

RESEARCH ARTICLE



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Autonomous Terrain Vehicle

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Abstract

Objective: The covid-19 outbreak affected the door-to-door delivery of essentials as it was difficult to maintain “physical distancing” causing a threat to the lives of people involved in the process. We aimed to design a fully autonomous vehicle that would be capable of moving over all types of terrains without any human intervention. Overall, the primary objectives of the vehicle are to be able to navigate to a given location, to be capable of moving over all terrains & climbing staircases, capable of detecting the hurdles and obstacles coming along the way and capable of carrying a payload. **Method:** The Raspberry Pi is the main control unit. Closed-loop feedback algorithm has been implemented. The direction and speed are controlled using the PID. The real time video is captured using the onboard camera. IMU sensors monitor the physical orientation of the vehicle. The battery provides required current and voltage to all the peripherals. **Findings :** In order to make sure that the bot is moving in a straight line and not deviating from the path required, line detection has been implemented. The image frames detected by the cameras are imported into Python in BGR color format which is later converted in HSV format. The upper and lower color limits are defined. Edge detection is done using Canny Transform and Line prediction requires Hough Line Transform. **Novelty:** This paper presented the mechanics and sensor system design of a small-sized and affordable, yet highly maneuverable all-terrain robot. The robot size can be altered according to its use. The project proved that an autonomous all-terrain robot can be designed and built with a relatively small budget. Because of the sensors and the processing unit, it was estimated that the chosen platform should be able to carry at least 3 kg of electronics.

Keywords: Navigate; Raspberry Pi; Line detection; Maneuverable; Sensors

1 Introduction

The covid-19 outbreak has tremendously changed the way of living. In such tough times, technology has been a boon for people confined in their houses.

All the day-to-day chores could be done smoothly indoors because of the advancements that have been made in technology. One of the most crucial challenges that the entire world is facing right now is to carry out the daily tasks without violating the 'physical distancing norms'. The door-to-door delivery of necessary goods is very important in such crucial times. However, it is difficult to carry out delivery without risking the lives of the people involved. In order to overcome this problem, we aimed to design a fully autonomous all-terrain vehicle capable of moving over all terrains and detecting staircases and hurdles coming along the path as shown in Figure 1. The authors of⁽¹⁾ present a deep learning-based approach for staircase detection which statistically filters images and has a novel mechanical design for an autonomous stair climbing bot. Its primary objective is to solve the problem of indoor locomotion over the staircases with the proposed implementation. The basic two problems of interests that were discussed in⁽²⁾ were that the bot required to move smoothly over the environment and it had to collect precise information regarding the surroundings and the hurdles.⁽²⁾ also mentions that due to the onboarded sensors and because of the overall processing unit the minimum capacity for the payload was 3 kgs. The ability to carry a payload makes the bot useful for delivering goods from one place to another. The average weight of the payload for our robot is approximately 6 kg inclusive of the weight of the robot itself. The authors of⁽³⁾ have investigated the causes of motor overheating by utilizing hardware and software techniques.⁽⁴⁾ prefers wheeled mechanism over that of the legged mechanism because of its simple structure and less power consumption. The fact that the vehicle can cover a distance of 200-300 meters and maneuver without any human intervention makes it a perfect tool to deliver goods in buffer zones and containment areas involving 'zero-contact'. The mechanical structure of the vehicle has a rocker-bogie mechanism. The rocker-bogie mechanism is applied on the mars rover in order to get control of the uneven surfaces and rough terrains. The authors of⁽⁵⁾ suggest that axles over the wheels do not allow it to move over rough terrains and thus bogie is preferred. The bot consists of 6 wheels, three on either side. The six wheels make the suspension better and the overall weight is also distributed evenly. The sensors and cameras are embedded in the vehicle, making the design compact.⁽⁶⁾ makes use of laser for obstacle detection, whereas we have used sensors which are cheaper. The sensors and cameras chosen are of good resolution and quality which ultimately increases the life of the robot. The image detection is performed using thresholding and slicing. Our robot is novel and an advancement to the prior work done in robot automation with minimum cost.

