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# Control of Wheel Chair Designed For Quadriplegics Using MEMS In Medical Application.

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**ABSTRACT**

This paper presents a novel embedded system using micro electromechanical systems to control the movement and gyroscope to improve the stability of electric vehicles like wheelchair. Considering that the vehicle motion is governed by tire forces, tangential tire force which was calculated give practical payback in motion control. This paper also provides a feature of obstacle detection with the help of IR sensors, intimating the user through a light indication using LED and a voice command using voice board APR 9600. The parameters obtained from MEMS and gyroscope are digitized by an analog to digital converter ADC0809 and displayed using 16x2 LCD display. On receiving the digitized parameters of MEMS from ADC the controller controls the wheelchair using a 4 relay control system. This paper is truly an effort in radically improving independence and mobility for people who are not capable of propelling a manual electric vehicle.

**Keywords:** Quadriplegia, MEMS, Intuitive control

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## INTRODUCTION

### Automated Wheelchairs

Basically a wheelchair is designed for physically challenged people to serve as a replacement for their walking mechanism. The device comes in various forms where it is propelled by motors or by the seated occupant turning the rear wheels by hand. Often there are handles at the back of the seat for somebody else to do the pushing. But these manually operated wheelchairs required lot of upper body strength, so the wheelchair evolved to cater to the needs of its user. In the last few decades many types of wheelchair was proposed for disabled people.

### Recent Developments in Wheelchair

A recent development related to wheelchairs is the hand cycle. They come in a variety of forms, from road and track racing models to off-road types modeled after mountain bikes. There have been significant efforts over the past 20 years to develop stationary wheelchair trainer platforms that could enable wheelchair users to exercise as one would on a treadmill or bicycle trainer. Some devices have been created that could be used in conjunction with virtual travel and interactive gaming similar to an Omni directional treadmill.

In 2011, British inventor Andrew Slorance developed Carbon Black the first wheelchair to be made almost entirely out of carbon fiber . The chair was launched at Naidex in October 2011. Working alongside Andrew Slorance as a collaborative National Health Service development partner, A National Health Technology Cooperative Devices for Dignity (D4D) provided Andrew with funding and expert guidance to support him taking the product to market.

Recently, EPFL's CNBI project has succeeded in making wheelchairs that can be moved by thought transference. In 2012 artist Sue Austin, who has been a wheelchair user since 1996, demonstrated a prototype self-propelled underwater wheelchair, developed with help from dive experts and academics. The model, powered by two dive propulsion vehicles, is steered with a bespoke fin and foot-operated acrylic strip.

### Quadriplegia

Quadriplegia, also known as tetraplegia is a paralysis caused by illness or injury to a human that results in the partial or total loss of use of all their limbs and torso; paraplegia is similar but does not affect the arms. The trouncing is usually sensory and cruise, which means that both sensation and control power are lost. It also refers to a condition when a person has a spinal cord injury above the first thoracic vertebra or spinal cord stroke; this usually affects the cervical spinal nerves resulting in paralysis of all four limbs.

### Intuitive Control

The term "Intuitive Control" means to maximize the ease of movement, it must be both safe and comfortable. Next is "Materials and Craftsmanship." This refers to the eminence of everything the users see, hear, touch and operate in the vehicle.

Another quality expected by all users is exceptional performance. Exceptional performance means nothing unless the vehicle responds precisely to the user’s intentions. The Human-Machine Interface (HMI) is a fundamental element that swiftly communicates the driver's intent to the medium, and conveys precise response from the vehicle to the driver by complementing this with safety features that enhance driver awareness and support hazard recognition, the current wheelchairs offers safe and comfort-to-drive vehicles.

### Necessity for an Intuitive Wheelchair

The emergence of advanced mobility devices shows promise for the contribution of engineering to the amelioration of mobility impairments for millions of people who have disabilities or who are aged. Some of the developments in wheelchairs are going to necessitate new service delivery systems, changes to public policy, and assured greater synchronization between end users, policy makers, producers, investigators, and service contributors.

The quadriplegic people need a wheelchair for their mobility and, in majority cases they aren't able to use a manual wheelchair, but the hands-free controller systems currently available are obtrusive and expensive. By adopting a behavior-based approach wheelchairs can be built which can operate daily in complex real-world environments with increased performance in efficiency, safety, and flexibility.

