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Design and Development of Head Motion Controlled Wheelchair

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Abstract: *The aim of this project is to design and develop a head-motion-controlled wheelchair that enables individuals with severe physical disabilities to achieve safe and independent mobility using simple head-tilt gestures. The system is targeted for users who are unable to move their hands or legs but can perform controlled head or eye movements. A tilt-based communicator system equipped with tilt sensors is used to capture head orientation data, which is then transmitted wirelessly to the wheelchair control unit. Based on the detected head tiltforward, backward, left, or right—the wheelchair moves in the corresponding direction, allowing intuitive and hands-free navigation.*

The prototype integrates tilt sensors, wireless modules, and a microcontroller-based control system to ensure reliable and responsive operation. The wheelchair has been practically implemented and tested with a user sitting on it, demonstrating stable performance and a weight-bearing capacity of up to 100 kg. The design focuses on achieving functionality at a significantly lower cost compared to commercial assistive wheelchairs, while maintaining ease of operation and user safety.

The head-motion-controlled wheelchair provides a valuable mobility solution for quadriplegic patients and individuals with 45% or more disability, offering an accessible, gesture-based alternative to joystick or voice-controlled systems. Experimental results confirm that the system is user-friendly, robust, and capable of effectively translating head gestures into precise wheelchair movement.

Keywords: Tilt Sensors, Wireless Control, Gesture-Based Control, Head Motion Interface, Assistive Technology, Gear Ratio.

I. INTRODUCTION

Mobility is essential for independent living and greatly influences the emotional, psychological, and physical well-being of individuals. Loss of mobility due to spinal cord injuries, neurological disorders, or congenital impairments often results in dependency on caregivers for basic movement, thereby affecting self-confidence. Studies show that approximately 43 million people—around 17% of a 250-million population—are disabled, with 52% paraplegics and 47% quadriplegics among individuals suffering from spinal cord injuries [1]. Quadriplegic patients, in particular, experience severe limitations in their upper and lower limbs, making conventional joystick-based electric wheelchairs unsuitable for them.

This project proposes the design and development of a head motion controlled wheelchair using a tilt-communicator system. The system is designed for individuals who cannot move their hands or legs but can generate voluntary head movements. By detecting head tilts in four directions—forward, backward, left, and right—the wheelchair can be controlled without manual intervention. The wheelchair stops whenever the user maintains a neutral head posture, enhancing safety and operational stability.

Globally, several research groups have undertaken initiatives to create advanced assistive technologies aimed at enhancing the independence and social integration of disabled individuals [3], [4]. While automatic and programmable wheelchairs exist, they are often expensive and unaffordable for the average user. Additionally, quadriplegic patients cannot operate joystick-based systems due to motor impairments [5].

To overcome these limitations, the proposed system uses low-cost analog and digital circuits, along with tilt sensors, to provide a robust, easy-to-use, and affordable mobility solution. The design eliminates the need for complex microcontroller programming, making the system cost-effective while maintaining reliable gesture-based control.

This paper is organized into seven sections: section ii describes the basic working principle of the electronic circuits. Section iii and iv present the proposed block diagram and circuit design details. Section v discusses the mechanical design. Section vi provides the results, and section vii concludes the study.

II. WORKING PRINCIPLE OF THE SYSTEM

The head motion control system operates on a simple principle:

head movement → tilt sensor activation → signal processing → wireless transmission → motor actuation.

A. Head tilt detection

Tilt sensors detect the angular displacement of the user's head. When the head tilts in any direction, the tilt switch closes or opens its internal contacts, generating a corresponding digital signal.

B. Signal conditioning and interpretation

The sensor outputs are fed into a comparator and signal conditioning stage. This stage eliminates noise and ensures clean digital transitions for reliable system operation.

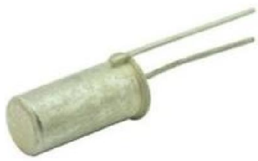

Figure1: Tilt Sensor

Atilt sensor can measure the tiltingin two axes. It usually consists of a free mass rolling ball inside it and a conductive plate at the bottom that opens or closes connection with the circuit.

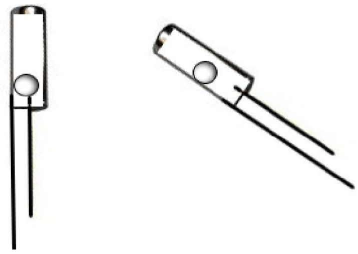

Figure 2: Schematic diagram of tilt sensor with open and closed circuit

The tilt sensors are connected in a potential divider circuit that generates appropriate voltage signals. These signals are fed to a diode logic circuit that converts these signals into desired signals required to move the motors in the wheelchair in appropriate directions. The diode logic is simple and easy to implement and replaces the use of complex and costly microcontrollers for generating the same logic. These signals are then given to a wireless transmitter fitted onto the top of the hat itself and sends the head tilt signals wirelessly to the wheelchair.

