Project - Steering Control of a Self Driving Car

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I Objective

The primary objective of the project is to develop and implement an advanced and robust steering control system that enhances the autonomous navigation capabilities of the vehicle. This entails the integration of state-of-the-art algorithms and sensor technologies to achieve precise and adaptive steering responses in diverse driving scenarios. The project aims to optimize the self-driving car's ability to navigate through obstacles and ensure passenger safety

II Tasks

1. Implement a robust object detection algorithm using computer vision techniques to identify and locate static obstacles on the road.
2. Utilize the camera sensor data to estimate the depth information of the detected static objects.
3. Develop a lane detection system to identify and track the road lanes. This task is essential for maintaining proper lane-keeping behavior during overtaking maneuvers. .
4. Integrate a control system for the DC steering motor based on the information gathered from the object detection, depth estimation, and lane detection modules.

III Introduction

In the rapidly evolving landscape of autonomous vehicle technology, the endeavor to enhance the capabilities of self-driving cars represents a pivotal frontier. This project centers around the critical task of Steering Control in a Self-Driving Car, leveraging the capabilities of a single-camera sensor to navigate and overtake static objects on the road. The overarching goal is to develop a sophisticated and adaptive system that seamlessly integrates object detection, depth estimation, lane detection, and precision steering control. By addressing these intricacies, the project strives to contribute to the realization of safer and more efficient autonomous transportation systems, making strides towards the future of intelligent and self-reliant vehicles.

In pursuit of this objective, the project delineates a comprehensive roadmap, beginning with the implementation of a robust object detection algorithm. By harnessing computer vision techniques and training a convolutional neural network, the system aims to identify and locate static obstacles, laying the foundation for effective autonomous navigation. Subsequently, the focus shifts to depth estimation, an imperative facet for understanding spatial relationships and facilitating informed decision-making in navigating the dynamic road environment. Simultaneously, the development of a lane detection system becomes integral, ensuring the self-driving car maintains precise lane-keeping behavior during overtaking maneuvers.

The culmination of these efforts converges on the core aspect of steering control, where the project integrates a dedicated control system for a DC steering motor. By weaving together insights from object detection, depth estimation, and lane detection, the steering control mechanism orchestrates smooth and adaptive responses, facilitating the self-driving car's adept navigation around static obstacles. Through rigorous testing and refinement, this project endeavors to push the boundaries of autonomous driving technology, ushering in a new era where vehicles can autonomously and safely negotiate complex road scenarios with a heightened level of precision and reliability.

IV Design

The design of steering control involves both software and hardware aspects. Both these aspects are explained separately in the following subsections

4.1 Software Design

The software design block diagram for steering and speed control is shown in Fig. 1.

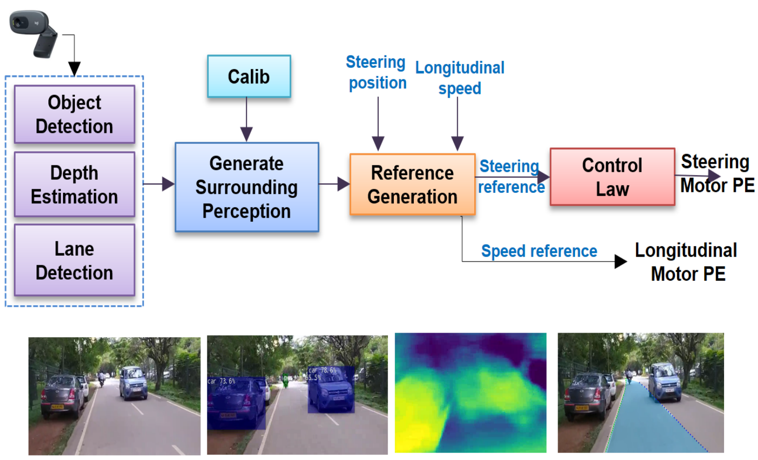


Figure 1: Algorithm breakdown of steering control

4.1.1 Object Detection :

The software design begins with the implementation of an Object Detection algorithm, utilizing a convolutional neural network (CNN). The CNN is trained on a dataset comprising static objects commonly encountered on roads. This algorithm processes input frames from the single camera sensor, identifying and localizing objects, providing crucial information for the subsequent perception stages. Block diagram of the object detection algorithm is shown in Fig. 2.

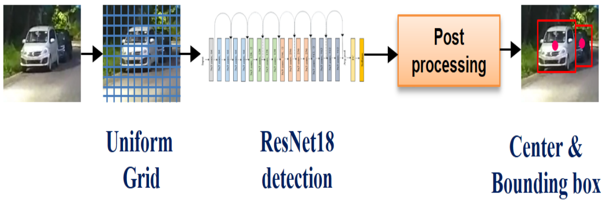


Figure 2: Object detection algorithm

4.1.2 Depth Estimation :

Following object detection, the software incorporates a Depth Estimation algorithm to discern the distance to detected objects. Depth information is vital for understanding the three-dimensional spatial relationships between the self-driving car and the obstacles. This stage involves leveraging stereo vision or monocular depth estimation techniques to enhance the car's perception capabilities. Block diagram of the depth estimation algorithm is shown in Fig. 3.

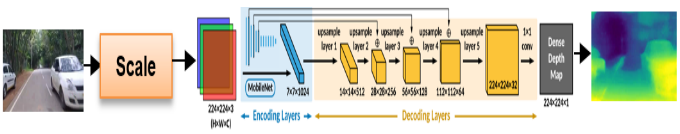


Figure 3: Depth estimation algorithm

4.1.3 Lane Detection :

Simultaneously, the software integrates a Lane Detection algorithm to identify and track road lanes. By processing the camera input, this module discerns lane markings, ensuring the autonomous vehicle maintains accurate lane-keeping behavior. The results from lane detection contribute to the overall perception, enhancing the system's awareness of the road layout. Block diagram of the object detection algorithm is shown in Fig. 4.