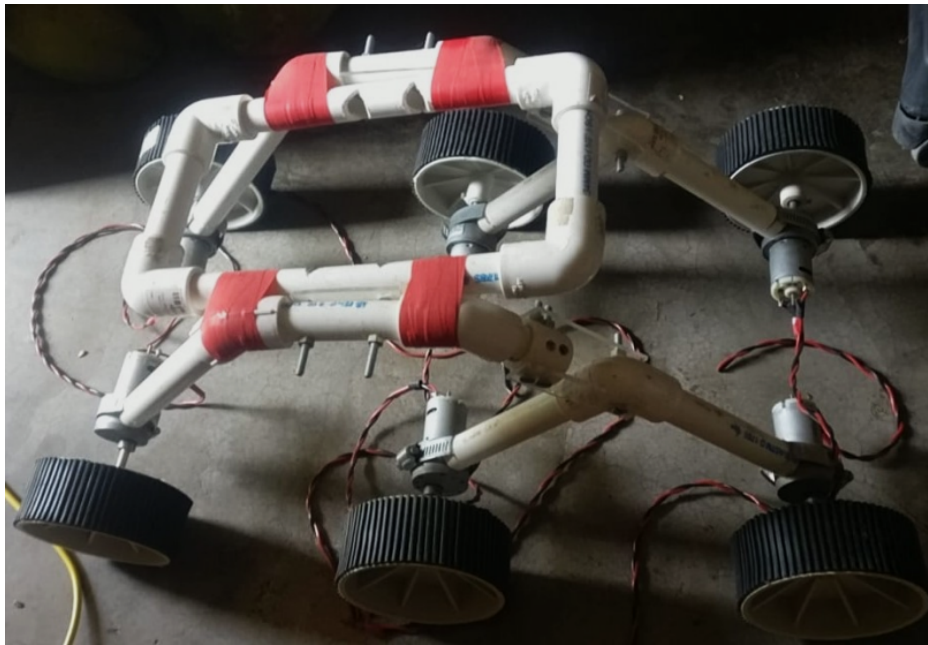


Fig 1. Construction of Rocker Bogie

2 Methodology

This research aims to reduce the human intervention that is capable of taking full control over the vehicle & can be driven on road in all adversities. The model consists of raspberry, camera, high torque motors, motor driver, battery, and IMU sensor (Inertial Measurement Unit) shown in Figure 2. Raspberry Pi acts as the brain for the autonomous all-terrain vehicle. It is the

main control unit. Auto bots usually work on closed-loop feedback algorithms provided by sensors and processed by processors. Additionally, we have used a Johnson High Torque motor. The motor drivers play the main role in the implementation of PID control. It is used to control both direction and speed. Then Camera Works as the input device for providing feedback to the closed-loop system. The camera is used to take high-definition videos as well as still photographs. Furthermore, we have also used IMU Sensors which are used to keep track of the physical orientation of robots. The IMU sensor is used to calculate and report an exact force, angular rate, and direction, which can be achieved by using a blend of sensors Gyroscope, Magnetometer, and Accelerometer. Finally, Battery will be connected to a power circuit that provides appropriate voltage and current to all peripherals.

