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Acknowledgement

We would like to thank Dr. Samer Mayaleh for supervising our project and for giving us his unlimited encouragement to reach our best potential. We would also like to thank all the instructors of the Engineering college specially the Electrical Engineering department who taught us the meaning of the Engineering sense before the material itself. Thanks to our families and friends for standing beside us to achieve the aim.

Abstract

The present day society demands the people to be independent, irrespective of their natural challenges, mentally or physically. Physically impaired people have to rely on someone for fulfilling their even minor needs. The probability of them to go and interact with the outside world is very minimal, unless they are provided with modern moving tools such as a Wheel Chair. There are two possibilities of either using manual driven or electric powered driven wheel chairs. The former solution is only for the people who have disability in lower limbs and also long term usage poses further health problems. Additionally the efficiency of the manual driven wheel chairs are merely 10-20%.

Thus the electric wheel chairs are more popular in such circumstances. Electric wheel chairs (EWC) provide functional mobility for people with both lower and upper extremity impairments. EWC are becoming increasingly important as more users transition from manual mobility to electric powered mobility specially in Palestine which has high percent of disabled people due to many reasons. Much research effort has been put toward the development of controlling the EWC. Advances have been made in the design of EWC over the past two decades, yet the controlling of these wheel chairs have not improved substantially. This project is thus aimed at the development of more precise controlling of EWC to meet their specific requirement and to make it affordable. More sophisticated variable speed electric drive is required for controlling EWC. Reversing, braking for electric motors and regenerating power.

So, light weight components with controlled speed and directions wheel chair is being implemented, also chair could be built with any dimensions for any human weight, different weights and dimensions means different power.

CHAPTER 1
Introduction

"Give me a wheelchair that is light and compact, that fits in a small plane when I need to fly out in the wet season. Make sure it's comfortable, does not give me pressure sores, to make me look like a cripple straight out of hospital. It has to be easy to push because I want to get out, go crabbing in the boat and go fishing on the beach." (Hales S 2001) This quotation describes the needs of a wheelchair user in an Aboriginal community.

Problem Statement

Independent mobility is crucial for development of physical, cognitive, communicative and social skill for physically impaired people. The high price of the electric wheel chairs. This project is thus aimed at the development of more sophisticated control scheme for electric powered wheelchair.

Objectives of the Project

The following objectives are set for the project work;

- To study the need of the wheelchair control
- To study the existing control structure of the wheelchair control
- To identify the problems associated with the existing control system
- To identify the motors, batteries, drivers, encoders, sensors and all other components will be used
- To implement the design of the chair to have the desired prototype

Scope of the work

Wheelchairs are required for the mobility of the disabled people. It can be categorized into two types: manual and electric powered wheelchairs. In modern society, wheelchairs demand is increasing rapidly. It is used by disabled and aged people. It is seen that driving manual wheelchair for a long time will cause pain and injury in wrist, elbow and shoulder. Thus electric powered wheelchairs have gained popularity and are increasingly used in modern society. This section takes an overlook about the current scenario of the state of the art in intelligent control of power wheelchairs.

CHAPTER 2

Contrarians and Standards

Constraints

We faced a lot of contrarians, firstly, a lot of choices were available, a lot of techniques, no much components were available here in Palestine, the prices of the components is too high.

Standards /Codes

Why standards?

- Standards ensures minimum levels of performance
- Allows accurate comparison between products.
- Stimulates quality improvement.
- Reduces manufacturer's liability exposure.
- Gives engineers something to do!

- **ANSI/NEMA MG 1-2011**

Assists users in the proper selection and application of motors and generators. Contains practical information concerning performance, safety, testing, construction and manufacture of ac and dc motors and generators.[1]

- **ANSI Z535.4-2011**

Delivers specifications for design, application, use, and placement of safety signs and labels on a wide variety of products. A new type of product safety sign, the "safety instruction sign," was added to join the existing types of signs, hazard alerting signs, and safety notice signs, which were also more clearly defined and named in this edition. The definitions for "accident," "harm," and "incident" were refined to more clearly delineate a separation between physical injury and other safety-related issues (e.g., property damage). It was revised to correspond with ANSI Z535.2, ANSI Z535.5, ANSI Z535.6.[1]

- **IEC 61508**

An international standard of rules applied in industry. It is titled Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES).[2]

- **IEC 61508**

An intended to be a basic functional safety standard applicable to all kinds of industry. It defines functional safety as: "part of the overall safety relating to the EUC (Equipment Under Control) and the EUC control system which depends on the correct functioning of the E/E/PE safety-related systems, other technology safety-related systems and external risk reduction facilities."[2]

- **IEEE-1-1986**

IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation. [3]

- **IEEE-11-1980**

IEEE Standard for Rotating Electric Machinery for Rail and Road Vehicles.[3]

- **ANSI C18.2M, Part 2‐2007**

American National standard for Portable rechargeable cells and Batteries—safety standard Specifies performance requirements for standardized portable lithium ion, nickel cadmium and nickel metal hydride rechargeable cells and batteries, to ensure their safe operation under normal use and reasonably foreseeable misuse.[1]

- **ANSI/NEMA MG 1‑2011**

Motors and Generators assists users in the proper selection and application of motors and generators. contains practical information concerning performance, safety, testing, construction and manufacture of ac and dc motors and generators.[1]

CHAPTER 3

Methodology

Mechanical Solution

Building wheelchair system basically based on mechanical studying. There are two mechanical parts have been studied in this project, the dimensions of all parameters (seat, motors, wheels, gear, batteries and drive kit), the other part was the power calculations.

Seat

Seat Dimensions and weight depend on person used wheelchair; in wheelchairs an additional small space will be add for more comfort. The following details will explain:

Wheelchair Seat Width

Seat width is usually the first measurement determined when fitting a person for a wheelchair. This measurement is decided by taking the widest point between the hips and the knees when sitting comfortably and adding about 1". When referring to a wheelchair as a 16", 18" or 20", which are the most common sizes, people in the wheelchair industry are referring to the usable seat width, not the overall width of the wheelchair.[4]

Wheelchair Seat Depth

Seat depth is probably the second most important measurement which must be considered. The seat depth measurement of the user is determined by measuring from the back of the user's pelvis to the back of their shins when sitting straight with the lower legs dropping at 90 degrees from their knees. The longer the seat depth of the wheelchair, the more stable the user will be and their weight will be distributed over a larger area which in turn will reduce sitting discomfort.[5]

The seat depth of the wheelchair is determined by subtracting about 1" from the user's seat depth for most manual and power wheelchairs. In cases where the wheelchair users use their feet to aid in propulsion or maneuvering of the wheelchair, one would normally subtract about 2" from the user's seat depth to determine the wheelchair seat depth so the upper calves of the user don't rub against the seat of the wheelchair when propelling the chair.[5]

Some user's may have what's known as a leg length discrepancy which means that one leg is longer than the other. leg length discrepancy can be caused by either a physical shortness on one leg or being unable to sit with the pelvis flat against the wheelchair back support. When considering seat depth for a wheelchair, the user's shorter leg will determine the wheelchair seat depth. If the longer leg isn't well enough supported with the shorter seat depth, extra support for that leg can be achieved by ordering a custom seat cushion which extends farther forward on the longer leg side.[5]

Wheelchair Seat Height

Seat height is more about function than comfort. Ideally the seat height will put the user at a height that will allow them to work at a table or desk comfortably and enabled transfers to toilets, commodes, beds and other chairs and also provide enough ground clearance for the different types of terrain the user may travel over. When discussing seat height in respect to wheelchairs the seat height of the chair does not include the thickness of the wheelchair cushion. So, if you need a 19" seat height and your cushion is 2" thick you would order a wheelchair with a 17" seat height.[5]

Wheelchair Back Height

Back height will vary from user to user and wheelchair type to wheelchair type. People with good upper body control and posture can get away with low back heights from just above the pelvis to the mid back level. Users who require more back support should opt for a higher back height but if they propel their wheelchair with their arms too high a back height will impede the range of motion in their shoulders which will reduce the efficiency of their pushing their chair. People who require a lot of support and use power wheelchairs, or aren't self-propelling, should have a back height as high as their shoulders, if needed. In cases where the wheelchair has a tilt or recline function the back height should be at least to the top of the shoulders and have an extension or a headrest added to support the user's head. Most models of wheelchairs offer some type of back height adjustment of up to 4" for fine tuning after delivery.[5]

Wheelchair weight

The weight of wheelchair contains the weight of seat, wheels, motors, batteries and drive kit.

The following table shows the dimensions used

Dimension	Ranges
Width	480mm
Depth	460mm
Seat Height	500mm
Back Height	400mm
Arm Height	330mm
Total weight(Kg)	60

Table 1: Seat Parameters

Wheels

The main purposes when choose wheels are the diameters, weight and max. loading capacity.

Diameters:

Front caster wheels	Around 15 cm
Back wheels	Around 30.48 cm

Table 2: Wheel Diameter

Weight

It depends on the material manufactured by, its structure and hub. Most caster wheels are Pneumatic wheels (This topic not a big deal).

Loading capacity:

The following figure explains weight distribution of weight on back and front wheels.

W= total weight.

Wf : the weight .

Center of mass normally closer to the back wheels. Around (70-80) % of weight on the back wheels, when choose wheels they should have a load capacity higher than required (+10 kg).

Figure 1: Weight Destribution

Rear Fastening Straps:

To ensure that the rear slewing brackets not will be damaged the angle of the rear fastening straps may not exceed 25 degrees as shown below [6]:

Figure 2: Tilt Angle

Motors, batteries and control kit locations

Motors

Two motors will be used each one has the half power required. Each motor located in the hub of the back wheels. A built in gear being used between the motor and the wheel.

Batteries and control kit

A package under the seat between the front wheels and back ones will carry the batteries and control kit (it is near to back wheels).

The figure(3) below will explain:

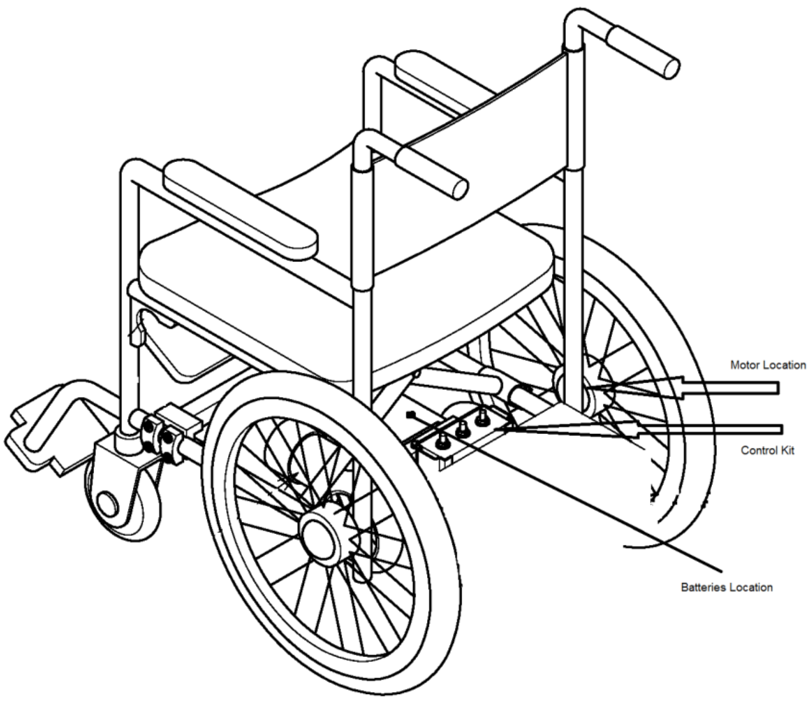


Figure 3: Batteries and Kit Placement

Slope

In this project, slope's roads in west bank were taken into account, because mechanical calculations depend on the slope.