**Sensing Technology in Automated Systems**

Sensors and actuators are components of automotive electronic control systems. Hence, the types of sensors and actuators required are dictated by the desired control system function. There are basically four blocks in a automated control system 1) sensors, 2) software, 3) controller hardware, and 4) actuators. All of these functional blocks work together to achieve the desired control results. Automotive sensors and actuators represent a major market for the MEMS technology. However, there are many development issues that must be brought into balance for a sensor or actuator technology to be commercially viable for automotive applications.

## PROPOSED SYSTEM

**General**

The proposed system is intended to design and build an inexpensive, intuitive and practical powered wheelchair with head and neck based control providing the ability to move without the use of physical control mechanisms.

This proposed system is targeted to provide mobility to quadriplegic people who are incapable of voluntary movement of muscles other than the head and the neck muscles. This makes use of Micro electromechanical systems (MEMS) to monitor the movement of neck and head muscles of the operator and use it to control the vehicle. This allowed the user to control forward motion by leaning their head forward and turning the vehicle by rotating their head left and right. One added advantage of this system is that it does not hinder with the user's ability to communicate while operating the vehicle. This system also proposes to control the lateral stability of the vehicle while moving on curved paths with the help of counter action provided by means of a servo motor which consists of a shaft assembly that controls the angle of inclination between the wheel and the surface. The infra red sensors identify any obstacle lying in the path of travel and it is intimated to the user through an LED and a voice synthesizing board built into the system.

**Block Diagram**

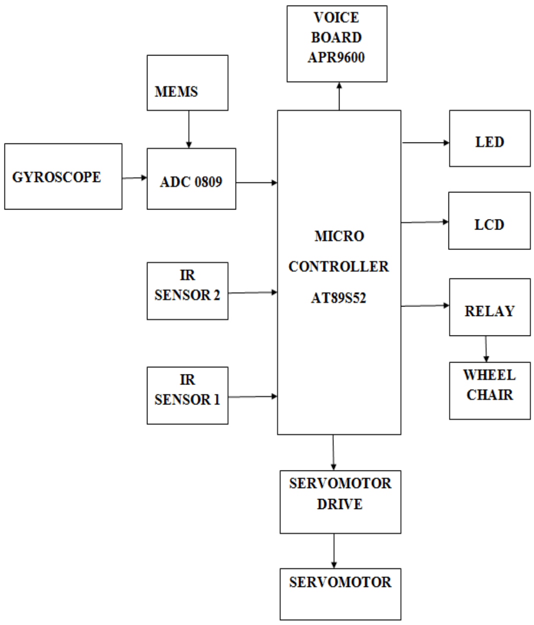


**Figure 1: Architecture of proposed system**

The microcontroller is the central part of the system which is responsible for coordinating the input and output devices used in the design. It takes the input provided by the various sensors and based on the parameters obtained the calculation is done as to how the control of the various output modules is to be done in order to provide the desired outcome. Fig 1 shows the architecture of proposed system.

The MEMS is responsible for measuring the movement of the neck and head of the operating person and provide this data to the microcontroller after digitization by the ADC. Likewise the gyroscope provides the data of the lateral tire force which assists the microcontroller in stabilizing the vehicle to prevent the setup from falling off.

The IR sensors provide proximity details while detecting obstacles in the path of travel. The microcontroller uses these values to drive the relay switch which in turn drives the in-wheel motor to move the vehicle. The Servomotor is responsible for providing the counter force required to stabilize the vehicle during high inclination angle measurements made by the gyroscope.

The LED is used to provide indication to the user during hazardous situations and also a voice synthesizing board APR 9600 is used to provide voice commands to notify the user about obstacles.

**Functions**

The basic functions involved in the project are movement detection, digitization of detected parameters, stability maintenance, and obstacle detection. They are discussed as follows.

**Movement detection by MEMS**

The main component involved in the project is a sensor named micro electromechanical sensor which detects even minute movements of the body part in which it is placed. There is a voltage change for every movement detected and this analog value from the sensor is digitized using an ADC 0809. The digitized parameters from the analog to digital converter are given to the AT89S52. First the digitized parameters namely X, Y and Z are displayed using a 16x2 LCD display.

