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Accelerometer Based Hand Gesture Controlled Wheelchair

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ABSTRACT*:* Wheelchairs are used by the people who cannot walk due to physiological or physical illness, injury or any disability. Recent development promises a wide scope in developing smart wheelchairs. The present article presents a gesture based wheelchair which controls the wheelchair using hand movements. The system is divided into two main units: Mems Sensor and wheelchair control. The Mems sensor, which is connected to hand, is an 3-axis accelerometer with digital output (I2C) that provides hand gesture detection, converts it into the 6- bit digital values and gives it to the PIC controller. The wheelchair control unit is a wireless unit that is developed using other controller.

Keywords: Accelerometer, I2C, Hand gesture recognition, Wheelchair control, Wireless.

I. INTRODUCTION

In today's time, an estimated 1% of the world's population needs a wheelchair. An increased percentage of elderly and disabled people who want to enhance their personal mobility, for them wheelchair is the best assistive device. A disabled or an invalid individual (usually the disability of the lower part of the body) can find it convenient to move around and maneuver using the help of a chair constructed on wheels which can either be pushed by another individual or propelled either by physical force or electronically. Such a chair is called as a Wheelchair.

Traditional wheelchairs have some limitations in context to flexibility, bulkiness and limited functions [1]. Our approach allows the users to use human gestures of movement like hands and synchronize them with the movement of the wheelchair so that they can use it with comfort and ease on all kinds of terrains without the hurdle or cardiovascular problems or fatigue.

Some existing wheelchairs are fitted with pc for the gesture recognition [2]. But making use of the pc along with the chair makes it bulkier and increases complexity. This complexity is reduced by making use of the mems accelerometer [3-4], the size of which is very compact and can be placed on the fingertip of the patients.

Other existing systems, which make use of the similar kind of sensors are wired, which again increases the complexity of the system. They also limit the long range communication. This complexity is removed by using the RF transmission. Signals through RF travel larger distances. Irrespective of line of sight communication, signals through RF travel even when there is obstruction between the transmitter and receiver.

The processing speed of this system is made faster by making use of I2C protocol.

A. Block Diagram

The system comprises of two main parts: Transmitter part and receiver part. In transmitter part the hand gesture is recognised by the sensor, digital output is transmitted to the controller and then transmitted to receiver side by the rf transmitter. Fig. 1 shows the block diagram of the transmitter unit.

The same data is received at receiver side by the rf receiver. DC Motors which are interfaced to the controller by the motor driver controls the direction of the wheelchair. Fig. 2 shows the block diagram of the receiver unit.

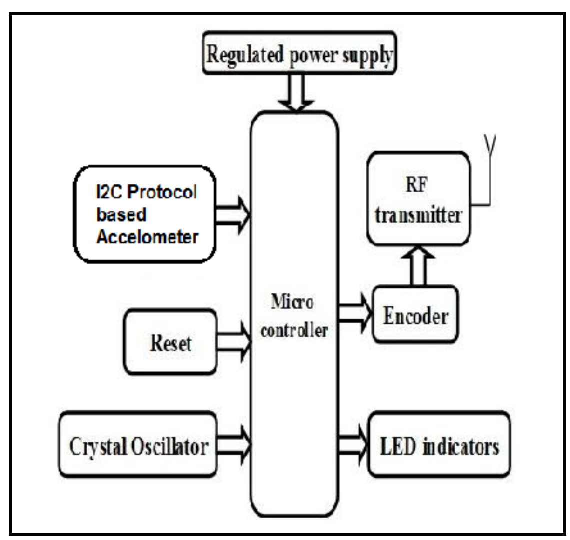

Fig. 1. Transmitter block diagram.

