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Head Motion Controlled Electric Wheelchair using PIC Microcontroller

Maitreya Vaze , Saikiran Chari, Abhishek Bist , Akshay Tawade
Fr.C.Rodrigues Institute of Technology, Vashi

Harshada Bhosale
Asstt. Prof.
Fr.C.Rodrigues Institute of Technology, Vashi

ABSTRACT :
Quadriplegics is paralysis of the lower body in which the person suffering is unable to move his four limbs and torso. Joystick controlled wheelchair cannot be used by such people. Medical devices available in market are complex and costly. This project aims at developing a simple and cost effective wheelchair which suffices their need. The wheelchair designed makes use of head movement to decide the direction of motion. MEMS sensor ADXL335 senses the direction of movement of head and sends it to PIC microcontroller PIC 16F877A. The controller converts analog to digital signal followed by serial transmission and reception. H bridge circuit is used to drive two motors which move the wheelchair in the specific direction. The control circuit was simulated and tested in Proteus software. The hardware of control circuit was tested on a wheelchair.

KEYWORDS:
Quadriplegics, PIC microcontroller, MEMS sensor, Electric wheelchair.

I INTRODUCTION

Spinal cord injuries at the neck level caused due to road accidents, sport injuries, falling from a height etc. can cause a type of paralysis in which the patient is not able to move his limbs and torso on his own. Such people are known as Quadriplegics or Tetraplegics. This makes them totally dependent on others for their mobility. Joystick operated wheelchairs cannot be used by them. Different mechanisms have been implemented to develop wheelchairs to suit their needs. Much work has been done and published in literature which proposes different techniques to implement hands free control of electrically powered wheelchairs. Significant among them being control based on hand gestures, eye movement tracking, facial expressions etc [1-7].

K.Matsuzawa et al in their paper have proposed an electric wheelchair control system based on a brain computer interface (BCI) headset having 14 electrodes and two gyroscope sensor [4]. The headset was mounted on the users head and the users bio signals were subsequently measured. Control command of electric wheelchair was assigned to users face expression and head movement. F.B.Taher et al propose technique of eye tracking system based on fuzzy logic controller to control an electrically powered wheelchair with webcam placed in front of the user [5].G.Jang et al propose EMG (Electromyographic) based continuous control scheme including simple classifier for electric powered wheelchair [6]. They propose a scheme in which surface EMG signals on face muscles are utilized for electric powered wheelchair control system. In this paper we have implemented head movement for controlling the motion of the wheelchair in the desired direction [8]. Acceleration sensor is used to sense the head movement in four directions forward, backward, right and left and also no head movement for standstill. Permanent magnet DC motor is used for moving the wheelchair. Two PIC microcontrollers are used for control purpose. Firstly the control circuit was tested in Proteus software which showed successful results. A prototype model was fabricated of the control system and tested on a wheelchair.

II SYSTEM IMPLEMENTED

In this project head motion of the person is sensed using acceleration sensor ADXL335. The block diagram of the implemented control circuit is shown in fig.1.

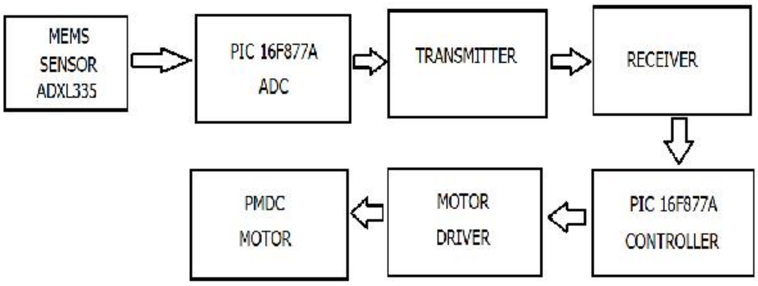

Fig.1 Block diagram of implemented control

Following components have been incorporated to produce the motion in the desired direction.

A) MEMS acceleration sensor ADXL335 – It senses the direction of head motion and accordingly sends signal to PIC micro-controller 1. The direction of head motion is sensed in 4 directions forward, backward, right and left. The output signal is analog signal. The sensor used in this project is MEMS (micro electro mechanical system) accelerometer which detects the tilt and change in acceleration in the direction of motion. This sensor can detect change in three planes or axes. In this case we will be controlling motion in four directions hence we make use of two axes. The output from the sensor is analog i.e. voltage between 0-3.2 V. This analog signal will be converted into digital signal before transmitting. ADC of the microcontroller 1 is used for this purpose. RF transmitter and receiver are used for transmission and reception. The digital signal at the receiver is given again to a PIC micro-controller 2.

