بسم الله الرحمن الرحيم

ISLAMIC UNIVERSITY OF TECHNOLOGY

(IUT)

Department Of Electrical And Electronic Engineering

Microcontroller Based Joystick Controlled Wheelchair

A project report presented
By
Md. Salek Mahmud (082403)
Towfiq-ur- Rahman (082429)
Md. Delwar Hossain (082413)

SUPERVISED BY

Dr. Md. AshrafulHaque
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A project report submitted to the Department Of Electrical And Electronic Engineering in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical And Electronic Engineering

Department Of Electrical And Electronic Engineering (EEE)

Abstract

When people are unable to walk properly due to old age or as a result of some accident or paralysis due to stroke they may often lose their ability to control their movement and means to travel from one place to another.The prime objective of this research was to develop a prototype system which can provide mobility assistance to individuals.This thesis investigates the method of locomotion via a wheelchair which is controlled using input from a joystick and is analyzed via a microcontroller and out drives the motor. This thesis also consider the design consideration of a simple, low cost battery driven wheelchair where the control is achieved using a microcontroller. Two dc motors are differentially driven using PWM signal from microcontroller which provide easy control over speed and direction. There are further proposed design consideration which includes self-sustaining power supply using PV cells with the wheelchair and also long distance wireless control and use of sensors for autonomous control of the wheelchair.

Keywords-*microcontroller, joystick, wheelchair, pwm*

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Chapter 1

Introduction

1.1 The context

The basic purpose of this thesis was to design a prototype model of wheel chair which will help in the locomotion of the physically disabled people. The electronic controlled wheelchairs are present in Bangladesh which are very expensive and are out of reach for the middle class and poor people. The design was mainly targeted to build a prototype which will be cost efficient and also effective and long lasting. It does include simple battery powered motors which is controlled by a microcontroller which takes input from the user. The project also keeps scope for further development of the prototype which can be modified into a more sophisticated design.

If we classify the smart wheelchairs by the form factor : Some of the designed systems are simply mobile robots with a chair on top (e.g. Mister Ed, VAHM). And some are based on modified commercial wheelchairs (e.g., OMNI SENARIO) or the third group which are collections of components with an add-on unit that can be attached or removed from the wheelchairs (e.g., SWCS, Hephaestus).

From control point of view, we can divide smart wheelchairs to three groups; 1) Autonomous, 2) Semi-Autonomous, 3) Autonomous and Semi-Autonomous mode. The first group , operate very similar to autonomous robots; the user gives the destination and the smart wheelchair plans and executes a path to the target location. Autonomous systems typically require either a complete map of the area or some sort of modification to their environment. The disadvantage is that they can't avoid unplanned obstacles or navigate in unmapped environments. The second group of smart wheelchairs limit their assistance to collision avoidance and leave the planning and navigation duties to the user (e.g., NavChair, TinMan). The advantage is that they aren't limited to modeled and planned environments and can operate in unmodified environments. However, they can be used by user who is able toeffectively plan and navigate the wheelchair to a destination. A final group of smart wheelchairs offers both autonomous and semiautonomous navigation (e.g., VAHM, SENARIO). Different input methods have been used for smart wheelchairs ranging from the traditional input methods such as joystick and switches to the more advanced techniques such as touch screen interfaces and voice recognition .in our design we have chosen the third group of wheelchairs.

1.2 The problems

The proposed prototype system consists of several components that can be attached to the wheelchair and convert it into smart wheelchair, providing navigation assistant to the user and ensuring a collision-free journey.

This system differs from normal systems in a number of respects, from the hardware

1. The type and number of motors which have been used and

2. how they have been implemented on the wheelchair
3. the computational hardware which is an embedded microcontroller, and last but not least
4. the interface between the components and the underlying wheelchair .

Also the thesis contains the proposed innovative ideas about future development of the prototype into a much more sophisticated system but keeping the cost as less as possible but increasing efficiency and longevity.

1.2 The solution

The total project system was divided into **three** different parts and the **mechanical design**.

The **mechanical design** consists of building the wheelchair and coupling the motors with the wheels and creating a platform for the batteries and the circuitry to be placed and creating small plastic pipelines which would carry the wires which connects all the subsystems together building a complete system.

The **three subdivisions** contain the

1. inputsystem 2. Control system and 3. The driver system to the motors.

The input system consists of a joystick which gives analog input to the control system. The joystick consists of two potentiometers which give varying value of resistance in a two dimensional axis system and determine the amount of signal going to the control system. The control system takes the input from the joystick and converts it into digital signals using the inbuilt ADC and accordingly the microcontroller gives output to the driving system.

The coding done in the microcontroller relates the potentiometers value with PWM signals and supplies accordingly. The output driver system acts according to the output from the control system and drives the motor in required speed and direction.

