DEVELOPMENT OF A RECHARGEABLE ELECTRONICALLY CONTROLLED MOTORISED WHEELCHAIR FOR DISABLED AND ELDERLY PEOPLE

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ABSTRACT

The physically challenged, old-age people, and most paralysed patients need means of transportation from place to place to ease their movement. The earlier available wheelchairs are manually driven that need extra effort of either the physically challenged or an assisting person to move. Nowadays, the level of communication and socialization strongly depends on easy access to mobile transportation. This paper presents a developed motorized wheelchair that facilitates movement of physically challenged people both in the hospital and in their home by taking into account aesthetics, low cost, ease on maintenance with market competitive advantage using locally sourced materials. The developed wheelchair is designed to work for 3 hours under a maximum load of 90 kg with navigation buttons. A working efficiency of 65 % was obtained under full operation. This design brings a new competition into the wheelchair market and gives more comfort to the physically challenged peoples' mobility than the existing manually driven ones.

Keywords: Motorised, Disabled, Physically challenged, Wheelchair, Paralysed patients

1.0 INTRODUCTION

World Health Organization (WHO, 2011) reported that about 15% of the global population have disabilities. Studies indicate that, some 15% of people with disabilities require wheelchairs. In 2016, it was projected that more than 110 million people who needed wheelchairs didn't have one (Wheelchair Foundation, 2016). According to reports, just a small percentage of persons who require wheelchairs have access to one, and of those who do, only a small percentage have access to an adequate wheelchair.

Since its inception in 1595 (as an invalid chair) for Phillip II of Spain by an unknown designer, the wheelchair has remained the ideal mode of transportation for disabled individuals. They've subsequently grown into complex mechanical and electromechanical devices with multiple degrees of freedom, as well as robotic systems (Abdulkadir, 2012; Ikeda, 2013; Rajasekar, 2013; and Razak, 2013)
Geonea *et al*. 2015 reported that wheelchair evolution shows that earlier wheelchair used belts in the drive-train. The motor turns a rotor which had a belt wrapped around it, and the belt transmitted the power to the wheels.

Nowadays, wheelchair uses direct current (DC) drive, that is, the motor turns the gears/shafts which in turn move the machine through a gear transmission to the wheels. Motorized wheelchair is a system where a DC motor is used to move the wheelchair by controlling it with a joystick or keypad module (Chatterjee and Roy, 2021, Chikkamath, *et al.,* 2016). There are different types of designs for motorized wheelchairs. They are majorly categorized by the number of rear and front wheels.

Motorized wheel chair comprises a major controller unit which allows the user to provide the input in the form of a joystick or keypad module (Shahin, *et al.,* 2019; Shibata, 2015). The controller unit then interprets the command and performs the necessary actions to transport the wheelchair to the desired location.

This study presents a developed motorized wheelchair using locally sourced materials for the physically challenged people thereby making mobility easier for them.

2.0 MATERIALS AND METHODS

2.1 Mechanical Components

The materials used in wheeled mobility items, like any other product, have an impact on both the manufacturer and the end user. Durability, strength, affordability, aesthetic, design and production flexibility, and minimum weight are all factors that were taken into account during fabrication. The following are some of the places where new technologies may be beneficial namely the frames, tires and wheels and seating materials.

2.1.1 Frame

The frame of the wheelchair is made with an alloy steel pipe and a metal plate which serve as the basis for the back rest and the seat. These materials were used because of their high strength – weight ratio, durability, aesthetic value and they are relatively cheap.

The chassis of the wheelchair is made with 1 inch (2.54 cm) thick alloy pipe because it bears the load of the DC motor, battery and foot rest. The other part of the frame is made 0.5 inch thick alloy pipe.

The frame is well painted in other to prevent it from rusting.

2.1.2 Tyre and Wheel

To prevent shocks to the user and harm to the electronics linked with power chairs, tyres should enable static energy to discharge. Tyres and wheels should be light and affordable at the same time.