Power Calculations

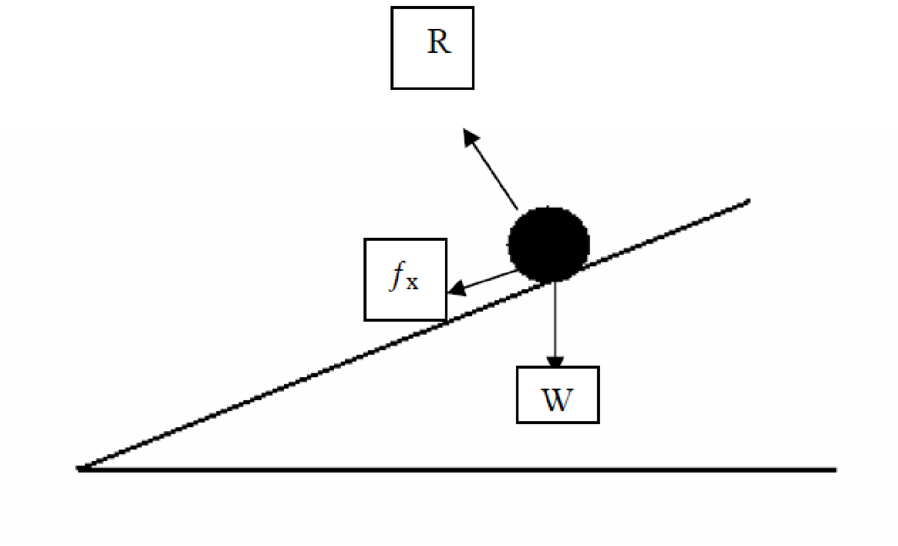


Figure 4:Forces Analysis

R: Incline reaction to wheelchair weight.
fx: friction force.
W: wheelchair weight.

Coefficient of friction: $\mu = 0.4$.
SEE ABENDIX #1

…………………………………………………………………………..

Speed control and drive, power circuits

To control the speed under different torques in wheelchair the following flow chart should consider:

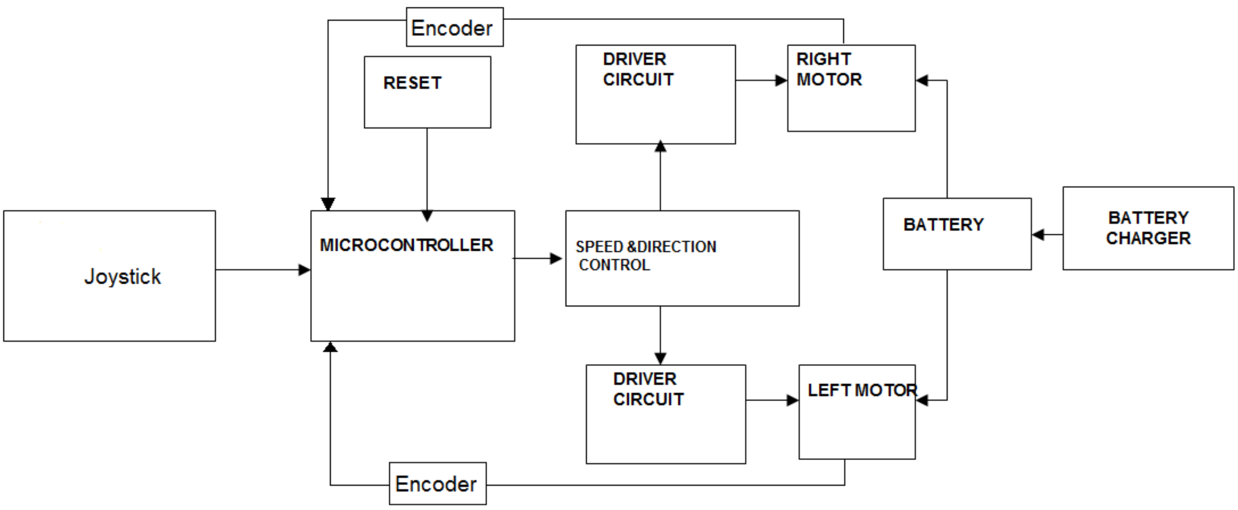


Figure 5: Over all Speed Control System

Motor

To move the chair motor will be used; many characteristics should be studied to choose the motor, overcome motor's constrains and control it.

Motor selection

There are many characteristics were considered when motor had been chosen:

1. Easy to control.

2. The motor should be small and lightweight.

3. High economic efficiency.

4. Durable and easy to maintain.

5. Low noise.

6. Low cost.

7. Must be able to be used under various conditions and humidity.

8. Regenerative braking.

Following three parts will explain choosing the motor:

After comparing the type of motors among AC or DC the DC has been chosen and the Permanent Magnet one among the DC motors.

- Brush or Brushless:

The following table shows a simple comparison between the Brush and the Brushless [9]:

Attribute Brush Type Brushless	Brush	Brushless
Cost	★	
Mean Time Between Maintenance		★
Mean Time Between Failures	★	
Flat Speed / Torque Curve		★
High efficiency		★
High Output to frame size ratio		★
Higher speed range		★
Extreme Environments	★	
Simple installation	★	

Table 3: Comparison between Brush and Brushless Motors

Dead Band Region

When analyzing friction in electric motors (as would be in mechanical systems), two cases must be considered: static friction (stiction) and kinetic friction. The opposing torque produced by stiction prevents the motor from turning. When the voltage supplied to the motor is sufficiently high to start turning the motor, kinetic friction will provide a constant torque that will oppose the motion, though it will decrease as the motor is turning at a higher angular velocity ω.

In between the applied voltage that causes the motor to produce enough torque to turn is the dead band region, where the voltages applied in that region causes no motion of the motor.

Following figure(7) relates the effects of friction on a motor (through angular velocity) as a function the voltage applied. Figure 1 also shows the dead band of a typical motor.

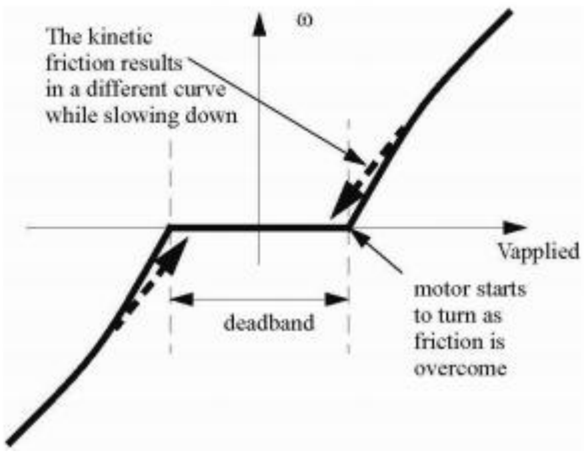


Figure 6: Speed Vs Voltage

From Figure , it can be seen that stiction prevents the motor from turning until an applied voltage is high enough to overcome its effects and begins to turn. Figure 1 also shows that the kinetic friction of a motor results in a curve different than the stiction curve when slowing down.

There are several methods that can be used to determine the dead band of a motor. One method is shown in Figure(8). This method determines the dead band by connecting a motor to a power supply and determining the voltage at which the motor turns and stops in both directions.

The PWM value at which the motor begins to turn will correlate to the static friction coefficient.[9]

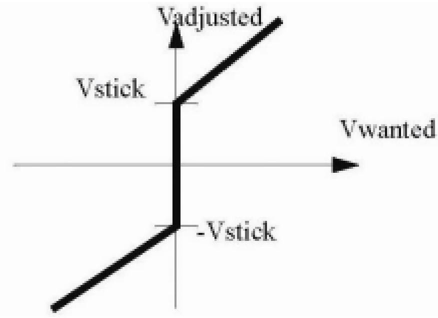


Figure 7: Voltage Adjusting

Soft start/stop function

Starting a motor is a very hazardous moment for the system. Since an inductance whose energy storage capacity is basically empty, the motor will first act as an inductor. In a sense, it should not worry too much because current cannot change abruptly in an inductor, but the truth of the matter is that this is one of the instances in which the highest currents flowing into the motor. The start is not necessarily bad for the motor itself as in fact the motor can easily take this Inrush Current .The power stage, on the other hand and if not properly designed for, may take a beating.

Once the motor has started, the motor current will go down from inrush levels to whatever load the motor is at. For example, if the motor is moving a few gears, current will be proportional to that load and according to torque/current curves.

Stopping the motor is not as harsh as starting. In fact, stopping is pretty much a breeze. What we do need to concern ourselves is with how we want the motor to stop. Do we want it to coast down as energy is spent in the loop, or do we want the rotor to stop as fast as possible? If the latter is the option, then we need braking. Braking is easily accomplished by shorting the motor outputs. The reason why the motor stops so fast is because as a short is applied to the motor terminals, the Back EMF is shorted. Because Back EMF is directly proportional to speed, making Back EMF = 0, also means making speed = 0.[10]

This is a modified start where the DC power supply is applied to the load using a PWM with a duty cycle going from 0% to 100%.

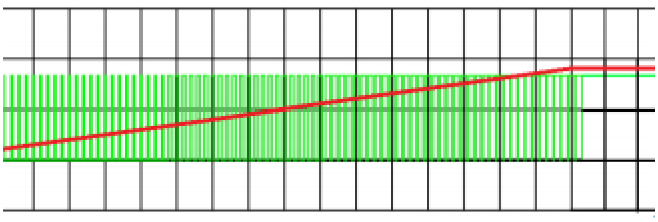


Figure 8: Soft Starting by PWM

In the graph, the green line is the control voltage of the switch; the red line is the average voltage on the motor. Soft Start/Ramp Up time is the duration of this PWM ramp, used to avoid initial inrush current and abrupt motor movement.

The same applies for the soft stop function. During the “ramp” time, the PWM goes from 100% to 0% producing a soft stop, without mechanical jolts.[11]

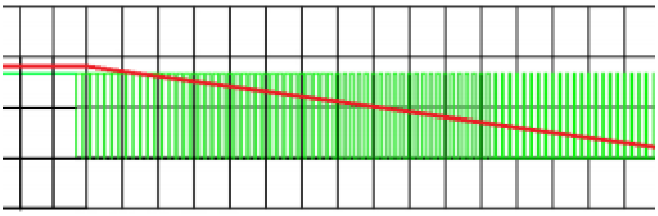


Figure 9: Soft Stopping by PWM

Battery Basics and Terminology

Voltage

Battery packs are made up of individual cells connected together. Each cell has a more or less constant voltage dependent on its chemistry. For NiCad/NiMH, this is about 1.2V, for lead acid it is 2.0V, and for lithium cells it is on the order of 3.7V. Typical Electrical Vehicle and scooters are designed to run on 24, 36, or 48 Volts, so a number of cells have to be series connected into a 'battery' that has the desired net voltage. A nominal 36V pack could be made from 10 lithium cells, 18 lead acid cells, or 30 NiMH cells.[12]

Amp-Hours

As you draw current from a battery pack, the voltage will very slowly decrease until the cells start to go flat and then the voltage will plummet. The time that the battery lasts for is directly related to its capacity, measured in amp-hours (Ah). A pack that can deliver 1 amp for 1 hour has a capacity of 1 Ah. Most Electrical Vehicles' batteries are on the order of 10 amp-hours. Suppose your machine uses 15 amps on average and has a 10Ah pack, then you would expect it to last for - quick, mental calculation... - 40 minutes. .[12]

Watt Hours

The figure that matters most when comparing how far a given battery pack will take you is not the amp-hour capacity but the total energy stored watt-hours. To make things more familiar, one watt-hour is one-thousandth of a kWh, the unit of energy used to measure household electrical usage. The watt-hours stored in a battery pack is approximated by taking the actual amp-hours and multiplying it by the pack voltage.