The LCD displays the command given to the relay like up, down, left and right are also displayed along with the parameters. At the same time based on the parameters received from ADC the microcontroller gives instruction to the relay which in turn controls the movement of wheelchair. Figure 2 shows the flow of control for mems.

**Stability maintenance with gyroscope and servomotor**

Another crucial component used in the project is gyroscope. Gyroscope measures the angle orientation and the measured parameters namely G and Z are digitized using the ADC 0809. The digitized parameters are given to the microcontroller and then displayed using a 16x2 LCD. The controller gives the instruction to the servomotor based on the gyroscope parameters and this servomotor helps in maintaining stability through the provision of counter action in the form of rotation from 0 to 180 degrees.

**Digitization of parameters by ADC**

In this project there is a necessity to digitize the two analog parameters received from two sensors namely mems and gyroscope. The digitization of the parameters is done using an analog to digital converter, ADC 0809. The important component in ADC 0809 is the analog comparator that accepts analog input values and gives digital output.

- The 8-channel multiplexer can accept eight analog inputs in the range of 0 to 5V and allow one by one for conversion depending on the 3-bit address input.
- The successive approximation register (SAR) performs eight iterations to determine the digital code for input value. On the positive edge of START pulse the SAR is set and start the conversion process on the falling edge of START pulse.

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**Obstacle detection by IR sensor**

Considering the safety purposes when moving around in a wheelchair a feature of obstacle detection is introduced in the project. This obstacle detection is done using two infra red sensors. But in future the number of sensors can be increased as per user's requirements.

Basically these IR sensors consist of a transmitter section and a receiver section. The transmitter continuously keeps transmitting the signal, when an obstacle is present the signal transmission is cut, that is the receiver does not receive the transmitted signal thus detecting the presence of obstacle.

The most important thing is to intimate the user about the detection of obstacle. This intimation is carried out through a light indication and a voice command. The light indication is given with the help of a Light emitting diode (LED) and the voice command is given using a voice board APR9600, where APR stands for Automatic Playback recorder. APR9600 is a single chip voice recorder and playback device with nonvolatile storage and playback capability for 60 seconds. It can record and play multiple messages at random or in sequential mode.