4.1.4 Steering Reference Generation :

The generated perception, consisting of object detection results, depth estimation, and lane detection outputs, serves as the foundation for steering reference generation.

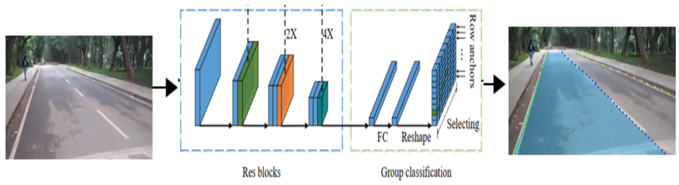


Figure 4: Lane detection algorithm

The software employs a sophisticated algorithm to interpret this perception data and generate a precise steering reference. The steering reference encapsulates the desired steering angle or trajectory adjustments needed for the self-driving car to navigate around static obstacles while adhering to lane-keeping requirements.

4.1.5 Control Law Application :

The steering reference is then fed into a Control Law, a set of algorithms designed to translate the desired steering input into actual control signals for the DC steering motor. This involves the application of feedback control mechanisms that continuously adjust the steering angle based on the real-time perception of the environment. The control law ensures the self-driving car exhibits smooth and adaptive steering responses, optimizing its ability to navigate through complex road scenarios while overtaking static objects. The control law output is given to a gate driver circuit for controlling the DC motor.

4.2 Hardware Design

The project leverages the powerful NVIDIA Jetson Orin Nano platform for the implementation of its sophisticated algorithms. With its cutting-edge architecture, the Jetson Orin Nano provides a high-performance edge computing solution tailored for AI applications in autonomous systems. Equipped with multiple CUDA cores, AI accelerators, and a dedicated image signal processor, the Jetson Orin Nano enables efficient parallel processing and accelerated neural network inference, making it an ideal choice for real-time object detection, depth estimation, and lane detection tasks. Its compact form factor and low power consumption further enhance its suitability for deployment in autonomous vehicles, ensuring that the project benefits from a robust and energy-efficient hardware foundation. Jetson Orin Nano is shown in Fig. 5.

The hardware design block diagram for steering and speed control is shown in Fig. 6.

4.2.1 Power Supply Section :

The hardware block diagram begins with the Power Supply Section, where the system is powered by a 48V input from the battery. This voltage is efficiently stepped down to 21V using a flyback transformer, providing a stable power source for the entire system. The output from the

Figure 5: Block diagram of the hardware

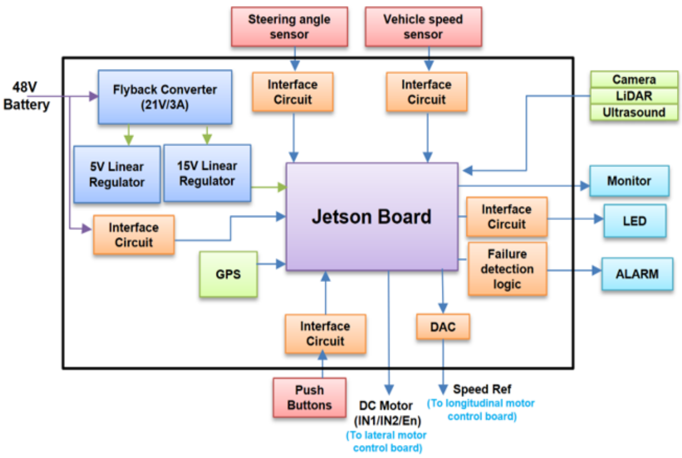


Figure 6: Block diagram of the hardware

flyback transformer is then regulated to 15V, serving as the primary power supply for the NVIDIA Jetson board. Additionally, the 15V is further regulated to 5V, facilitating the power requirements of various sensors integrated into the system.

4.2.2 Sensor Interface:

The Sensor Interface subsection encompasses the connection between the 5V regulator and the diverse sensors utilized in the project. The NVIDIA Jetson board interfaces with a camera sensor to capture visual data crucial for object detection and lane detection algorithms. An ADC-DAC module is incorporated to interface with a current sensor, as well as position and speed potentiometers. This interface enables the system to gather real-time data on the vehicle's current consumption, steering wheel position, and speed, providing essential input for the steering control algorithm.