A higher voltage setup therefore needs fewer amp-hours to deliver the same range. So a 24V 8Ah battery can deliver 192 watt-hours, while a 48V 4Ah pack also has 192 watt-hours. Assuming that both batteries are of the same chemistry, then you could expect they would weigh the same, cost the same, and provide the same performance on appropriately designed electrical Machine (ie, one designed for 24V and the other for 48V). [12]

Energy Density

When comparing between battery chemistries, one of the most relevant metrics is the Energy Density in watt-hrs / kg. This figure says how heavy a battery pack will have to be to achieve a certain range. For Lead Acid it is 20-30 whrs/kg, for NiCad it is 35-40 whrs/kg, NiMH is 50-60 whrs/kg, Li-ion is ~110 whrs/kg, and Li-Polymer is up to 160 whrs / kg. Knowing these values makes it easy to project the weight of a pack without having to look up data from the manufacturer.[12]

Lithium Batteries Vs. Lead Acid Batteries

	Lithium	Lead Acid
1. Battery specific energy (Wh/Kg)	110-190	30-50
2. Discharge cycles 80% D.O.D	2000+	300-600
3. Charge Time, Hours	0.5-2	2-5
4. Solar charge acceptance, round-trip	98%	36%
5. Self discharge/month %	1-2%	5%
6. Average operating voltage per cell	3.2	2
7. Relative battery/pack cost	2-4X	1X
8. Relative safety	1.5	2
9. Relative environmental	1	3 [13]

Table 4: Lithuim Vs Lead Acid Comparison

1. 4 Times stronger or 4 times lighter
2. 6-8 Times longer life than lead acid
3. ½ to 2 hour recharge times: 4 Times Faster
4. 3 times more energy Harvested
5. Maintains 75% of it's energy after 1 Year
6. Replaces: 6.4V, 9.6V, 12.8V, 16V, 24V, 36V, 48V, ETC.
7. Higher initial cost, Lower cost-of-ownership
8. Safer than Any lead acid battery
9. Finally: An Eco-Friendly Green Battery

Joystick

Table 5: Joystick Buttons

This is a joystick very similar to the 'analog' joysticks on PS2 (PlayStation 2) controllers. Directional movements are simply two potentiometers - one for each axis. Pots are ~10k each. This joystick also has a select button that is actuated when the joystick is pressed down.

Description

The Joystick Shield kit contains all the parts you need to enable your microcontroller with a joystick as you, the shield sits on top of your microcontroller and turns it into a simple controller. Five momentary push buttons (4+ joystick select button) and a two-axis thumb joystick gives your microcontroller functionality on the level of old Nintendo controllers. Soldering is required, but it's relatively easy and requires minimal tools.

The momentary push buttons are connected to microcontroller digital pins ; when the pin been pressed, it will pull the pin high , we use 3 push buttons :
the first push button used As hardware interrupt which will interrupt the whole system and forces the chair to stop even there's an input command from the joystick .

Vertical movement of the joystick will produce a proportional analog voltage on analog pin AN0, likewise, horizontal movement of the joystick can be tracked on analog pin AN1.

Table6 : A joystick

the voltage rages (0-5) volts giving(2.5) at the steady state condition of the joystick moving the joystick forward will increase the voltage until it reaches 5 volt also moving the joystick reward will decrease the voltage until it reaches (0) volt , this also verified for the left to right movement , the ADC will receive these values and output a PWM value accordingly .[14]

How does it work?

Imagine a volume control or other knob. These controls are generally made from potentiometers, which are variable resistors. By connecting the potentiometer as a voltage divider, you can get a varying voltage out of the device, which can be fed to an analog to digital converter on a microprocessor. This allows the software to read the knob position.[14]

This joystick contains two potentiometers, connected with a gymbal mechanism that separates the "horizontal" and "vertical" movements. (If the joystick is flat on a table, these movements are more "front / back" and "left / right", but you get the idea.) The potentiometers are the two blue boxes on the sides of the joystick. If you move the joystick while watching the center shaft of each potentiometer, you'll see that each of the potentiometers pick up movement in only one direction. Clever, isn't it!

This joystick also contains a switch which activates when you push down on the cap. The switch is the small black box on the rear of the joystick. If you push down on the cap, you can see a lever pushing down on the head of the switch. The lever works no matter what position the joystick is in.

Assembly

The retail package includes the joystick and a "breakout board" (the red printed-circuit board, or PCB). You'll solder the breakout board to the joystick. Once this is done, it will be much easier to connect the joystick to your project (you won't have to solder wires to all those little pins). To attach the breakout board to the joystick, follow these steps:[14]

1. Test-fit the breakout board to the joystick. If any pins on the joystick are bent, gently straighten them. The joystick goes into the side of the board with the white outline (*not* the side with the SparkFun logo). Insert the joystick into the board, matching the white outline, and ensure that all the pins go into their holes (if they don't, you may not have the joystick oriented correctly).

2. If everything fits OK, carefully solder the pins from the opposite side of the board. Never soldered before? It's easy, check out our tutorials. If this is your first time soldering, practice a bit before working on this board. Before and during soldering, ensure that the joystick stays tight against the breakout board. There are 14 solder connections to make, including the four posts at the corners of the joystick.

3. If you'd like to connect a 5-pin header to the board, or solder bare wires to the output holes, you may do that now. Once you're done soldering, you're ready to use your joystick!

Figure10 : Joystick Pins

Use it

The breakout board provides five labeled connections. You'll connect these lines to your project or microcontroller:

- VCC: connect this to your positive supply (usually 5V or 3.3V)
- VERT: this is the vertical output voltage (will be half of VCC when the joystick is centered)
- HORIZ: this is the horizontal output voltage (will be half of VCC when the joystick is centered)
- SEL: this is the output from the pushbutton, normally open, will connect to GND when the button is pushed (see example code below)
- GND: connect this to your ground line (GND)

Note that the pushbutton (SEL) is connected to GND when pressed, and open (disconnected) when unpressed. Use a pullup resistor on your digital input so that when it's unpressed, your input will read 1 (HIGH), and when pressed, the input will read 0 (LOW). Many microcontrollers have internal pullup resistors you can use for this purpose. [14]

Microcontroller

Is a low voltage system which can receive/ immigrate signals from/to switches or sensors then do different commands as it was programmed.

Different kinds of microcontroller can be used. Choosing the microcontroller depends on many characteristics, the world of controllers is very wide which can choose easily.

Most important thing should be studied before choosing the microcontroller is microcontroller pins number: this rated with number of sensors output and output pins needed.

Arduino

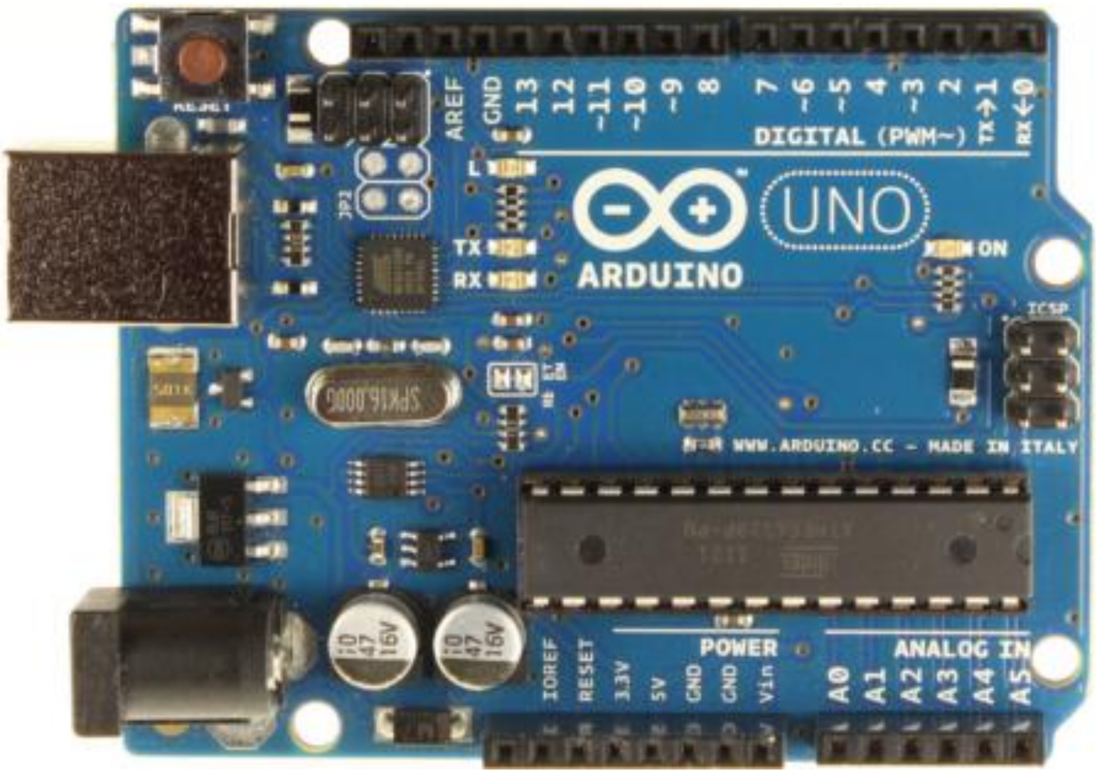


Figure 11: Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.[8]

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform[8]

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Table 7: Arduino Uno characteristics

Drive circuit

Why drive circuit?

While the microcontroller is a low voltage system and the motor is a high voltage system a specific circuit should built between. This circuit should work as an isolation between two voltages and achieve the required commands that microcontroller programed to do. This circuit is drive circuit which regulating direction and speed of a motor. This is achieved by using a Power bridge (H-bridge).

H bridge characteristics

H-bridge is an electronic circuit, containing four switching elements, which enables a voltage to be applied across a load in either direction, in an H like configuration. This circuit allows DC Motor to run clockwise or anti-clockwise.
H-bridge shown in the following figure:

H-bridge

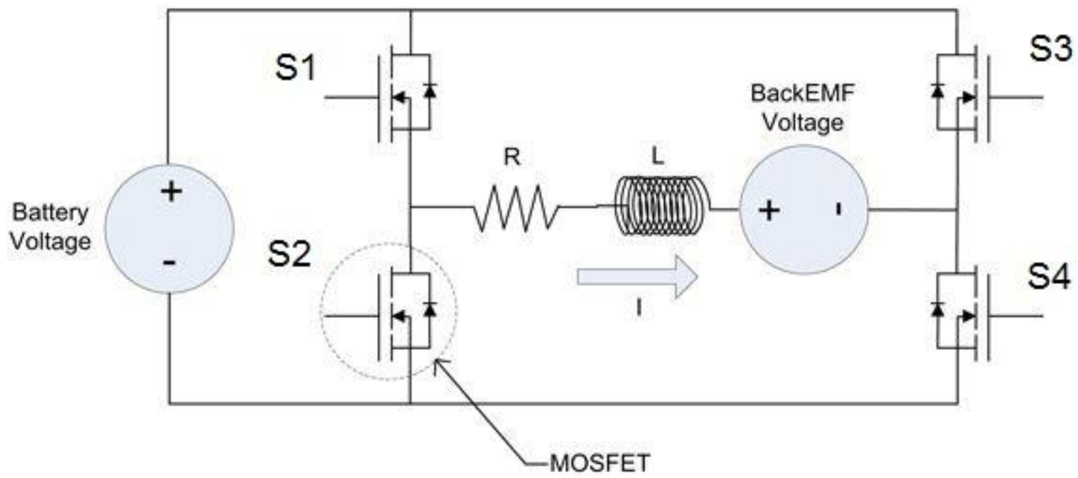


Figure 12: H-Bridge

Two important components H-bridge contains :

1. Power switches:

(IGBT's , MOSFET's , …………) which operate as switches when a spesific current supplied to its gate.