**Flow of Control**

**Working of MEMS**

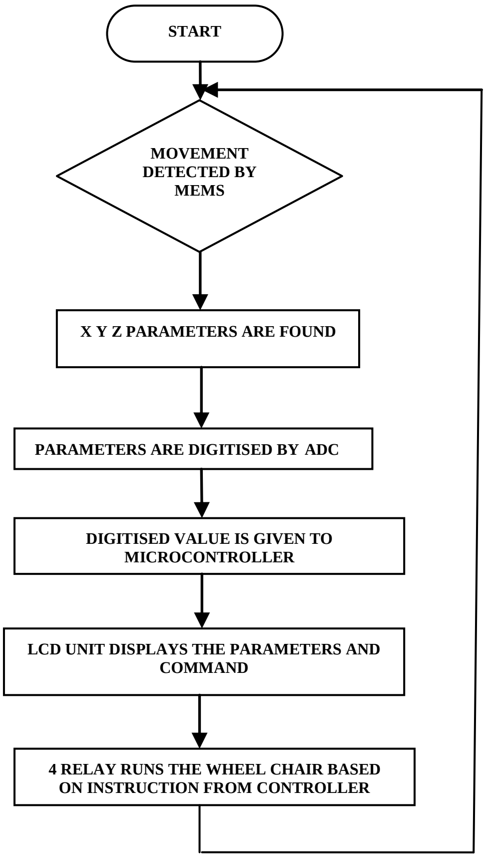


**Figure 2: Flow chart for working of mems**

ISSN: 0975-8585

**Gyroscope working**

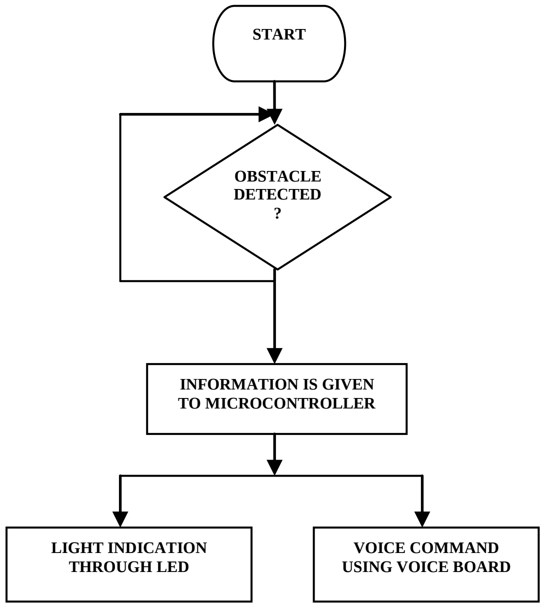


**Figure 3: Flow chart for gyroscope working**

**Circuit Diagram**

**Circuit for microcontroller unit**

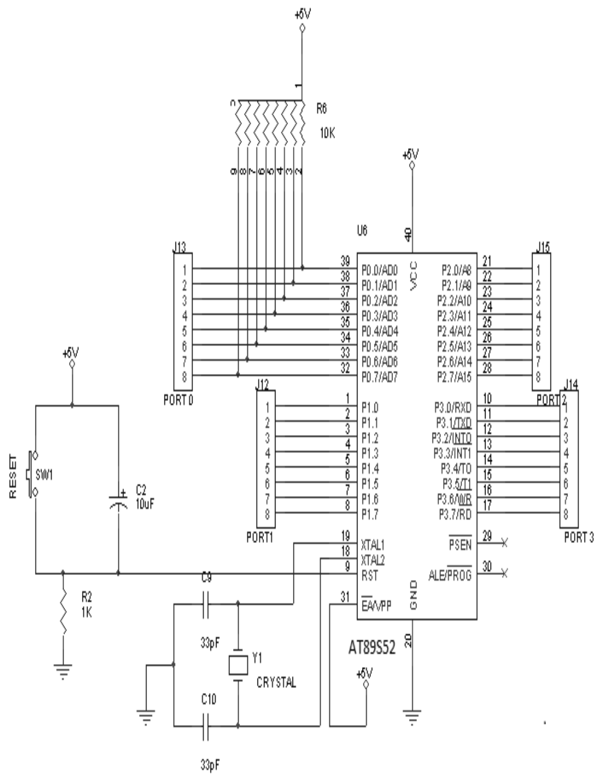


**Figure 4: AT89S52 Controller circuit**

**Circuit diagram for ADC 0809**

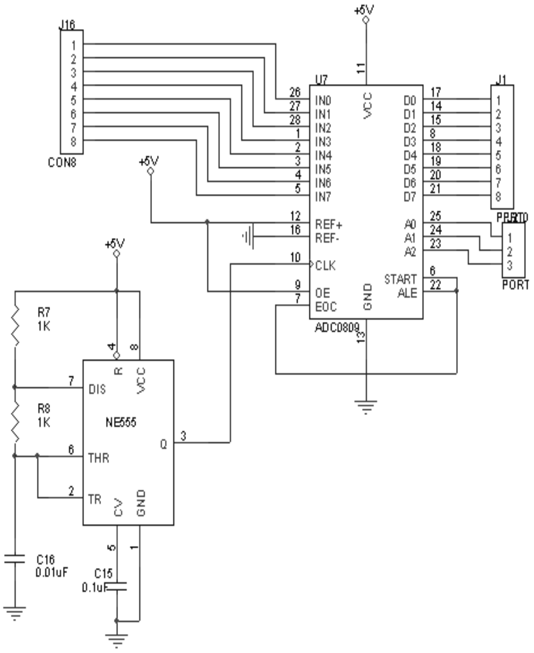


**Figure 5: ADC0809 circuit diagram**

**Circuit diagram for relay control unit**

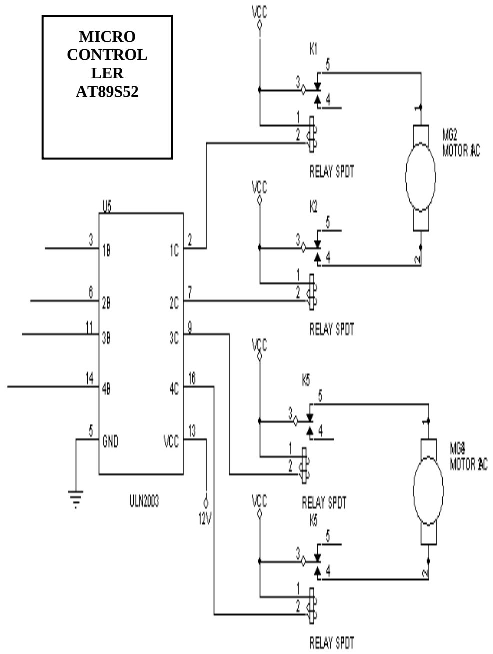


**Figure 6: Relay circuit diagram**

Here 4 relays are used for controlling two gear motors. Pin 3 and pin 1 of each relay is connected to a 5v power supply and pin 2 of each relay namely relay 1, relay 2, relay 3 and relay 4 are connected to pins 2, 7, 9, 16 of ULN2003 driver circuit respectively. Pin 5 of relay 1 and relay 3 are connected to one end of first and second gear motor respectively.

ISSN: 0975-8585

## HARDWARE AND SOFTWARE REQUIREMENTS

### Hardware Modules

The hardware modules used in the project are as follows:

### Relay

A relay is an electrically activated button. When the current is allowed to pass through the coil of the transmit generates a magnetic field which exerts a pull on a lever and transforms the switch get in touch with. The wind current can be on or off so relays have two switch arrangements and they are double throw (changeover) switches.