Finally, at the receiver end, a wireless receiver receives and decodes these signals back to the desired ones and drives a ULN2003 amplifier. The ULN2003 IC drives the SPDT relays used in the receiver section that controls the motors. DC geared motors are used to drive the wheelchair. As the idea for designing intelligent wheel chair can be easily implemented, this product could prove to be a great application for market and for assisting many handicapped persons in economical ways.

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III. BLOCK DIAGRAM

Transmitter section

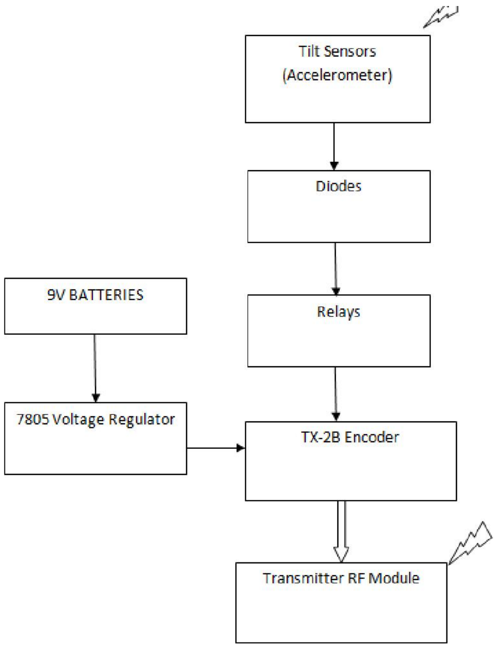

Figure 3: Block Diagram of Transmitter section of Head Motion Controlled Wheelchair

Receiver section

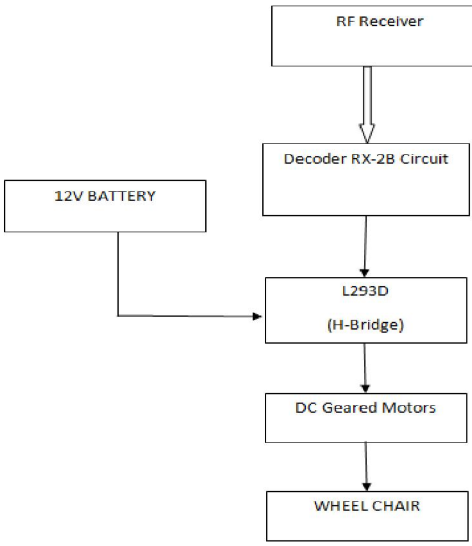

Figure 4: Block Diagram of Receiver section of Head Motion Controlled Wheelchair

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Circuit Diagram

Transmitter Circuit Diagram (Remote Fitted On Head)

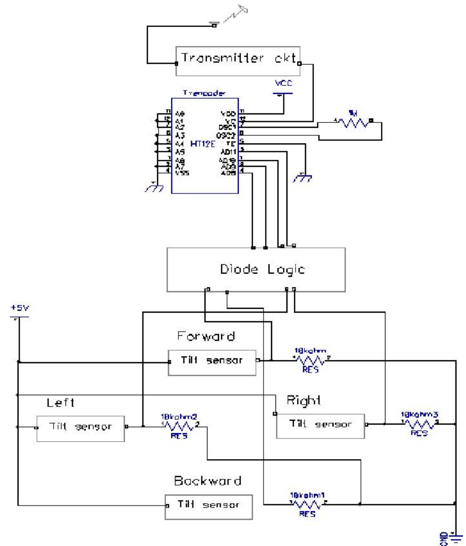

Figure 5: Circuit Diagram of Transmitter Section

Receiver Circuit Diagram

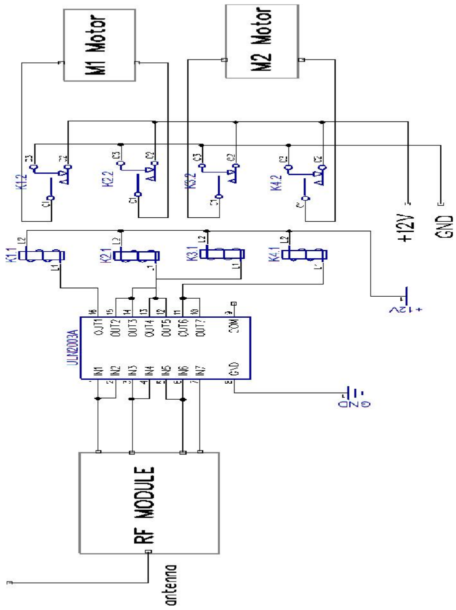

Figure 6: Circuit Diagram of Receiver Section

Description of components used:

Various components used in this project are described below:

Tilt Sensors:

As discussed earlier, tilt sensor is used to detect the direction of head tilt by means of a free mass rolling ball inside that either closes or opens a contact between its pins. Each tilt sensor is connected in series with a 10k resistor to make a potential divider circuit and generate 0 V when tilted in a particular direction and 5 V when no tilt is made as it is clear from figure 4.