2. Catch diode:

It is impossible in any real circuit to turn on or off the high- and low-side switches at exactly the same time. They are either a bit early or a bit late. In one case, both the high- and low-side switch would be on for a short while, in the other both would be off momentarily.[15]

Catch diodes provide a low resistance path for collapse current to the motor to provide a reasonable voltage. When a switch is turned off, electromagnetic field generated in the motor winding, due to on-time condition, collapses but current still flows through it. Thus catch diodes provide a path for this collapse current which keeps a reasonable amount of voltage on the motor. The diodes should have short turn-on delay, thus Schottky-type diodes are generally used.[16]

How H-Bridge operate (Four Quadrant operations):
SEE ABENDIX #2

Regenerative braking

In the motion control industry, the term “regeneration” or “regenerative braking” refers to using the power associated with the BackEMF voltage of an electric motor to charge a battery. This is the opposite of the normal operational mode where the battery is used to provide power to an electric motor. However since an electric motor can act as a generator, a system can be designed where the power flow (in or out) of the motor and battery can change in real-time. So, instead of throwing away the BackEMF power into heat loss, it can be used to recharge the battery, thereby recovering energy.[17]

Whenever the back-EMF is greater than this voltage, you get regenerative braking. This will happen whenever the PWM duty cycle decreases faster than external forces (friction, for example) will slow the motor. Any resistance in the circuit reduces the energy you can recover from the mechanical load. In the most extreme case where the PWM duty cycle is decreased to 0% and the motor terminals are shorted together, the current is so high that losses reach 100%.[18]

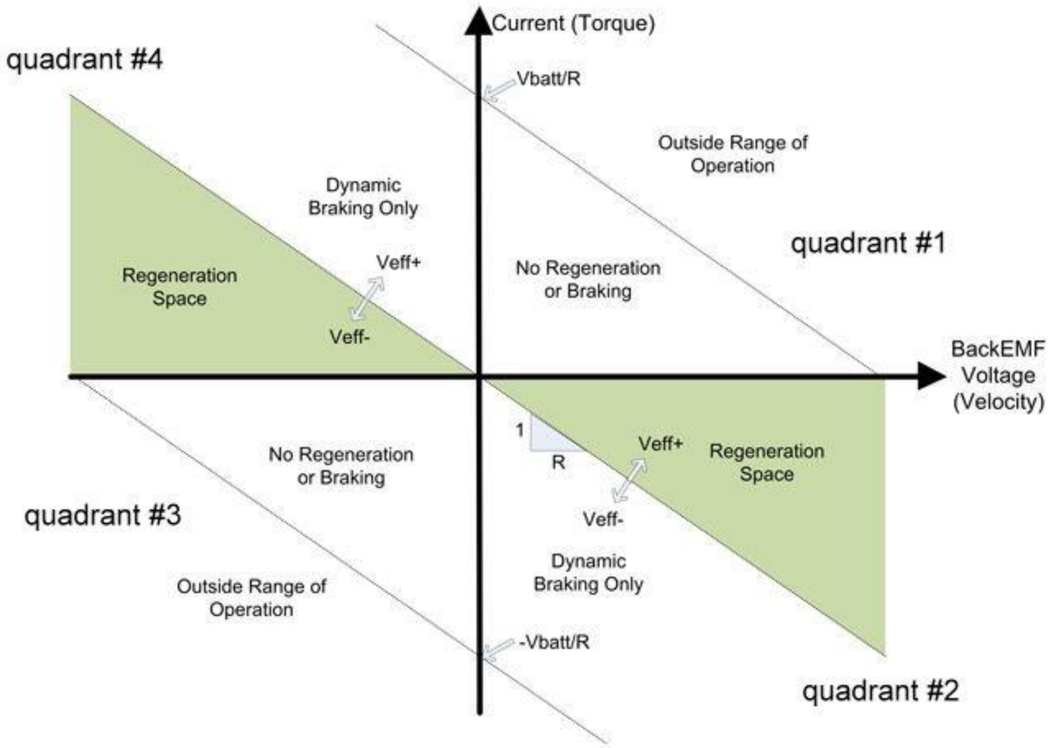


Figure 13: Regenarative Regions

$V_{eff} = Ri + L(di/dt) + V_{emf}$

This equation for motor when it applied by dc supply as shown

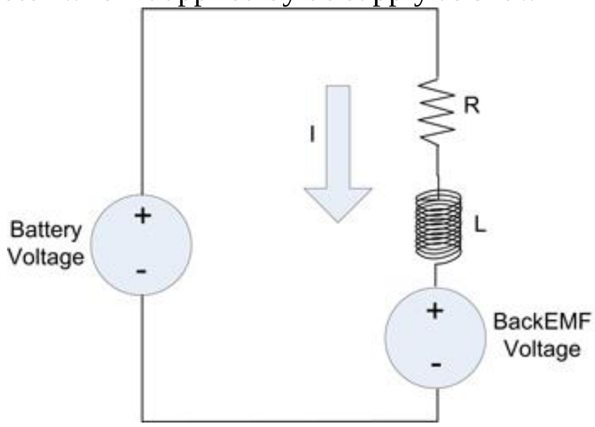


Figure 14: Motor's Circuit

In quadrant #2 ,when V_{eff} is positive and the V_{emf} is negative , that's mean "regenerative braking" is applied by h-bridge catch diode , but when V_{eff} is negative , that's mean "dynamic braking" is applied by torque in the opposite direction of the motion .

And quadrant #4 as quadrant #2

Control input voltage using PWM

Obviously the power generated by the battery must be equal to the power given to the motor (the controller has very high efficiency). Indicating the duty cycle as DC:
Power generated by the battery:

Vbb x Iaverage = Vbb x Ipeak x DC

Power received by the motor:

Imot x Vmot = Imot x Vbb x DC

Therefore:

Vbb x Ipeak x DC = Imot x Vbb x DC

Ipeak = Imot / DC

As an example, measuring 5 Amp continuous current in the motor when the duty cycle is 10% means that the peak of current in the battery is 50 Amp, something to take into account in designing the mechanical and electrical power connections.[8]

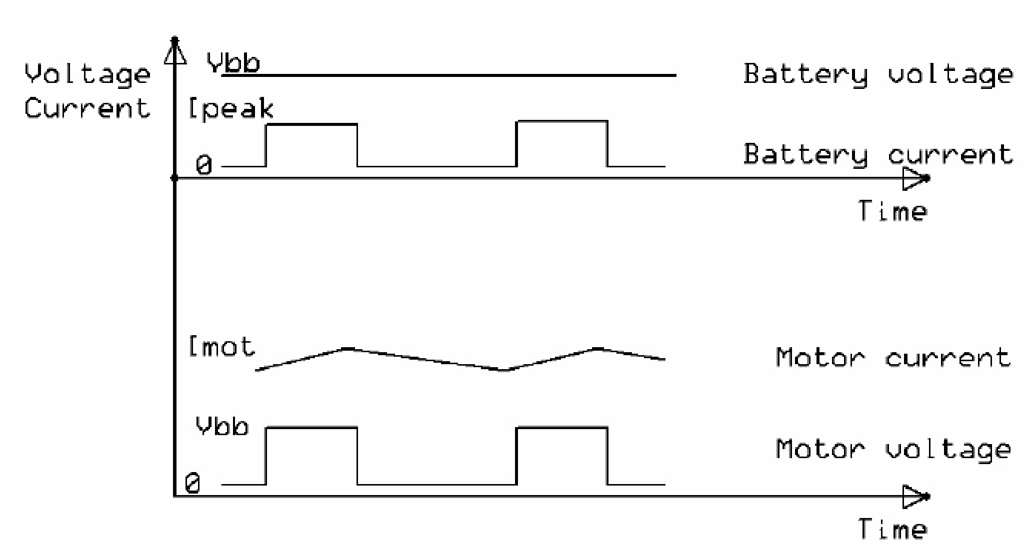


Figure15 : Voltage control using Duty Cycle

In reality what described above is not what is observed, since the current at the battery Ibb is close to a DC current, due to the smoothing effect of the of large electrolytic capacitors mounted in the controller.
Consequently the battery delivers a constant amount of power (constant voltage/constant current):

Pbb = Vbb x Ibb

The motor conversely has its voltage Vbb chopped by the duty cycle DC and a constant current Imot; the two powers need to be the same, therefore:

Vbb x Ibb = (Vbb x DC) x Imot ……………….Imot = Ibb / DC

In conclusion the current flowing in the motor is larger than the current measured at the battery except than when the duty cycle becomes 100%.
The example above refers to the controller and the motor in the first quadrant.

Algorithms and Circuit

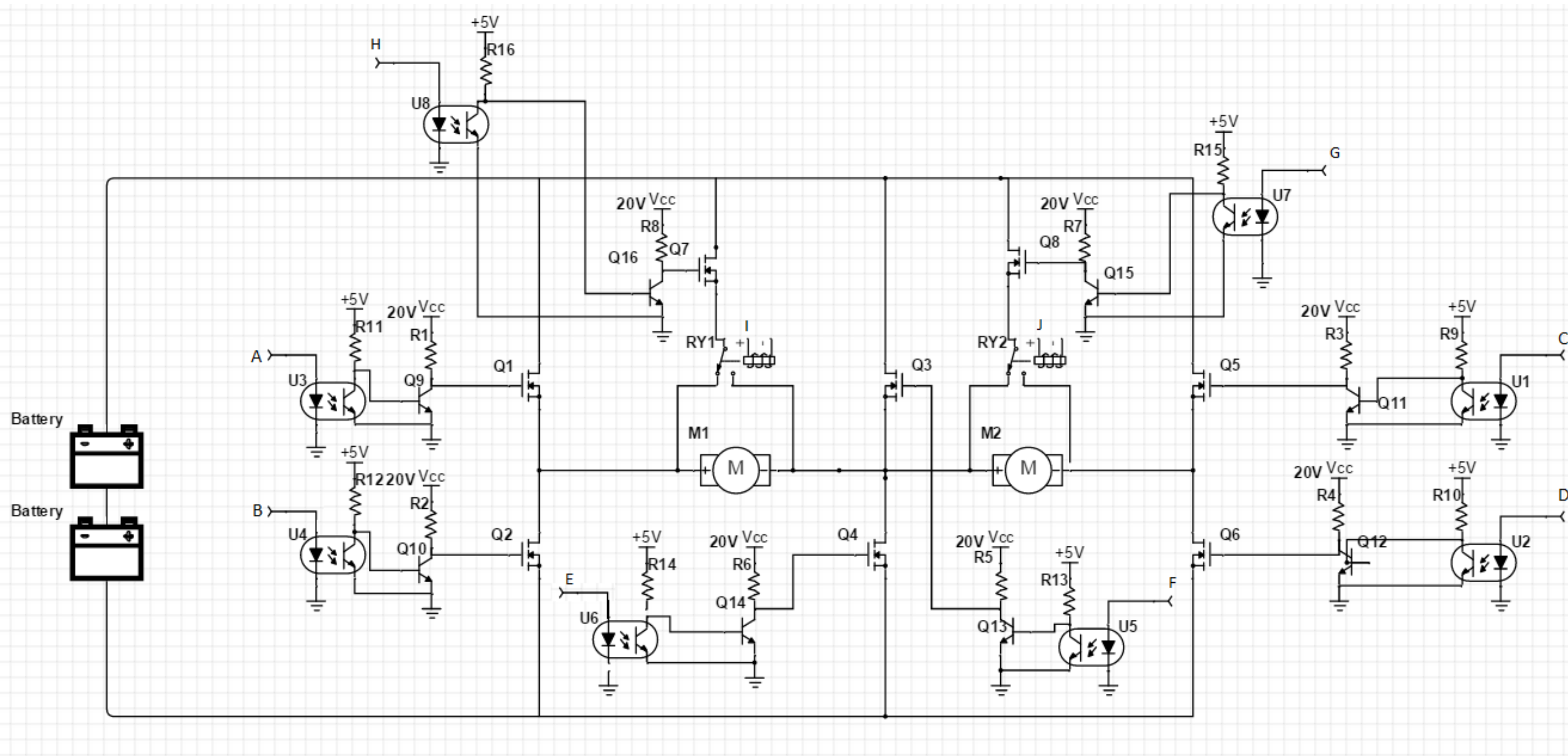


Figure16 : The whole circuit

Batteries: 12 V each.

