

Motorized Hand Bike for a Manual Wheelchair

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ABSTRACT: This paper involves the design of a motorized hand bike that can be attached to a manual wheelchair for greater mobility on roads without strain. The hand bike consists of an electric motor, powered by a rechargeable battery, a motor controller, electric throttle and mechanical brakes for driving controls. A force sensitive resistor (FSR) sensor, present on the handle, is pressed before applying brakes. Depending on the force applied on the FSR, the microcontroller reduces the PWM duty cycle to the motor. An ultrasonic sensor mounted on the bike, reduces the PWM duty cycle rapidly on detecting an obstacle.

KEYWORDS: Manual wheelchair, Hand bike, Brushless DC motor, Force Sensitive Resistor sensor, Obstacle detection.

I. INTRODUCTION

In general manual wheelchairs are mostly preferred than motorized wheelchairs by disabled people. Besides the fact that manual wheelchairs weigh lighter than motorized ones, have less maintenance, costs less and have greater portability; they have an added advantage of promoting physical fitness in the upper extremity of the disabled person. In spite of providing exercise, this repetitive motion of propelling the wheelchair, may cause injury in the shoulder due to overuse. Therefore the only disadvantage of using a manual wheelchair is the possibility of contracting an upper body repetitive strain injury (RSI) due to continuous propulsion of the hand rim wheelchair.

II. RELATED WORK

Many methods have been suggested by authors to overcome this disadvantage prevalent in manual wheelchair. Few of them are as follows. Amar Nishant Singh et al developed a tricycle that can be driven by either an electric motor or a hand crank [1]. The hand crank drives the front wheel and operates independently from the motor. Yu Munakata et al developed a prototype of an external motorized system with an active caster wheel mounted on a manual wheelchair [2]. The motion of this motorized wheelchair was controlled by a 2DOF joystick. Motorizing the manual wheelchair by means of an electric motor and using a joystick to control movements was developed by Ruoyu Hou et al [3]. Another method involves the propulsion of a manual wheelchair through a handcycling unit attachable to the wheelchair. The shoulder load during handcycling at different speed conditions and that of normal wheelchair propulsion under similar conditions of external power in persons with spinal cord injury were compared and studied by Ursina Arnet et al [4], [5]. It was observed that mobility by handcycling also causes a considerable amount of shoulder pain due to continuous cycling. Richard Simpson et al developed a power assist wheelchair with obstacle detection, to aid disabled person with visual impairments [6]. Benjamin Andrew Salentine conducted a survey on the pros and cons of both the manual and power assist wheelchairs and how they affect the quality of life and self-perception [7]. Hand propelled tricycles and side wheel attached scooters are available to aid the disabled people to ride on roads. But they would require a separate manual or power wheelchair for indoor use. Mobility vehicles are available separately for indoor and outdoor purposes but there is no common vehicle suiting both the purposes.

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In this paper, the above mentioned disadvantage is eliminated by an additional front wheel fixed with an electric motor, fitted to a handle with driving controls, which is attachable to the wheelchair. Compared to the propulsion of hand rim wheelchair, this technique is more efficient and causes much lesser strain to the shoulders. It enables the user to ride the wheelchair even on roads with ease. For indoor purposes the hand bike can be detached from the wheelchair, if not needed and could be used normally. In this way physical fitness is maintained by exercising through the propulsion of hand rim wheelchair while also taking care to avoid contracting an upper body RSI by using the hand bike whenever necessary. The motorized hand bike eliminates the need for separate mobility vehicles for indoor and outdoor use.

III. METHODOLOGY

The basic model of the hand bike is as shown in the Figure 1. The design of the motorized hand bike consists of a brushless DC motor powered by a rechargeable battery. The hand bike has clamps for attaching itself to the frame of the footrest in a manual wheelchair. Therefore it can be detached easily from the wheelchair when it is not needed. It has controls for moving in forward direction, rotatable handle for making turns and mechanical hand brakes.