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a battery circuit which operates at low voltage can use a relay to switch a 230V AC mains circuit. Electrical connection are not there inside the relay between the two circuits; the link is magnetic and mechanic. Fig 7 shows the diagram of relay.

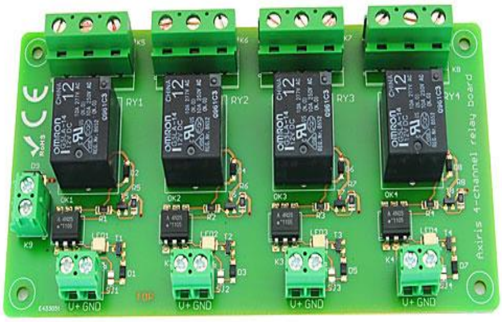

**Figure 7 Diagram of relay**

### Specifications

It draws a current of 30 milliamps and has a minimum pull in voltage of 9V DC. It provides diode protection across relay coil and gives 7 amps @30 volts DC and 10 amps @ 125 volts AC. Its size is 1.1”X1.55”(28mm X 39mm) Ea with an operating voltage of 12 volts DC.

### ADC 0809

The ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog signal-to-digital signal converter, 8-channel multiplexer and microprocessor attuned control logic.

The 8-bit A/D converter uses successive approximation as the conversion technique. The ADC0809 put forwards high rapidity, high precision, negligible heat dependence, outstanding long-term accurateness and repeatability, and consumes very less power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. Fig 8 shows the block diagram of ADC 0809.

ISSN: 0975-8585

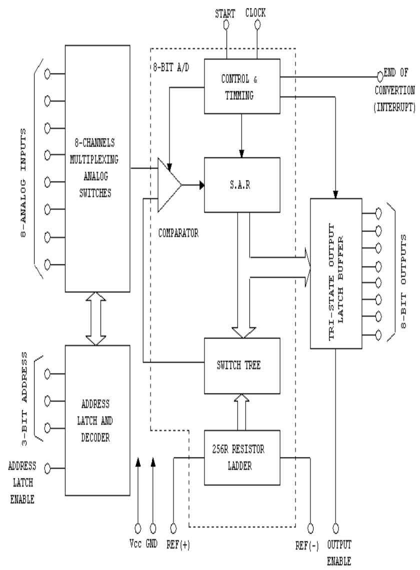


**Figure 8: Block diagram of ADC 0809**

**Gyroscope**

A gyroscope is a device for measuring or maintaining orientation, which is working on the theory of conservation of angular momentum. A mechanical gyroscope is basically a rotating wheel or disk whose axle is free to take any direction. This direction changes much less in reaction to a given peripheral torque than it would without the huge angular momentum bracket together with the gyroscope's high tempo of spin.

