OPTIMIZATION OF CONDITIONING CIRCUIT BOARD INTERFACE FOR CILI-PADI PICKING ROBOT

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
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DECLARATION

I declare that this report entitled "Optimization of Conditioning Circuit Board Interface for Cili-padi Picking Robot" is the result of my own work except for quotes as cited in the references.

Signature : ……………………………………….

Author : Muhammad Azim Bin Ruslee

Date : 25th June 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : …………………………………

Supervisor Name : Dr. Norihan Binti Abdul Hamid

Date : 25th June 2021

DEDICATION

To my beloved mother, father and family.

ABSTRACT

The electrical wiring systems are mostly standardized with several rules, regulations and laws hence should installed correctly and safely according to electrical regulations and standards. If the electrical wiring is carried out incorrectly or neglect the regulation standard, it may expose to short circuits, electric shocks, damage on device or leads to the malfunctioning of device beside can reduce device/electrical component lifetime. This project is focusing on hardware parts from three separate projects that work together to build a “Cili-padi picking robot”. Main target for the project is to optimize and ensure all components that required to connect to the microcontroller is well organize and may use within the voltage specification. At the end of this project, it is expected to achieve a switching box to place a complete “Cili-padi picking robot” circuit.

ABSTRAK

Sistem pendawaian elektrik kebanyakannya diseragamkan dengan beberapa peraturan dan undang-undang, oleh itu perlu dipasang dengan betul dan selamat mengikut peraturan dan piawaian elektrik. Jika pendawaian elektrik dijalankan dengan salah atau mengabaikan taraf peraturan, ia boleh terdedah kepada litar pintas, kejutan elektrik, kerosakan pada peranti selain boleh mengurangkan hayat komponen elektrik. Projek ini memberi tumpuan kepada bahagian perkakasan dari tiga projek berasingan yang bekerjasama untuk membina "Cili-padi picking robot". Sasaran utama projek ini adalah untuk mengoptimumkan dan memastukan semua komponen yang diperlukan untuk menyambung ke mikrokontroler disusun dengan baik dan boleh digunakan dalam spesifikasi voltan tertentu. Pada akhir projek ini, ia dijangka mencapai kotak panel untuk meletakkan litar "Cili-padi picking robot" yang lengkap.

ACKNOWLEDGEMENTS

Alhamdulillah and thanks to all mighty Allah for giving me strength to complete this Final Year Project (FYP). This thankful is also are gratitude to FKEKK and internal PJP Grant from Universiti Teknikal Malaysia Melaka for the financial support. I would like to extend my gratitude to my supervisor, Dr. Norihan Binti Abdul Hamid and Dr. Wira Hidayat Mohd Saad for the guidance motivation and allow me to complete my project successfully even though there is some limitation on the component provided. Nobody has been more important to me in the pursuit of this project than my family members. I would like to thanks my parents for love, guidance and their pray. Its drive my passion because they are the ultimate role models in my life. Finally, I would like to give millions of thanks to everyone who assisted and supported me throughout my journey in bachelor's degree life.

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LIST OF SYMBOLS AND ABBREVIATIONS

IoT : Internet of Things

Pi : Raspberry Pi

USB : Universal Serial Bus

HDMI : High-Definition Multimedia Interface

CPU : Central Processing Unit

CPU : Central Processing Unit

GPU : Graphical Processing Unit

RAM : Random Access Memory

GPIO : General Purpose Input Output

IT : Information Technology

CAD : Computer-aided Design

PCB : Printed Circuit Board

DC : Direct Current

AC : Alternate Current

UART : Universal Asynchronous Receiver/Transmitter

PWM : Pulse Width Modulation

CHAPTER 1

INTRODUCTION

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1.1 Project Background

In Cili-padi fertigation process, the most time-consuming and laborious is cili-padi picking. It has been reported that the picking operation takes up 80% of the fertigation process. “Cili-padi Picking Robot” were the project as considered to encounter this problem. Therefore, the objectives of this project are to construct and optimize a conditioning circuit that connected to microcontroller. Next, is to achieve control panel circuit with an optimal usage level and lastly is providing a working robot that can fulfil the minimum requirement of the Cili-padi picking robot sensor and actuator conditioning circuit specification.