4.2.3 Jetson Interfacing :

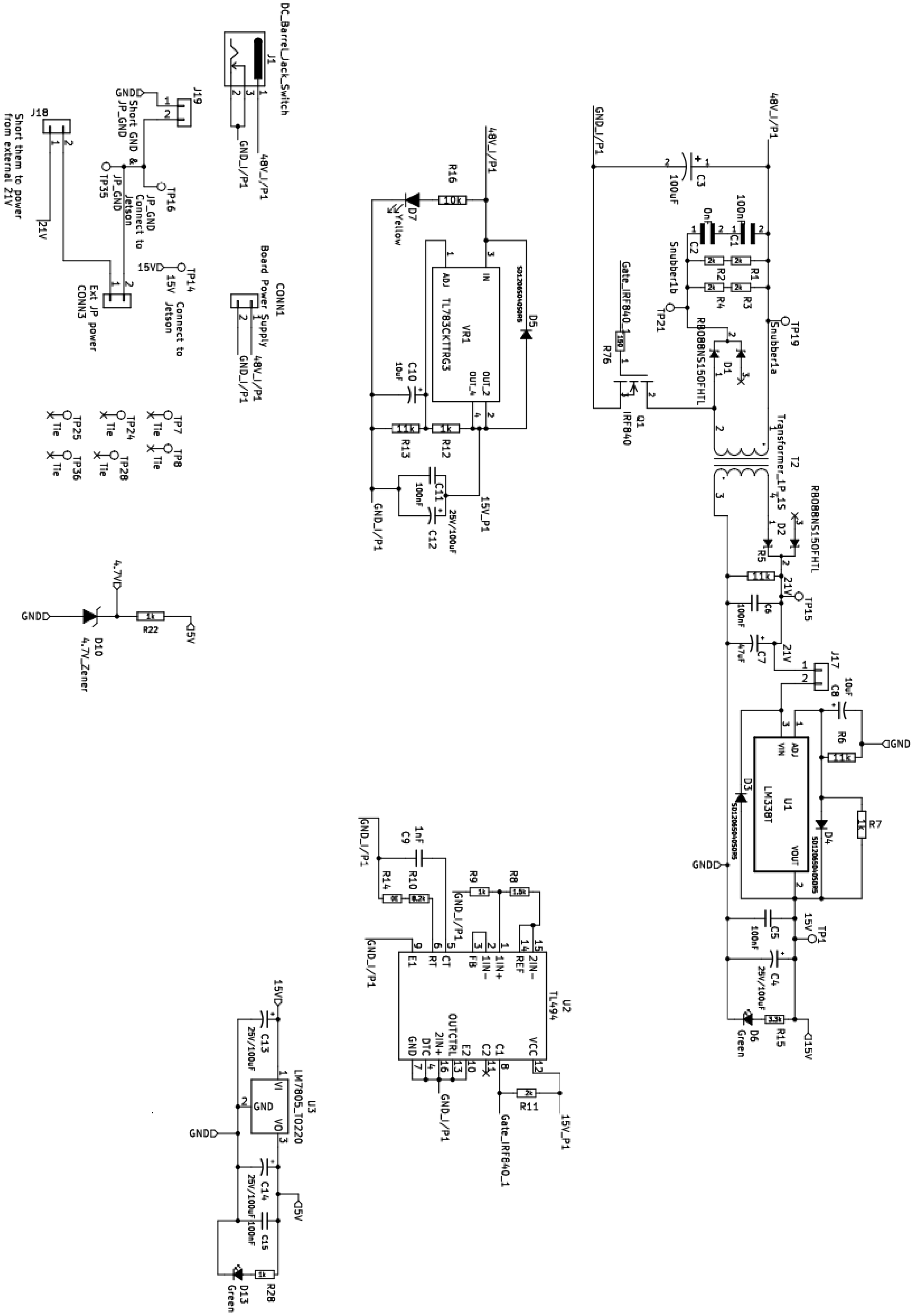
In this subsection, the focus is on the interaction between the NVIDIA Jetson board and the various components within the system. The Jetson board receives its regulated 15V power supply and communicates with the camera sensor and ADC-DAC module. The AI processing capabilities of the Jetson are harnessed for real-time analysis of sensor data, allowing for intelligent decision-making in the steering control algorithm.

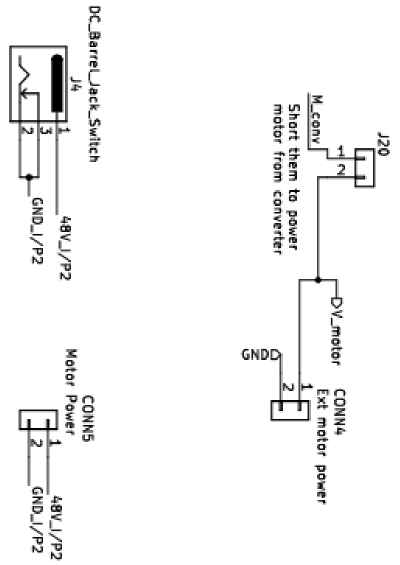
4.2.4 Steering Control and Actuation :

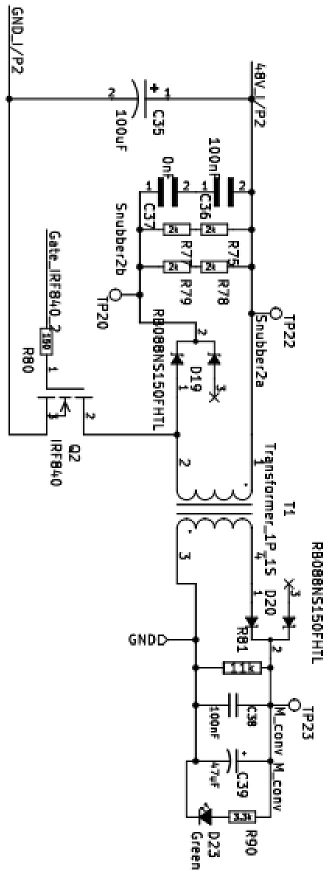
The final subsection highlights the Steering Control and Actuation component. The PWM (Pulse Width Modulation) output generated by the Jetson board is directed to a gate driver chip, specifically the DRV8873. This chip serves as the intermediary between the digital control signals and the physical actuation of the steering system. By converting the digital signals into the appropriate voltage and current levels, the DRV8873 efficiently drives the DC steering motor. This ensures precise and responsive control over the steering mechanism based on the decisions made by the Jetson board.