Q1 ,Q2,…,Q8 : IR1404(Power Mosfet with catch diode).

Q9,Q10,…,Q16:2N 3904 NPN Transistor.

R1,R2,…,R8:1 Kohm

M1:Left Motor.

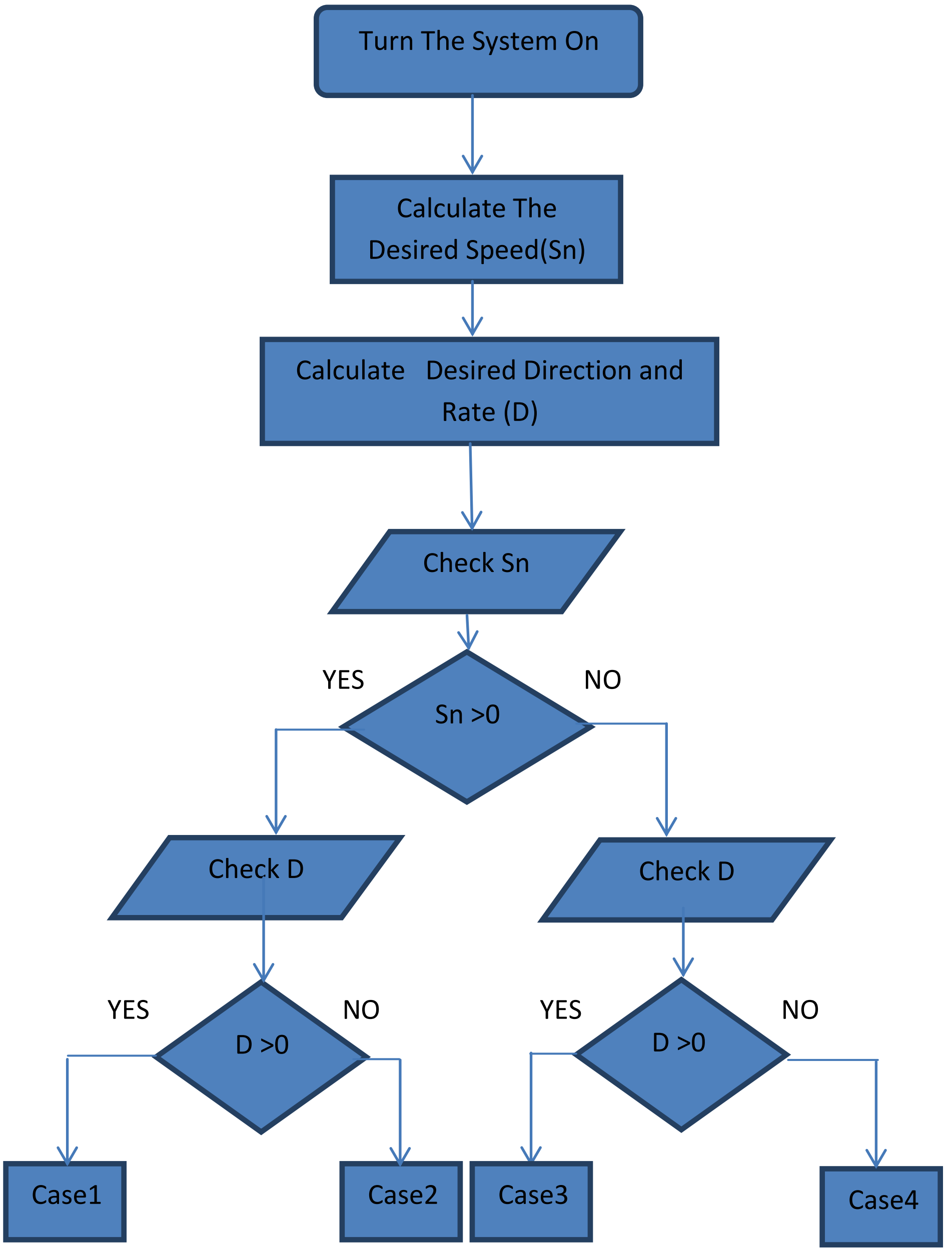
M2:Right Motor.

RY1,RY2: Relays 5VDC/24VDC.

A,B,C,D,G,H : Each one connected with M.C pins through an isolator.(The input is PWM signal with vary duty cycle).

F,E,I,J: Each one connected with M.C pins through an isolator.(The input is High or Low).

The Follwing Algorithem For Right Motor:



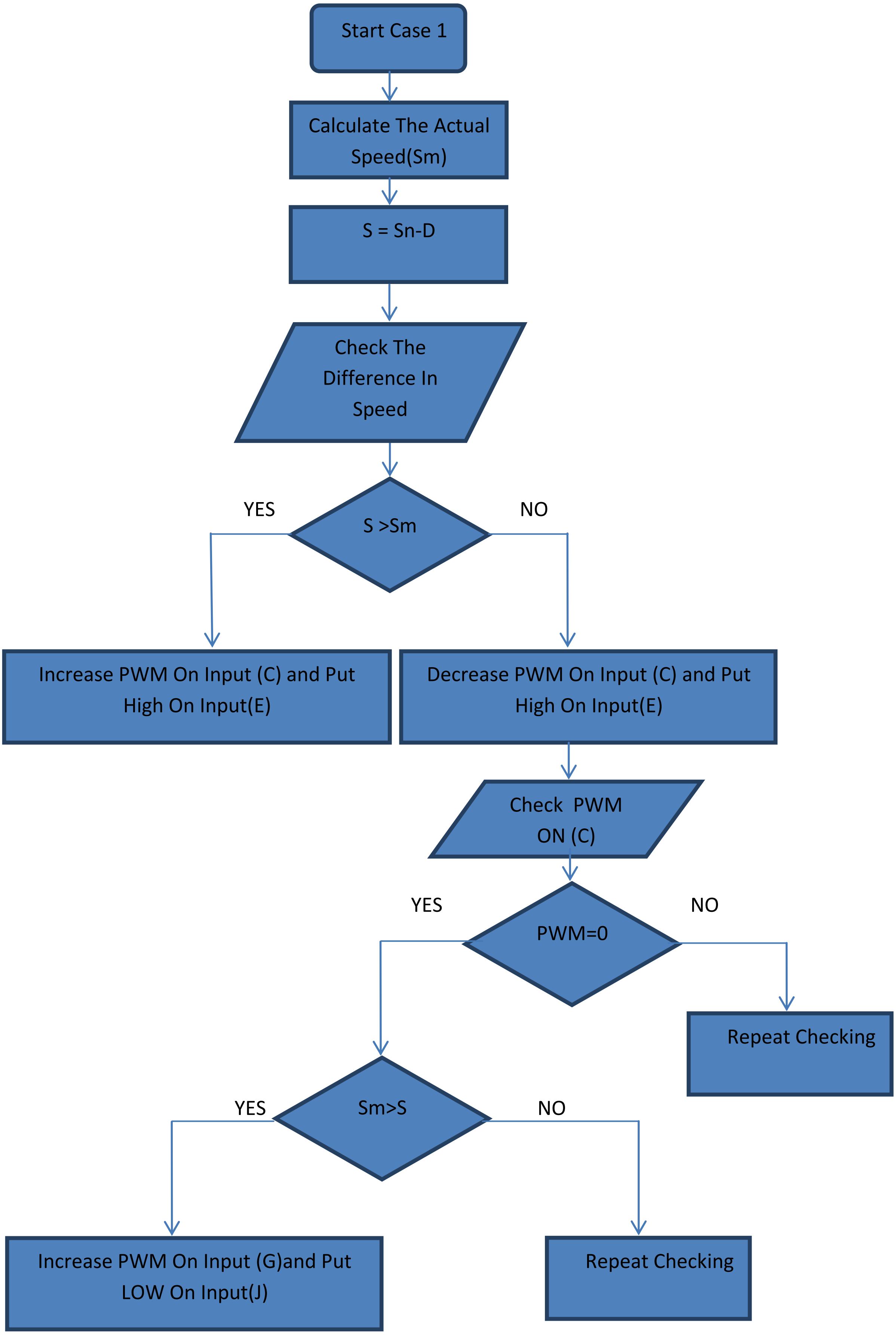
Case1: Joystick bent Right-Forward and Actual Speed less than needed.

Case2: Joystick bent Left-Forward and Actual Speed less than needed.

Hint: no direction or no speed measured can be included under any condition.

Case3: Joystick bent Right-Backward and Actual Speed less than needed.

Case4: Joystick bent Left-Backward and Actual Speed less than needed.



SEE ABENDIX #3 for the rest cases

Arduino Code

```
int pwmPort3 = 3 , pwmPort5= 5 , pwmPort6 = 6,pwmPort9 = 9,
pwmPort11 = 11,pwmPort10 = 10;
int pwmValue3 = 0 , pwmValue5= 0 , pwmValue6 = 0,pwmValue9 =
0,pwmValue11 = 0,pwmValue13 = 0 ;


int xValue,yValue;
float SPD;
float SPD2;
int  D = 0 ;
int sm;
int sm2;
float t1,t2;
int s;
int s2;
void setup() {
  // put your setup code here, to run once:

Serial.begin( 9600 );

pinMode( A2,INPUT );
pinMode( A3,INPUT );




}

void loop() {
  // put your main code here, to run repeatedly:

  // read the value from the sensor:
   xValue = analogRead(A2);
   yValue = analogRead(A3);
```

```
   //t1 is in milli second
   t1 = readOptical();

   SPD = (yValue*8/512) - 8;
   D = (xValue*4/512) -4;

   sm = 439.2/t1;
   //t2 is in milli second
   t2 = readOptical2();

   sm2 = 439.2/t2;
   int s;

fun1();
fun2();
fun3();
fun4();

}
//return time in milli seond
float readOptical()
{
  float count = 0;
   while( analogRead(A0) == 0)
   {
     delayMicroseconds(100);
     count++;

   }
  return count/1000 ;
}
//return time in milli seond
float readOptical2()
{
```

```
  float count2 = 0;
   while( analogRead(A1) == 0)
   {
     delayMicroseconds(100);
     count2++;

   }
  return count2/1000 ;
}

void fun1()
{
  digitalWrite(7,LOW);
  digitalWrite(8,LOW);

  while(SPD > 0 && D > 0 )

   {
     digitalWrite(10,HIGH);
     digitalWrite(12,HIGH);
    s = SPD- D;
    s2 = SPD;
     while( sm  < s && sm2  < s2 )
     {
    //2.5 = 1% duty cycle
    pwmValue3+= 12.5;
    analogWrite(pwmPort3 , pwmValue3 );
    pwmValue5+= 12.5;
    analogWrite(pwmPort5 , pwmValue5 );
    digitalWrite(8,HIGH);
    delay(50);

     }
     while( sm  < s && sm2  > s2 )
     {
```

```
//2.5 = 1% duty cycle
pwmValue3+= 12.5;
analogWrite(pwmPort3 , pwmValue3 );
pwmValue5-= 12.5;
analogWrite(pwmPort5 , pwmValue5 );
digitalWrite(8,HIGH);
while (pwmValue5 == 0 && sm > s2 )
   {
```

Choosing switches in H Bridge

It is important to choose a switching device that can efficiently handle the high current. For this type of application, there are two types of switches to choose from, one is the Insulated Gate Bipolar Transistor (IGBT) and the other is a Metal Oxide Semiconductor Field Effect Transistor (MOSFET).[7]

MOSFETs and IGBTs: Similar But Different

The IGBT technology is certainly the device of choice for breakdown voltages above 1000V, while the MOSFET is certainly the device of choice for device breakdown voltages below 250V.

Between 250 to 1000V, there are many technical papers available from manufacturers of these devices, some preferring MOSFET's, some IGBTs. However, choosing between IGBTs and MOSFETs is very application-specific and cost, size, speed and thermal requirements should all be considered.