Control panels consist of power circuits or control circuits (or both) which deliver signals that direct the performance of machinery or equipment. Control panels design begins with weighing design needs and specifications and preparing schematics, but the design process can be quite complicated in order to ensure that all applicable regulatory standards and safety requirements are followed.

The design of a control panel for equipment is a significant endeavour that results in an interface that controls a machine or process [2]. Choosing an adequate enclosure and a back panel to store the electrical hardware is not a straightforward task. As a result, the machine's hardware must be correctly wired and integrated. Any incorrect setting can lead to machinery failure.

1.2 Problem Statement

In order to ensure the outcome of this project is achieved, the problem that has been encountered is the interconnection between the components is made through numbers of currents carrying wires and it makes the interconnection bulky. Other than that, the robot needs a switching box to place the systems and a proper circuit path planning. Short-circuit will occur if the problem is ignored. Lastly, to achieve double layer PCB layout, the layout of the PCB is close to each other that it can cause signal interference.

1.3 Objectives

The project aims to come out with a proposed optimize controller board design for Cili-padi picking robot. To realize that below objective need to be achieved:

i. To simulate and validate the conditioning circuit of all actuator and sensor that is connected to the microcontroller
ii. To design the centralize switching box and circuit path planning
iii. To analyze the circuit connectivity and functionality

1.4 Scope of Project

The hardware that will be used in this project is a conditioning circuit that connected to an Arduino Mega and Nvidia Jetson-Nano that will act as a microcontroller and comprised of actuator and sensors. Nvidia Jetson-Nano is chosen because of its high performance with its small and compact size. The sensors are needed to senses and corrects for positioning mistakes, and is robust to the vision module's localization faults. The actuators are needed to moves the wheels and the robot arm. After that, the results will be tabulated and analyzed.

1.5 Thesis Outline

This report contains five chapter. The first part is about the project introduction that will explain about the project summary, problem statement, objectives and scope of works. In chapter 2 contains the related information on the project that can be found on any reference books, internet, journal or other sources of information. Chapter 3 will explain about the method used to design the centralize switching box. Chapter 4 will elaborate on the results and discussion and chapter 5 will conclude this project and some suggestion for future works.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction to NVIDIA Jetson-Nano

NVIDIA Jetson-Nano is an NVIDIA product that uses GPU compute to develop IoT solutions. This board includes GPIO ports and a GPU core to make it simple for developers, makers, and IT users to create programs. As a result, some sensors and actuators can be integrated into NVIDIA Jetson-Nano devices. Each GPIO pin can function as either an input or an output pin. NVIDIA Jetson-Nano also provides GPIO pins for UART, PWM, SPI, I2S, and I2C. To access the GPIO, use the *Jetson*.GPIO library from Jetson websites [3].

2.2 Sensors and Actuators Integration in Embedded Systems

Sensors and actuators are important components of many embedded systems, and they can cause catastrophic events. Detecting sensor and actuator problems is challenging and has a significant impact on system performance. It is necessary to identify and correct all failure modes while integrating sensors and actuators with the rest of the subsystem [4].

2.3 Design of a Configurable All Terrain Mobile Robot Platform

A mobile robot known as CoMoRAT (Flexible Mobile Robot for All Terrain Applications) was created and produced at METU with the goal of having a configurable research platform. CoMoRAT can be propelled by wheels, tracks, or a combination of the two. Apart from its capacity to ride well on a variety of terrains, the robot body is built in such a way that adding new hardware to the platform involves minimal manufacture and installation effort [5].

2.4 Development of Multi-Terrain Mobile Robot Platform Based on Modular Concept

Malaysia's diverse geographical topographies have prompted the creation of a multi-terrain platform for remote operated vehicles. Western countries have introduced a slew of items, but due to natural geographical disparities in design criteria, many of them fall short of expectations. To reduce development costs, the general design is being localized to fit off-the-shelf materials and small-scale manufacturing procedures. The entire system is being modelled in Pro/Engineer, a

CAD program. The pulley system was the starting point for the design. The driving belt has two driving pulleys on the upper part and two support pulleys on the lower part. One of the driving pulleys is driven by the DC motor which is directly attached at the side [6].