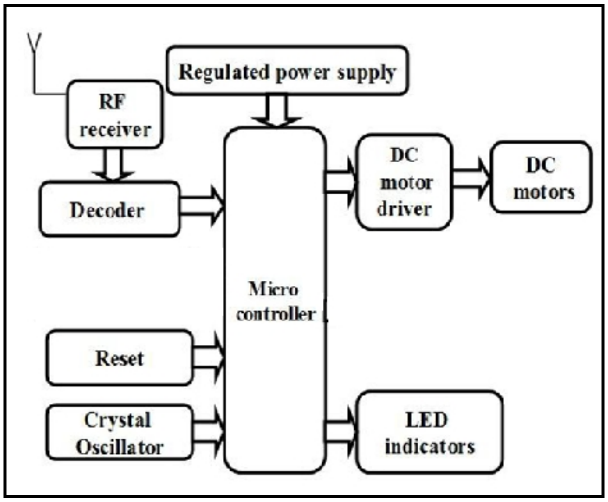

Fig. 2. Receiver block diagram.

II. METHODOLOGY

In this project wheelchair is operated using hand gesture and to sense the hand gesture mems accelerometer is being used.

Micro Electro Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. An accelerometer is an electromechanical device that measures acceleration forces. MEMS accelerometer is a single chip with small size and low cost. Because of their small size and weight, accelerometers are attached to the fingertips and back of the hand. In this model we are using MMA7660FC accelerometer, which is 3axis accelerometer and gives digital output (I2C) [5].

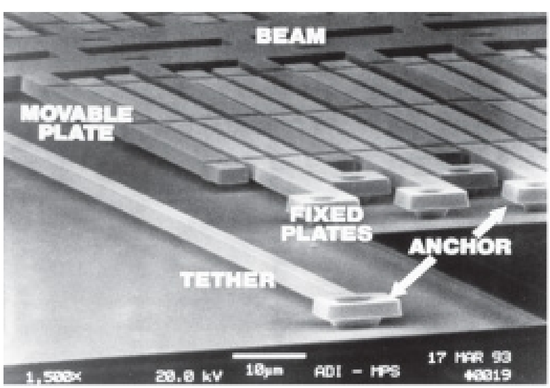

Fig. 3. Mems accelerometer.

The MMA7660FC is a ±1.5 g 3-Axis Accelerometer with Digital Output (I2C). A ±1.5 g accelerometer is more than enough for gravity measurements. A ±2 g is used to measure the motion of the car and at least ±5 g or more for a project that experiences sudden starts or stops.

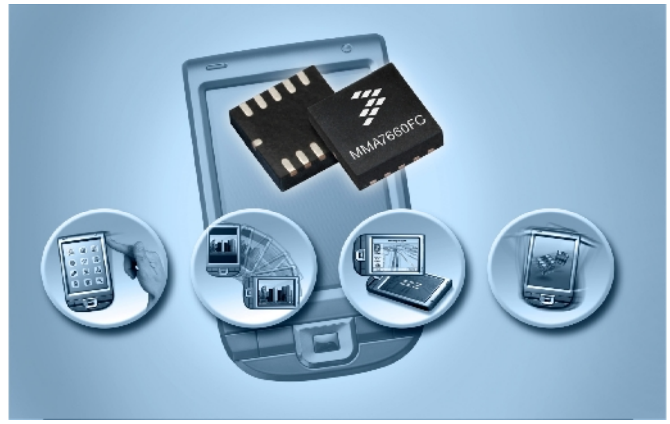

Fig. 4. MMA7660 accelerometer IC.

The sensor can be modelled as a movable beam that moves between two mechanically fixed beams. Two gaps are formed; one being between the movable beam and the first stationary beam and the second between the movable beam and the second stationary beam. The ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors.