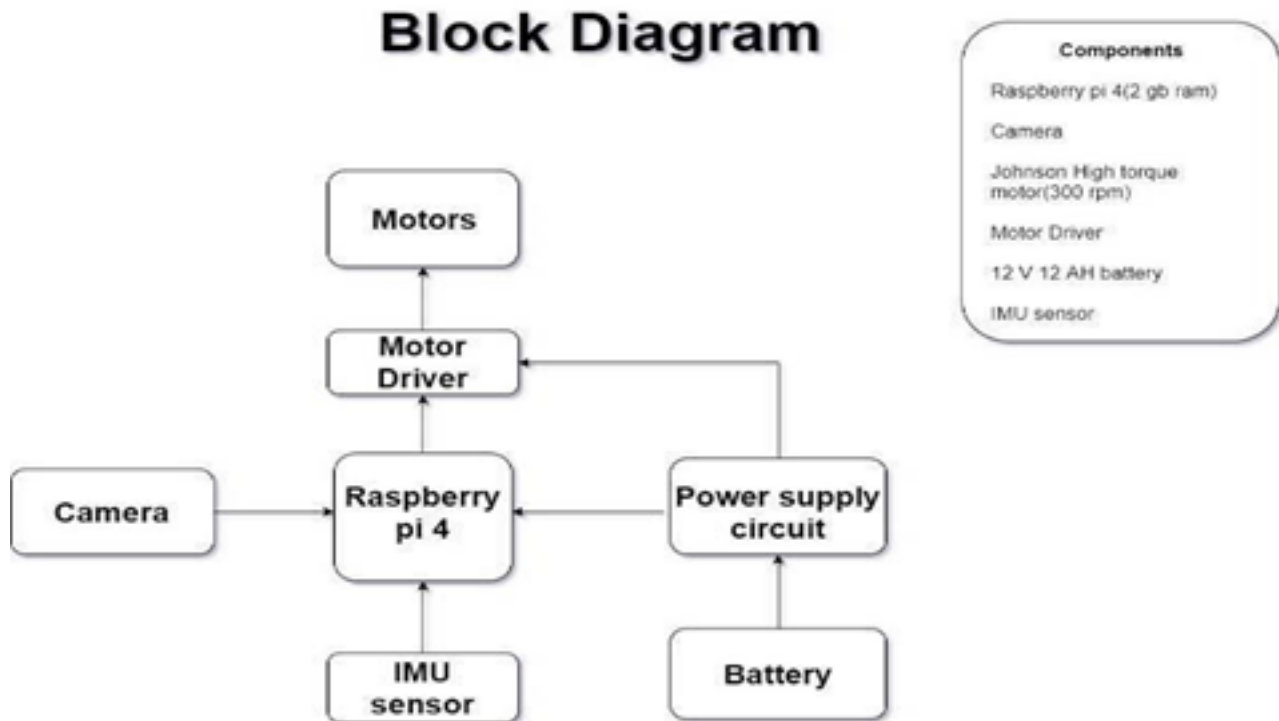


Fig 2. Represents block diagram of Autonomous all-terrain vehicle

3 Hardware and software implementation

3.1 Rocker Bogie Mechanism

The main aspect in manufacturing of rocker-bogie mechanism is to find the dimensions of rocker and bogie linkages and also angles between them. The lengths and angles of this mechanism can be altered. By assuming accurate stair dimensions, rocker-bogie can climb the stair with stability IT can climb up to an angle of 45° . The angle of linkage is 90° . So, by using the Pythagoras theorem, we can find the dimensions of the model. The main goal of the research work is to make models that can climb stairs. To achieve proper stair climbing the dimensions of linkages should be accurate. To climb stairs with higher stability, it is required that just one pair of wheels should be in a rising position at a time. Now to find the length of bogie linkages, the front pair of wheels should be placed at the end of the rising and the other pair should be placed just before the start of the rising end. There should be some space between the vertical edge of the stair and the second pair of wheels to strike the wheels. Considering the right-angled triangle XYZ as shown in Figure 3, Using Pythagoras in ΔXYZ assume lengths XY and XZ is x.

$$\begin{aligned}
 YZ^2 &= YX^2 + XZ^2 \\
 240^2 &= x^2 + x^2 \\
 240^2 &= 2x^2
 \end{aligned}$$

$x = 170 \text{ mm}$. Hence, $YX = XZ = 170 \text{ mm}$.