Since external torque is reduced by placing the machine in gimbals, its direction remains nearly fixed, in spite of any motion of the podium on which it is mounted. Fig 9(a) shows the gyroscope IC.

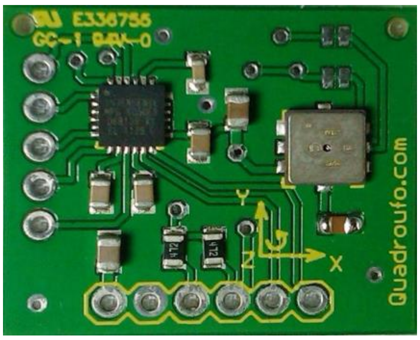


**Figure 9(a) Gyroscope IC**

**Working principle**

The effect is that, once you rotate a gyroscope, its hinge wants to keep pointing in the similar direction. If the gyroscope are allowed to place in a set of gimbals so that it can carry on pointing in the similar direction, it will. This is the origin of the gyro-compass. The gravity defying theory of gyroscope is termed as precession. Figure 10(b) shows a simple gyroscope which is showing the precession.

If you place two gyroscopes whose axles are at right angles to one another on a podium, and place the platform within a set of gimbals, the platform will stay behind completely stiff as the gimbals turn around in any way. This is this fundamental of inertial navigation systems (INS).

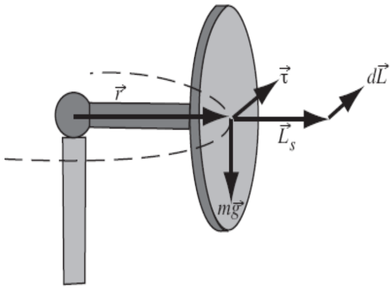


**Figure 10 (b) A simple gyroscope, showing precession**

**SENSORS**

Two sensors used in this project are discussed below:

**MEMS (Micro Electro-Mechanical Systems):**

In early MEMS systems a multi-chip approach with the sensing element (MEMS structure) on one chip, and on the another chip the signal conditioning electronics was used. While this approach is trouble-free from a process standpoint, but it had many disadvantages like overall silicon area is larger, multi chip modules require additional assembly steps, yield is generally lower for multi chip modules, larger signals from the sensor are required to overcome the stray capacitance of the chip to chip interconnections, and stray fields which requires a huge sensor arrangement**,** larger packages are generally required to house the two-chip structure.

**Description**

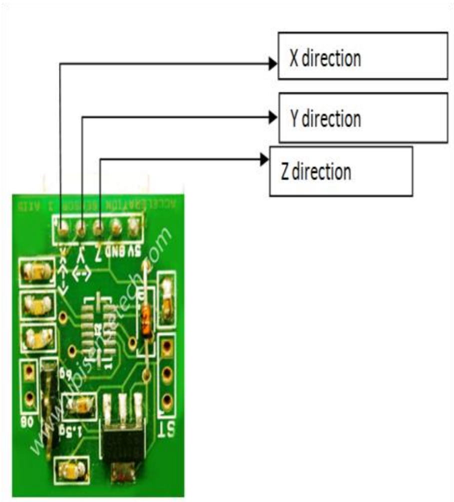


**Figure 11 MEMS IC**

The latest generation ADXL2O2E is the result of almost a decade's worth of experience building integrated MEMS accelerometers. Fig 11 shows the MEMS IC. Poly silicon springs suspend the MEMS structure above the substrate such that the body of the sensor (also known as the proof mass) can move in the X and Y directions. Acceleration leads to the deflection of the proof mass from its middle position. About the four sides of the squared proof mass consist of 32 sets of radial fingers.

**Infra red (IR) sensor**

Infra red sensor can be used for most indoor applications where no important ambient light is present. However, this sensor can be used to compute the speed of entity moving at a very high velocity, like in production or in tachometers. In such functions, ambient illumination ignoring sensor, which depends on transmitting 40 KHz pulsed signals cannot be used because there are time gaps between the pulses where the sensor is 'blind'.

The solution proposed doesn't contain any important modules, like photo-diodes, photo-transistors, or IR receiver ICs, only a couple if IR led, an Op amp, a transistor and a couple of resistors. In need, as the title says, a standard IR led is used for the principle of detection and the circuit is extremely simple.