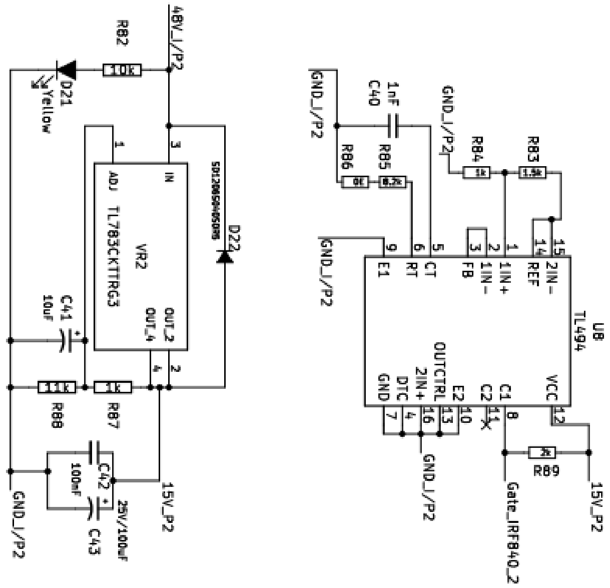
In summary, the hardware block diagram outlines a comprehensive system architecture that seamlessly integrates power supply management, sensor interfaces, Jetson processing capabilities, and the actuation of the steering system. This design ensures a robust and well-coordinated hardware foundation for the successful implementation of the self-driving car steering control project.

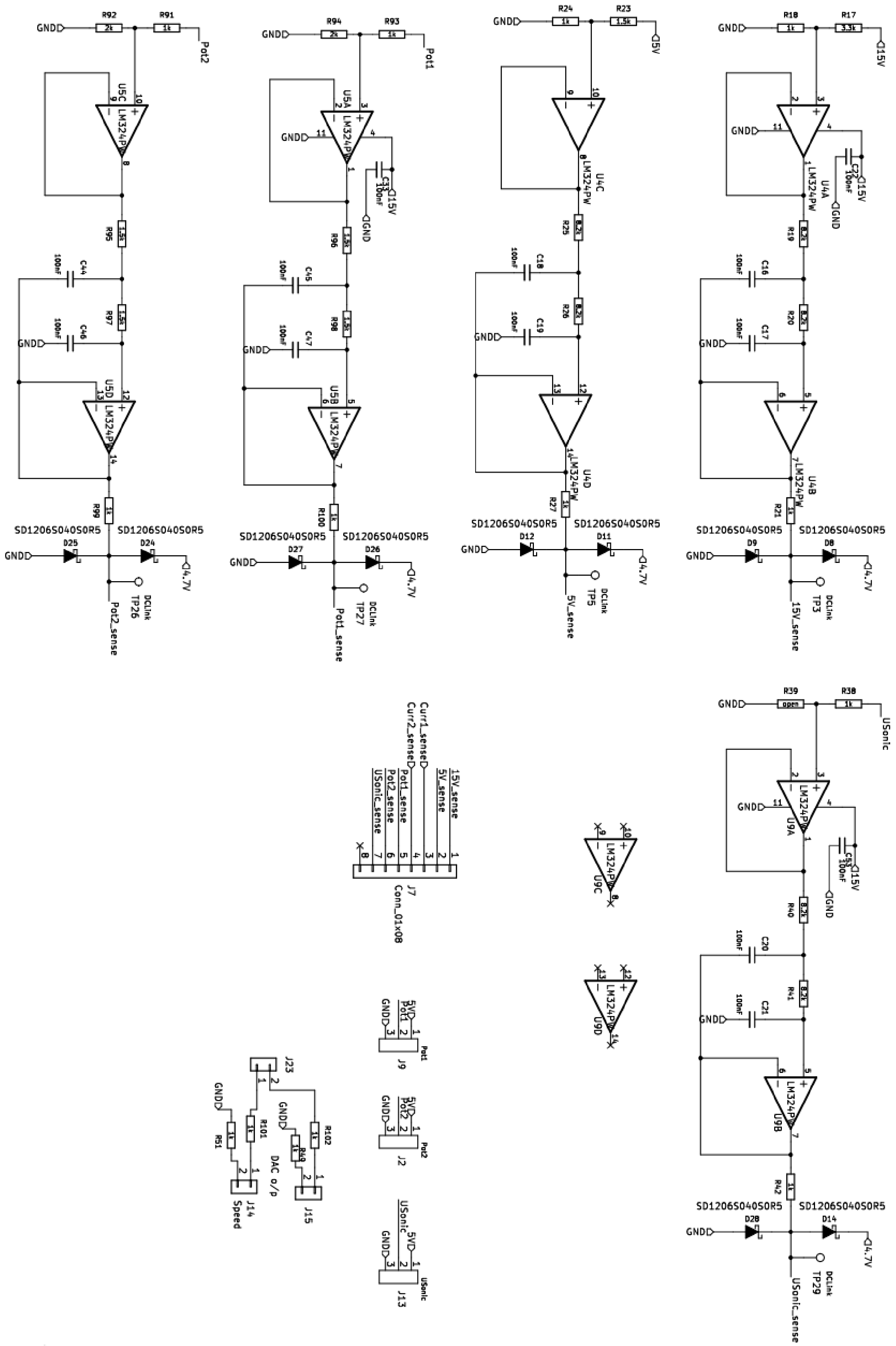
Schematic of the designed PCB are shown in Fig. 4.2.4 - Fig. 4.2.4. Top and bottom layout diagrams of the designed PCB are shown in Fig. 7 and Fig. 8 respectively.