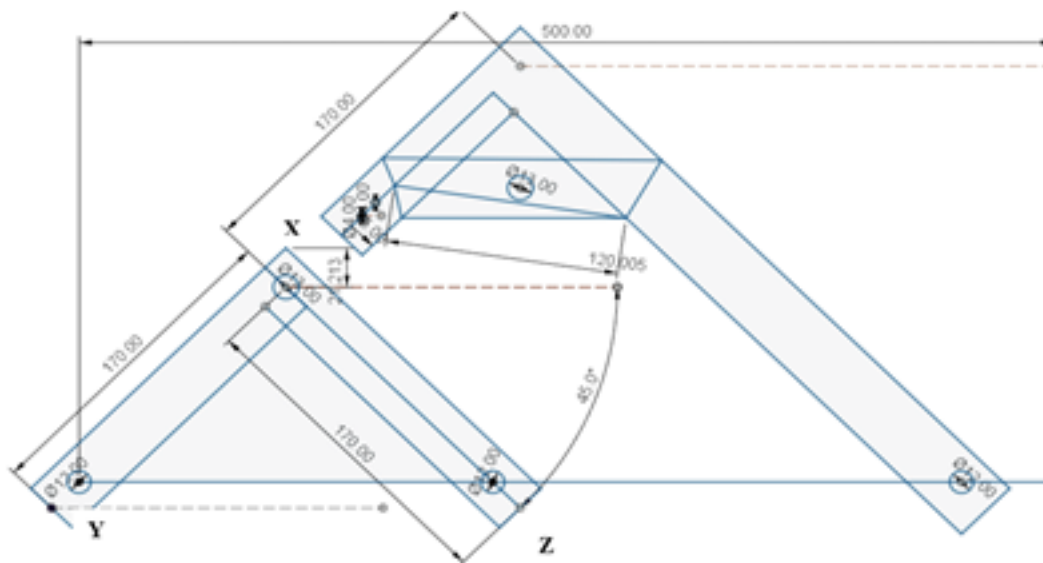


Fig 3. Dimension of Rocker Bogie made on Fusion-360 Software

3.2 Motor Driver

Power transistors A, B, C, D shown in [Figure 4](#) are used to form an H bridge configuration to drive the motor in clockwise and anticlockwise direction using a microcontroller. Now A and B are TIP127 PNP transistors while C and D are TIP122 NPN transistors. For the motor to rotate clockwise transistor A should be open and transistor D should be open, B and C should be closed, also for the motor to rotate anticlockwise Transistor B should and C should be open, transistors A and D should be close. According to the truth table shown in [Table 1](#) motor driver rotates in clockwise and anticlockwise direction. Furthermore, A1 and B1 are TIP122 transistor used to drive transistor A and B respectively using microcontroller digital pins of the microcontroller are connected to the base of A1, B1, C, and D By giving PWM signal to A1 or B1 the motor speed is also controlled. E.g., PWM with a duty cycle of 50% will drive the motor at half speed i.e., 100 rpm. Additionally, we have also design PCB layout of motor driver shown in [Figure 5](#).

Table 1. Truth Table

A1	B1	C	D	State
0	0	0	0	Motor OFF
0	0	0	1	Motor OFF
0	0	1	0	Motor OFF
0	0	1	1	Motor OFF
0	1	0	0	Motor OFF
0	1	0	1	Prohibited
0	1	1	0	Motor CLK
0	1	1	1	Prohibited
1	0	0	0	Motor OFF
1	0	0	1	Motor CLK
1	0	1	0	Prohibited
1	0	1	1	Prohibited
1	1	0	0	Motor OFF
1	1	0	1	Prohibited
1	1	1	0	Prohibited
1	1	1	1	Prohibited

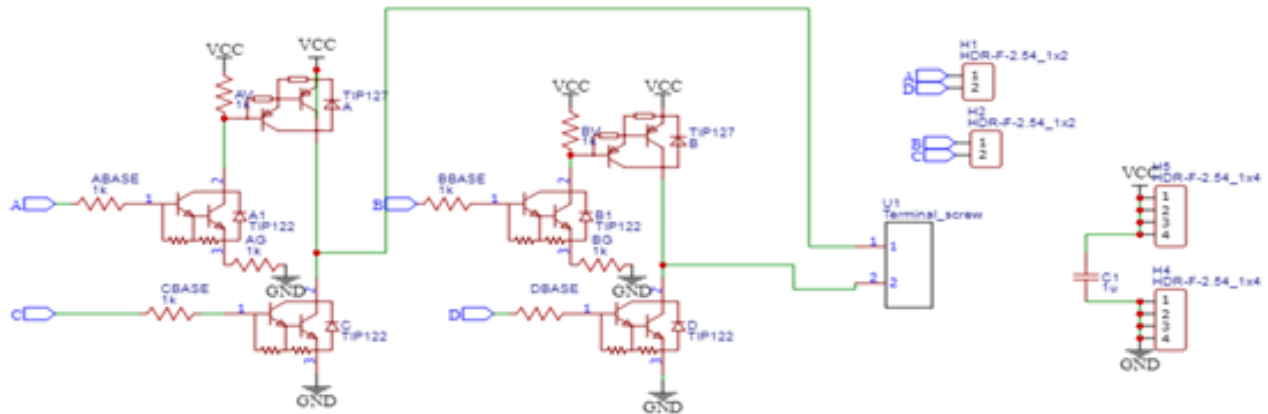


Fig 4. Motor driver layout (EasyEDA Software)