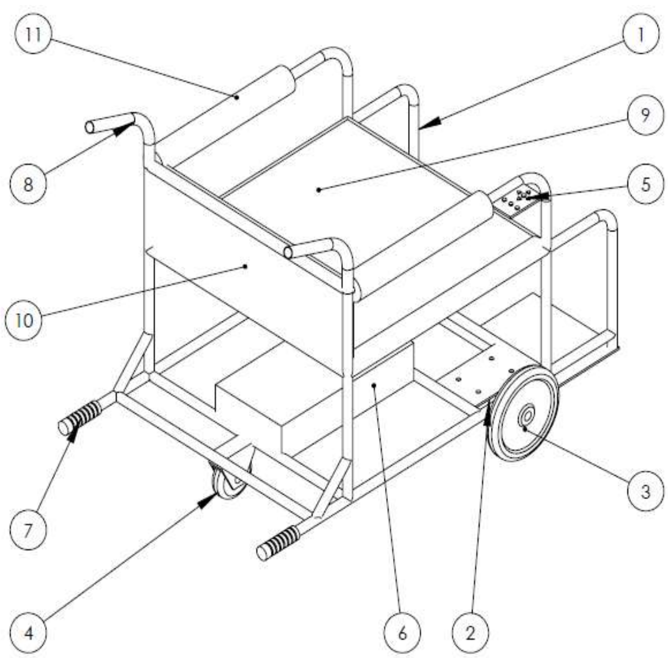
For this design, a tubeless tyre is used compared to a pneumatic tire usually being used so as to move satisfactorily on various surfaces without compromising ride, traction and non-barking. It has a low maintenance cost and has a microcellular structure that reduces weight while maintaining wear and rider comfort.

In the design, two front wheel tyre and one rear wheel tyre, which is located at the centre are used.

2.1.3 Seat

The wheelchair seat is finished with a leather cushion for better comfort and aesthetics. The material being used is also able to absorb shock or vibration from the DC motor. Also included in the sitting design, is a foot rest for the user to prevent leg pain and the arm rest that allows the arms in comfort position.

The isometric view of the design and the part list are shown in Fig. 1.



Part No	Part Name	Qty.
1	Supporting Frame	1
2	Motor Driver	2
3	Wheel	2
4	Wheel_2	1
5	Key Pad	1
6	Control Panel	1
7	Robber Handle	2
8	Robber Handle_2	2
9	Seat	1
10	Back Rest	1
11	Arm Rest	2

Fig. 1: Isometric View of the design with Part list

2.2 Electronics Section

This is the section that makes the wheelchair to be motorized. It is the 'heart' of the project. This section is broken down into four sub-sections namely: the power supply unit, keypad module, the DC motor and motor driver unit, microcontroller unit and battery and the battery charging unit

2.2.1 Power Supply Unit

The power supply unit is made of two sections; power supply from AC and power supply from DC (battery).

The AC power supplied is used for the charging of the battery. This is achieved by using 220V AC supply, this voltage is then stepped down to 12V using a step-down transformer (220/12V 1500mA). The output from the transformer is converted to a DC voltage using a bridge rectifier. The output from the rectifiers will contain some ripples; these ripples are then filtered using 4750µf capacitor. After filtering, the voltage is regulated to 14.5V using LM 2578 which then supply the battery charger.

The microcontroller, motor driver and DC motor are all DC components therefore; a DC voltage is supplied to them using a battery. The battery being used is a 12V DC source and a 5V is required to power the PIC

18F4550 microcontroller therefore, the 12V DC from the battery is regulated to 5V DC using LM317 regulator. The output from the regulator contains some ripples which is filtered using 1µf capacitor. The filtered +5V DC is then used to power the microcontroller.

2.2.2 Microcontroller unit

The 'brain box' of this project is the control unit which makes use of PIC 18F4550 microcontroller. The microcontroller receives signal from the command of the joystick button being pressed by the user and send the respective signal to the motor drivers which then drive the DC motor. Thus the system provides complete movement of the wheelchair under various button commands.

PIC 18F4550 is a High-performance, Low-power Atmel 8-bit Microcontroller developed with Advanced RISC Architecture which includes 131 Powerful Instructions among which majority are single-clock Cycle Execution. PIC 18F4550 is a 40pin microcontroller. Pin 1 is the +Vcc pin that powers the microcontroller. Pins 2,3,4,5 and 6 are the input pins that receive commands from the push buttons. Pin 20, 21, 22, 27 are the output pin connected to LED which send signal to the LED for the commands indicated by the push button. Pin 13 and 14 are connected to the motor driver. The microcontroller operates at a voltage of +5V and works with some set of instructions called Program. This program is stored in the EPROM (Electrical Programmable Read Only Memory) and is executed one by one with respect to the command input.