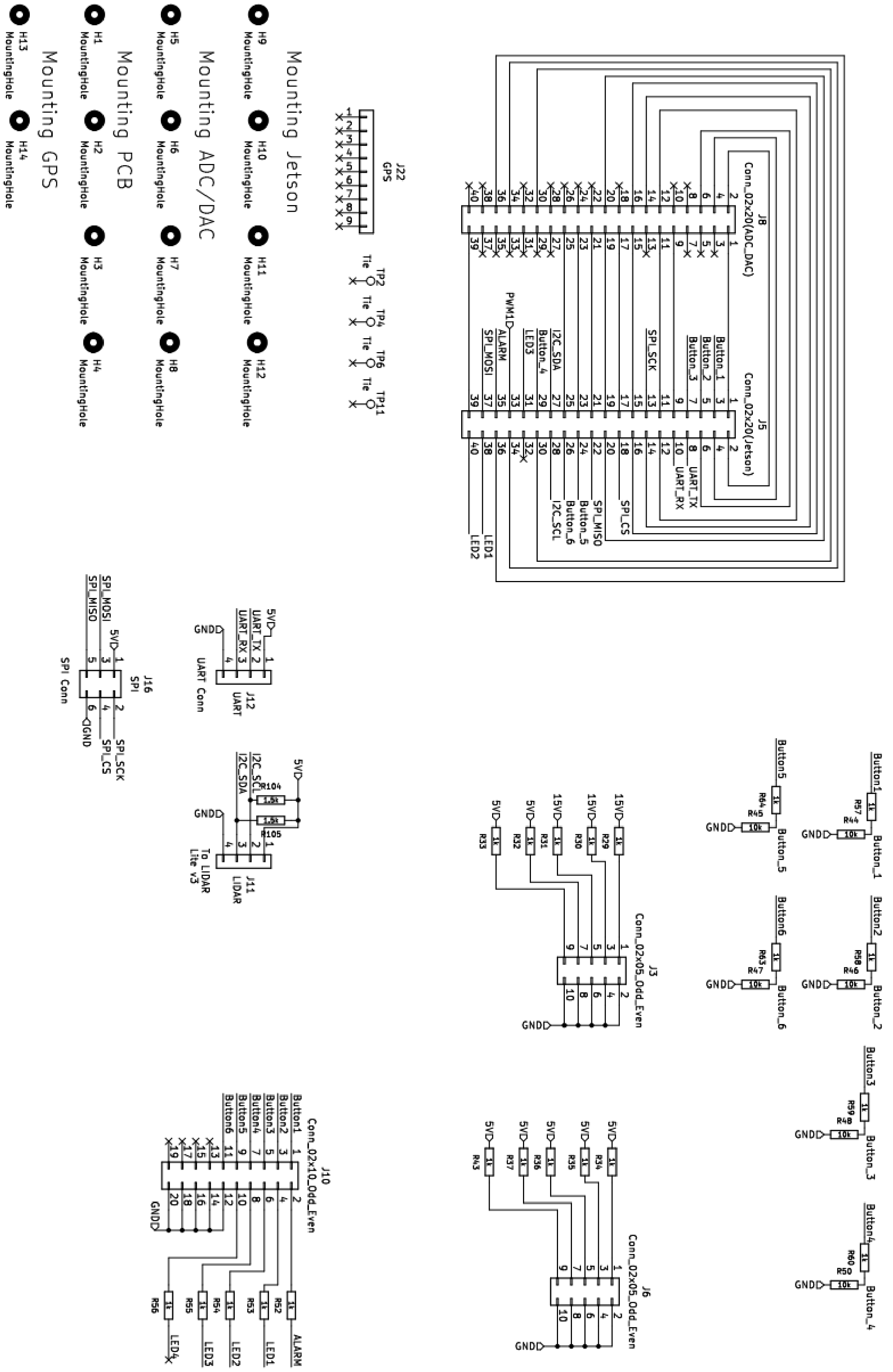

DC_Barrel_Jack_Switch
J1
48V_I/P1
GND_I/P1
J19
GNDD
Short GND &
JP_GND
TP16
JP_GND
Connect to
Jetson
TP35
J18
Short them to power
from external 21V
21V
15VD
TP14
15V Connect to
Jetson
Ext JP power
CONN3
CONN1
Board Power Supply
TP7
TP8
TP24
TP28
TP25
TP36
Tie
48V_I/P1
R16
10k
D7
Yellow
VR1
TL783CKTRG3
SD12065040505R5
D5
C10
10uF
R13
11k
R12
1k
C11
100nF
C12
25V/100uF
15V_P1
GND_I/P1
4.7VD
GNDD
D10
4.7V_Zener
R22
1k
5V
48V_I/P1
GND_I/P1
C3
100uF
100nF
C1
C2
R1
R2
R3
R4
2k
Snubber1b
Snubber1a
Gate_IRF840_1
R76
150
TP21
TP19
RB088NS150FHTL
D1
Q1
IRF840
Transformer_1P_1S
T2
D2
R5
11k
21V
TP15
C6
100nF
C7
47uF
J17
C8
10uF
R6
11k
GND
U1
LM338T
D3
D4
R7
1k
GNDD
C5
100nF
C4
25V/100uF
15V
TP1
D6
Green
R15
3.3k
15V
U2
TL494
C9
1nF
R14
R10
8.2k
R9
1k
R8
1.5k
R11
2k
Gate_IRF840_1
15V_P1
GND_I/P1
15VD
C13
25V/100uF
U3
LM7805_TO220
GNDD
C14
25V/100uF
C15
100nF
5V
R28
1k
D13
Green