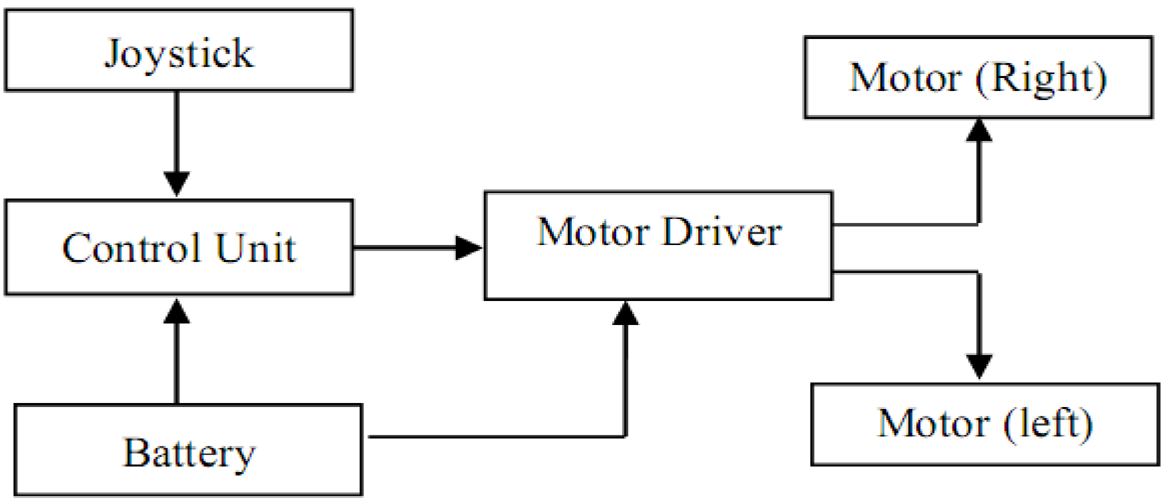


Figure 1: Block diagram of battery-operated wheelchair

Chapter 2

The Mechanical design

In an unmodified commercial electric power wheelchair a joystick or any user interface system (switches, touchscreen displays, etc.) is linked to the wheelchair main controller (which acts as a motor controller) and the controller is connected to the two motors. Batteries are also connected to the controller, providing the necessary power for the system. The user selects the desired speed and direction using the joystick and the controller drives the motors based on the signal received by the joystick. In our prototype which has been designed for cost effectiveness consists of a normal usual wheel chair which consists of two big circular wheels at the rear end and omni-directional small circular wheels at the front. It contains a thin leather seat and whole body is made out of steel structure with two plastic handles at the rear end for pushing the chair. It has been then modified further according to our design considerations. A platform was added at the bottom end to create space for the batteries and other circuitries to be placed. There was a box type structure which will hold the two 12V lead acid batteries connected in series to make it 24v dc supply. The DC motors which were available in the markets had a specification of 40v with 450rpm was coupled with the rear wheels using mechanical coupling and they were supported vertically using steel rods and additional plate with screws for horizontal support. Additional plastic pipelines were added to the wheel chairs for carrying the wires which connects the inputs system and control system with the batteries.

The wirings were made using red wire as positive terminal and black wires as negative terminal and crocodile clips were used to connect them together.

Figures

Figure2: Battery Casing

Figure 3: Motor Coupling

Figure 4 : Rear Wheel

Chapter 3

The input system

3.1 The joystick control

The **SFE Thumb Joystick** is very similar to the analog joysticks on PS2 (PlayStation 2) controllers. The directional movements are simply two potentiometers - one for each axis. The pots are ~10k each. The SFE thumb joystick also has a select button that is actuated when the joystick is pressed down. The analog joystick needs 5V to operate and will output two voltages which go to the wheelchair controller and represent the speed and direction of the chair. The handle moves a narrow rod that sits in two rotatable, slotted shafts. The shafts are connected each to a potentiometer. Tilting the stick forward and backward pivots the Y-axis shaft from side to side. Tilting it left to right pivots the X-axis shaft. When you move the stick diagonally, it pivots both shafts. Several springs center the stick when you let go of it. By moving the contact arm along the track, the resistance acting on the current flowing through the circuit will be increased or decreased. The connection between the joystick and motor controller was interrupted by cutting the wires that send the X-Axis and Y-Axis states of the joystick to the motor controller by two. Then one end of the wires which comes from the joystick were fed to the two ADC (Analog to Digital Convertor) pins of the microcontroller and the other end of the wire which goes to the motor controller were fed to the two other pins of the microcontroller that outputs PWM (Pulse Width Modulation) signals. The motion of the wheelchair depends on the position of the joystick. The duty cycle of PWM signal is generated according to the analog inputs from joystick, and the PWM signals determine the speed of the motors. The frequency of PWM is 20kHz. The analog signal acquired from the joystick is converted into digital format in the microcontroller which is used as the reference current signal for the closed –loop current control. X-axis and Y-axis of the joystick are used to describe the position of joystick knob. Different reference currents are assigned to each position. As shown in figure 3. The numbers (0-10) represents the strength of the reference current signal. The number on the left hand side indicates the left motor whereas the number on the right hand side indicates the right motor. The reference is taken as (5,5). If the number is larger than 5 the motor rotates forward and if it is less than 5 the motor rotates reverse direction. For rotating right the right motor is given low current or no current at all and the left motor is rotated so that the wheel chair moves right. The wheelchair is rotated in the left direction using the same mechanism.

					10,10					
				9,10	9,9	10,9				
			8,10	8,9	8,8	9,8	10,8			
		7,10	7,9	7,8	7,7	8,7	9,7	10,7		
	6,10	6,9	6,8	6,7	6,6	7,6	8,6	9,6	10,6	
5,10	5,9	5,8	5,7	5,6	5,5	6,5	7,5	8,5	9,5	10,5
	4,8	4,7	4,6	4,5	4,4	5,4	6,4	7,4	8,4	
		3,6	3,5	3,4	3,3	4,3	5,3	6,3		
			2,4	2,3	2,2	3,2	4,2			
				1,2	1,1	2,1				
					0,0					

Figure 5: Left And Right Motor Current Refference Distribution Over joystick

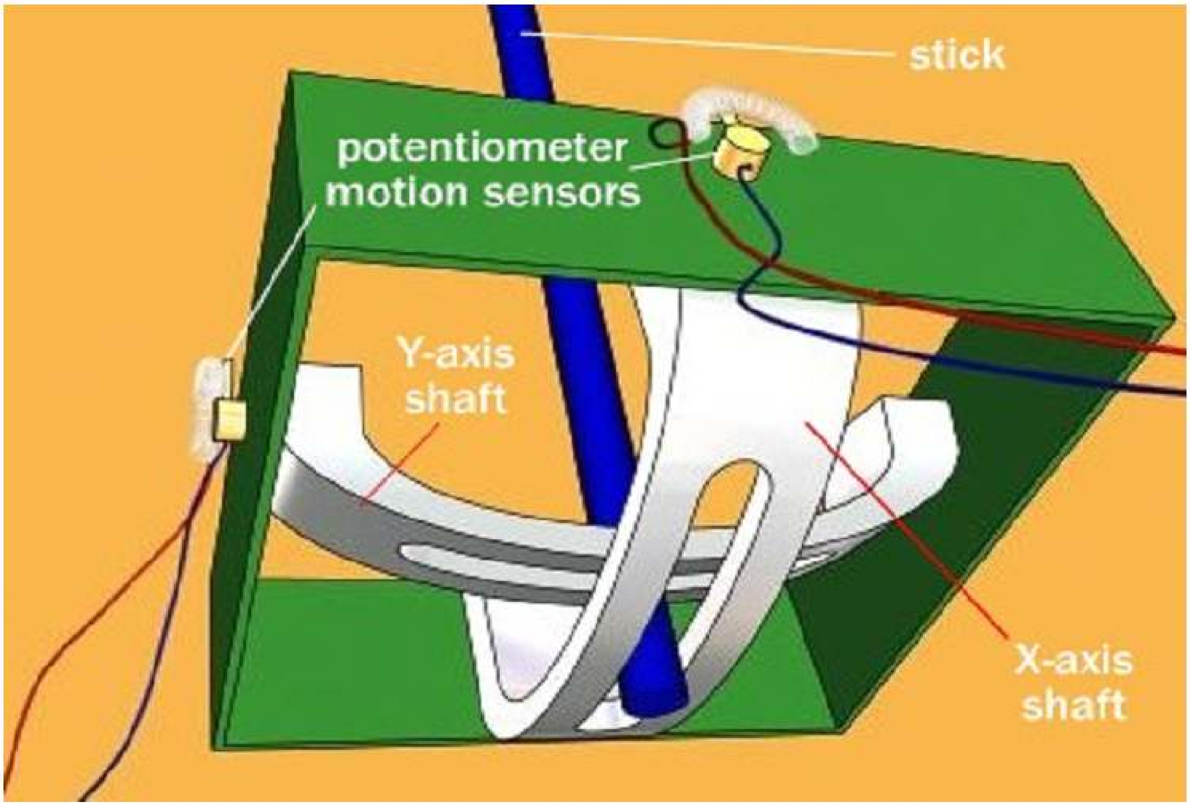
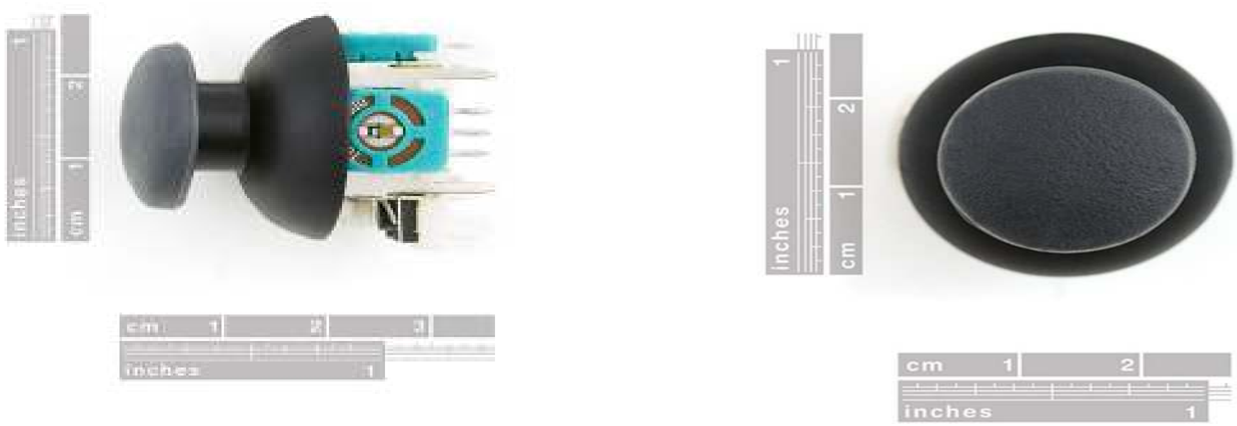