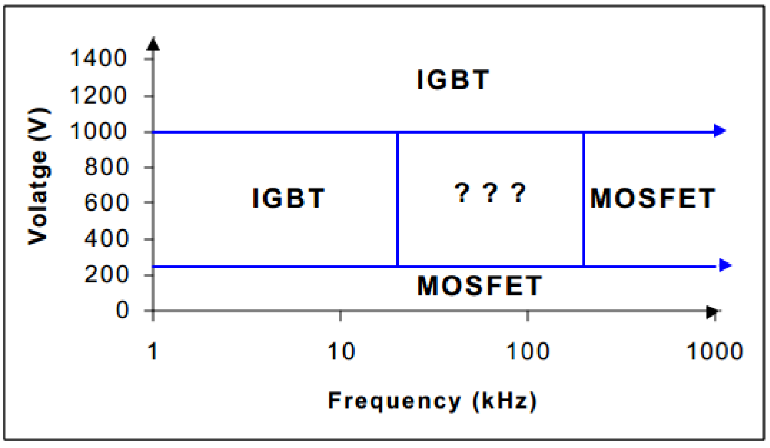


Figure 17: IGBT, MOSFET Switching Frequency

Figure 3 shows some of the boundaries where it is fairly clear as to what is preferred, the MOSFET or IGBT, the specifics are further detailed below. As a general guideline, this is good starting point. [19]

IGBTs have been the preferred device under these conditions:

- Low duty cycle
- Low frequency (<20kHz)
- Narrow or small line or load variations
- High-voltage applications (>1000V)
  · Operation at high junction temperature is allowed (>100°C)
- >5kW output power

Typical IGBT applications include:

· Motor control: Frequency <20kHz, short circuit/in-rush limit protection

- Uninterruptible power supply (UPS): Constant load, typically low frequency
- Welding: High average current, low frequency (<50kHz), ZVS circuitry
- Low-power lighting: Low frequency (<100kHz)

MOSFETs are preferred in:

- High frequency applications (>200kHz)
- Wide line or load variations
- Long duty cycles
- Low-voltage applications (<250V)
- < 500W output power

Typical MOSFET applications include:

- Switch mode power supplies (SMPS): Hard switching above 200kHz .
- Switch mode power supplies (SMPS): ZVS below 1000 watts .
- Battery charging.

Power MOSFET

A MOSFET generally has three interfaces with the circuit: the Gate (used to control switching), the Source, and the Drain. In an N-Channel MOSFET, when a voltage between the Gate and the Source is greater than the "Gate Threshold Voltage" is applied to the gate, current is allowed to pass from the Source to the Drain. Because we either want all the current, or none of the current to pass to the motor through the MOSFET, we simply either throw the gate to 0V or to the maximum voltage in the circuit. [7]

Frequency

The frequency of the resulting PWM signal is dependent on the frequency of the ramp waveform. What frequency do we want? This is not a simple question. Some properties and conditions are:

- Frequencies between 20Hz and 18 kHz may produce audible screaming from the speed controller and motors.
- RF interference emitted by the circuit will be worse the higher the switching frequency is.
- Each switching on and off of the speed controller MOSFETs results in a little power loss. Therefore the greater the time spent switching compared with the

static on and off times, the greater will be the resulting 'switching loss' in the MOSFETs.

- The higher the switching frequency, the more stable is the current waveform in the motors. This waveform will be a spiky switching waveform at low frequencies, but at high frequencies the inductance of the motor will smooth this out to an average DC current level proportional to the PWM demand. This spikiness will cause greater power loss in the resistances of the wires, MOSFETs, and motor windings than a steady DC current waveform.[20]

Gate Driver:

The bipolar transistor, is current driven, Power MOSFETs, with their insulated gates, are voltage driven. A basic knowledge of the principles of driving the gates of these devices will allow the designer to speed up or slow down the switching speeds according to the requirements of the application.

It is often helpful to consider the gate as a simple capacitor when discussing drive circuits.
Power MOSFETs and IGBTs are simply voltage driven switches, because their insulated gate behaves like a capacitor. Conversely, switches such as triacs, thyristors and bipolar transistors are “current” controlled, in the same way as a PN diode.

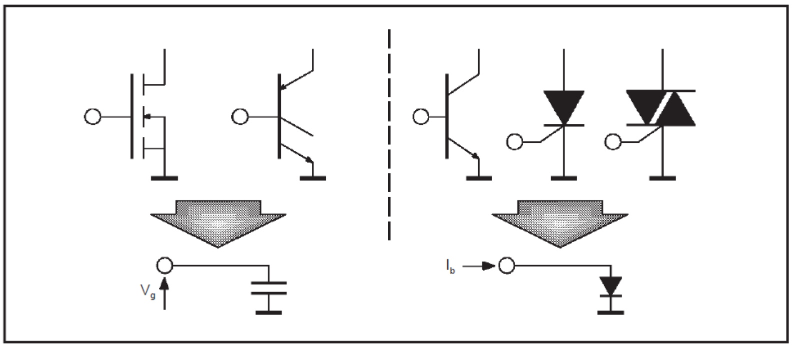


Figure 18: IGBT, MOSFET gates

As shown in figure below, driving a gate consists of applying different voltages: 15V to turn on the device through S1, and 0Vto turn off the device through S2.[21]

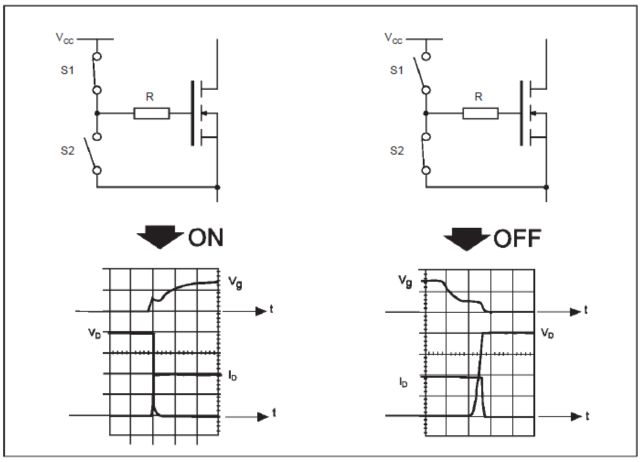


Figure19 : MOSFET ON/OFF

Power MOSFETs require a gate drive circuit to translate the on/off signals from an analog or digital controller into the power signals necessary to control the MOSFET.

In order for the MOSFET to conduct, two requirements must be met:

- The MOSFET should have a reference ground
- The voltage between the gate and the source should be between 5V and 20V.

Since the sources of the MOSFETs in the upper side are connected to the end terminals of the motor, a floating ground exists. Therefore we need to create a virtual ground in order for the MOSFET to conduct. In addition to that, the gate of the MOSFET is voltage controlled and not current controlled thus a voltage between 5V and 20V should be supplied between the gate and the source of the MOSFETs.

An example of drivers: IR2110 driver.[7]

Thermal Explanation

The TIP120 will work for low currents, but a heat sink is needed for high current. The reason is that most transistors have a voltage drop between their collector and emitter of about .7 volts. Recall that power is P = I * V. With say, 5 amps and a .7V drop, the TIP120 will dissipate 5 * .7 = 3.5 watts. That's wasted power that could have been used by the load with a more efficient device.

Now calculate power again. The resistance from Source to Drain of the IRF3708 is very high when it is off, but a maximum of only .029 ohms when it is on. Recall from **How To Read A Schematic**_ that V = I * R. That means we can replace the V in the power equation above with I * R since the two are equal. Thus,

$P = I * (I * R) = I^2 * R.$

If we use the same 5 amp current and .029 ohms we get:
$P = 5^2 * .029 = 25 * .029 = .725$ watts,
which means wasted power is reduced by almost 5 times.[22]

Some switches and these specifications:

The switch Model	The switch type	Rated Voltage	Rated Current	R(on) max
TIP 120	NPN General Purpose Amp.	60	8	1.4Ω
IRF3708	MOSFET	30	62	12 mΩ

IRF1010Z	MOSFET	55	75	7.5 mΩ
IRFP064N	MOSFET	55	110	0.008 mΩ

Table 8: Some Power Switches Proprieties

Heat sink & cooling system

All semiconductor devices have electrical resistance, just like resistors and coils, etc. This means that when power diodes, transistors and MOSFETs power as heat energy will be dissipated. To save devices from thermal damaged, the heat must be removed at a fast enough rate to prevent excessive temperature rise.

A heat sink simple system is used to dissipate heat. The heat sink helps to dissipate (remove) the heat by transferring it to the surrounding air.

The rate of producing waste heat is called the thermal power P. Take the IGBT as an example, so the thermal power is determined by the collector current I_C and the resistance across the IGPT:

$P = I_C \times V_{CE}$

Heat sink ratings

Heat sinks are rated by their thermal resistance (Rth) in °C/W. For example 2°C/W means the heat sink (and therefore the component attached to it) will be 2°C hotter than the surrounding air for every 1W of heat it is dissipating. Note that a lower thermal resistance means a better heat sink.

How you work out the required heat sink rating:

Work out thermal power to be dissipated, $P = I_C \times V_{CE}$
If in doubt use the largest likely value for I_C and assume that V_{CE} is half the supply voltage.
For example if a power transistor is passing 1A and connected to a 12V supply, the power P is about 1 × ½ × 12 = 6W.

Find the maximum operating temperature (Tmax) for the transistor if you can, otherwise assume Tmax = 100°C.

Estimate the maximum ambient (surrounding air) temperature (Tair). If the heat sink is going to be outside the case Tair = 25°C is reasonable, but inside it will be higher (perhaps 40°C) allowing for everything to warm up in operation.

Work out the maximum thermal resistance (Rth) for the heat sink using:
Rth = (Tmax - Tair) / P
With the example values given above: Rth = (100-25)/6 = 12.5°C/W.

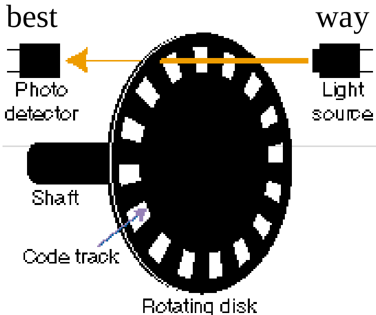
Choose a heat sink with a thermal resistance which is **less** than the value calculated above (remember lower value means better heat sinking!) for example 5°C/W would be a sensible choice to allow a safety margin. A 5°C/W heat sink dissipating 6W will have a temperature difference of 5 × 6 = 30°C so the transistor temperature will rise to 25 + 30 = 55°C (safely less than the 100°C maximum).

All the above assumes the transistor is at the same temperature as the heat sink. This is a reasonable assumption if they are firmly bolted or clipped together. However, you may have to put a mica sheet or similar between them to provide electrical insulation, then the transistor will be hotter than the heat sink and the calculation becomes more difficult. For typical mica sheets you should subtract 2°C/W from the thermal resistance (Rth) value calculated in step 4 above.[23]

Optical Encoder

Encoder Types:
Encoders basically come with either 1 or 2 sensors. The encoders that come with 1 sensor can measure speed and distance but cannot determine which direction the motor is spinning. Encoders with 2 sensors (often called quadrature encoders) have 2 sensors that are 90° degrees out of phase. These sensors can determine what direction the motor is spinning as well as measuring speed and distance. In many cases they also offer better resolution.