2.2.3 DC Motor and Motor Driver

The motorized wheelchair uses two DC motors each of 12V, 200W. It converts electrical energy received from the battery into a mechanical energy that moves the wheelchair.

The majority of microprocessors run on low voltages and draw a little amount of current, whereas motors demand a higher voltage and current. As a result, the CPU is unable to supply electricity to the motors. This is the most important requirement for a driver.

The Electric Motor Switching and Driver Stage Consists of MOSFET IRF260W, Electric motor 200W each, MOSFET driver TLP250, Keypad Module and Heat Sink. Fig. 2 and Fig. 3 show the circuit diagrams of motor switching and the motor driver respectively.

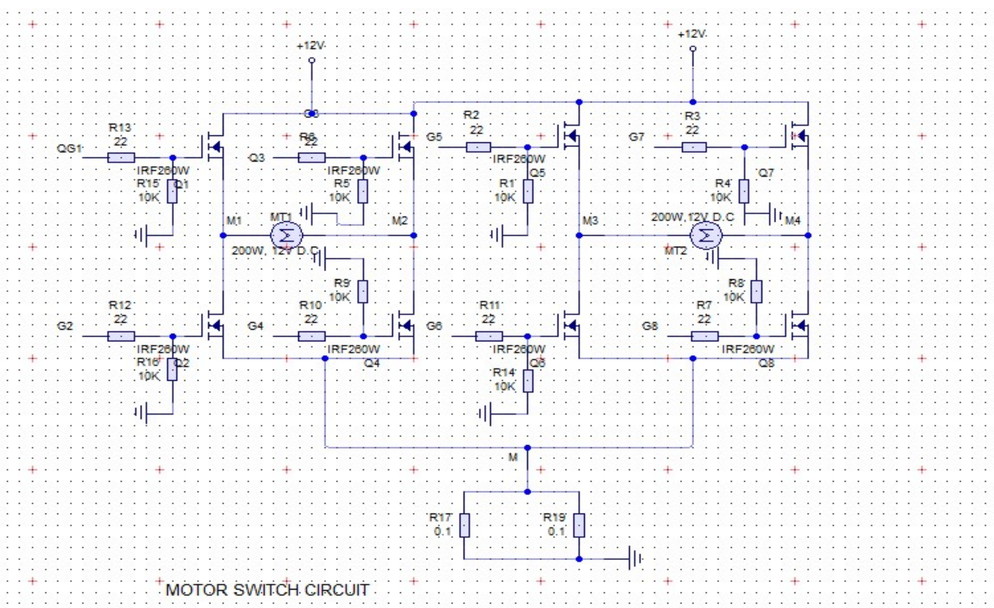


Fig. 2: D.C Motor and Switching MOSFET.