Figure 6: Analog Joystick

Table 1: Variations of motor speed and direction with reference to joystick voltage

Analog Voltage	Speed	Motor Direction
0.00 – 2.00	Max-Min	Counter Clock Wise
2.02 – 2.98	Zero	OFF
3.00 – 5.00	Min-Max	Clock Wise



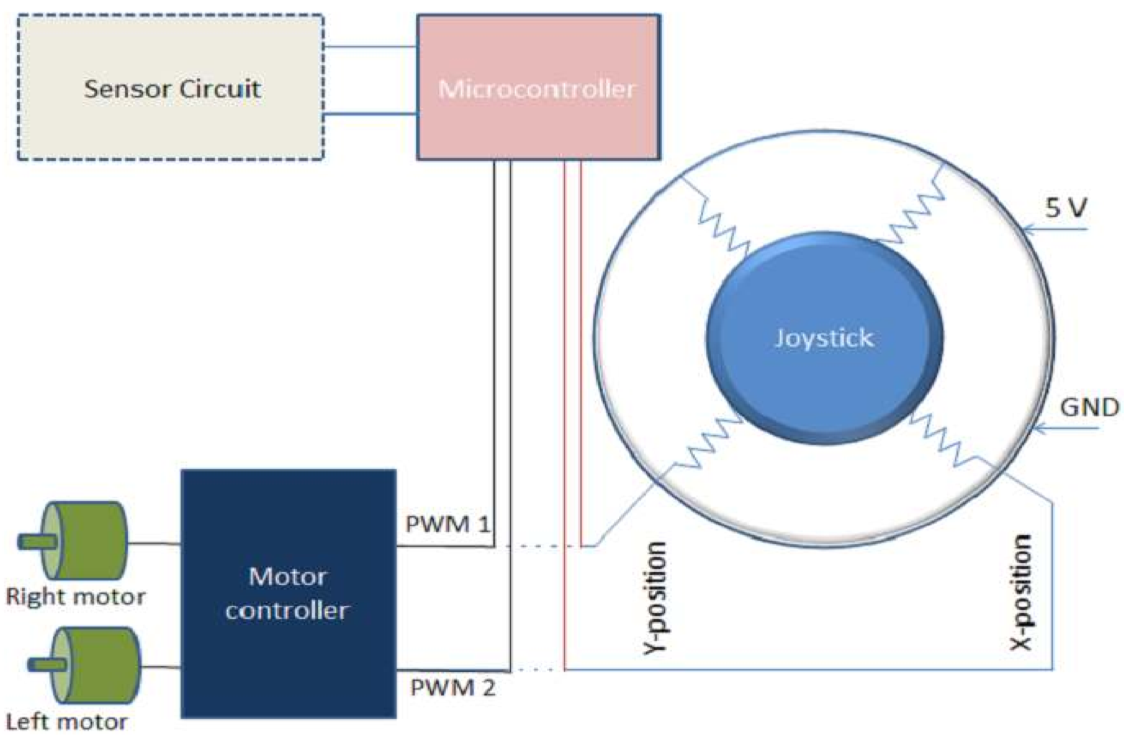


Figure 7: Joystick interfacing with the system

Chapter 4

The control system

4.1. The microcontroller

A microcontroller is a computing device capable of executing a program and is often referred to as the —brain or —control center in a robot since it is usually responsible for all computations, decision making, and communications.

In order to interact with the outside world, a microcontroller possesses a series of pins (electrical signal connections) that can be turned HIGH (1/ON) or LOW (0/OFF) through programming instructions. These pins can also be used to read electrical signals (coming from sensors or other devices) and tell whether they are HIGH or LOW. Most modern microcontrollers can also measure analogue voltage signals (i.e. signals that can have a full range of values instead of just two well defined states) through the use of an Analogue to Digital Converter (ADC). By using the ADC, a microcontroller can assign a numerical value to an analogue voltage that is neither HIGH nor LOW.

Unlike microprocessors (e.g. the CPU in personal computers), a microcontroller does not require peripherals such as external RAM or external storage devices to operate. This means that although microcontrollers can be less powerful than their PC counterpart, developing circuits and products based on microcontrollers is much simpler and less expensive since very few additional hardware components are required.

