototype</td><td></td><td></td><td></td><td colspan="8">Task 10</td></tr>
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Ankit's Contribution

Ankit Kumar (101606027)

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<tr><td>Research papers and Existing Database</td><td></td><td></td><td colspan="2">Task 3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Flex Sensor Calibration w.r.t. Research papers</td><td></td><td></td><td colspan="3">Task 4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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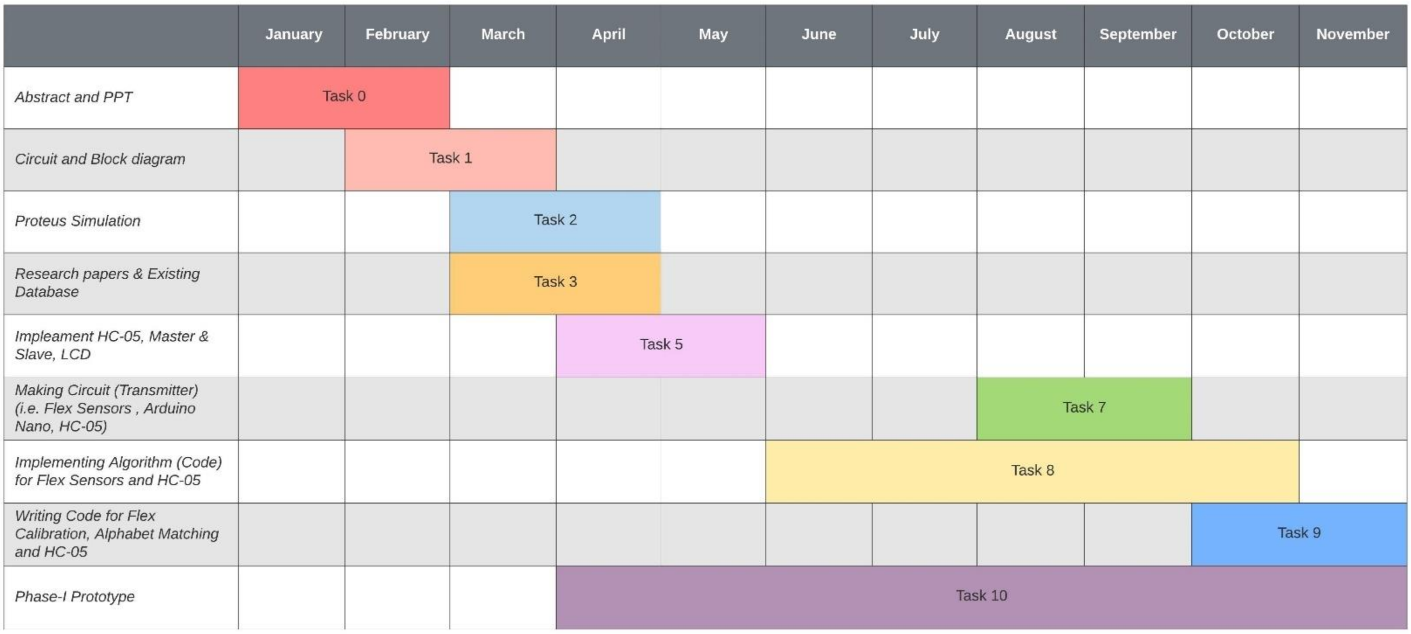
Archit's Contribution

Archit Sethi (101606040)



Kritagya's Contribution

Kritagya Sain Vyoli (101786010)

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APPENDIX

A.1 ARDUINO CODE USED IN PROTOTYPE

A.1.1 Transmitter code of the Prototype

```
void setup()
{
 Serial.begin(9600);
 //Serial.println("Program Started");
 //Serial.println("Please wait Initializing...");
 delay(1000);
 lcd_init();
 init_flex_thres();
 digitalWrite(led1,HIGH);
digitalWrite(led2,HIGH);
digitalWrite(led3,HIGH);
digitalWrite(led4,HIGH);
digitalWrite(led5,HIGH);
delay(2000);
digitalWrite(led1,LOW);
digitalWrite(led2,LOW);
digitalWrite(led3,LOW);
digitalWrite(led4,LOW);
digitalWrite(led5,LOW);
}

void loop()
{
//serial_print();
check_flex_sensor();
if(strcmp(arr,"00000")==0)
{
}
else
{
if(flag==0)
{    previousMillis = millis();
                flag=1;}}
```

```
//Check after 1 sec
if(flag==1)
{if(millis() - previousMillis > 1000)
       {
       flag=0;
       check_flex_sensor();
       match_record();
       previousMillis = millis();
}}}
```