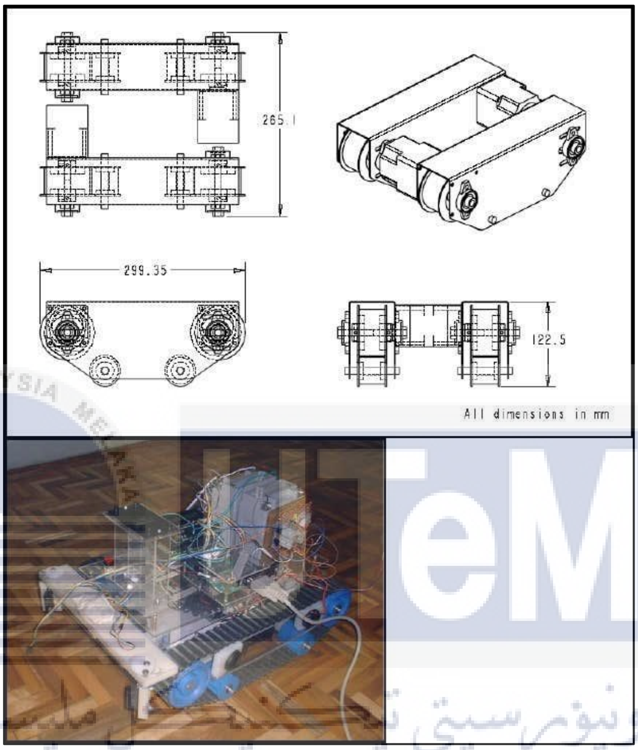


Figure 2.1:Autonomous Personal Mobile Robot System Project [6]

2.5 Introduction to Double layer PCB – Construction and working

Double-layer PCBs (also known as Double-Sided Plated Thruor DSPT) circuits are the first step toward higher-level innovation. By using vias to replace a top and base layer, they account for closer (and possibly extra) direction follows. A thin layer of guiding material, similar to copper, is connected to both the top and bottom sides of the board in a double layer PCB. On different layers of the PCB, there is a through that contains two cushions at a comparing position on different layers. Another advantage of using two-sided loads is the increased warmth scattering that an additional layer of copper provides. This can be accomplished during the drawing process by only expelling enough copper to produce the tracks and leaving the excess copper rather than removing it completely [10].

Figure 2.2: Double layer printed Circuit board [10]

2.6 Mobile robot control system

The control system of a mobile robot based on the Atmega microcontroller is discussed in this article, along with its schematic diagram and operating algorithm. The chassis, low-level controller (Arduino Nano), single board computer (NVIDIA

Jetson Nano), power and logical circuit, robot-to-operator communication system, and referee system are the essential components of the robot. The robot is separated into two sub-systems, computer vision node and executive node, each with its own set of tasks. The computer vision node consists of a First-Person View camera that receives video pictures and an NVIDIA Jetson microcomputer that processes video data and sends commands to the executive node. The main goal of this website is to help people form gun teams, fire autonomously, and work with video. The executive unit is made up of an Arduino Nano microcontroller that processes visual data and sends commands to motor drivers that control stepper and direct current motors, respectively [12].

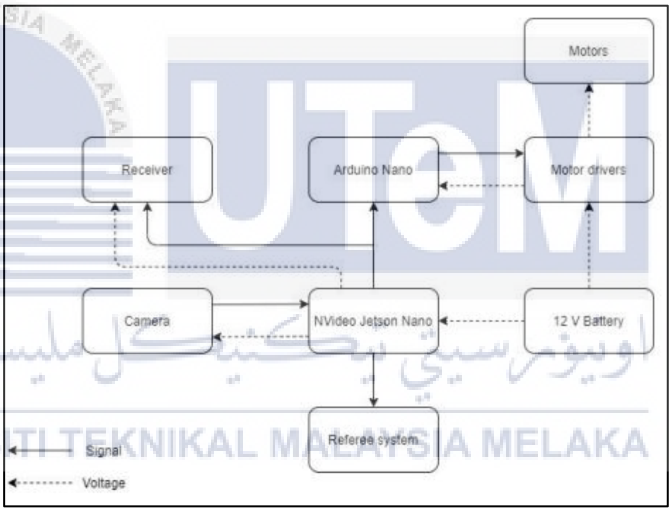


Figure 2.3: Signal distribution schematics [12]

2.7 Embedded Mobile ROS platform for SLAM Application with RGB-D Cameras

This project's goal was to develop a tracked vehicle with autonomous navigation capabilities for usage in tough terrain. The NVIDIA Jetson Nano, a CUDA-enabled single-board computer, is used to process the source stereo image provided by an Intel RealSense D345i depth camera. To allow for future extension and communication, the design mainly relies on the use of the Robot Operating System (ROS) and Simultaneous Location and Mapping (SLAM) algorithms. The system is set up in a controlled process and is being implemented one step at a time. The chassis and power system are first configured to support future modules, after which the vehicle control is developed using an ESP32 microcontroller and TOSHIBA TB67H420FTG Dual H Bridge motor controller [13].