Analogue-to-digital converters (ADC) are used to translate analogue voltage signals to a digital number proportional to the magnitude of the voltage, this number can then be used in the microcontroller program. In order to output an intermediate amount of power different from HIGH and LOW, some microcontrollers are able to use pulse-width modulation (PWM). For example this method makes it possible to smoothly dim an LED.

So an embedded microcontroller was chosen as the computational hardware since it provides much better real-time operation than most of the operation systems. It is also relatively cheap compared to a laptop or a PC, it consumes less power, it is much lighter in weight, and doesn't block the user's view if used on a wheelchair. Although a computer is much easier for debugging or optimization purposes, and is easier to interface with the sensors and joystick, ultimately the embedded microcontroller is a better practical choice.

The embedded microcontroller used in this project is PIC16F887A (appendix) with an inbuilt ADC (analog to digital converter). The microcontroller is also connected with a LCD display which shows the value of current that is passing through the output and also shows the speed of the individual motors. The microcontroller first takes analog input from the joystick potentiometers which gives varying voltage depending on the distance covered by the joystick in both X-axis and Y-axis. This is taken into the microcontroller ADC which converts the analog signal into a digital one and this value is then analyzed with the look up table given in the program and a PWM signal is generated according to the strength of the digital signal generate. In this way the microcontroller sends output to the driver system. The LCD displays the speed of the right motor and the left motor and shows which direction it is going.

4.2 The programming code of the microcontroller

```
Lcdpinout settings

sbit LCD_RS at RB0_bit;

sbit LCD_EN at RB1_bit;

sbit LCD_D4 at RB2_bit;

sbit LCD_D5 at RB3_bit;

sbit LCD_D6 at RB4_bit;

sbit LCD_D7 at RB5_bit;


Pin direction

sbitLCD_RS_Direction at TRISB0_bit;

sbitLCD_EN_Direction at TRISB1_bit;

sbit LCD_D4_Direction at TRISB2_bit;

sbit LCD_D5_Direction at TRISB3_bit;

sbit LCD_D6_Direction at TRISB4_bit;

sbit LCD_D7_Direction at TRISB5_bit;  */


//above codes ar for LCD initialisation


void main()

 {

unsigned char low,high,duty ;

duty=0x00;

trisc=0;
```

```
trisd=0;
portd=low;
CMCON = 7;    //Disable comparator

ADCON1=0xC4;

PWM1_Init(1000) ;    //initializing pwm 1
PWM1_Set_Duty(duty);
PWM1_Start();

PWM2_Init(1000);     //initializing pwm 2
PWM2_Set_Duty(duty);
PWM2_Start();

while (1)
{
ADCON0 = 0x81;                  //reading channel 0
delay_us(50);                   //Acquisition Delay
GO_DONE_bit = 1;                //Set GO_DONE bit to start conversion

while (GO_DONE_bit == 1);       //Wait for bit to be cleared
                        //If bit is cleared, this means conversion is over
low = ADRESL;
high = ADRESH;                  // here ADRESH will not be used as only 8 bit req
```

```
duty=ADRESL;

portd.RD0=0;
portd.RD1=1;

PWM1_Set_Duty(duty);
PWM1_Start();

ADCON0 = 0x89;                  //reading channel 1
delay_us(50);                   //Acquisition Delay
GO_DONE_bit = 1;                //Set GO_DONE bit to start conversion

while (GO_DONE_bit == 1);       //Wait for bit to be cleared
                        //If bit is cleared, this means conversion is over
low = ADRESL;
high = ADRESH;                  // here ADRESH will not be used as only 8 bit req
duty=ADRESL;
portd.RD2=0;
portd.RD3=1;
PWM2_Set_Duty(duty);
PWM2_Start();
}
}
```

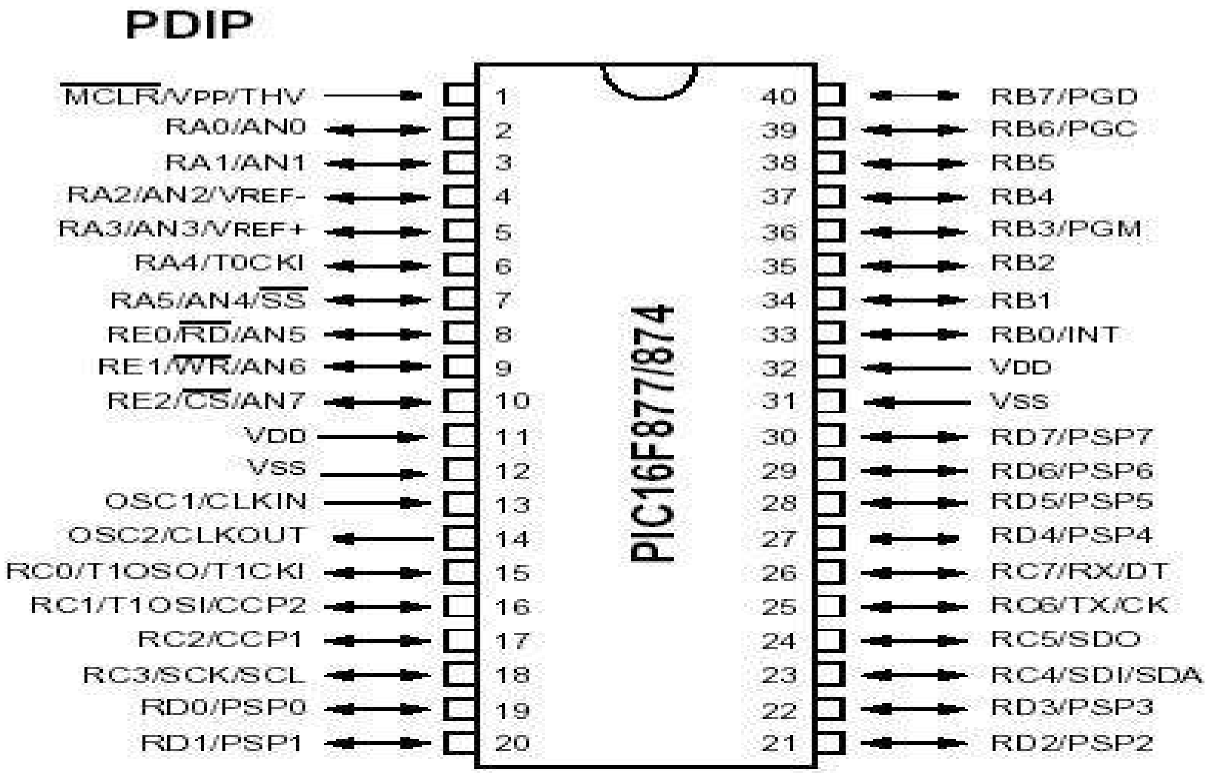


Figure 8:PIC 16F877A Pin Configuration

4.3Motor Controller

In an electric wheelchair the controller acts as the command center for the wheelchair and is responsible for amperage, speed control and the maintenance of straight line propelling and turning control when the chair is in use. The controller derives its energy from two rechargeable batteries, and the controller gives the individual the ability to move the chair forward, backward, left and right and to make any variation of turns up to 360 degrees.