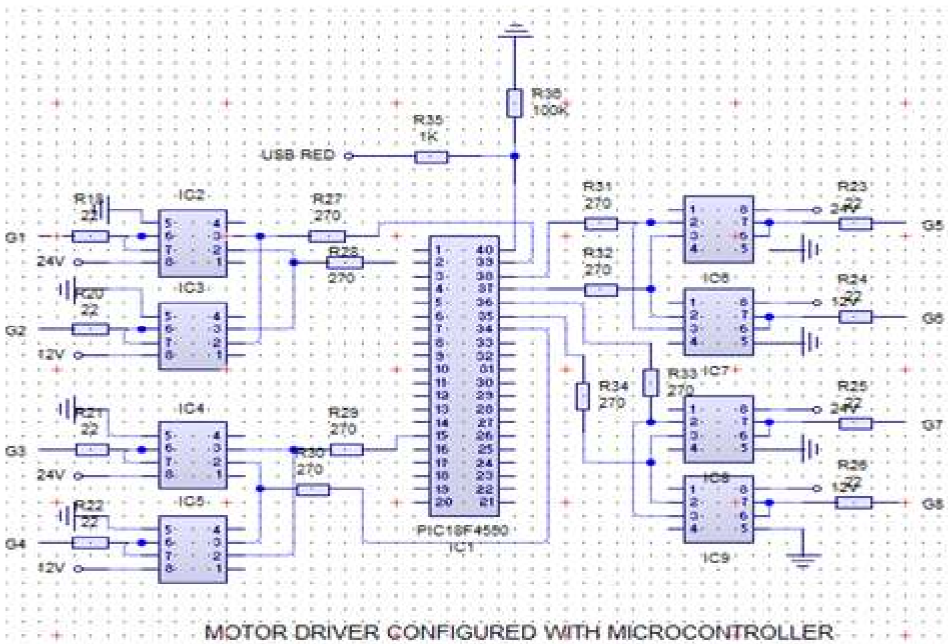


Fig. 3: Motor driver circuit

2.2.4 Battery and Battery charger

The motorized wheelchair is powered with a 12V, 14AH lead acid battery. A 12V battery is considered due to the DC motor voltage which is also 12V.

The battery charger works by feeding an electric voltage to the battery for a period of time and thereby making the cells inside the battery to hold on to some of the energy passing through them.

The battery is charged with 220 AC voltage source. The voltage is stepped down to 12V. This AC voltage is then converted by a bridge rectifier to DC voltage. The DC voltage is filtered by a 1000uf capacitor. The 12V rectified voltage is then fed into a voltage regulator which now regulates the voltage to 14.5V. The 14.5V rectified voltage charges the DC battery. The battery charger has an overvoltage protector to prevent over voltage and also incorporated in the circuit is overcharging protection. It has LED lights to indicate charging (green light) and fully charged (red light). The battery charging and power circuit is shown in Fig. 4.

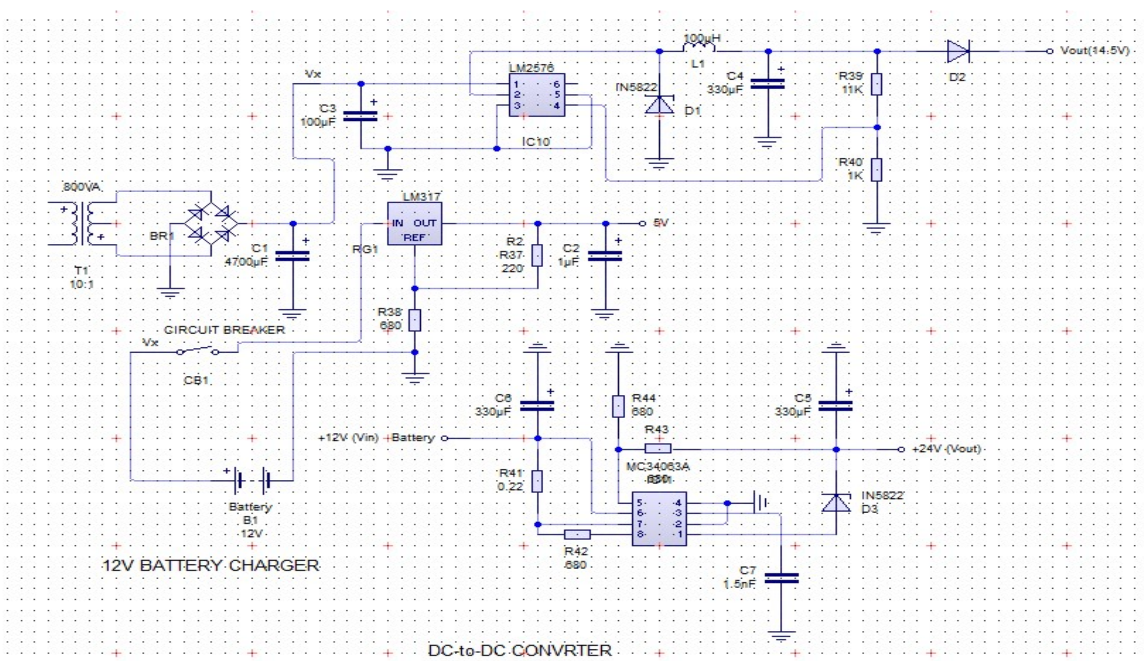


Fig. 4: Battery Charging and Power Circuit

2.3 Firmware Techniques.

The software governs the operation of the system and so it is vital that the software is built in a flawless manner so as to get the intended result. All of the essential features of the function and the operation of the devices used in the system are controlled by the stored program in a microcontroller.

Assembly is thought to be the ideal language for applications that require the least amount of memory, the fastest execution speed, and accurate control of peripheral devices (Knaggs and Welsh, 2004). However, because writing in this language requires more understanding of C programming, the wheelchair source code was written in C. Fig. 5 shows the flow chart of the control unit.