To start with, we need a device that will measure the speed of the motor shaft. The best way to do this is to fit an optical encoder. This shines a beam of light from a transmitter across a small space and



detects it with a receiver the other end. If a disc is placed in the space, which has slots cut into it, then the signal will only be picked up when a slot is between the transmitter and receiver.[24]

-
-

Figure 20 :Rotating Disk

Results and analysis

The following main elements have been used in the hardware prototype:

Site of motors & drive kit	Shwon previous
Motors and wheels	PW-8F 8'' Brush motor
Microcontroller	Arduino Uno
Batteries	LIFEPO4 24V 12Ah

Table 9: Prototype Main Elements

The main topics considered were the efficiency either mechanical and electrical, i.e : the motors selected has an electrical advantage (high efficiency >90%), also has a mechanical advantage (light weight and internal gear).
Another important part should be studied is the economic part, to have a vision about the market. And finally we got the movable electric wheelchair we the desired and required characteristics.

Estimated prices

Description	Estimated price
Seat structure	30 $
PW-8F 8"DC PM Brush motor	400 $
LiFePO4 10AH 24V and a Charger	250 $
Two Optical encoders	10 $
Joystick	10 $
Microcontroller	40 $
Other equipments	60 $
Total expected price	1100$

Table 10: Estimated Prices

CONCLUSION AND FUTURE WORK

The social need is the independence of the physically challenged people. The mobility of the physically impaired people is made possible by the use of wheelchairs. Initially manual driven wheelchairs were used by physically handicapped people. However, the electrically driven wheelchairs are gaining popularity in the society. With the advent of fast and reliable power semiconductor switching devices, the power electronic converters are increasingly used for the control of electric motors. Lot of research effort has been put towards the development of fast and simple motor speed control methods. This project is also aimed at the development of advanced control algorithm for fast and simple speed control of DC motor driving the wheelchair. Studying wheelchair's elements was considered to explain advantages and disadvantages for them to know how choose elements and develop powered wheelchair. This project is a key for implementation and development of wheelchairs. In the near future a wheelchair will be able to go up stairs and down stairs as well.

Appendices

1. Power calculations :

Weight of the Wheelchair:

W=mass*g

Reaction of the incline:

R=W*cos(the phase)

Friction force

fx = μmax × R

Weight opposite the direction of the movement:

Wx=W*sin(the phase)

At equilibrium

ΣFx = F - fx - Wx = 0

F= fx +Wx

Torque at the wheel

T = F × r [7]

Calculation of rpm:

V = 2πr × RPM × (60/1000) km/hr

ω =RPM/60

Power Calculations:

$$Power\ (in) = Electrical\ Power = Volts * Current(Amps)$$

$$Power(out) = \frac{Speed\left(\frac{radian}{sec}\right) * Torque(Newton.meter)}{Efficiency}$$

746 Watts = 1 Horse Power

The previous calculations are general equations to calculate power needed for any weight or slope.

2. H Bridge:

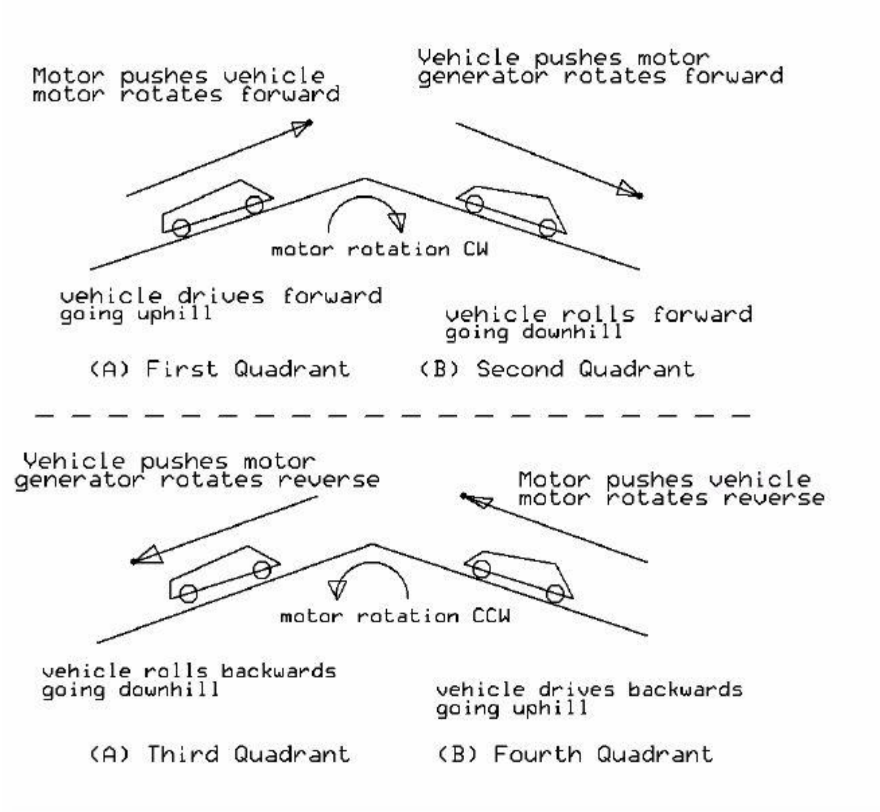


Figure 21: Wheel Chair Movements

In h-bridge

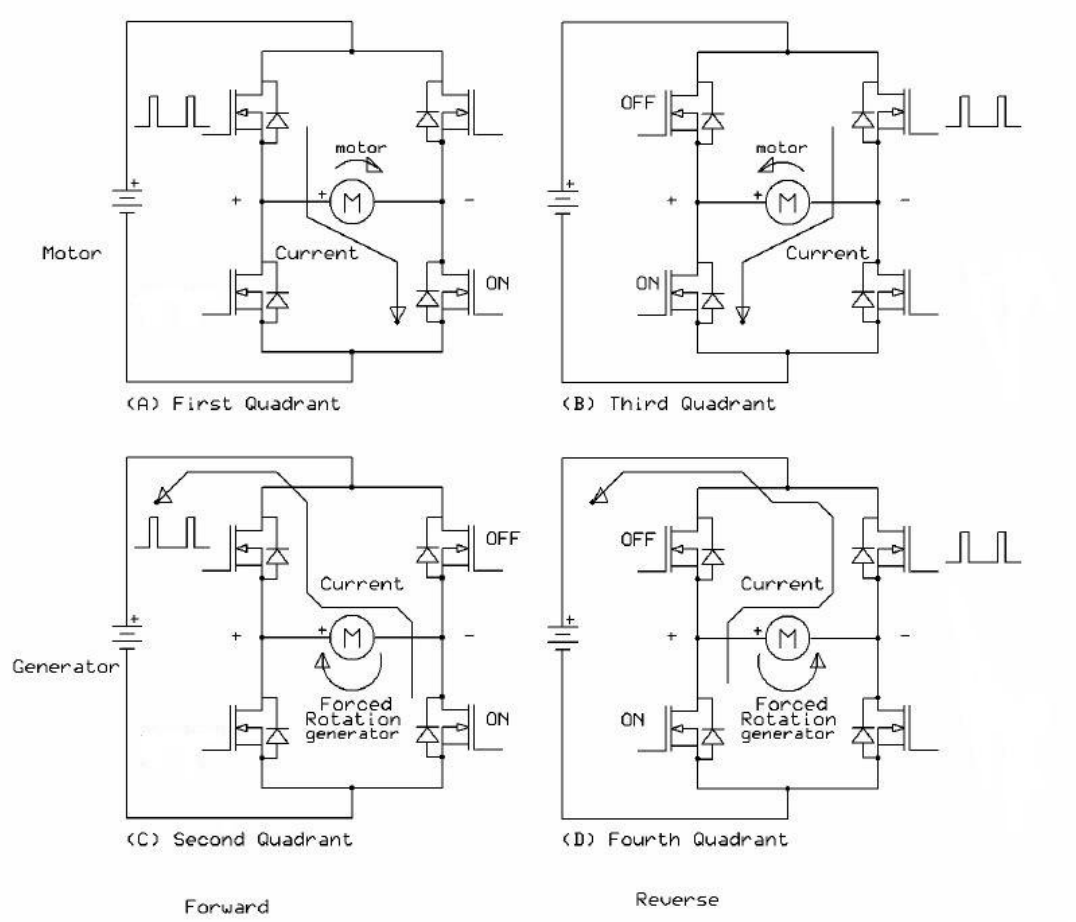
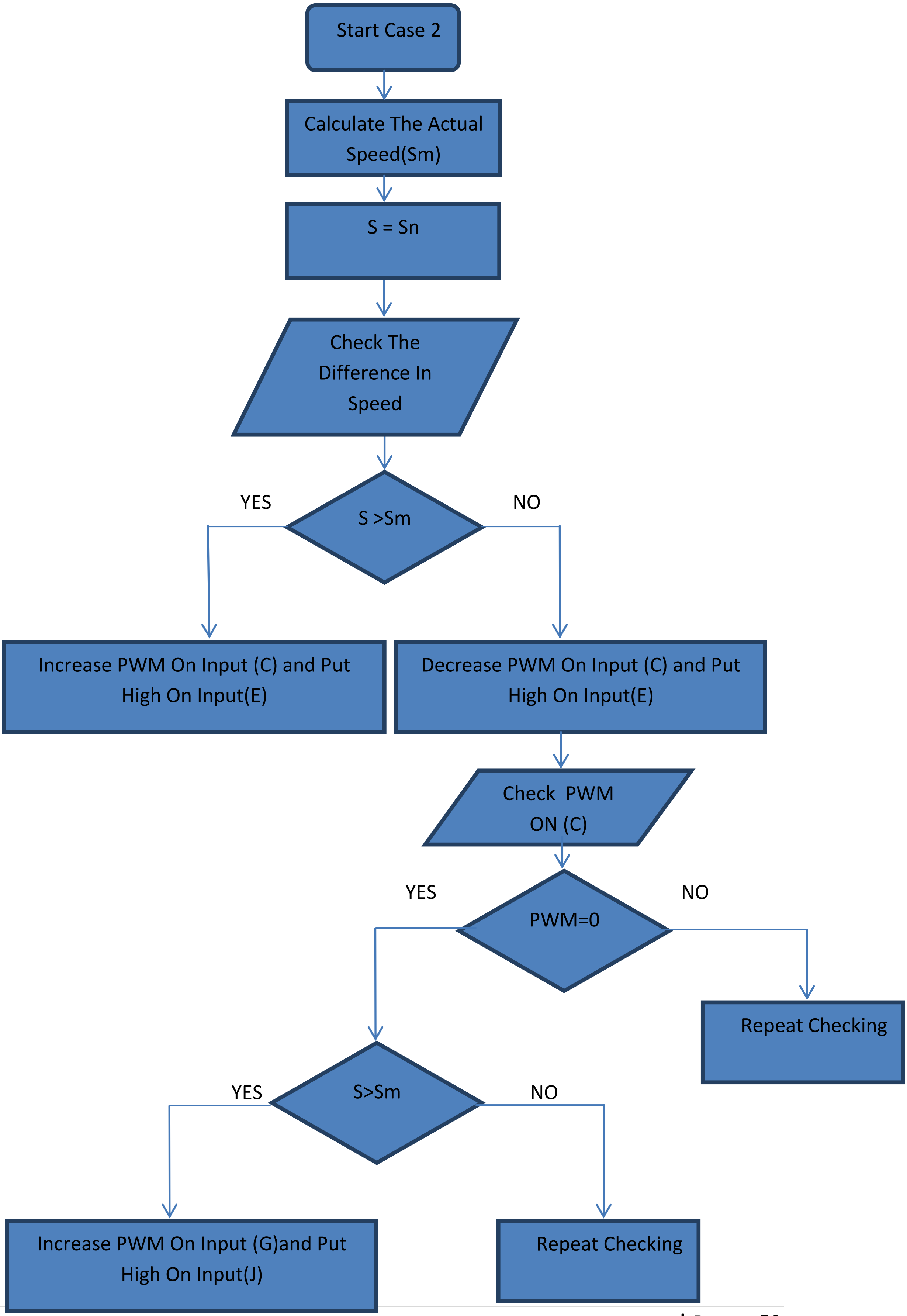