The electric wheelchair used is a rear-wheel drive system powered by two permanent magnet dc motors. Rear-wheel drive is the traditional and most popular power wheelchair style. They are generally faster than front-wheel models, but provide poor turning capabilities in comparison to front-wheel drive wheelchairs and mid-wheel drive wheelchairs models.

The wheel chair has two dc motor attached to each of the left and right wheels. By controlling the individual speed of both motors , the motion i.e. that is the speed and direction of the wheelchair can be controlled. For example , the wheelchair turns left if the right wheel rotates faster than the left wheel and vice versa. A dc chopper not only allows adjustable speed control but it also eliminates the discontinuous conduction mode and allows bidirectional rotaion. It consist of an H-bridge circuit which allows the speed and direction of the motor to be controlled by power semiconductor switches. The switches ar required to withstand high current drawn by the motor under load condition.

Consideration had to be made

1. The first consideration is the motor's nominal voltage. The wheelchair has two DC motors which each operate to the maximum 24V capacity so the motor controller must be powerful enough to provide 24V to each motor.

2. The next consideration is the continuous current the controller needs to supply. We need tofind a controller that was able to provide current equal or above the motor's continuous current consumption under load.

The wheelchair DC motors need 250W power when used on a flat field

$$P=VI$$

P – Power (W)

V – Voltage (V)

I – Current (A)

Based on the above power formula the current each motor needs to operate is 10.41A in flat case.

The stall current also has been measured by holding the armature and supplying a small amount of voltage to the motor and since the motors are each a powerful 24V, it's not possible to hold the armature when more voltage is applied so maximum voltages of 1V and 1.6V has been tried . Maximum current draw is at zero RPM (stall) where the motor is unable to turn . Maximum current draw is referred to as 'stall current' or'stall amps'. Knowing the stall current of a motor is valuable when planning for worst-case design parameters.

Chapter 5

Pulse Width Modulation

The speed of a DC motor is controlled by the voltage level that is applied to the motor's windings. For this reason, the motor can be controlled by simply varying the supply voltage with a variac or some other such device. This however wastes a great deal of energy through heat dissipation. This can be avoided by implementing pulse width modulation, or PWM.

PWM allows one to switch full power to the load a certain amount of the time. With an inductive load, such as a motor, this is ideal. The percentage of the cycle that power is being delivered to the load is known as the duty cycle.

With PWM, the only power losses are due to switching and are substantially less than regulating the DC power. This creates a far more efficient motor controller.

5.1 Frequency:

Using the switch example, the frequency would be how fast the switchwas turned on and off. If the frequency is too low (switch is changed slowly), then the motor will run at full speed when the switch is on, and completely stop when the switches off. But if the frequency is too high, the switch may mechanically fail. In reality there is no switch, but rather an electronic board named an H-Bridge that switches the motor on and off. So in electrical terms; if the frequency is too low, the time constant of the motor has enough time to fully switch between on and off. Similarly the upper limit on the frequency is the limit that the H-Bridge board will support, analogous to the mechanical switch. For this project we chose a switching (PWM) frequency that was greater than in 30kHz, which would take it out of the audible range. Because the controller was to be controlled by a PIC chip, we chose 74kHz; a frequency easy to implement with the PIC chip..

5.2 Duty Cycle:

The duty cycle is analogous to how long the upper switch (switch1) remains on as a percentage of the total switching time. In essence it is an average of how much power is being delivered to the motor. Duty cycle gives the proportional speed control of the motor. Figure 2.4 is an example of 1/4, 1/2, and 3/4 duty cycles. Effectively, these duty cycles would run the motor at 1/4, 1/2, and 3/4 of full speed respectively.

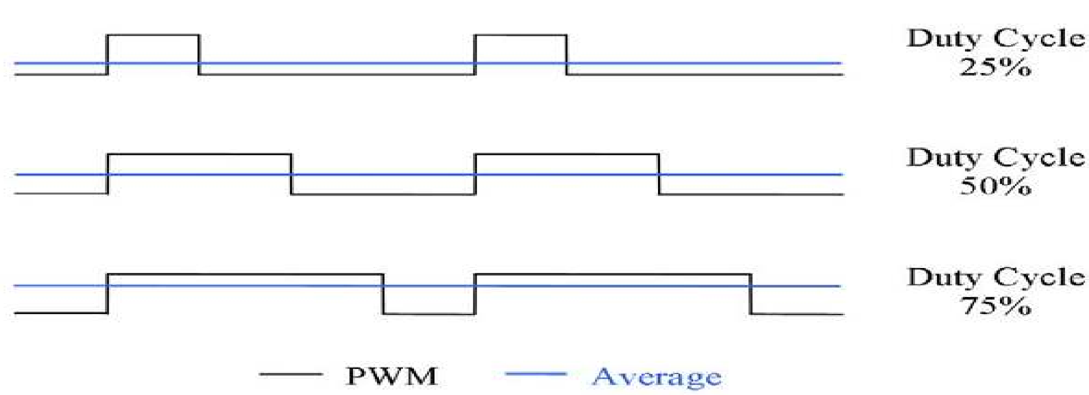


Figure 9 :PWM Duty Cycle

Chapter 6

H-Bridge

6.1 H-Bridge Fundamentals

An H-Bridge is a device with four switching elements that resembles a capital H. These devices are commonly configured with four transistors at the "tips" of the H and the load connected in the center of the horizontal "rung" of the "H." Depending on which of the four transistors is "on," current can be supplied to load in two different directions.

In addition to being able to handle the high amount of current, ideally the H- Bridge transistors should have as little impedance as possible and as high a switching speed as possible. Based on these requirements N-type Metal Oxide Semiconductor Field Effect Transistor (NMOS) have a lower "on" resistance than P-type Metal Oxide Supplement Field Effect Transistors (PMOS) and thus are ideally suited for H-Bridge applications.

A basic H-Bridge circuit diagram is shown in Figure

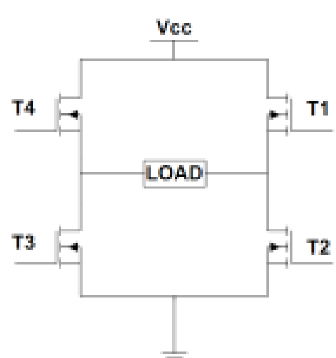


Figure 10 :Basic H-Bridge Circuit

6.2 Modes of operation

The transistor arrangement on the H-Bridge allows for several modes of operation. As seen in Figure 1, an H-bridge has four transistors and four useful modes of operation based on which of the transistors is active and allowing current flow.