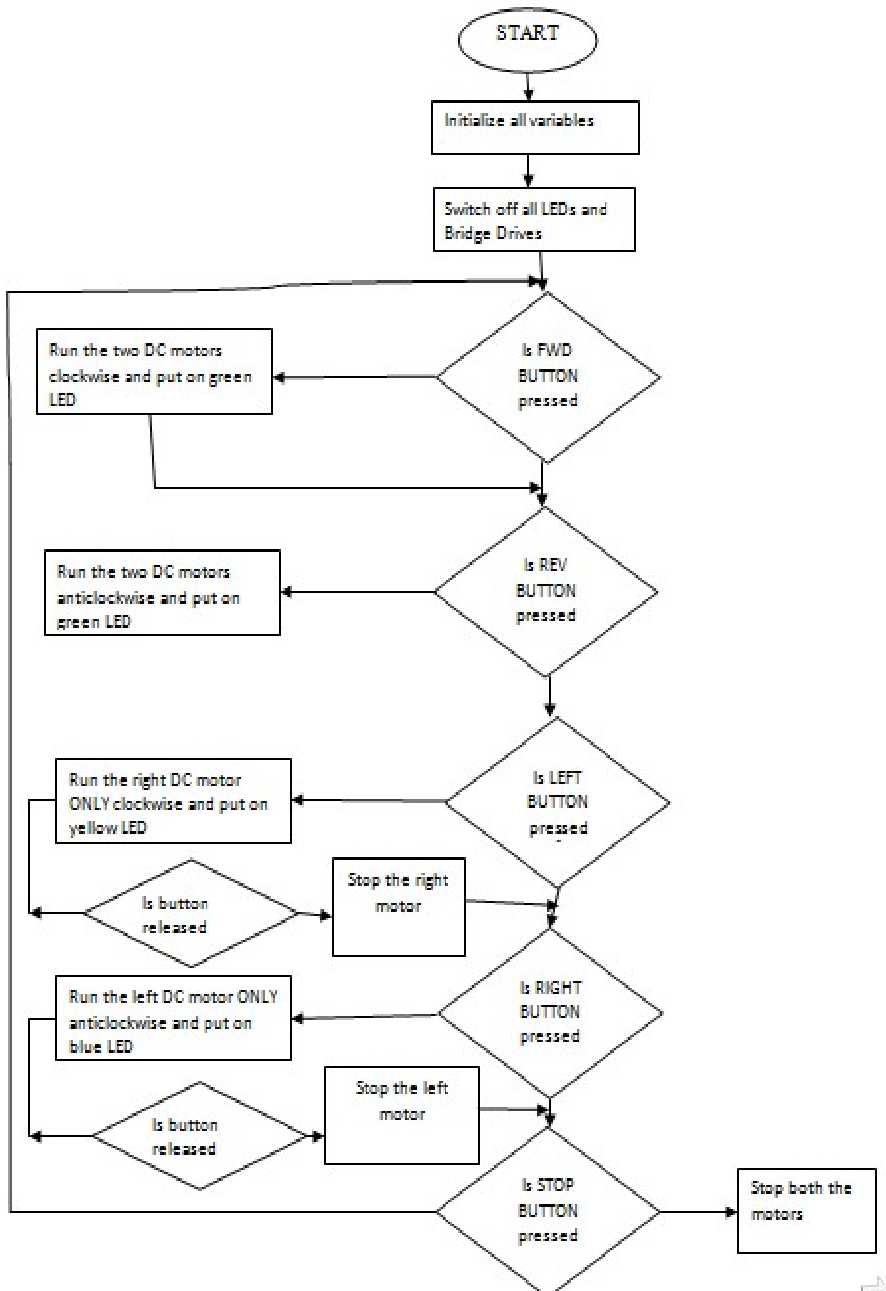


Fig. 5: Project Flow chart

2.4 Design Analysis

The design analysis of the wheelchair is based on the specified parameters of the bought out components as stated in Table 1.