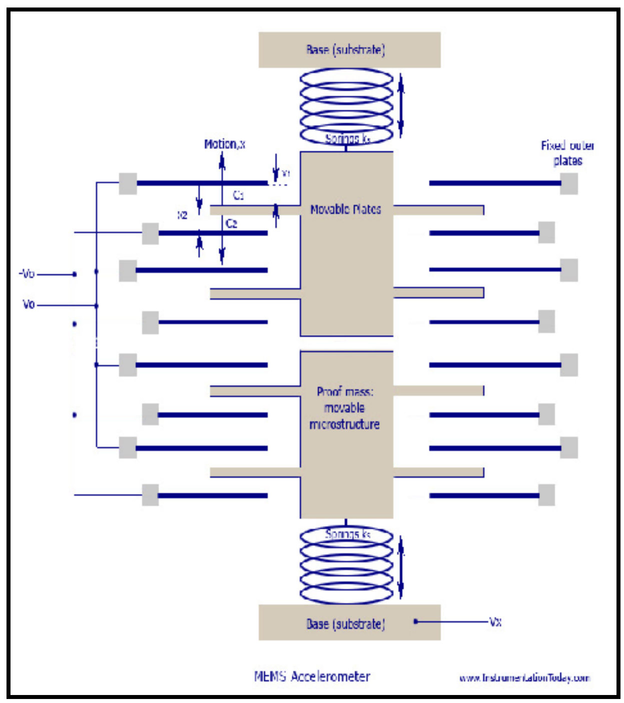

Fig. 5. G cell accelerometer structure.

The parallel plate capacitance is given as

$$Co = \epsilon_0 \epsilon \frac{A}{d} = \epsilon_A \frac{1}{d} \quad ...(1)$$

Where A = area of electrodes
D = distance between them

The free space capacitances between the movable plate & 2 stationary outer plates C1 & C2 are functions of displacements x_1 and x_2.

$$C_1 = \epsilon_A \frac{1}{x1} = \epsilon_A \frac{1}{d+x} = C_0 - \Delta C \qquad ...(2)$$

$$C_2 = \epsilon_A \frac{1}{x2} = \epsilon_A \frac{1}{d-x} = C_0 + \Delta C \qquad ...(3)$$

If x not equal to 0, then capacitance difference is found to be

$$C_2 - C_1 = 2\Delta C = 2\epsilon_A \frac{x}{d^2 - x^2} \qquad ...(4)$$

Solving the linear equation

$$\Delta C x^2 + \epsilon_A x - \Delta C d^2 = 0 \qquad ...(5)$$

For small displacements $\Delta C x^2$ is negligible

$$x \approx \frac{d^2}{\epsilon_A} \Delta C = d \frac{\Delta C}{C_0} \qquad ...(6)$$

This concludes that displacement is directly proportional to capacitive distance. Capacitance difference is in the form of analoge voltages.

We can see in Fig. 5, every sensor has a lot of capacitor sets. Upper capacitors are wired parallel for overall capacitance C_1, and lower once for overall capacitance C_2; otherwise capacitance difference would be negligible.

This capacitance difference is converted into voltage by the following relation

Where

$$(V_x + V_0)C_1 + (V_x - V_0)C_2 = 0 \qquad ...(7)$$

V_O = voltage amplitude with respect to parallel plate capacitor
V_x = voltage output

$$V_x = V_0 \frac{C_2 - C_1}{C_2 + C_1} = \frac{x}{d} V_0 \qquad ...(8)$$

The output using equation (8) is in the form of analog voltage which is then converted into the digital value.

Features

1. Gesture input for straight motion: 60 ms
2. Gesture input for directional motion (left or right): 95 ms
3. Processing speed is 100kbps
4. Power consumption
   Active mode: 47-294 Micro amperes.
   Off mode: .4 Micro Amperes
   Standby mode: 3 Micro Amperes
5. Cross axis Sensitivity (ability to reject an acc applied 90 deg from true axis) is ± 1%
6. Operating voltage = 5V DC
7. Min Voltage = 19.53 mV
8. Max Voltage = 5 V
9. Current for x axis = 350 Micro Amperes
10. Max distance between TX and RX: 100 m
11. Speed and distance of wheelchair depends upon the battery used
12. Noise = ±1 count
13. I2C interface speed = 400 KHz
14. Input leakage current = .025 Micro Amperes

The mems sensor has inbuilt I2C protocol using which the processing speed of the system is increased. Another advantage of I2C is, by using its two lines we can connect up to 128 devices to the controller.