The two most common modes of operation allow current to flow from the source, through \the load and to ground. Depending on the combination of active transistors on the high and low side, the motor will spin in both directions (T1 and T3 for one direction and T2 and T4 for the other). The current path is shown as the red line in Figure 2.

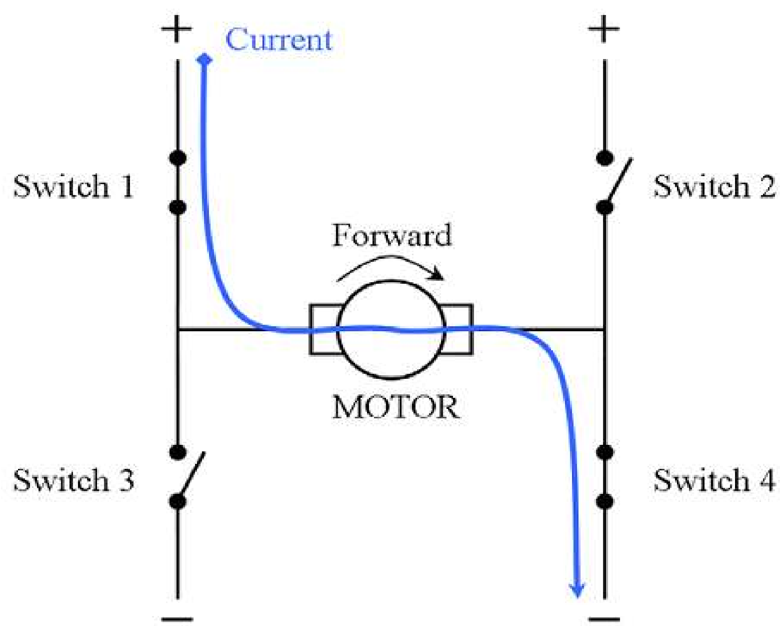


Figure11: Forward Direction

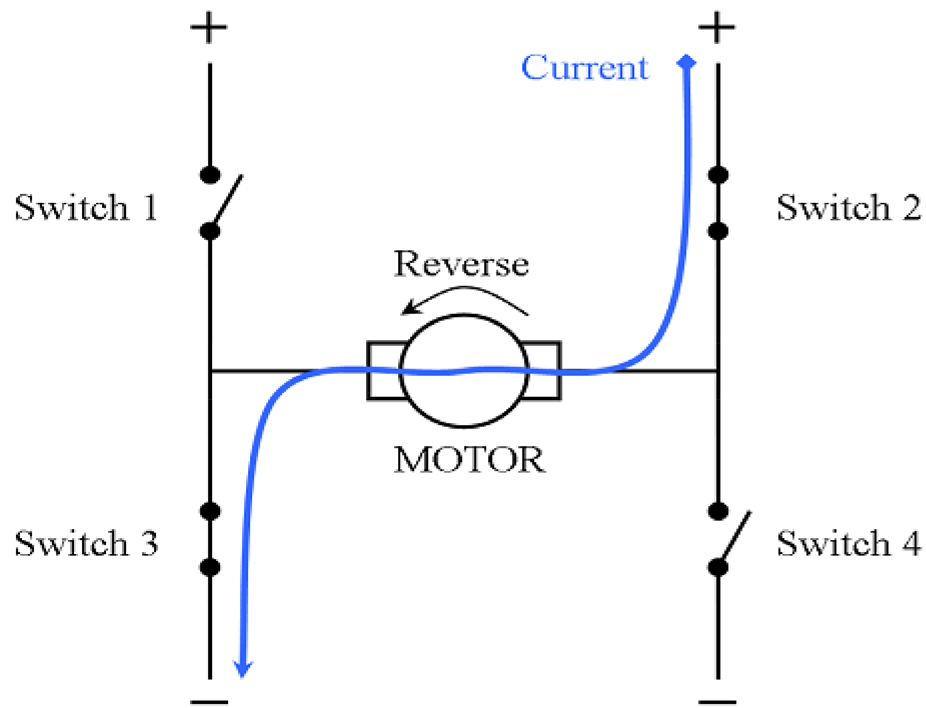


Figure 12 :ReverseDirection

By switching all transistors off, the motor is said to be free-wheeling. In this state the motor will spin until all the energy in the system is dissipated due to shaft friction and windage. The current flow for this mode has exactly the same path as the first two modes, only opposite direction through the flyback diodes, which are not shown in Figure 2.The final useful mode is the breaking mode. This occurs when the two terminals of the motor are shorted together. In this mode the motor shaft slows down because the back EMF of the motor generates voltage across shorted terminals. While this mode is not considered for this application, future designs will implement a breaking feature due to the necessity of this mode. Current flow in this mode is shown as the blue and purple lines in