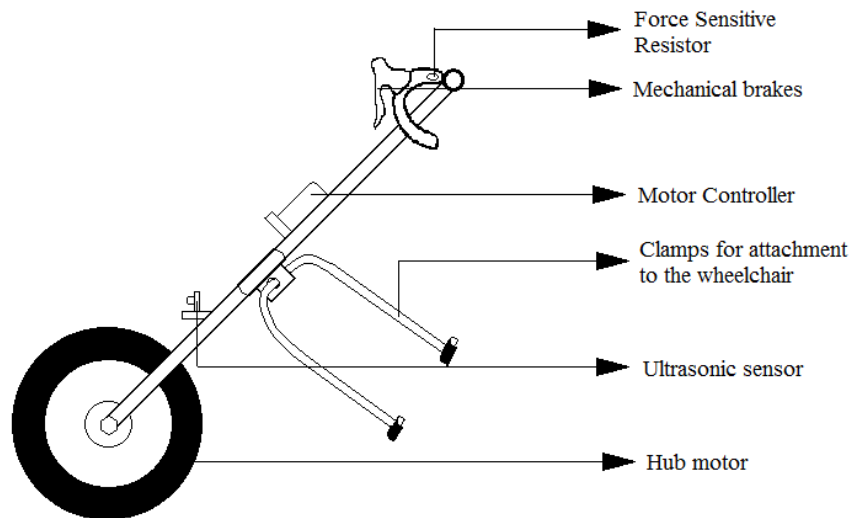


Figure 1: Basic model of the Motorized Hand Bike

The hand bike contains

- A. **Brushless DC motor:** It is also known as a hub motor or a BLDC motor. They are typically brushless motors and contains a number of separate coils and an electronic circuit. The circuits switches the power ON and OFF in the coils and this creates force in each of them, thus making the motor spin. The electric motor is powered by a rechargeable lithium ion battery.
- B. **Motor Controller:** The main purpose of the motor controller includes hall sensor communication, motor speed measurement, PWM output to the motor, protection from over-voltage, over current and thermal protection.
- C. **Microcontroller:** ATMEGA32 microcontroller is used to analyse the inputs from the throttle, Force Sensitive Resistor and from the ultrasonic sensor and then accordingly calculates the analog input that is to be fed into the motor controller. This analog input decides the PWM duty cycle to be given to the motor.
- D. **Electric Throttle and Brake:** The electric throttle has three connections – a 5V supply, a ground wire and an analog output which varies depending upon the degree to which the throttle is rotated. The first and the second connections are given from the motor controller while the analog output is connected to the analog input of the microcontroller. The analog output varies from 1V to 4V. The mechanical brake is fixed to the hub motor.

- E. Force Sensitive Resistor (FSR) Sensor: Force sensitive resistor (FSR) sensor is present on the handle and is pressed before applying brakes. When force is applied on the FSR, it signals the microcontroller to provide a PWM output with lesser duty cycle to the motor i.e., lesser voltage is supplied to the wheel. This reduces the wear and tear of the braking system when the brakes are applied to the wheel running on a lesser input voltage. Depending on the force applied on the FSR sensor, the microcontroller varies the PWM output to the motor controller of the BLDC motor. Greater the force applied on the FSR, lesser is the PWM duty cycle.
- F. Ultrasonic Sensor: It is employed to automatically reduce the speed on detecting an obstacle within the threshold distance. On detecting an obstacle the microcontroller rapidly reduces the PWM duty cycle to the motor. It helps in providing stability to the wheelchair in the case of application of sudden brakes.
- G. Rechargeable Battery: Lithium ion battery is used as the power source, since it is light weight and easily portable.