B) PIC micro-controller (PIC 16F887A) - It is used for analog to digital conversion as well as transmission and reception. The output of MEMS sensor is analog. It is converted to digital signal and serial transmission and reception is executed. The other PIC microcontroller is used to generate the control pulses for driving the switches of the H-bridge driver of the two motors.

C) Motor Control - A H-bridge is designed for this purpose. According to the pulses received from the PIC microcontroller 2 it controls the direction of rotation of the two motors.

D) PMDC Motor - PMDC worm gear motor is used to drive the wheelchair. Permanent Magnet DC motors are employed in various battery powered applications. Their ability to produce high torque at low speed make them suitable substitutes for gear motors in many applications. In this project PMDC motor is used. The power requirement to drive a wheelchair is less and for less power rating PMDC motor is ideal as it is small in size and for lower ratings it gives higher efficiency. Thus taking into account the cost factor and required functions PMDC motor is used to drive the wheelchair. It is controlled by the motor driver. The direction of motor rotation is decided by the motor driver and direction of motor rotation decides the direction of the wheelchair.

III CONTROL MODES

The wheelchair control mode depends on the direction of head motion. The wheelchair moves in the direction in which the head is moved. There are five modes of operation. They are listed below :-

- Mode 1- Forward
- Mode 2- Reverse
- Mode 3- Right
- Mode 4- Left
- Mode 5- Stationary Mode

If the head is stationary the wheelchair is stationary. If the head moves in forward direction the wheelchair moves forward. Similarly, the wheelchair moves in the direction of head motion.

(A) **MODE 1** :- When the head is moved in forward direction, the voltage of the X_{out} pin of the MEMS sensor increases beyond 1.8V.The voltage of X_{out} will depend on the acceleration of head. The microcontroller is programmed in such a way that whenever the voltage from the X_{out} pin increases beyond 1.8V, the microcontroller will detect forward motion. The output of the microcontroller for forward motion is given in table 3.1. Both the motors will move in clockwise direction.

(B) **MODE 2** :-When the head is moved in backward direction, the voltage of the X_{out} pin decreases below 1.3V. The voltage of X_{out} will depend on the acceleration of head in backward direction. Whenever the voltage from the X_{out} pin decreases below 1.3V, the microcontroller will detect motion in reverse direction. The output of the microcontroller for backward motion is given in table 3.1. Both the motors will move in anti-clockwise direction.

(C) **MODE 3**:- When the head is moved in right direction, the voltage of the Y_{out} pin increases beyond 1.8V. The voltage of Y_{out} will depend on the acceleration of head in right direction. Whenever the voltage from the Y_{out} pin increases beyond 1.8V, the microcontroller will detect motion in right direction. The output of the microcontroller for right motion is given in table 3.1. For the wheelchair to move in right direction the right motor will move in anti-clockwise direction and the left motor will move in clockwise direction.

(D) **MODE 4** :- When the head is moved in left direction, the voltage of the Y_{out} pin decreases below 1.3V. The voltage of Y_{out} will depend on the acceleration of head in left direction. Whenever the voltage from the Y_{out} pin decreases below 1.3V, the microcontroller will detect motion in left direction. The output of the microcontroller for left motion is given in table 3.1. For the wheelchair to move in left direction the left motor will move in anti-clockwise direction and the right motor will move in clockwise direction.

(E) **MODE 5** :- If there is no head motion the voltage from both X_{out} and Y_{out} is 1.6V. But the microcontroller is programmed in such a way that if the voltage from both X_{out} and Y_{out} is between 1.3V-1.8V the wheelchair remains stationary.

Table 3.1 Output From Mems Sensor

Voltage (V)	Direction of Motion
1.3 – 1.8V (X_{out} and Y_{out})	NO MOTION (Both left and right Motor do not move)
> 1.8 (X_{out})	FORWARD (Both left and right Motor move clockwise)
< 1.3 (X_{out})	REVERSE (Both left and right Motor move anti-clockwise)
> 1.8 (Y_{out})	RIGHT (Left Motor moves clockwise and right Motor moves anti-clockwise)
< 1.3 (Y_{out})	LEFT (Left Motor moves anti-clockwise and right Motor moves clockwise)

The signal from the ADC of the micro-controller is serially transmitted by RF transmitter. The receiver will serially receive this signal and send it to the second microcontroller. This signal is available at the output port of the second microcontroller. The signal at the output port is given to the motor driver which drives the motor. This process of signal transmission and reception is same for all operating modes. The output bits from the second micro-controller to control the motor driver are shown in table 3.2.