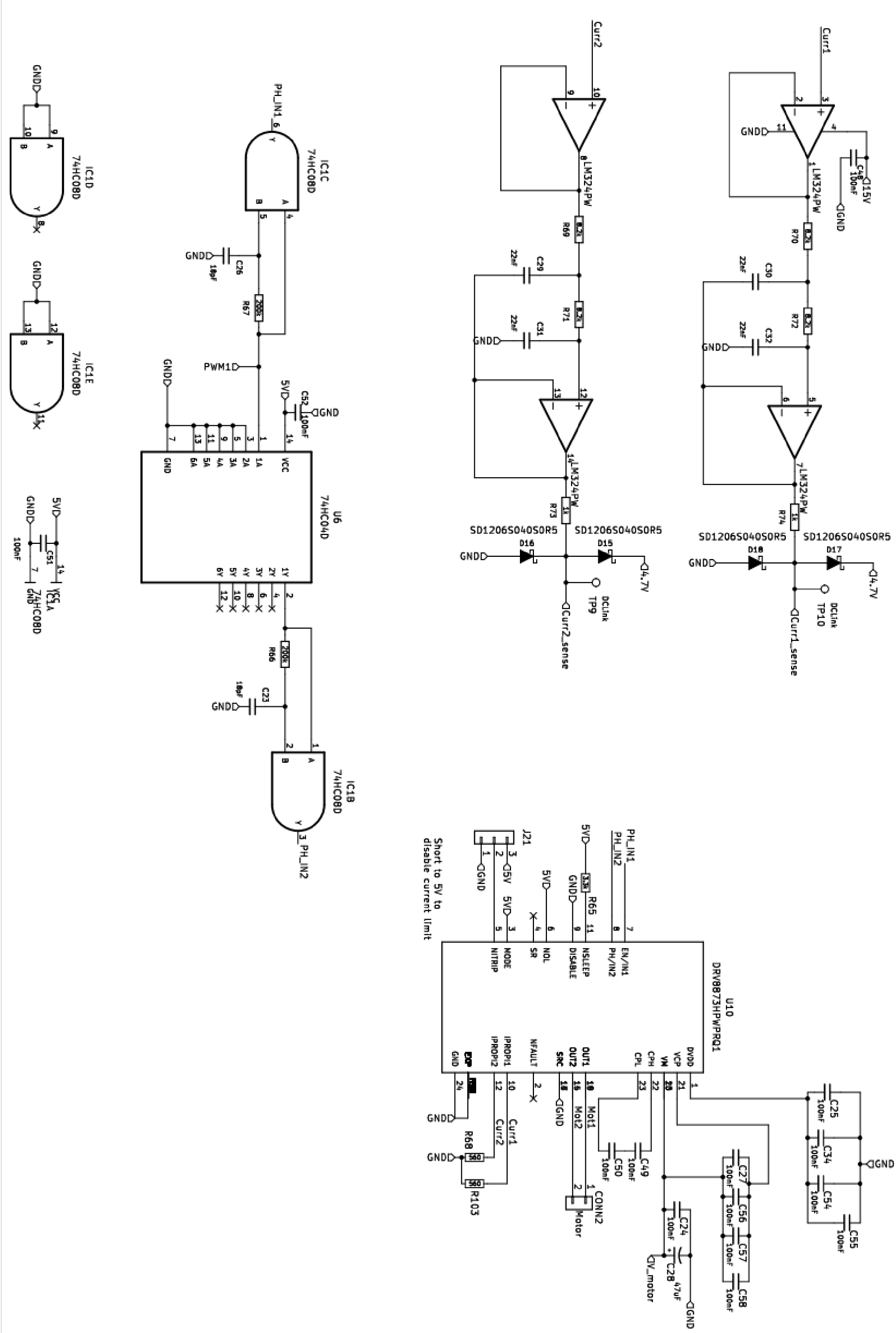

DC_Barrel_Jack_Switch
J4
48V_I/P2
GND_I/P2
CONN5
Motor Power
J20
M_conv
Short them to power
motor from converter
DV_motor
GNDD
CONN4
Ext motor power


48V_I/P2
GND_I/P2
C35
100uF
100nF
C36
C37
R75
R78
R79
Snubber2b
Snubber2a
TP20
TP22
Gate_IRF840_2
R80
Q2
IRF840
D19
RB088NS150FHTL
Transformer_1P_1S
T1
D20
R81
GNDD
TP23
C38
100nF
C39
M_conv
R90
D23
Green


48V_I/P2
R82
10k
D21
Yellow
D22
VR2
TL783CKTTRG3
C41
10uF
R87
R88
C42
100nF
C43
25V/100uF
15V_P2
GND_I/P2
C40
1nF
R83
R84
R85
R86
U8
TL494
R89
Gate_IRF840_2


LM324PW
U5C
U5D
U5A
U5B
U4C
U4D
U4A
U4B
U9A
U9B
U9C
U9D
SD1206S040S0R5
Pot2_sense
Pot1_sense
5V_sense
15V_sense
USonic_sense
Curr1_sense
Curr2_sense
J7
Conn_01x08
DCLink
GND
15V
5V
4.7V
DAC o/p
Speed


Mounting Jetson
Mounting ADC/DAC
Mounting PCB
Mounting GPS
J22
GPS
J8
Conn_02x20(ADC_DAC)
J5
Conn_02x20(Jetson)
J12
UART
UART Conn
J16
SPI
SPI Conn
J11
LIDAR
To LIDAR Lite v3
J3
Conn_02x05_Odd_Even
J6
Conn_02x05_Odd_Even
J10
Conn_02x10_Odd_Even


IC1D
74HC08D
IC1E
74HC08D
IC1C
74HC08D
IC1B
74HC08D
U6
74HC04D
IC1A
74HC08D
PH_IN1
PH_IN2
PWM1
LM324PW
Curr1
Curr2
Curr1_sense
Curr2_sense
SD1206S040S0R5
DCLink
TP9
TP10
U10
DRV8873HPWPRQ1
J21
Short to 5V to disable current limit
CONN2
Motor
V_motor