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Diode Logic

A diode is a device that allows unidirectional current flow through a circuit. We have used 1N4007 diodes to provide the desired logic indicated in Table 1 for moving the wheelchair in four directions. With the use of diode logic, we have avoided the use of microcontrollers in the circuit.

Table 1: Digital Logic for moving wheelchair in different directions

S.No.	Digital Logic	Direction of Motion
1.	1010	Forward
2.	0101	Backward
3.	1001	Left
4.	0110	Right
5.	1111	Stop

ULN2003: It consists of 7 independent Darlington pairs that generate a high current output of upto 1 Ampere. This IC is used to drive 4 Relays that operate the motors in the wheelchair.

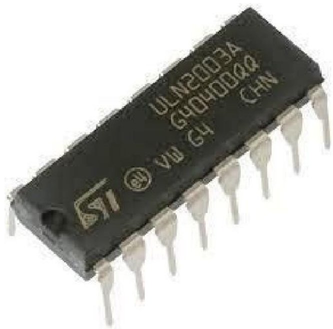

Figure 7: ULN2003 IC used in our project

Relays: A **relay** is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. In our project, we have used 4 SPDT relays in order to operate the two DC motors of the wheelchair.

DC Motor:

DC geared motors are used in our wheelchair to drive the system in forward, backward, left and right directions as indicated in table 1. 12 V DC motors have been used powered by a rechargeable battery of 12 V, 7 Ah.

Figure 8: DC Geared motor used in our project

IV. MECHANICAL DESIGN

We have deigned the wheelchair chassis considering the cost-effective features. The Mechanical design has been made using a chassis of Mild Steel that is a rectangular frame supported by from two castor wheels and rear drive wheels. The power is provided to the rear wheels using the DC geared motor shown in the figure 7. Castor wheels act as free wheels to allow easy rotation of the wheelchair. The drive shaft includes custom designed Hubs for mounting the motor onto the shaft of wheels through a gear transmission system. A gear reduction using two spur gears with the gear ratio of 1:10 is used to drive the rear wheel. This is done in order to reduce the load on the motor shaft while a person sitting on the wheelchair and operating it.

Complete chassis made using welding and lathe machining. A chair is fitted on the top of the chassis for sitting and again fitted using welding joints on the base. Circuit board of the receiver unit is placed on the back of the chair using nut-bolts.

The complete assembled wheelchair operated by head movements is presented in the following figure.

Figure 9: Head Motion controlled wheelchair

V. RESULTS AND DISCUSSION

After completing the development of the head-motion-controlled wheelchair, extensive testing was conducted under various operating conditions. The system performed reliably during all tests, confirming the effectiveness of the head-tilt–based control mechanism. The transmitter unit equipped with tilt sensors responded accurately to forward, backward, left, and right head movements. Users were able to initiate motion and stop the wheelchair smoothly by simply returning their head to a neutral position.

The wireless communication module demonstrated stable performance, successfully transmitting control signals from the head-mounted transmitter to the receiver unit installed on the wheelchair. Although the current RF module provides sufficient range for indoor applications, the system could be further enhanced by integrating higher-range wireless technologies such as ASF or FSK-based 434 MHz modules to improve overall stability and responsiveness.

Cost analysis revealed that the complete system—including mechanical structure, electronic circuitry, and control modules—can be constructed for approximately **30,000 INR**, which is significantly lower than commercially available automatic or joystick-controlled wheelchairs. The project successfully meets its goal of delivering a **cost-effective, reliable, and user-friendly mobility solution** for individuals with severe motor impairments.

VI. CONCLUSION

The developed head-motion-controlled wheelchair proves to be an effective mobility solution for individuals suffering from quadriplegia or spinal cord injuries who cannot move their hands or legs. The system effectively interprets head-tilt movements, providing effortless control in all four directions without the need for manual input. Compared to

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conventional joystick-controlled wheelchairs, this design offers greater ease of operation, enhanced accessibility, and increased independence for users with more than **45% physical disability**.

The simplicity of tilt-sensor–based control, combined with an economical design that avoids costly microcontrollers, makes this system a practical alternative to expensive powered wheelchair solutions currently available in the market. Overall, the project successfully meets its objectives by delivering an affordable, intuitive, and reliable assistive device that significantly improves mobility and quality of life for physically challenged individuals.

A cost-effective and user-friendly head-motion-controlled wheelchair has been successfully designed and implemented. The system uses tilt sensors and wireless communication to translate simple head gestures into wheelchair movement, addressing the mobility needs of individuals with severe motor impairments. The design avoids complex microcontrollers to reduce cost while maintaining reliability and safety. This wheelchair provides an affordable, practical, and efficient solution for quadriplegic and mobility-impaired individuals, significantly improving their independence and quality of life.

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