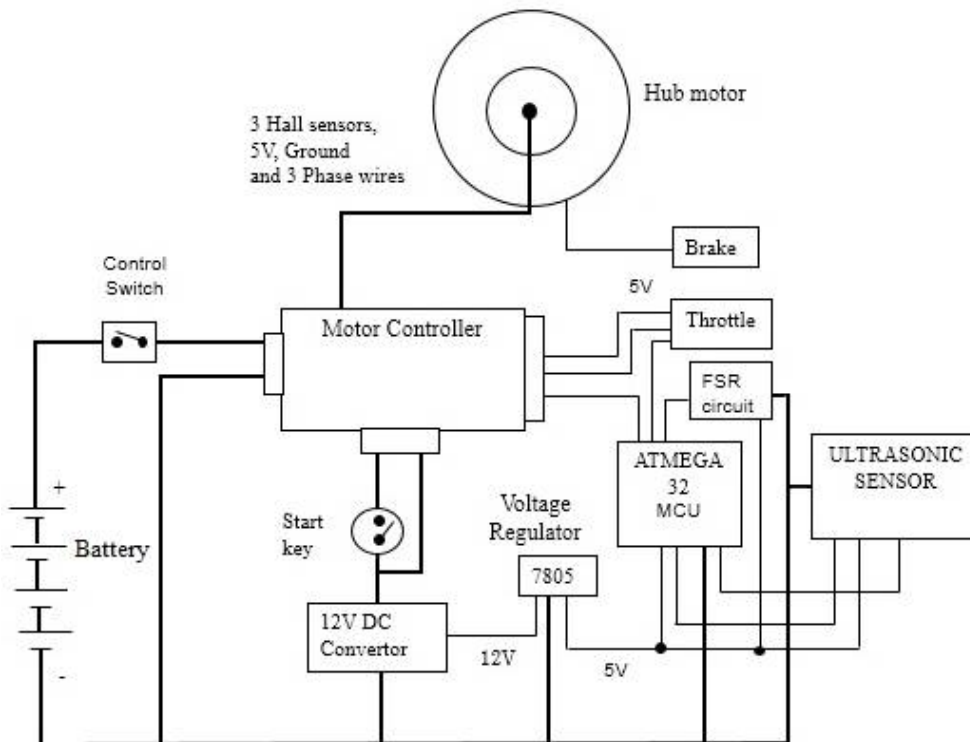


Figure 2: Block diagram

The block diagram of the whole circuit is as shown in the Figure 2. The battery is connected to the motor controller through a control switch. Only when the start key is turned ON, the power is supplied to the motor controller circuit and to the 12V DC converter. The 12V output from the DC converter is given to the input pin of 7805 voltage regulator, which produces a 5V output. This 5V supply is provided to the microcontroller, throttle, FSR sensor and ultrasonic sensor. The analog outputs from the throttle and the FSR sensor are connected to the AD0 and AD1 pins of the ATMEGA32 microcontroller respectively. The echo pin of the ultrasonic sensor is connected to the interrupt pin of the microcontroller. The microcontroller periodically sends a high-level signal for 10µs to the trigger pin of the ultrasonic sensor and checks the interrupt pin. If the interrupt pin is high, there are no obstacle detected and the microcontroller gives the analog output from the throttle to the motor controller; if there is no input from the FSR sensor. If the interrupt pin goes low, an obstacle is detected and the microcontroller rapidly reduces the analog value sent to the motor controller which in turn reduces the PWM duty cycle to the electric motor.

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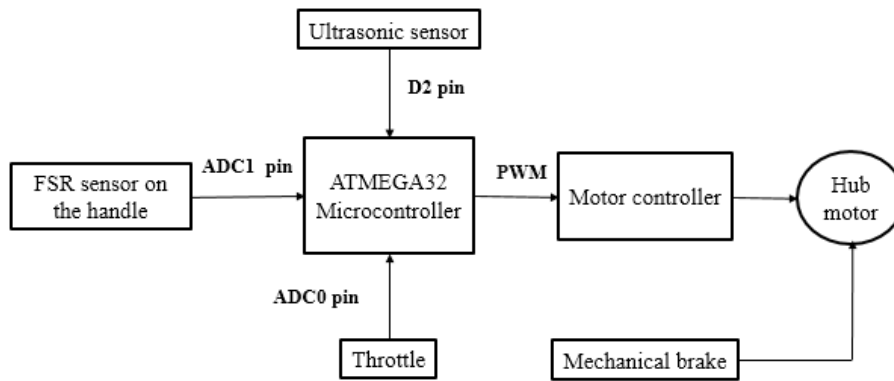


Figure 3: Flow diagram representing the control flow mechanism

When there is no obstacle detected, the microcontroller checks for any input from the FSR sensor. If there is no input detected it sends the input analog voltage from the throttle to the motor controller. If any input voltage is detected on the AD1 pin, the PWM duty cycle decreases from the current duty cycle according to the force applied on the FSR. The motor controller sensing the decrease in input voltage from the microcontroller, reduces the PWM duty cycle to the hub motor rapidly. If the force on the FSR is maximum, PWM duty cycle will be 0% and there will be no supply to the motor. Thus when the brakes are applied, the motion of the wheel ceases and stops. This method decreases the wear and tear of the braking system. Figure 3 depicts the flow diagram representation of the workflow explained above.