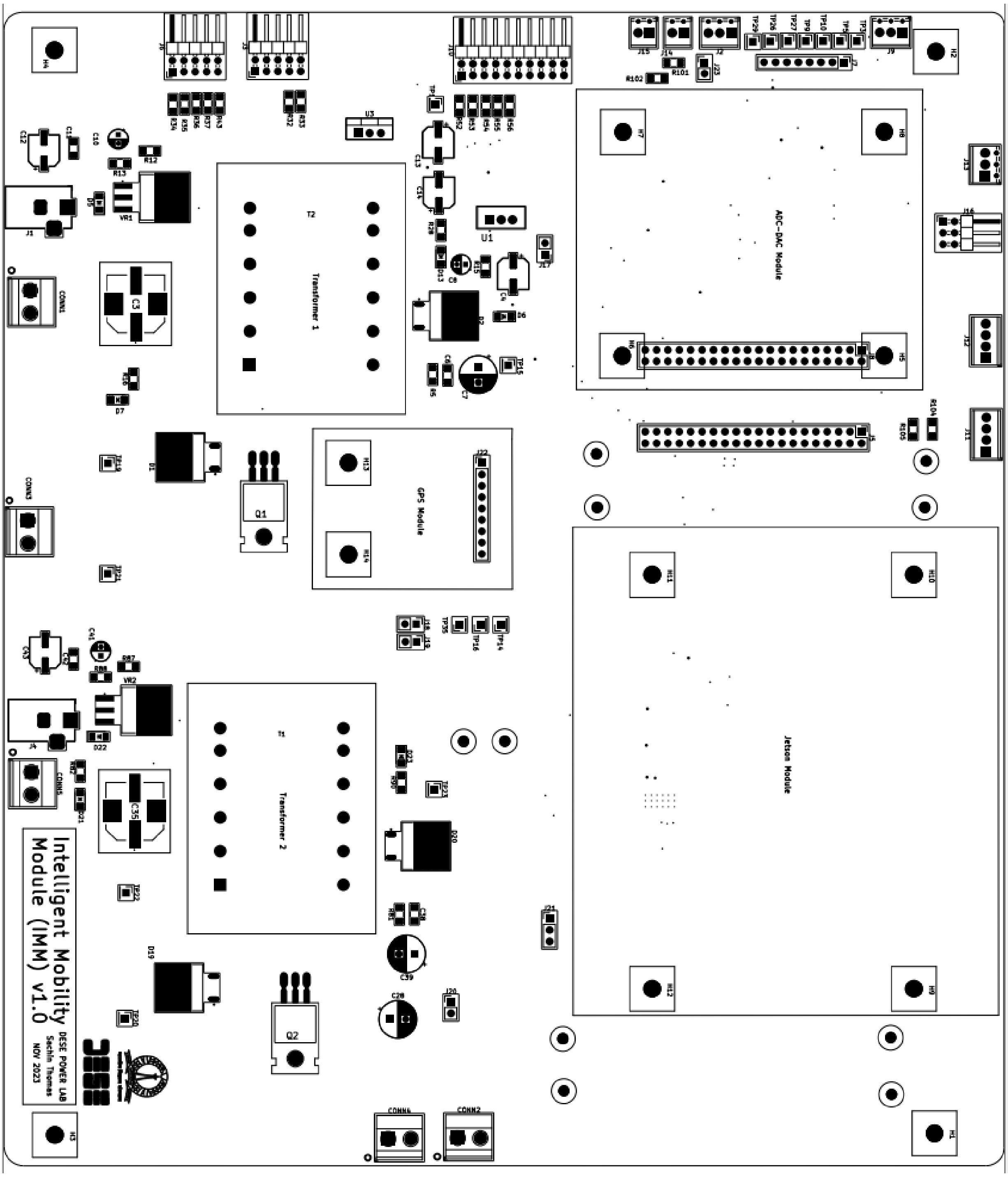


Figure 7: Position diagram of the top layer

Figure 8: Position diagram of the bottom layer

V RESULTS

The designed board was fabricated and all the components were wired. The wired board is shown in Fig. 9.

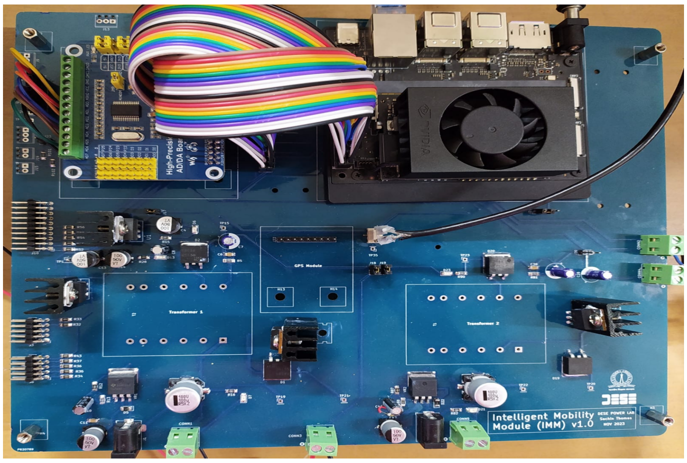


Figure 9: Wired PCB for steering control

The circuit diagram and the steering motor hardware are shown in Fig. 10 and Fig. 11. Test setup of steering motor control is shown in Fig. 12.