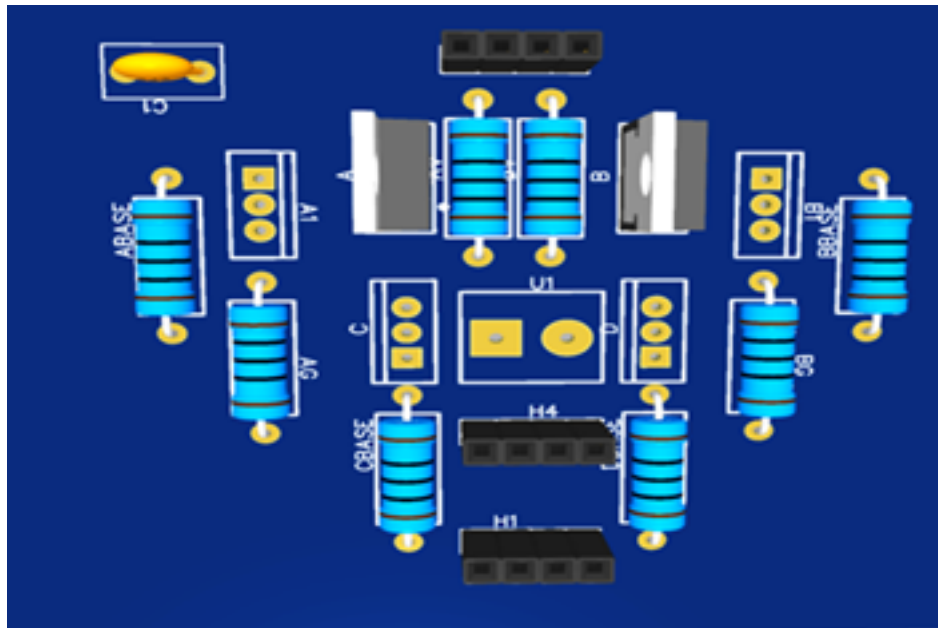


Fig 5. Motor Driver PCB Layout (EasyEDA Software)

3.3 Road and Staircase detection

The captured image is of size 1920*1080px which is resized to 320*240, sliced to 320*60 (Top 25%)

The image is blurred using a Gaussian filter to remove noise whereas blurred image can be seen in Figure 6. Initially, the image is converted into HSV (Hue Saturation Value) shown in Figure 7 from RGB. When an image becomes HSV it is further converted to a grayscale image seen in Figure 8. Now by using thresholding (threshold value 127) the image is converted into a binary image which can be seen in Figure 9. When the image is finally converted into binary, we can find the contours in the white region. By calculating the area of contour, we can find the center coordinate of the largest contour on the X-axis shown in Figure 10. Now error can be found out with the reference to the center of the frame i.e., on the x-axis. Both before and after error is shown in Figure 11. Now, error can be calculated by formula

error = $cX - 160$. Now the error has been passed to the PID system.

PID (proportional integral derivation) is a closed-loop feedback control system for error correction

It works on Proportional tuning, Integral tuning, and derivative tuning to make the correction

Proportional tuning is achieved by applying a correction factor proportional to the error and it never makes the error zero. Integral tuning is achieved by applying correction factor proportional to integral of error i.e., summation of all errors. While derivative tuning is achieved by applying a correction factor proportional to the difference of error i.e., current error minus last error. This helps in minimizing the overshoot of the control system

$PID = K_p(\text{error}) + K_i \sum \text{errors} + k_d (\text{error} - \text{last error})$.