IV. SIMULATION AND RESULTS

The code for the above described workflow produced the simulation outputs as shown in the figure 4(a), 4(b) and 4(c). In figure 4(a) the throttle is kept at 50% output and there is no force applied on the FSR sensor. The PWM output is directly proportional to the throttle output. In figure 4(b) throttle is kept at maximum and some amount of force is applied on the FSR sensor. It can be noted that the PWM duty cycle reduces depending on the force applied on the FSR. In figure 4(c) on detecting an obstacle the PWM duty cycle reduces rapidly from the throttle output.

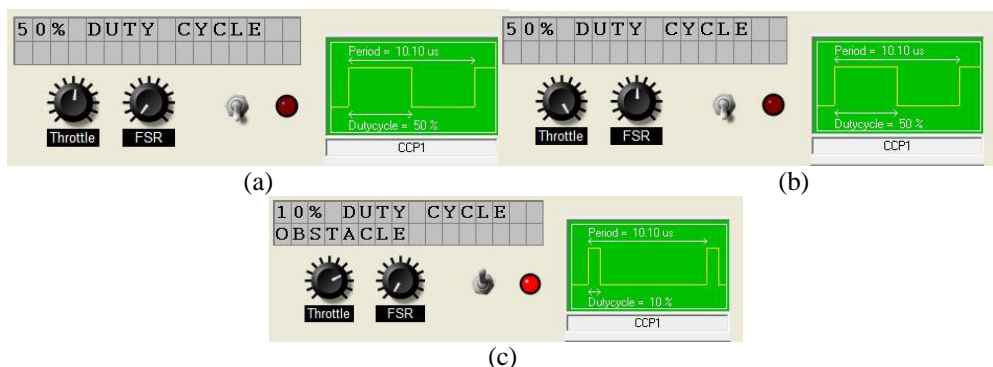


Figure 4: Simulation Results. (a) Throttle at 50; FSR at 0; 50% duty cycle; No Obstacle. (b) Throttle at 100; FSR at 50; 50% duty cycle; No Obstacle. (c) Throttle at random; Obstacle detected; 10% dutycycle

When there was no obstacle detected, the PWM duty cycle depended only on the output value from the throttle as long as FSR sensor remained undisturbed. When force was applied on the FSR sensor, the PWM duty cycle reduced depending on the amount of force applied on it. The detection of an obstacle reduced the PWM duty cycle rapidly depending upon the throttle value. The electric motor requires a minimum of 20% PWM duty cycle to pull the vehicle. It can be observed from the graph in figure 5(c) that when an obstacle is present the maximum PWM duty cycle is 15%,

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which is lesser than the required PWM duty cycle. Therefore the supply to the electric motor would be approximately 0V and so when the brakes are applied to a wheel running with no input supply, it ceases its motion and stops immediately.