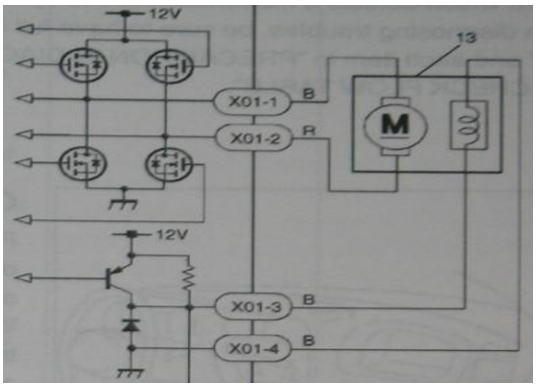


Figure 10: Schematic of the steering motor

In the given setup, a recorded video was run on the algorithm to observe the steering control performance. The output of surrounding perception algorithm for various scenes are shown in Fig. 13 - Fig. 15.

For these various conditions, the steering motor was adjusted correctly to avoid the objects as shown in the demo video.

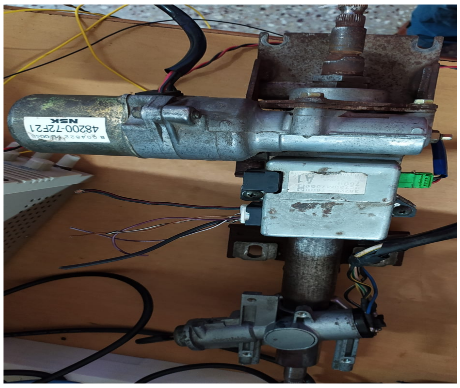


Figure 11: Steering motor

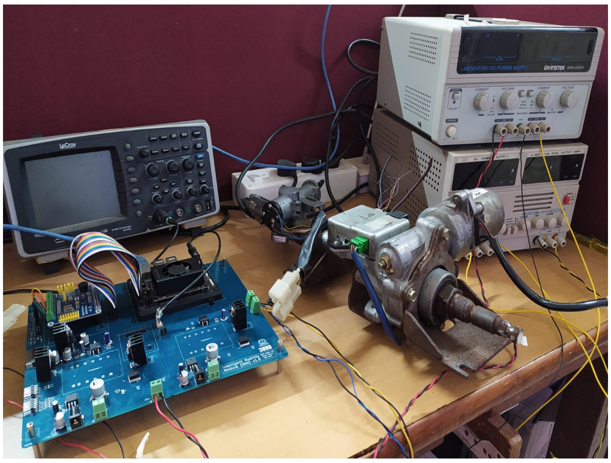


Figure 12: Steering motor control setup

VI CONCLUSION

In conclusion, the successful implementation of the steering control system for a self-driving car represents a significant milestone in advancing autonomous navigation capabilities. Through the integration of object detection, depth estimation, and lane detection algorithms, coupled with precise steering control using a DC motor, the project effectively demonstrated the vehicle's ability to dynamically respond and navigate around static obstacles. The project's success, showcased in the demo video, underscores the potential of intelligent steering systems in enhancing safety and efficiency in autonomous driving scenarios, laying a solid foundation for future developments in this transformative field.

In the project, it is evident that the seamless coordination between hardware components, sensor interfaces, and the robust NVIDIA Jetson platform contributed to the system's adaptive decision-making and real-time control. The achieved outcomes not only validate the efficacy of the implemented algorithms but also highlight the project's broader implications for the evolution of self-driving technology, promising safer and more reliable autonomous vehicles in the not-so-distant future.

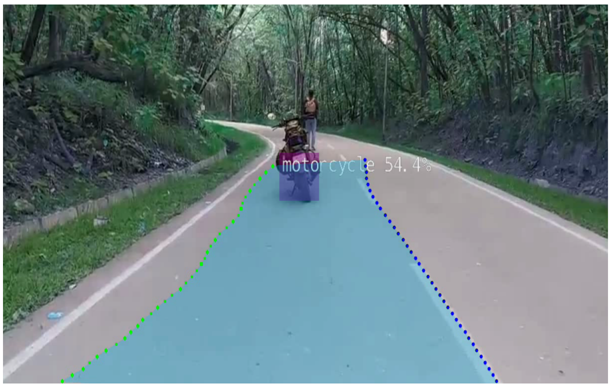


Figure 13: Perception output with a motorcycle object

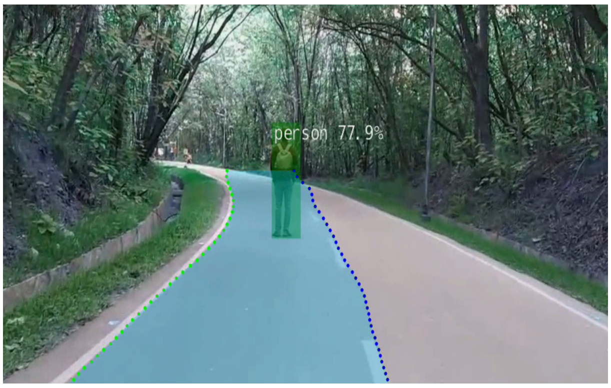


Figure 14: Perception output with a pedestrian object

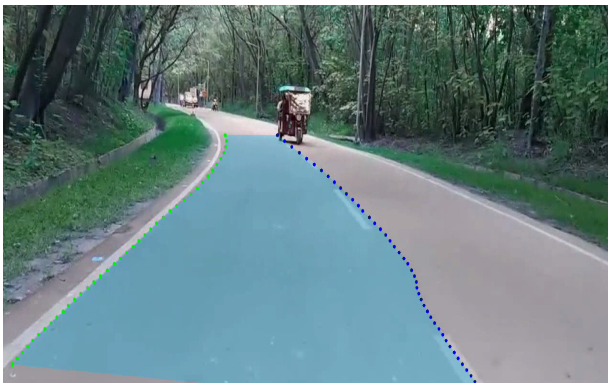


Figure 15: Perception output with no objects