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Table 3.2 Output bits of second micro-controller

4 bit output of PIC				Direction of motion
Input to Left H-bridge		Input to right H-bridge		
0	0	0	0	NO MOTION
1	0	1	0	FORWARD
0	1	0	1	REVERSE
1	0	0	1	RIGHT
0	1	1	0	LEFT

IV SIMULATION RESULTS

The microcontroller has to be programmed depending on its application. We have used MikroC software for our project. MikroC enables us to write compact and efficient code as compared to other software. To confirm that the programmed microcontroller gives us the desired results we run the program in a simulator. Proteus is used for this purpose. Proteus Virtual System Modelling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. Two different programs are to be written for two microcontrollers. The first microcontroller is programmed to work as an analog to digital converter. It converts the voltage signals from the MEMS sensor to its equivalent digital value. PIC 16F877A has 10 bit ADC. The result of ADC is stored in two 8 bit registers ADRESH and ADRESL. The program converts 10 bit data into 8 bit data. The microcontroller also performs serial transmission of the converted digital data. We use Asynchronous serial transmission for our project. The second microcontroller is programmed to enable serial reception of the data. The received data is available at PORT C of the microcontroller. The lower 4 bit of PORT C is given to the motor driver.

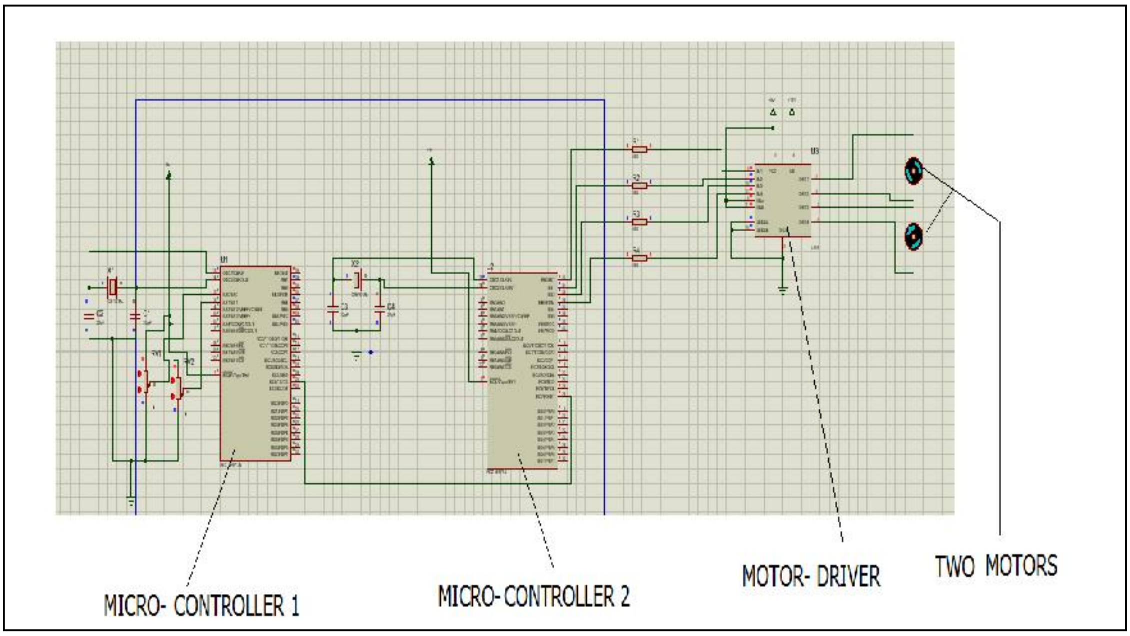

Fig.2 Simulated circuit in Proteus

The compiled program is tested in Proteus to ensure that the desired results are obtained. Two potentiometers are used which act as MEMS sensor. The outputs of the potentiometers are given to RA_0 and RA_1 pins of the microcontroller. Potentiometer 1 simulates the output voltage of X_{OUT} and Potentiometer 2 simulates the output voltage of Y_{OUT}. The .hex files of each microcontroller are loaded into the respective microcontroller. L298 motor driver is used to simulate the H- bridge operation of motor driver. By varying the potentiometers, we get different modes of operation.

V HARDWARE CIRCUIT

For head motion control of electric wheelchair following components need to be designed.

(A) MOTOR SELECTION

Assuming the total weight of wheelchair and the person seated on the wheelchair to be 150 kg.

Acceleration of the wheelchair = 0.5 m/s^2.

$F_a = m \times a = 150 \times 0.5 = 75$ N

Coefficient of static friction between wheel and surface = 0.3

Acceleration due to gravity = 9.81 m/s^2.