**Object Detection using IR light**

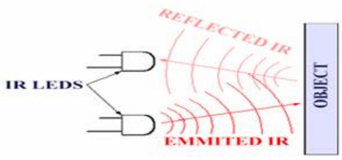


**Figure 12: Object detection by IR sensor**

**Working principle**

Fig 13 shows the circuit diagram of IR sensor which consists of two components. The first is an Infra-Red (IR) transmitter (commonly an LED), while the next is an Infra-Red receiver (generally a transistor). IR is send out of the sensor unit. If the IR is reflected backside, it is absorbed up using theIR receiver transistor. If black absorbs heat, then it also absorbs IR. While the sensor is placed over a black coloured line, no IR is reproduced back to the receiver. If the sensor deviated away from the line, then IR is send back. This is why Cybot chases a black coloured line'. For best results the black line is kept on a white background, which will give the tremendous two cases - white reflects IR.

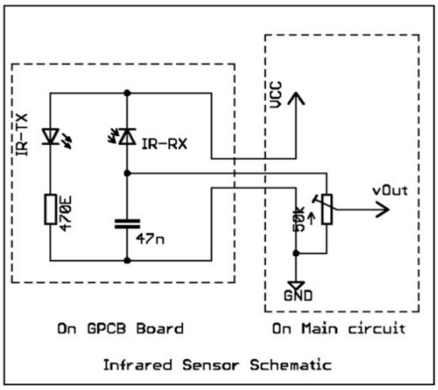


**Figure 13: Circuit diagram of IR sensor**

**VOICE BOARD (APR9600):**

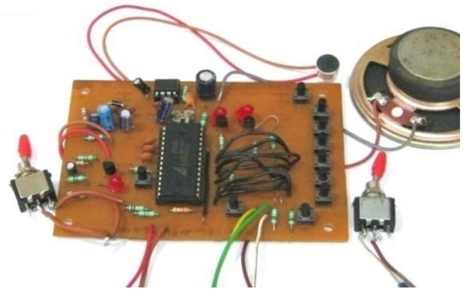

**Figure 14: Voice board APR9600 circuit**

During sound recording, sound is picked up using the microphone. A microphone pre-amplifier increases the strength of the voltage signal from the microphone. An Automatic gain control circuit is incorporated in the pre-amplifier, the extent of which is managed by an external capacitor and resistor. If the level of theVoltage of a sound signal is around 100 mV peak to-peak, the signal can be sent directly into the IC through ANA IN pin (pin 20). The sound signal is allowed to pass through a filter and a sampling and hold circuit. The continuous analogue voltage is then written into non-volatile flash analogue RAMs. It has a 28 pin DIP package. Supply voltage is in the range of 4.5V to 6.5V.

## RESULTS AND DISCUSSION

A snapshot of the two modules used in the project

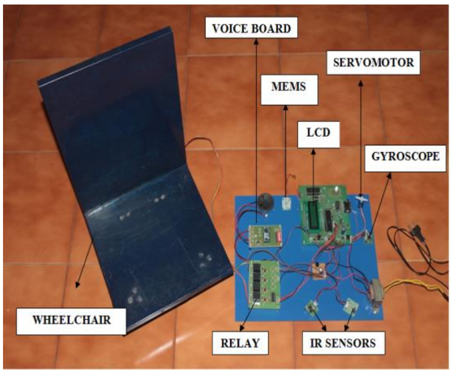


**Figure 15: Modules in the project**

Initially the power supply is switched ON. A red LED placed near the microcontroller IC keeps glowing indicating that power is being supplied. A white LED glows in the voice board APR9600 indicating that it is ON.The LCD initially displays a blank screen and the four red LEDs present in the relay board are in OFF condition indicating that there is no movement detected by MEMS. Fig 15 shows the modules in the project.

**For obstacle detection**

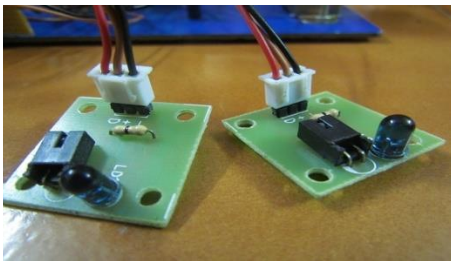

**Figure 16: Two IR sensors**

ISSN: 0975-8585

The figure 16 shows two infrared sensors namely IR sensor 1 and IR sensor 2. When any obstacle is present the transmitted signal is cut off and white LED glows and voice command is played.