The I2C bus was designed by Philips in the early ‘80s to allow easy communication between components which reside on the same circuit board. The name I2C translates into “Inter IC”. It is sometimes written as I^2C. Simplicity and flexibility are the key characteristics that make this bus attractive to many applications.

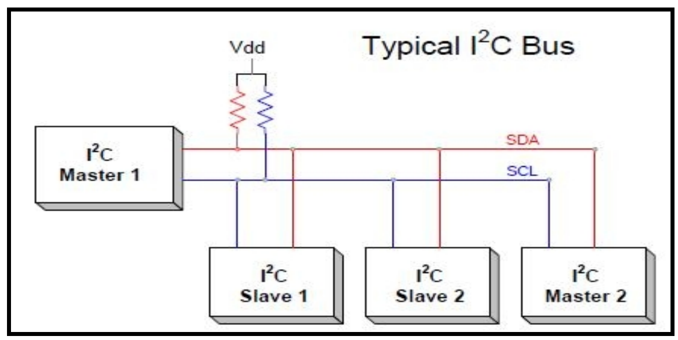

Fig. 6. I2C bus.

Most significant features include:

- Only two bus lines (SDA and SCL) are required
- No strict baud rate requirements.
- Simple master/slave relationships exist between all components
- Each device connected to the bus is software-addressable by a unique address
- I2C is a true multi-master bus providing arbitration and collision detection.
  All I2C addresses are either 7 bits or 10 bits. All of our modules and the common chips you will use will have 7 bit addresses. This means that you can have up to 128 devices on the I2C bus, since a 7bit number can be from 0 to 127.

III. RF MODULE WITH INTERMEDIATE RESULTS

Transmission through RF is better than IR (infrared) because of many reasons. Firstly, signals through RF can travel through larger distances making it suitable for long range applications. Also, while IR mostly operates in line-of-sight mode, RF signals can travel even when there is an obstruction between transmitter & receiver. Next, RF transmission is more strong and reliable than IR transmission. RF communication uses a specific frequency unlike IR signals which are affected by other IR emitting sources.

This RF module comprises of an RF Transmitter and an RF Receiver**.** The transmitter/receiver (TX /RX) pair operates at a frequency of 433 MHz an RF transmitter receives serial data and transmits it wirelessly [6] through RF through its antenna connected at pin4. The transmission occurs at the rate of 1Kbps - 10Kbps.The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter.

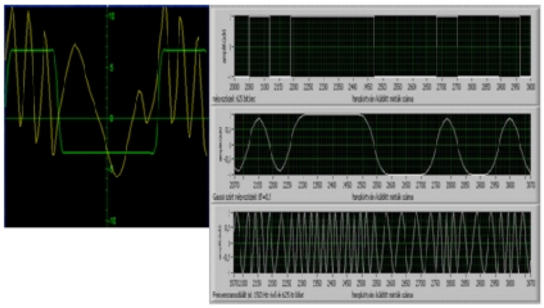

Fig. 7. General FSK modulated output from RF Transmitter at 433 Mhz.

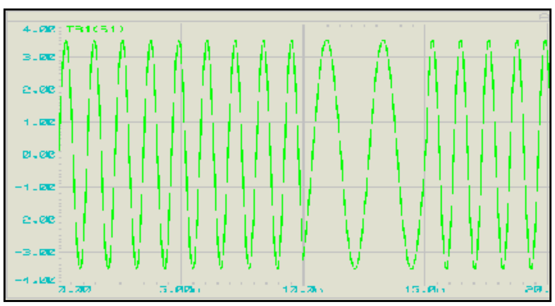

Fig. 8. 1101 =13 binary data output from RF TX.