Table 1: Design parameters and specifications

S/N	Component	Value	Remarks
1	Average Length:	870 mm	As designed
2	Average Width	640 mm	As designed
3	Average Height	940 mm	As designed
4	Tare Weight	30 kg. Approx.	Manufacturer specification
5	Motor	DC Motor - 12V, 200 W x 2	Manufacturer specification
6	Battery	Battery (Rechargeable): 12Volt, 14 AH	Manufacturer specification
7	Speed	10 km per hour (max)	Manufacturer specification
8	Gradient	14 Degrees	Manufacturer specification
9	Tyres	Rear 7"/Front 12" SolidEVATyre (Non-Puncturable)	Manufacturer specification
10	Charge Voltage	220 V, 50 HZ	Manufacturer specification
11	Charging time	6-8 hours	Manufacturer specification
12	Seating	Single	As designed
13	Drive	Front Wheel	As designed
14	Command button	Right hand	As designed
15	Pay Load	90 kg	As designed
16	Motor Shaft Diameter	10 mm	Manufacturer specification
17	Rating Motor Power	200 W	Manufacturer specification
18	Motor speed on NO-LOAD	180 r.p.m.	Manufacturer specification
19	Velocity ratio	1:1	As designed

2.5.1 Energy Conservation of the Battery

The energy, E, conserved by the battery is determined by equation (1) as stated by Lu, *et al.* (2010).

$$E = V \times I \times t \quad (1)$$

Where,

V *is the potential difference in Volts* (V);

I *is the rating current in Ampere* (A); *and*

t *is the time taken in seconds* (s).

By substituting the battery parameters given in Table 2, the energy;

E = 12V × 14Ah = 604,800 (J)

2.5.2 Load on Rear Wheels

The design analysis equations (2) – (5) are adapted from Textbook of machine design by Khurmi and Gupta (2005).

$$W = mg \quad (2)$$

Where;

W *is the weight in Newton* (N),

m *is the total mass in Kg and*;

g *is the acceleration due to gravity taken as* $9.81\ m/s$

Taking total mass, m to be 90 Kg (Table 1)

$W = 90 \times 9.81 =$ 882.9N shared on all the wheels.

2.5.3 Speed of the wheelchair

The Periphery, C, is determined from equation (3)

$$C = 2\pi R \quad (3)$$

Where;

R is the radius of the wheel in m

Radius of rear wheel (R) = 0.1 m

$Hence, C = 2\pi \times 0.1 = 0.6284\ m$

The speed of the wheel, v, in m/s on both no-load and on-load conditions are determined from equation (4)

$$v = \frac{C \times N}{60} \quad (4)$$

Where;

N is the rotating speed in r.p.m and;

For no-load condition, rotating speed N_1 is $180\ r.p.m$ as stated in Table 1;

Hence,

$$v_1 = \frac{0.6284 \times 180}{60}$$

$$v_1 = 1.885\ m/s$$

2.5.4 The Torque Developed by the Motors

The total torque driving torque, T (Nm), developed by the two motors under no-load condition is determined by equation (5).

$$T = \frac{P}{v} \quad (5)$$

Where,

P is the total rating power of the motors in Watts (W).

From Table 1, two electric motors are used with 200 W each making a total of 400 W.

Under no-load test, the velocity v_1 has been obtained from equation (4).

By substituting, the values, we have,

$$T = \frac{400}{1.885}$$

$$T = 212.2\ Nm$$

3.0 RESULTS AND DISCUSSION

3.1 The Structure of the Motorized Wheel Chair

The block diagram that shows the sequence of operation of the designed wheel chair is as shown in Fig. 6. The motorized wheel chair structure comprises of the command buttons, the control with charging unit, the DC motors and the fabrication is shown in Plate 1.