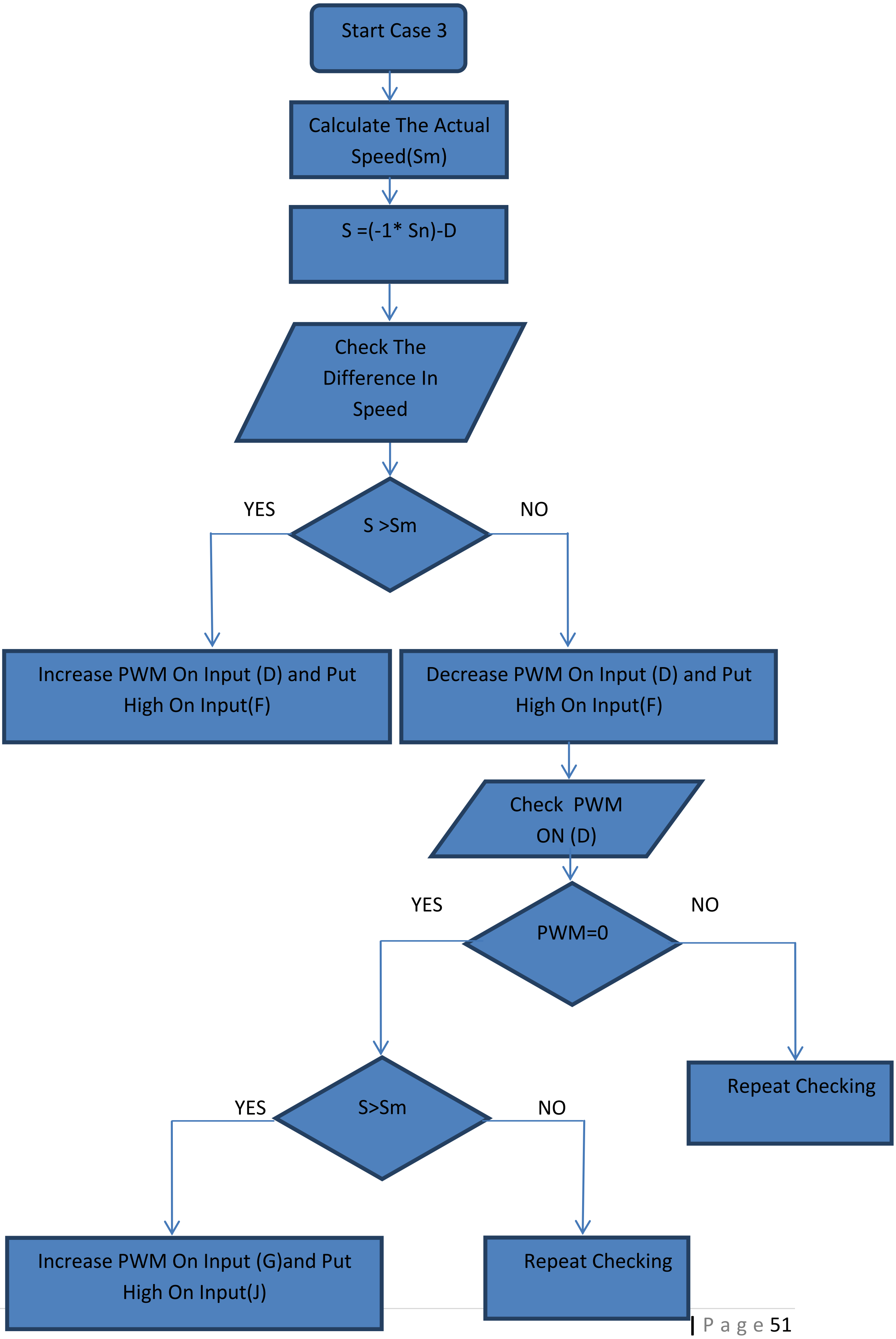
Figure 22: 4-Q Current Paths in H-Bridge

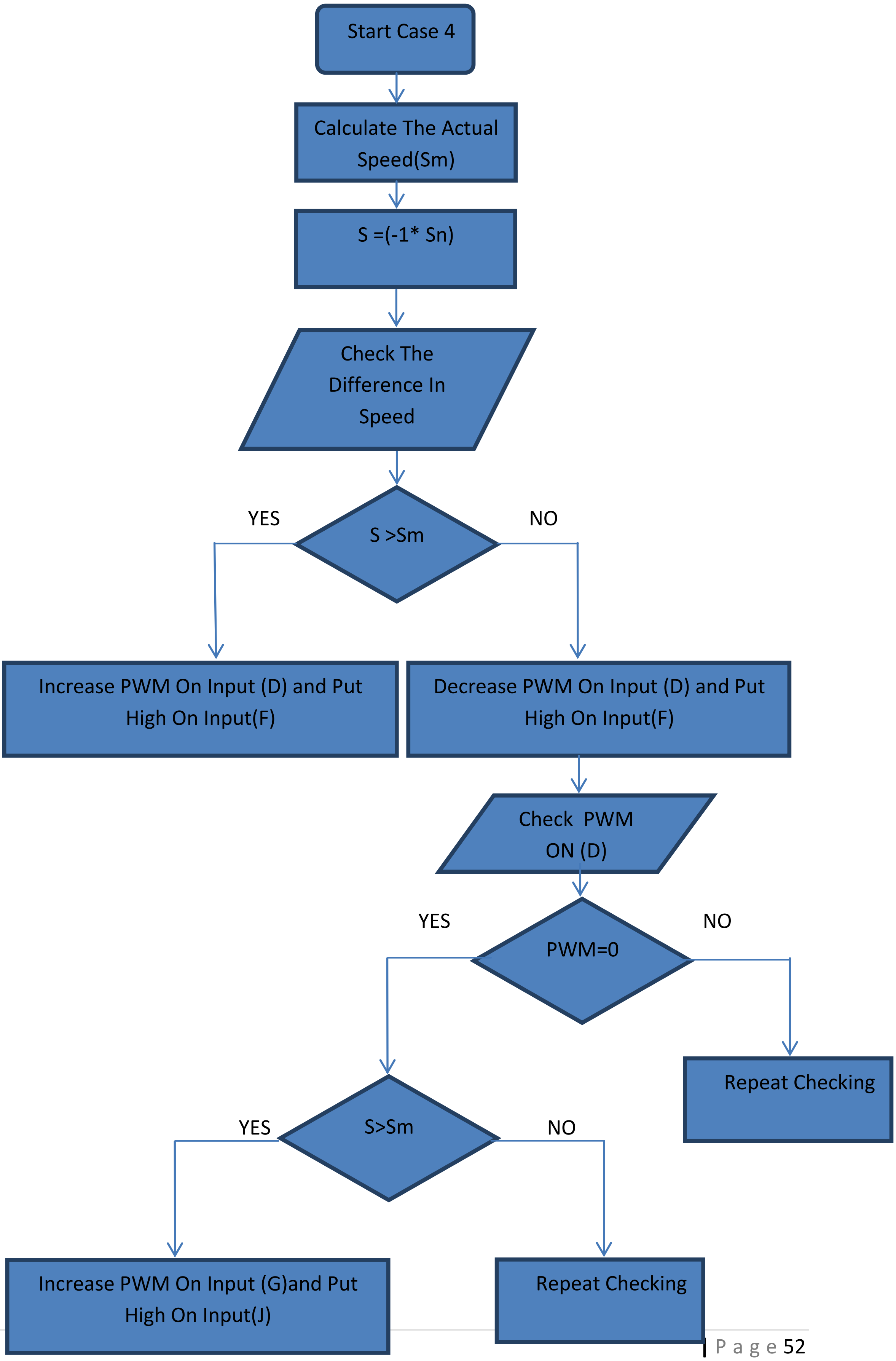
This bridge should achieve four quaderant , motor is a reversible machine; it acts in four quadrants of the Voltage / Current plane.

The motor can be assigned a positive pole, which corresponds to one of the two senses of rotation, for example the one moving a vehicle forward. Let's assume this is the clock-wise CW direction (A). Inverting the armature current inverts the direction, which becomes counter-clock-wise CW (C). A and C are the quadrants where the motor is motoring, that is absorbing electrical energy and making mechanical work. B and D are the quadrants where the motor is generating, that are it is mechanically pulled, like for example by an electrical wheelchair going downhill, and it acts as a DC generator.

3. **Speed Cases:**




Start Case 3
Calculate The Actual Speed(Sm)
S =(-1* Sn)-D
Check The Difference In Speed
S >Sm
YES
NO
Increase PWM On Input (D) and Put High On Input(F)
Decrease PWM On Input (D) and Put High On Input(F)
Check PWM ON (D)
PWM=0
YES
NO
Repeat Checking
S>Sm
YES
NO
Increase PWM On Input (G)and Put High On Input(J)
Repeat Checking


Start Case 4
Calculate The Actual Speed(Sm)
S =(-1* Sn)
Check The Difference In Speed
S >Sm
YES
NO
Increase PWM On Input (D) and Put High On Input(F)
Decrease PWM On Input (D) and Put High On Input(F)
Check PWM ON (D)
PWM=0
YES
NO
Repeat Checking
S>Sm
YES
NO
Increase PWM On Input (G)and Put High On Input(J)
Repeat Checking

4.

Figure 23: Encoding

5.

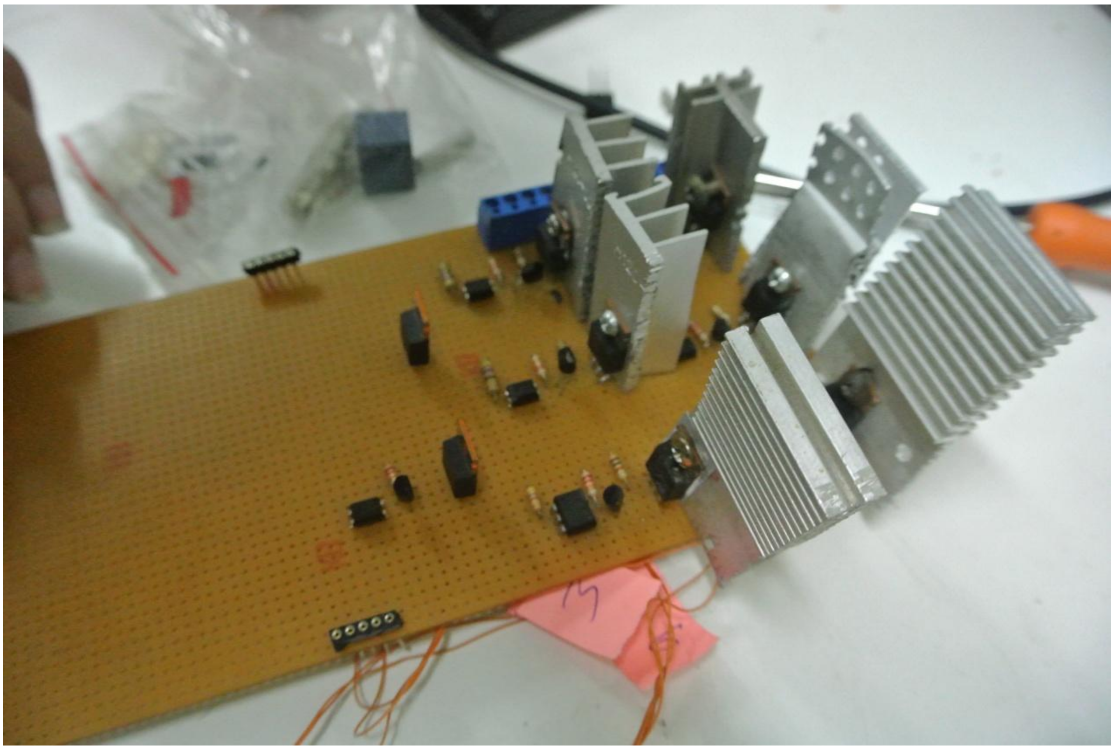


Figure 24: Heat Sinks and the implemented circuit

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