A.1.2 Receiver code of the Prototype

```
void setup()
{
  Serial.begin(9600);
  pinMode(buzzer, OUTPUT);
  digitalWrite(buzzer,LOW);
  lcd.begin(20,4);
  lcd.setCursor(0, 0);
  lcd.print("  Speaking System   ");
  lcd.setCursor(0, 1);
  lcd.print("  for Mute People   ");
  lcd.setCursor(0, 2);
  lcd.print("     using hand     ");
  lcd.setCursor(0, 3);
  lcd.print("      Gestures      ");
  delay(5000);
  lcd.clear();
  serialFlush();
}
void loop()
{
  read_data();
  if(millis() - previousMillis > 5000)
  {
    lcd.clear();
    digitalWrite(buzzer,LOW);
  }

      }
```

A.2 DATASHEETS, PIN DESCRIPTIONS AND SPECIFICATIONS

Features

- High Performance, Low Power AVR® 8-Bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 20 MIPS Throughput at 20 MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory Segments
  - 4/8/16/32K Bytes of In-System Self-Programmable Flash progam memory (ATmega48P/88P/168P/328P)
  - 256/512/512/1K Bytes EEPROM (ATmega48P/88P/168P/328P)
  - 512/1K/1K/2K Bytes Internal SRAM (ATmega48P/88P/168P/328P)
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[1]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    Temperature Measurement
  - 6-channel 10-bit ADC in PDIP Package
    Temperature Measurement
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Byte-oriented 2-wire Serial Interface (Philips I²C compatible)
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
  - Interrupt and Wake-up on Pin Change
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby
- I/O and Packages
  - 23 Programmable I/O Lines
  - 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF
- Operating Voltage:
  - 1.8 - 5.5V for ATmega48P/88P/168PV
  - 2.7 - 5.5V for ATmega48P/88P/168P
  - 1.8 - 5.5V for ATmega328P
- Temperature Range:
  - -40°C to 85°C
- Speed Grade:
  - ATmega48P/88P/168PV: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V
  - ATmega48P/88P/168P: 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
  - ATmega328P: 0 - 4 MHz @ 1.8 - 5.5V, 0 - 10 MHz @ 2.7 - 5.5V, 0 - 20 MHz @ 4.5 - 5.5V
- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48P/88P/168P:
  - Active Mode: 0.3 mA
  - Power-down Mode: 0.1 µA
  - Power-save Mode: 0.8 µA (Including 32 kHz RTC)

Note: 1. See "Data Retention" on page 7 for details.

8-bit AVR® Microcontroller with 4/8/16/32K Bytes In-System Programmable Flash

ATmega48P/V*
ATmega88P/V*
ATmega168P/V
ATmega328P**

**Preliminary

* Not recommended for new designs.

Rev. 8025I–AVR–02/09

Fig. A.2.1 Data Sheets ATmega328P

InvenSense	MPU-6000/MPU-6050 Product Specification	Document Number: PS-MPU-6000A-00 Revision: 3.4 Release Date: 08/19/2013

5 Features

5.1 Gyroscope Features

The triple-axis MEMS gyroscope in the MPU-60X0 includes a wide range of features:

- Digital-output X-, Y-, and Z-Axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250, ±500, ±1000, and ±2000°/sec
- External sync signal connected to the FSYNC pin supports image, video and GPS synchronization
- Integrated 16-bit ADCs enable simultaneous sampling of gyros
- Enhanced bias and sensitivity temperature stability reduces the need for user calibration
- Improved low-frequency noise performance
- Digitally-programmable low-pass filter
- Gyroscope operating current: 3.6mA
- Standby current: 5µA
- Factory calibrated sensitivity scale factor
- User self-test

5.2 Accelerometer Features

The triple-axis MEMS accelerometer in MPU-60X0 includes a wide range of features:

- Digital-output triple-axis accelerometer with a programmable full scale range of ±2*g*, ±4*g*, ±8*g* and ±16*g*
- Integrated 16-bit ADCs enable simultaneous sampling of accelerometers while requiring no external multiplexer
- Accelerometer normal operating current: 500µA
- Low power accelerometer mode current: 10µA at 1.25Hz, 20µA at 5Hz, 60µA at 20Hz, 110µA at 40Hz
- Orientation detection and signaling
- Tap detection
- User-programmable interrupts
- High-G interrupt
- User self-test

5.3 Additional Features

The MPU-60X0 includes the following additional features:

- 9-Axis MotionFusion by the on-chip Digital Motion Processor (DMP)
- Auxiliary master I^2C bus for reading data from external sensors (e.g., magnetometer)
- 3.9mA operating current when all 6 motion sensing axes and the DMP are enabled
- VDD supply voltage range of 2.375V-3.46V
- Flexible VLOGIC reference voltage supports multiple I^2C interface voltages (MPU-6050 only)
- Smallest and thinnest QFN package for portable devices: 4x4x0.9mm
- Minimal cross-axis sensitivity between the accelerometer and gyroscope axes
- 1024 byte FIFO buffer reduces power consumption by allowing host processor to read the data in bursts and then go into a low-power mode as the MPU collects more data
- Digital-output temperature sensor
- User-programmable digital filters for gyroscope, accelerometer, and temp sensor
- 10,000 *g* shock tolerant
- 400kHz Fast Mode I^2C for communicating with all registers
- 1MHz SPI serial interface for communicating with all registers (MPU-6000 only)
- 20MHz SPI serial interface for reading sensor and interrupt registers (MPU-6000 only)

InvenSense	MPU-6000/MPU-6050 Product Specification	Document Number: PS-MPU-6000A-00 Revision: 3.4 Release Date: 08/19/2013

- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

5.4 MotionProcessing

- Internal Digital Motion Processing™ (DMP™) engine supports 3D MotionProcessing and gesture recognition algorithms
- The MPU-60X0 collects gyroscope and accelerometer data while synchronizing data sampling at a user defined rate. The total dataset obtained by the MPU-60X0 includes 3-Axis gyroscope data, 3-Axis accelerometer data, and temperature data. The MPU's calculated output to the system processor can also include heading data from a digital 3-axis third party magnetometer.
- The FIFO buffers the complete data set, reducing timing requirements on the system processor by allowing the processor burst read the FIFO data. After burst reading the FIFO data, the system processor can save power by entering a low-power sleep mode while the MPU collects more data.
- Programmable interrupt supports features such as gesture recognition, panning, zooming, scrolling, tap detection, and shake detection
- Digitally-programmable low-pass filters
- Low-power pedometer functionality allows the host processor to sleep while the DMP maintains the step count.

5.5 Clocking

- On-chip timing generator ±1% frequency variation over full temperature range
- Optional external clock inputs of 32.768kHz or 19.2MHz

Fig A.2.2 Data sheet (MPU 6050)

Pin Category	Pin Name	Details
Power	**Vin, 3.3V, 5V, GND**	**Vin:** Input voltage to Arduino when using an external power source (6-12V). **5V:** Regulated power supply used to power microcontroller and other components on the board. **3.3V:** 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. **GND:** Ground pins.
Reset	**Reset**	Resets the microcontroller.
Analog Pins	**A0 - A7**	Used to measure analog voltage in the range of 0-5V
Input/Output Pins	**Digital Pins D0 - D13**	Can be used as input or output pins. 0V (low) and 5V (high)
Serial	Rx, Tx	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
IIC	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Table A.2.1 Arduino Nano Pin Configuration

Microcontroller	ATmega328P – 8 bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage for Vin pin	7-12V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed) Communication	16 MHz IIC, SPI, USART

Table A.2.2 Arduino Nano Technical Specifications

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Table A.2.3 Arduino Uno Pin Configuration

Microcontroller	ATmega328P – 8 bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

Table A.2.4 Arduino Uno Technical Specifications

Pin Number	Pin Name	Description
1	Enable / Key	This pin is used to toggle between Data Mode (set low) and AT command mode (set high). By default it is in Data mode
2	Vcc	Powers the module. Connect to +5V Supply voltage
3	Ground	Ground pin of module, connect to system ground.
4	TX – Transmitter	Transmits Serial Data. Everything received via Bluetooth will be given out by this pin as serial data.
5	RX – Receiver	Receive Serial Data. Every serial data given to this pin will be broadcasted via Bluetooth
6	State	The state pin is connected to on board LED, it can be used as a feedback to check if Bluetooth is working properly.
7	LED	Indicates the status of Module • Blink once in 2 sec: Module has entered Command Mode • Repeated Blinking: Waiting for connection in Data Mode • Blink twice in 1 sec: Connection successful in Data Mode
8	Button	Used to control the Key/Enable pin to toggle between Data and command Mode

Table A.2.5 Pin description of HC-05

Pin Number	Pin Name	Description
1	Vcc	Provides power for the module, can be +3V to +5V. Typically +5V is used
2	Ground	Connected to Ground of system
3	Serial Clock (SCL)	Used for providing clock pulse for I2C Communication
4	Serial Data (SDA)	Used for transferring Data through I2C communication
5	Auxiliary Serial Data (XDA)	Can be used to interface other I2C modules with MPU6050. It is optional
6	Auxiliary Serial Clock (XCL)	Can be used to interface other I2C modules with MPU6050. It is optional
7	AD0	If more than one MPU6050 is used a single MCU, then this pin can be used to vary the address
8	Interrupt (INT)	Interrupt pin to indicate that data is available for MCU to read.

Table A.2.6 Pin Description of MCU