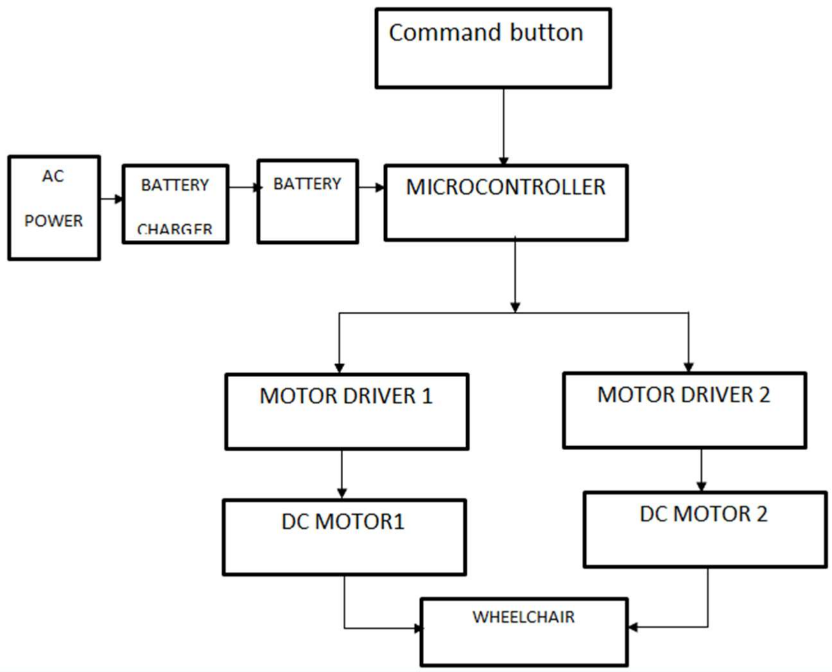


Fig. 6: Block diagram of the motorized wheelchair operation

Plate 1: The developed motorized wheelchair.

3.2 Testing

The motorised wheel chair was tested and the results be discussed in the subsections as follows. The tests reveal the performance evaluation of the project.

3.2.1 Movement of Wheelchair

Movement of the wheelchair is according to the pin configuration at motor driver. There are 3 pins to control the DC motor which are pin PWM, pin DIR, and GND pin. PWM and DIR pin are according to the truth Table 2.

Table 2: Pin configuration of the motor driver

Pin 2 (PWM)	Pin 3(DIR)	OUT A	OUT B	MOTOR
Low	X (don't care)	Low	Low	Stop
High	Low	High	Low	Clockwise
High	High	Low	High	Anti-clockwise

Based on data in Table 2, the movement of the wheelchair with the wheel direction and one wheel will be going inversely when turning to the right or left.

3.2.2 Testing of the Button Commands

After the completion of the project, all the button commands are tested whether is works accordingly. All the LED lights came up as the respective command buttons were pressed and the motorized wheelchair responds perfectly. The labels of the button and the corresponding commands are as stated in Table 3.

Table 3: Declaration of the Movement of the Wheelchair.

Button Command	Left Wheel	Right Wheel	Condition of Wheelchair
⬆	Forward	Forward	Move forward
⬇	Reverse	Reverse	Reverse
➡	Forward	Reverse	Turning to the right
⬅	Reverse	Forward	Turning to the left
■	Stop	Stop	Stop

3.2.4 Battery Charger Test

The battery charger circuit was tested to ascertain that it charges the battery properly. The input was connected to mains source and the output voltage was measured which gives 14.5V. The green LED light also came up which indicates that the battery is charging. When the battery is fully charge, the red LED light also came up and the voltage is simultaneously cut-off to prevent overvoltage.

3.2.5 Drive Test

The motorized wheelchair was taken for a test drive to ascertain its proper functionality, its average speed and battery hour of operation before it is recharged. After the test, it was determined that the motorized wheelchair moves at an average steady speed of 1.22 m/s and it took an average of 3 hours before the battery is drained.

Since, the higher the load, the lower the speed of a moving system, the lower the battery life hence the efficiency of the drive is determined by the rotating speed of no-load and on-load conditions using equation (6).

$$\eta = \frac{N_2}{N_1} \qquad (6)$$

$Where,$

η *is the efficiency of wheelchair,*

N_1 *is rotating speed of the wheel in r.p.m under no − load condition and*;

N_2 *is rotating speed of the wheel in r.p.m under on − load condition.*

The average measured value of N_2 through the use of a tachometer is 118 $r.p.m$ under full load of 90 kg and the motor rating speed (Table 1) is 180 $r.p.m.$

Hence,

$$\eta = \frac{118}{180}$$

$$\eta = 0.65 \text{ or } 65\ \%$$

4.0 Conclusion

A motorized wheelchair is designed and constructed. With the user sitting comfortably on the wheelchair and pressing the command buttons, the DC motor is controlled thereby moving the wheelchair to any direction the user wants to move. The wheelchair is powered by a rechargeable battery with an overall efficiency of 65 % under maximum loading condition. With this project, physically challenged people can now live a little more independent life. This motorized wheelchair is economical and affordable to common people and it requires no training to be able to operate.

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