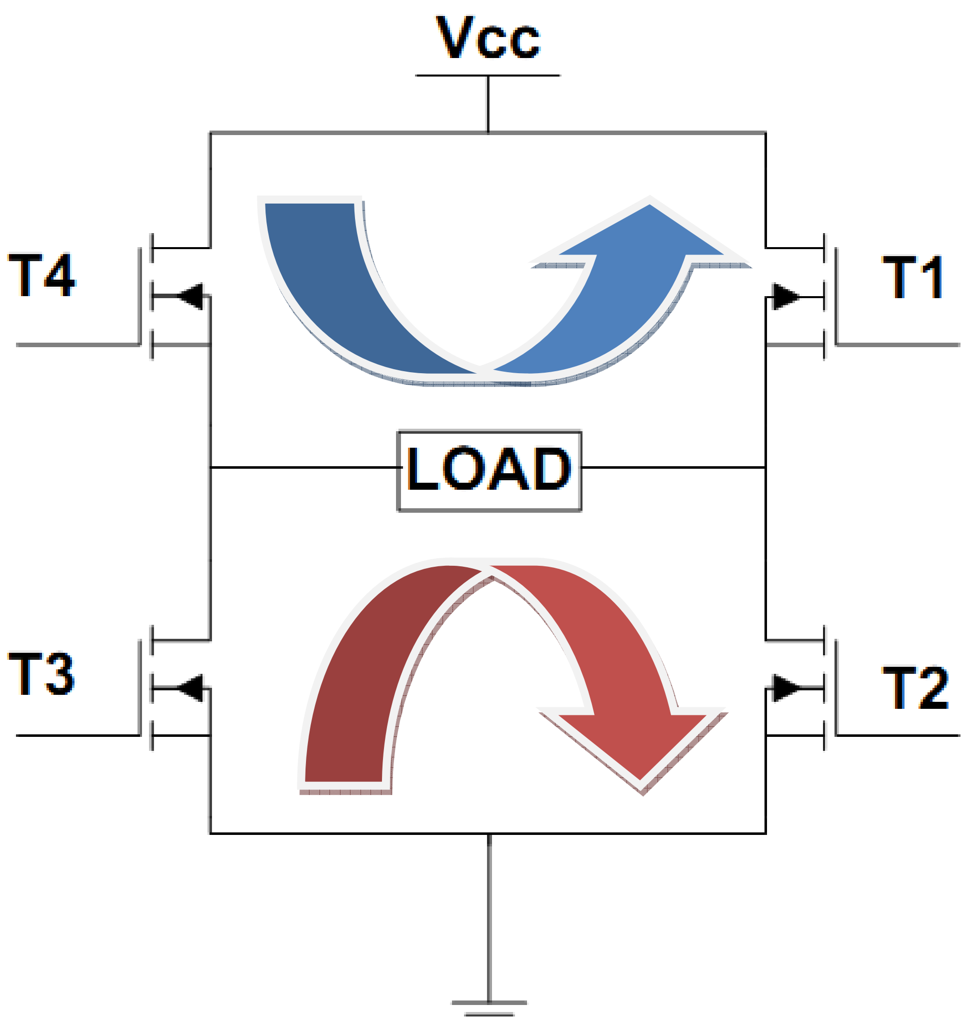


Figure 13:Breaking Current Direction

6.3 H-Bridge Design Considerations

The H-Bridge circuit must simply contain four switches that can be controlled as the user desires. The type of switch used is best determined by many factors including motor voltage rating, amperage rating, power supply, etc.These factors necessitated that the H-Bridge be able to be controlled with a TTL signal with a frequency of 74 kHZ, Since this signal was being produced by a microprocessor which are typically inadequate at sourcing current, voltage controlled FETs were used**.**

Due to the physical characteristics of NMOS devices, they dissipate less power than a PMOS device. By designing an NMOS exclusive H-Bridge, a more efficient circuit is created. However NMOS devices must have a gate to drain voltage, VGD that is higher than its threshold voltage, VT plus its gate to source voltage, VGS in order to be fully active, a high side driver must be used to control transistors T1 and T4 in Figure 1.

Flyback diodes are placed into the circuit in order to allow current to flow when all the transistors are off. If these did not exist current would go to zero instantaneously, inducing a huge voltage in the motor that would destroy the transistors in the circuit.In order to absorb the commonly occurring voltage spikes produced by switching the transistors, a high quality capacitor is placed on the input to the H-Bridge. This ensures that no voltage spikes are seen by the system and further protects the circuitry

6.4 Feedback EMF Reduction - Large Main Capacitor

The large main capacitors primary purpose is to suppresses transient spikes causedby the motor. Often when the motor accelerates, decelerates, or stops suddenly, anEMF ”feedback” voltage will spike on the main battery voltage. These spikes causemicro controllers to reset and are harmful to most low level electronics. By placing afilter capacitor in parallel with the battery, these feedback spikes can be reduced in magnitude.The reasoning behind this filter capacitor has its roots in basic electronics. Oneof the laws from basic electronics states that voltage can not change instantaneouslyacross a capacitor; therefore, since the capacitor is parallel to the battery, the battery voltage cannot change instantly. This results in a reduction of the feedback voltage spikes generated by the motor.

Chapter 7

Control Circuit

7.1 Shoot Through

If the top switch 1 and bottom switch 3 are on at the same time, even for a small amount of time?The battery will be shorted out and the H-Bridge will literally blow up. This is called Shoot Through and it is shown in Figure 3.4

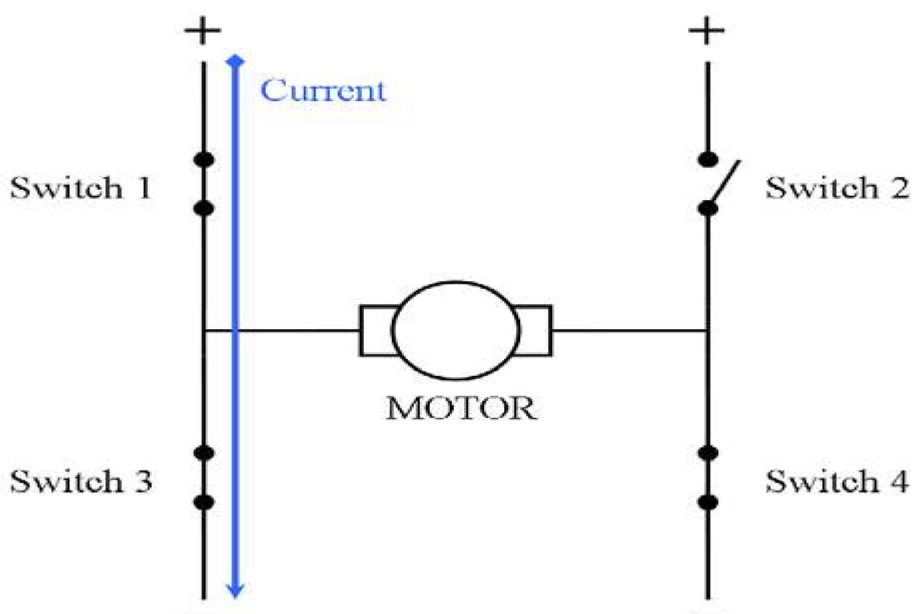


Figure 14:Shoot Through

7.2 Circuit Design

A dead short between supply and ground is extremely dangerous and is the primary concern of the drive circuitry. On a basic level the H-Bridge should use the direction bit to control which transistors turn off and on and should be able to turn them off and on based on the PWM signal. It was decided to design this circuit using 74 series digital logic devices because of their affordability, availability, and simplicity.

In order to simplify the operation of the H-Bridge, it makes sense that the high side transistor should stay active while the low side switches according to the PWM signal. This will simplify switching and reduce the amount of drive circuitry necessary for normal operation

Table2 Control Circuit Truth table

INPUTS		OUTPUTS			
PWM	DIR	T1	T2	T3	T4
0	0	1	0	0	0
0	1	0	0	0	1
1	0	1	0	1	0
1	1	0	1	0	1

As can be seen from the table, T1 is DIR inverted and T4 is DIR. T2 and T3 correspond to T4 and T1 respectively and are high with PWM. This is the desired characteristic. All that must be done now is to protect the circuit from shorting.