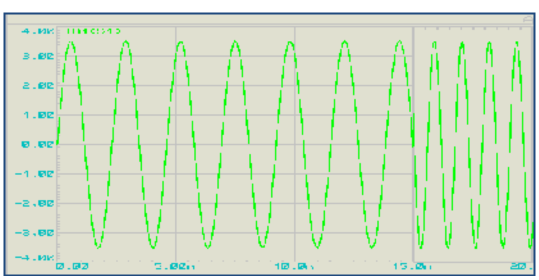

Fig. 9. 0001 =1 binary data output from RF TX.

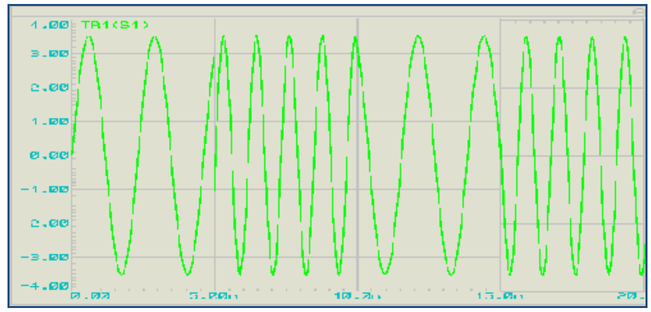

Fig. 10. 0101 5 binary data output from RF TX.

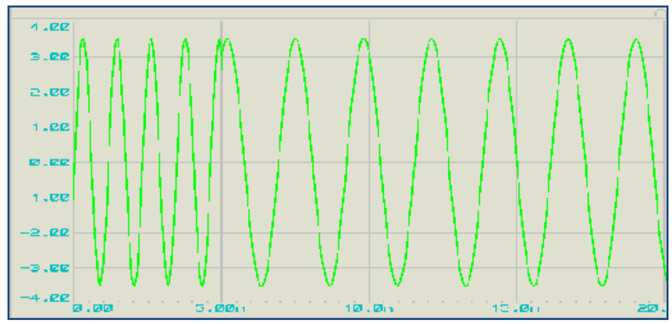

Fig. 11. 1000 = 8 binary data output from RF TX.

IV. WORKING

When the device is switched on, PIC microcontroller (acting as a master) sends the address 0x98 on the I2C bus to look if any slave with the same address exists or not. Now the MMA7660 accelerometer (acting as slave) sends the acknowledgement of its presence back to the controller. On receiving the positive acknowledgement, PIC microcontroller initializes the registers of the sensor. After the initialization of the sensor registers PIC microcontroller start calling the data stored in the sensor memory one by one. Data which is called is stored in two temporary registers Rd (0) and Rd (1) so that routine functioning of the controller is not disturbed. The data stored in temporary registers is then sent to the PIC controller for further processing. Fig. 12 shows the step by step functioning of the transmitter.

At the receiver, the value for x direction is initialized at port 1. The value at port 1 is then stored in accumulator register. Now the digital output received from the transmitter is compared one by one with the value of accumulator. If the value is equal to 13 then the motor connected at port 2 using motor driver performs stop function and the value motor driver is oooo. If it is not equal to 13 then the value of accumulator is compared to next output and so on. Fig. 13 shows the step by step functioning of the receiver.