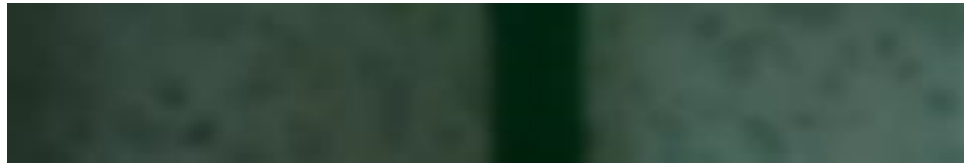


Fig 6. Blur image



Fig 7. HSV image



Fig 8. Gray image



Fig 9. Thresholding



Fig 10. Sliced image

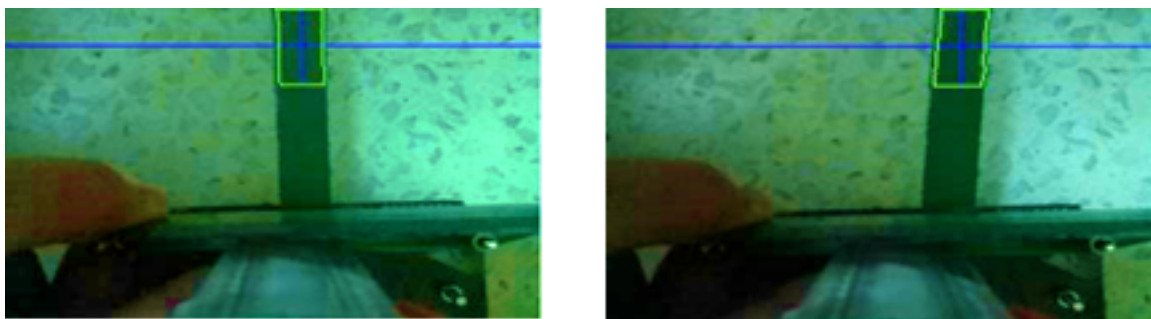


Fig 11. Frame image before and after correction of an error

3.4 Battery and Power Supply

Battery and power supply are used to provide appropriate voltage and current to all peripherals. In this model, we have used a Li-ion 3.7v 2600 battery total and 8 such batteries have been applied. We have applied two sets of batteries giving a total 7.4v power supply, containing 4 batteries in parallel shown in Figure 12, one set of batteries provides 3.7 v and $2600 \times 4 = 10400$ mAh. Every battery is connected with a TP4056 Li-ion in the battery charger to charge the batteries. Additionally, the battery system is connected to the cn6009 booster module to boost the input voltage to 12 v for the motor. Similarly, we have connected a buck module to obtain a 5v and 3.3v power supply. This forms our battery management system. Layout of Power supply designed in EasyEDA software is shown in Figure 13.