Because a direct short has devastating consequence to the circuit, the timing of switching must ensure no direct path from supply to ground. This is accomplished with a set of D flip-flops that will be clocked by the falling edge of the PWM signal. This feature ensures that on the first clock cycle that DIR changes, all the transistors are shut off, then on the following PWM cycle, the appropriate transistors are activated. The circuits signal propagation time is far less than that of the clock, ensuring correct operation.

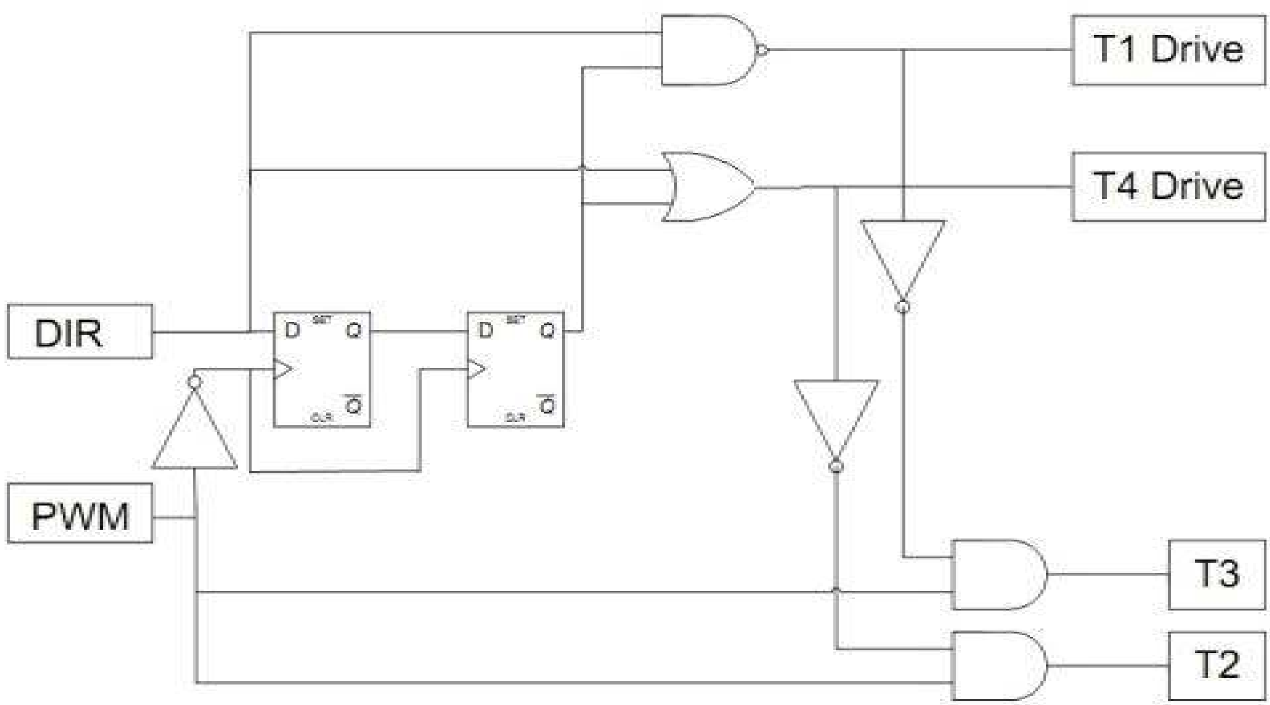


Figure15 : Control Circuit

Table 3NAND Truth Table

i/p 1	i/p 2	o/p
0	0	1
0	1	1
1	0	1
1	1	0

Table 4 NOR Truth TABLE

i/p 1	i/p 2	o/p
0	0	0
0	1	1
1	0	1
1	1	1

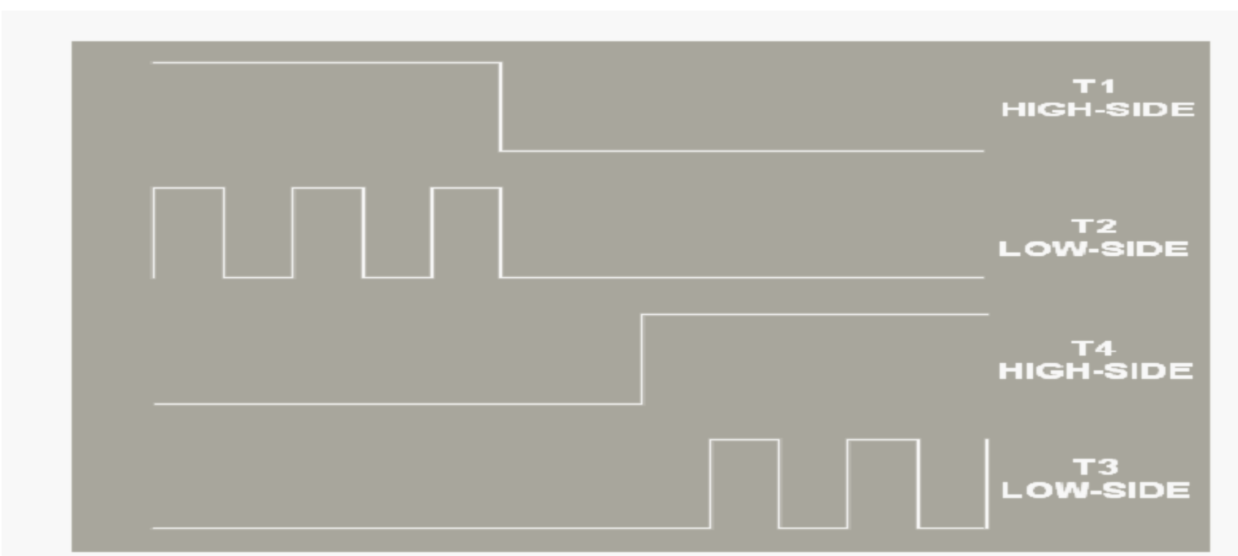


Figure 16:Operation Of H-Bridge Control Circuit

Conclusion

Aeasily controllable, low cost battery-operated wheelchair was developed using joystick control and electronic drive technologies.One issue is to guarantee that the control system is effective when it is subject to an erratic input signal and other variations of movement that a human being with such kind of disabilities exhibits.Moreover, an obstacle detection and avoidance system is under development to allow safe navigation.

Future Improvements

- Future improvements to the vehicle may include the addition of regenerative electronic breaking capabilities and use of lightweight batteries.
- Using multiple sensors combination: Each type of sensor has different advantages and disadvantages and the system reliability will be increased by using different kind of sensors. For example when using just sonars, reflection varies based on the surface material and this problem especially shown itself in case of wall-following.
- Testing the system with members of the disable community for better adjustments of the system.
- Implementation of voice recognition and wireless control

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