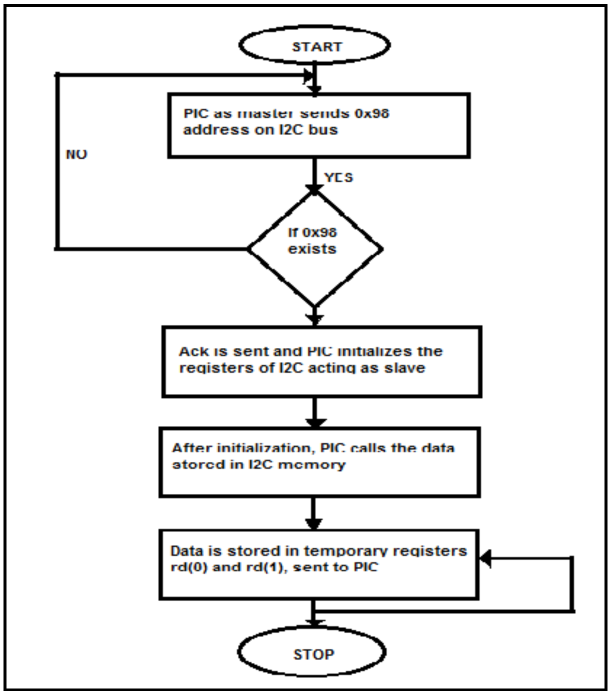

Fig. 12. Flow chart showing the transmitter working.

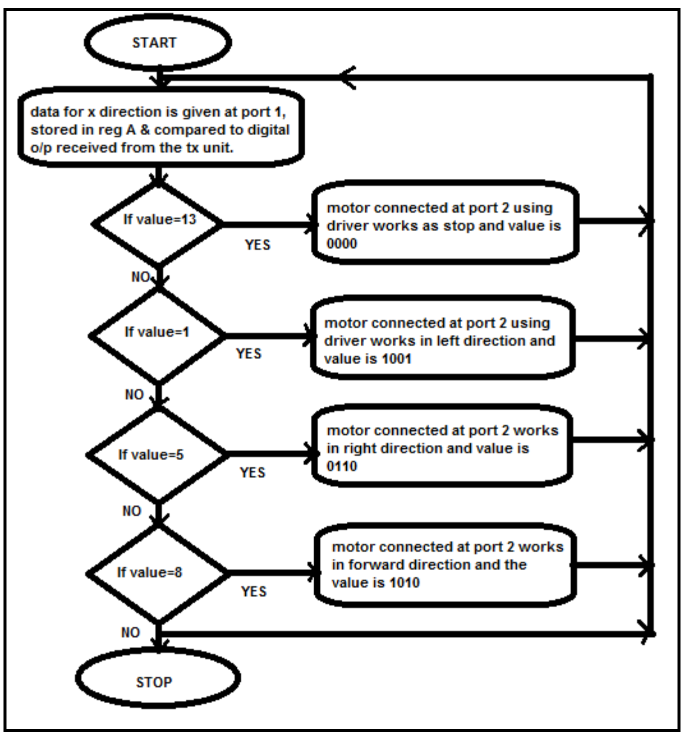

Fig. 13. Flow chart showing the receiver working.

V. RESULTS AND DISCUSSIONS

Using above procedure hardware is developed. Fig. 14 shows both the transmitter and receiver unit.

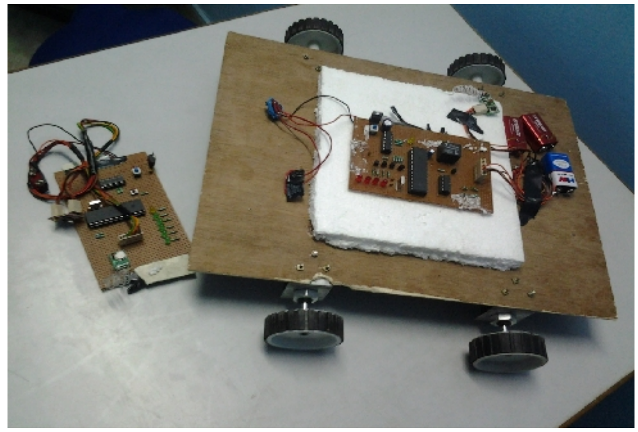

Fig. 14. Hardware Setup for TX and Rx.

Table 1: Shows the tilt of the hand and the corresponding analog and digital values.