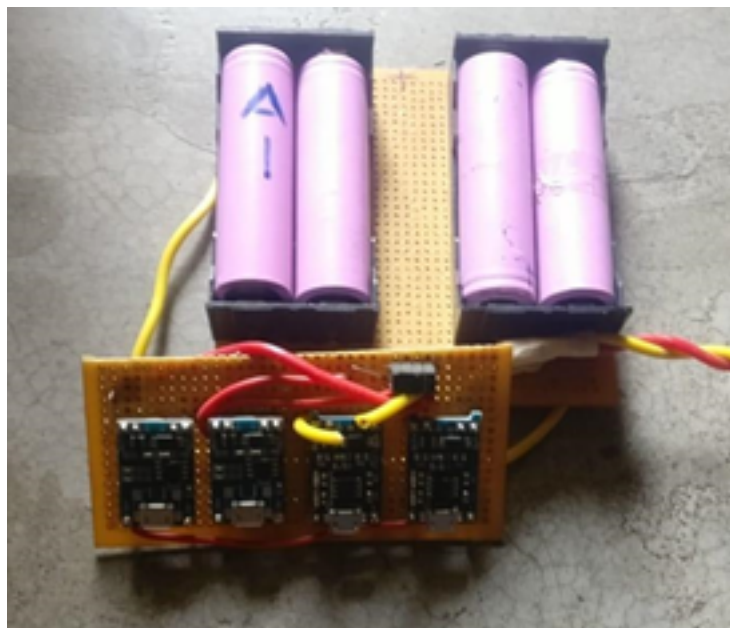


Fig 12. Batteries with charging modules

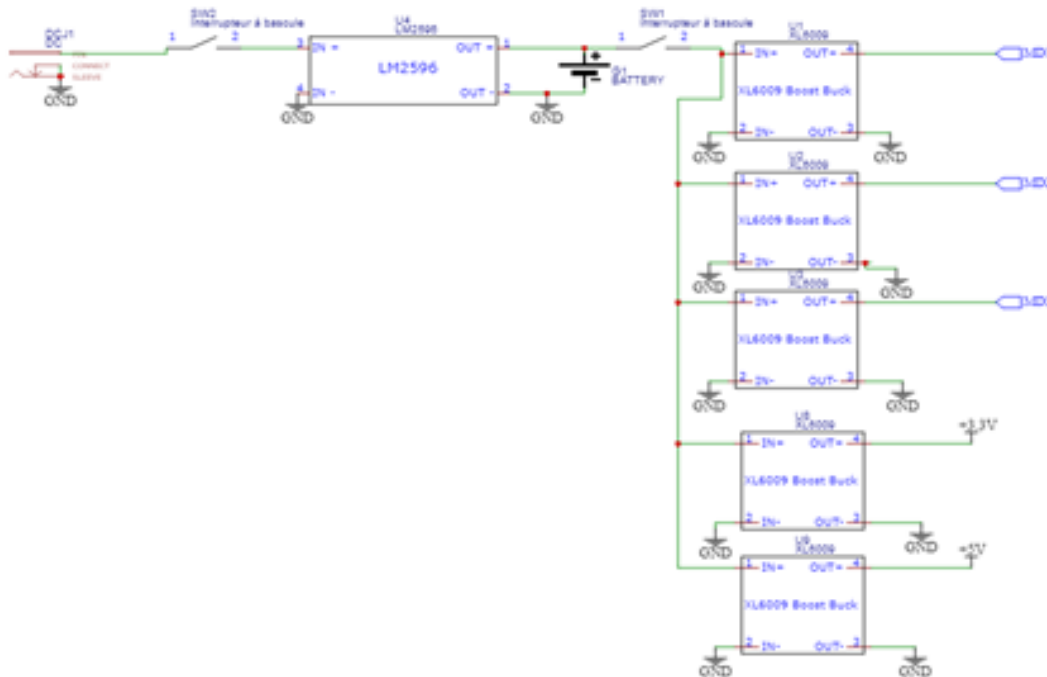


Fig 13. EasyEDA software Power supply layout.

4 Future Scope

1. The outbreak of covid-19 has affected all the sectors including the day-to-day life activities. The most crucial challenge that the entire world is facing today is to carry out daily activities without violating the 'physical distancing norms'. The door-to-door delivery of essential goods is very necessary in such tough times. However, it is difficult to carry out the delivery without risking the lives of the people involved and without breaking the norms. In order to overcome this problem, we use this vehicle which can deliver the essential goods at the doorstep in the containment and buffer zones involving 'zero human contact'.
2. Automatic vehicles are also finding their way in the construction industry. The main purposes are security, inspection, and monitoring.
3. Autonomous vehicles can be used in agricultural and farming fields. This technology helps farmers save money and their crops by proper monitoring of irrigation systems and performance analysis. Using ATV, farmers get complete updated information about crops. They help to spray water, pesticides, and fertilizers on crops at appropriate times.
4. The project also has a wide application in health care system. The autonomous feature allows the bot to be used for delivering medicines and other surgical equipment's in hospital premises. It can also be used to serve corona positive patients as it minimizes the risk of getting exposed to the virus.

5 Advantages

1. We have designed autonomous robot with rocker bogie mechanism as rocker- bogie allows the chassis of the rover to average its pitch overall wheel deflections while still maintaining load equalization on all wheels and avoiding a low oscillation frequency while earlier people used to use belt mechanism.
2. The robot was to be small in size and capable of maneuvering in a challenging environment, yet affordable and easy to manufacture compared to previous designed robots.
3. We have designed in such a way that it can be modified according to need as mentioned in future scope

6 Conclusion

The main purpose of this study is to develop an autonomous all-terrain that can drive fully themselves and will not require any driver at all. We have also presented a deep learning-based approach for stair detection through image processing to estimate the path for a robot to travel through roads or climb stairs. In addition to this, we have performed experiments for staircase detection and road detection in which we have used canny transform and Hough line transform to predict edges and lines. In this research we have calculated the dimensions of rocker bogie, presented design of motor driver and power supply and details enlisted how stair case detection has been carried out. Results shown in the image depicts how the robot detects its paths and objects. Overall, this research aims to develop an autonomous all-terrain wheeled robotic vehicle capable of maneuvering and navigating without any human intervention. The robot can be used for: to navigate for a location, to detect obstacles, to travel through rough surface and climbing of staircase and able to carry goods cover a distance of 200 to 300 meters.

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