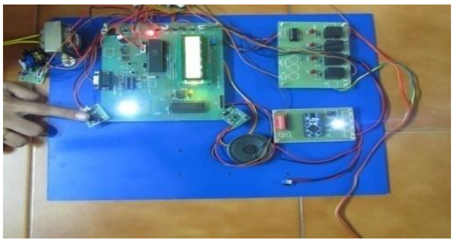

**Figure 17: White LED glowing on obstacle detected**

The figure 17 shows the glowing of white LED on detecting an obstacle in the path of IR sensor. At the same time the LCD unit displays whether the obstacle is detected by IR sensor 1 or IR sensor 2. Also, the relay LEDs are all in OFF state that on detection of obstacle the wheelchair stops its movement irrespective of MEMS position.

**For voice command**

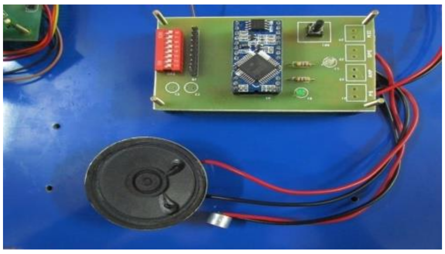

**Figure 18: Voice board APR 9600**

The voice board shown in figure 18 is APR9600, where the APR stands for Automatic Playback Recorder. The figure shows a 5 watts speaker along with a mike for playing and recording of voice command respectively. The voice command can be recorded for duration of 60 seconds.

**For stability control**

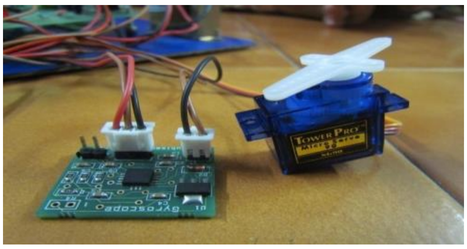

**Figure 19: Gyroscope and servomotor**

The figure 19 shows a setup of gyroscope and servomotor which together maintains the lateral stability. When the gyroscope detects the change in angle orientation then the LCD displays the detected parameters and the servomotor's shaft assembly shown as a white shaft part in the figure 19 turns about 0 to 180 degrees to provide counter action for restoring balance. Basically a servo drive receives a command signal from a microcontroller system, amplifies the signal, and transmits electric current to a servo motor in order to produce motion proportional to the command signal.

**For relay**

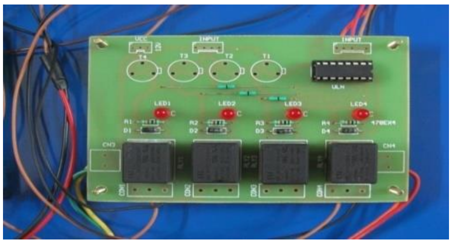

**Figure 20: Four relay board**

The relay shown in figure 20 is a four relay board which is entirely responsible for controlling the two gear motors fixed to the wheelchair. Each end of a gear motor is connected to two relays. When MEMS is operated, that is, when moved the particular relay responsible for the motor running is indicated by a red LED.

## CONCLUSION AND FUTURE ENHANCEMENT

This paper gives the user a satisfaction of intuitive control, most importantly without hindering the user's ability to communicate. This project made use of two sensors namely MEMS sensor and Infra red sensor for movement control and obstacle detection respectively. For efficient control of wheelchair a 4 relay board is used. For the maintenance of stability of wheelchair a combined functioning of gyroscope and servomotor are used. The tilt in wheelchair angle is noted and the counter action to maintain stability is provided by servomotor. Also the obstacle detected with the help of IR sensors is intimated to the user through light indication and also a voice command. Light indication is provided with help of a white LED and voice command is given using a voice board APR 9600. Here ADC 0809 is used for digitizing the parameters of MEMS and gyroscope. The digitized parameters are displayed using a 16x2 LCD display. This paper is made in an effort to overcome the disadvantages of its previous systems by providing the quadriplegic people independency in their mobility.

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