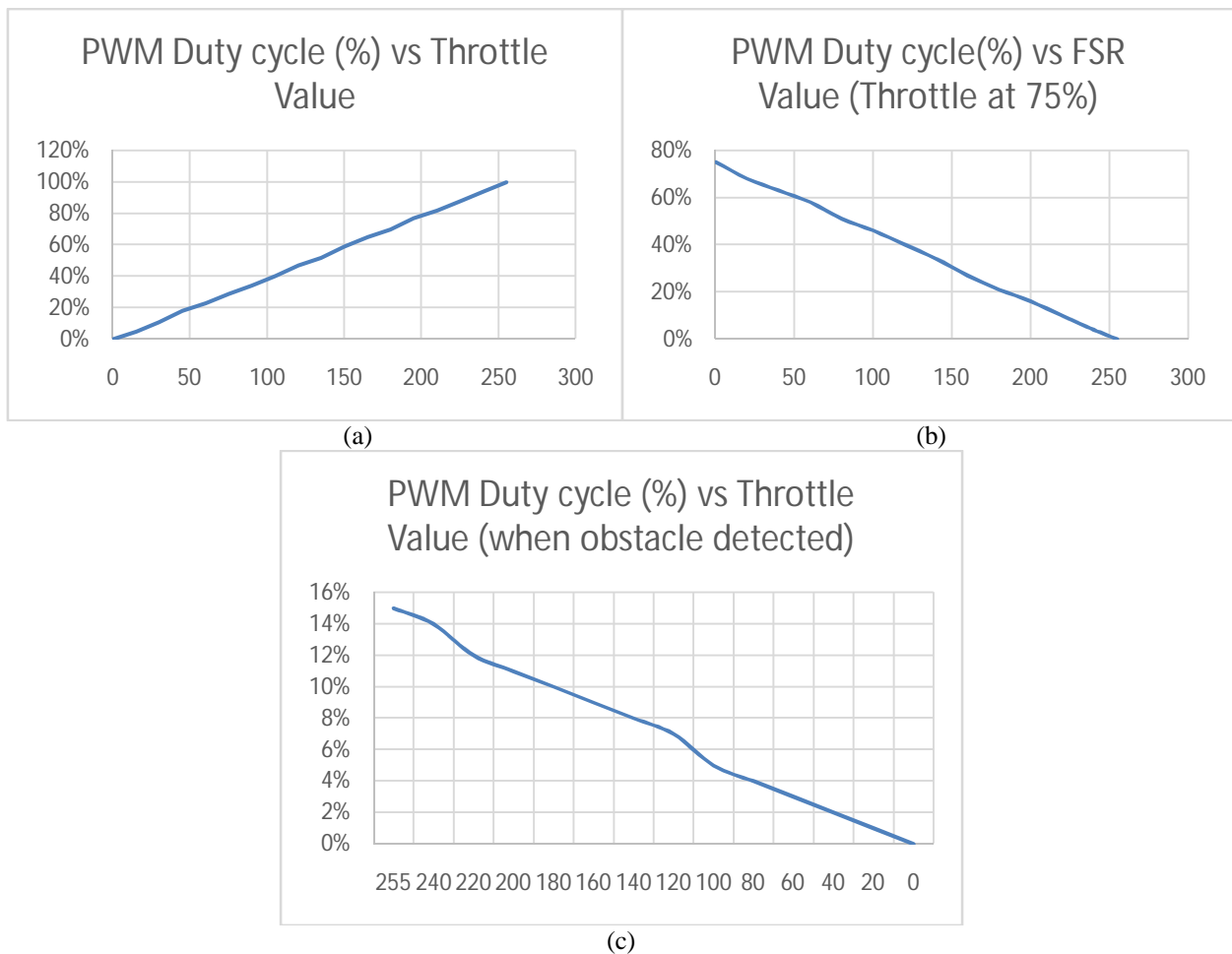


Figure 5: PWM duty cycle plots (a) PWM duty cycle vs Throttle value when FSR input is zero and no obstacle is present. (b) PWM duty cycle vs FSR value when the throttle is maintained at 75% output and no obstacle is present. (c) Reduction in PWM duty cycle when an obstacle is present.

The Figure 5(a) shows a linear relationship between the output value from the throttle and the PWM duty cycle from the motor controller. The Figure 5(b) shows the reduction in the PWM duty cycle as the force applied on the FSR sensor increases, when the throttle is maintained at a 75% output position. When maximum force is applied on the FSR sensor, no supply is given to the electric motor and thus when the brakes are applied, it comes to a halt immediately. This mechanism reduces the wear and tear of the braking system of the hand bike.

V. CONCLUSION

The motorized hand bike that can be attached to a manual wheelchair is presented in this paper. It aids the disabled people to easily ride on roads and reduces the strain on their shoulder. As the hand bike attached manual wheelchair can be used outdoors as well as indoors, it eliminates the need for a separate mobility vehicle for each purpose. Thus

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the motorized hand bike for the manual wheelchair would benefit the person with disability financially and also provides great portability, faster mobility, and requires less maintenance.

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