Force required for overcoming static friction $= \mu \times m \times g$

$F\mu = 0.3 \times 150 \times 9.81 = 441.45$ N

Radius of the wheelchair = 0.275 m

Total force (F) = Fa + Fμ = 75 + 441.45 = 516.45 N

Torque required to move wheelchair = F x r = 142.02 N-m

Selecting two 0.25 Hp and 60 rpm motors.

Angular velocity (ω) = $(2\pi \times 60)/60$ = 6.28 rad/sec

Torque of single motor = $\frac{P}{\omega}$ Nm = $(0.25 \times 746)/6.28$ = 29.7 N-m.

Total torque developed by two motors = 29.7×2 = 59.4 N-m

The torque developed by the motor is not sufficient to move the wheelchair since required starting torque is greater than torque developed by the motor. So, to increase the torque developed by the motor we use spur gear.

(B) SPUR GEAR : Torque required by wheelchair is 142.02 N-m and the torque developed by the motor is 59.4 Nm. Torque developed must be multiplied by at least 2 to achieve the required

Fig.3 Wheelchair fitted with motors

torque. This can be done by using the spur gear assembly. Gear Ratio is 1:3.214, thus the torque obtained is 186.5 N-m which is more than sufficient. Spur gear reduces speed by a factor of 3.214.

(C) MEMS SENSOR AND TRANSMITTER

A 9V 6F22 battery is used to power the sensor, PIC and transmitter. MEMS sensor requires a 3.3V power supply whereas PIC and transmitter requires 5V power supply. The 9V from the battery is given to the input pin of LM7805 and 5V is obtained at the output pin. This 5V is given to PIC, transmitter and input pin of LM3940. We get 3.3V from the output pin of LM3940. This is given to MEMS sensor. A switch is used to switch on or switch off the power supply. If the switch is ON, the LED glows. LED is used to indicate the availability of supply. Radio frequency amplitude shift keying (RFASK) 433MHz module is used for transmitting digital data.

Fig. 4 Output of MEMS sensor in standstill position Fig. 5 Output of gate driver when digital input is high

(D) RECEIVER

The receiver circuit is placed in the wheelchair. The receiver and PIC at the receiver requires a 5V supply, this 5V supply is provided by buck converter (LM 2596). The buck converter steps down 24V available from battery to 5V. A NOT gate is used to prevent short circuiting of one leg of the H-Bridge. The microcontroller receives the serial data from the receiver. Micro-controller processes the data according to the written program and gives 4-bit output data. It is available at PORT B of the microcontroller. The 4- bit data is given to HCPL3120.

(E) H- BRIDGE DRIVER

H-Bridge driver is used to control the switching of MOSFETs in the H-Bridge. A 15V supply is given to pin no. 8 of HCPL3120 and digital input (high or low) is given to pin no. 2 of HCPL3120 and pin no. 3 is grounded. When the digital input is low, the output of HCPL3120 is 0V. When the digital input is high, the output of HCPL3120 is 14V. This can be seen from Fig.5. This output voltage is given to the gate terminal of the MOSFETs. One driver circuit has two H-Bridge drivers which controls two motors.

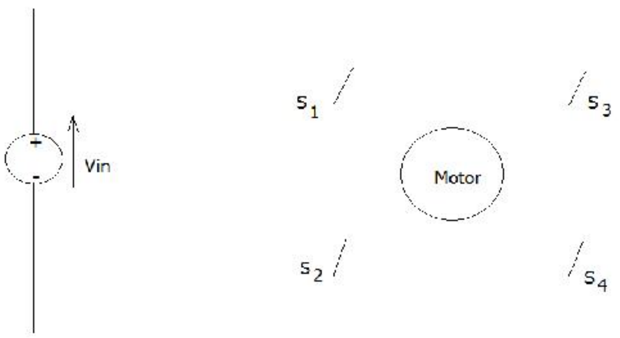

Fig. 6 Schematic diagram of H- bridge

When switches 1 and 4 are ON the motor will move in clockwise direction and when switches 2 and 3 are ON the motor moves in anticlockwise direction. Two MOSFETs of the same leg are never switched ON at the same time.

VI CONCUSION

Quadriplegics are people handicapped below the neck. They are incapable of moving their limbs on their own. The designed wheelchair is cost-effective solution to meet the needs of such people. The control circuit was successfully tested in proteus simulation. The MEMS sensor , microcontrollers and transmitter , receiver circuits gave the required outputs. Also in future speed control and obstacle detection in the path can also be implemented.

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