HAND GESTURE DIRECTION	ANGLE X	ANALOG VOLTAGES	DIGITAL O/P
LEFT	2.69°	19.53mV	0000 0001
RIGHT	13.55°	97.65mV	0000 0101
FORWARD	22.02°	156.24mV	0000 1000
STOP	37.54°	253.89mV	0000 1101

After receiving the output from the transmitter unit, the receiver unit which is the wheelchair is operated. Fig. 15 shows output part when motors attached to wheel, driven by motor driver performs a stop action by displaying 13 output on led's. Similarly digital binary output, as displayed on led's turns the wheelchair into the left direction. If wheelchair is to be moved in right direction then movement of hand should be in right direction giving the digital binary output 5 as shown in Fig. 17.

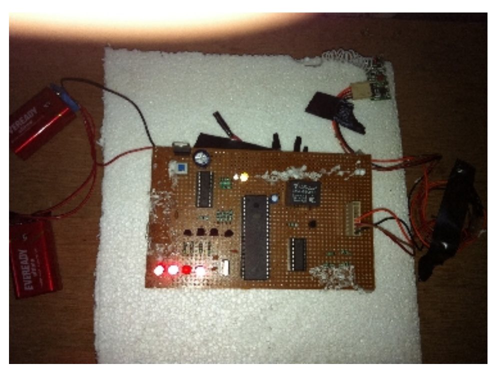

Fig. 15. Digital binary output 1101 shows stop action.

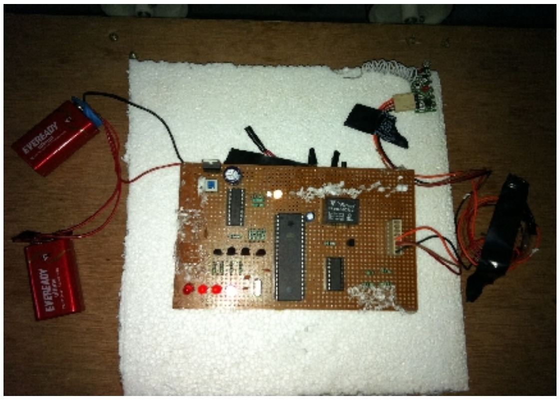

Fig. 16. Digital binary output 0001 shows left turn direction.

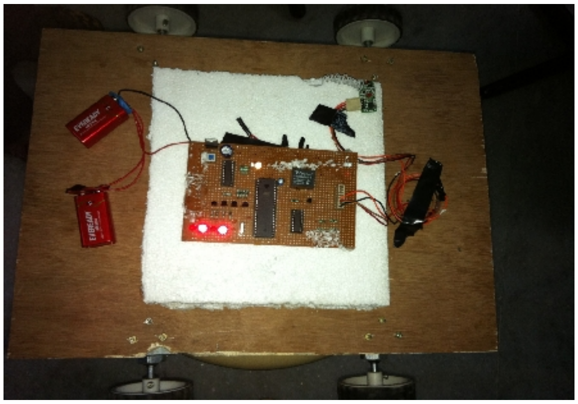

Fig. 17. Digital binary output 0101 shows right turn direction.

VI. CONCLUSIONS

In the race of man v/c machine, hand gesture controlled s/m comes as an e.g. of companionship of man and machine. Taking the technology to the next level from speech recognitions and wired connections is the technology of wireless hand gesture controlled s/m. Using a simple I2C chip we can connect up to 128 chairs using a single remote. The applications of the same can be plenty. This s/m gives the user independence and a psychological advantage of being independent. To avoid physical hardship to the user come the accelerometer to the rescue as with the slight twist of the finger the user gets the ability and freedom to turn the wheelchair into the desired direction. Of course some training is essential to use the acc as its quite sensitive but in the end there could not be a better use of technology for an individual who is deprived of the same physical strength.

In future several wheelchairs (up to 128) can be operated using a single remote with accelerometer and PIC as master and various wheelchairs developed using microcontrollers as slave. This system can be extended by including GSM which sends an SMS during emergency by assigning particular gesture command. By including GPS, position of the wheelchair can also be known. Wheel chair can be fitted with direct mind reader. For example, if a person is paralyzed and cannot move his body parts, in that case it can be used.

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