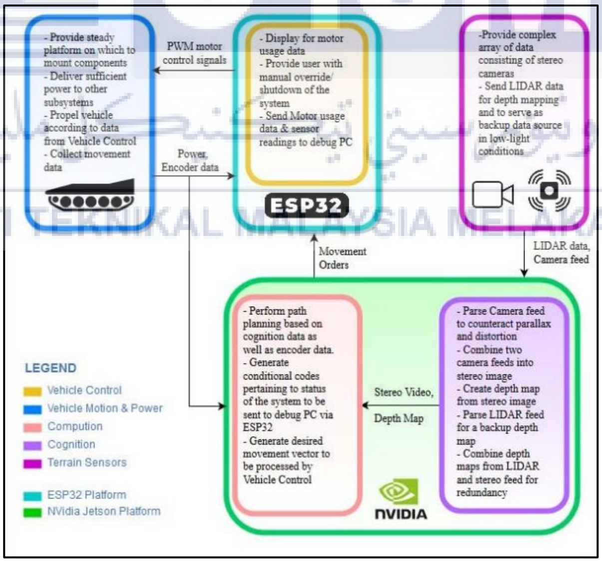


Figure 2.4: System design flow [13]

2.8 Autonomous Racing Robot

The thesis' goal is to provide a small-scale hardware and software solution for autonomous driving. The goal is to have the robot travel around the course autonomously and dependably without the need for human interaction. The hardware configuration of the robot is made up of four pieces. A laptop, an NVIDIA Jetson Nano, a Raspberry Pi (RPi), and MonsterBorg. RPi, laptop/Jetson, and Convolutional Neural Network (CNN) training are the three pieces of the software implementation. The MonsterBorg has a Jetson Nano and a Raspberry Pi on board, which are connected through an ethernet wire. Wi-Fi is used to link the laptop to the Raspberry Pi. The laptop is only used to collect training data and run Python scripts on the RPi and Jetson Nano [14].

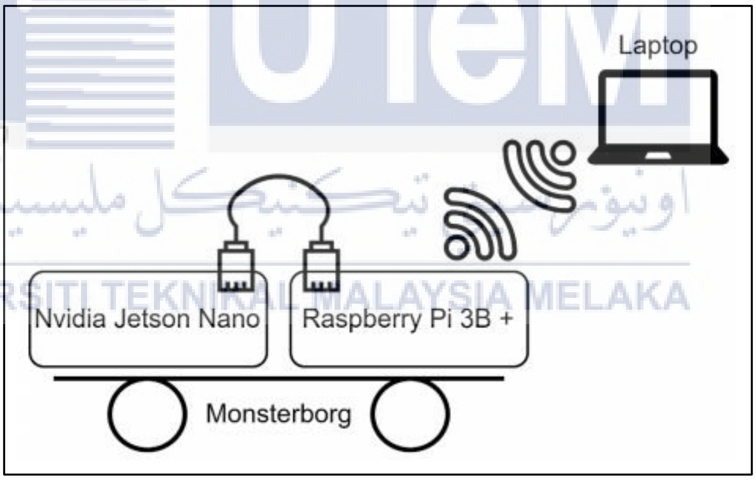


Figure 2.5: Hardware connections of Autonomous Racing Robot [14]

2.9 Edge Computing Driven Smart Personal Protective System Deployed on NVIDIA Jetson-Nano

NVIDIA Jetson Nano is being used as an edge computing platform for ML interference in the fields of IoT and Machine Learning. They focused on real-time apple detection to estimate apple yields and, as a result, control apple supplies. The Jetson Nano was utilized to help speed up complex machine learning operations. The goal of yield estimation became much more feasible due to the light weight, low power consumption, and form factor [15].

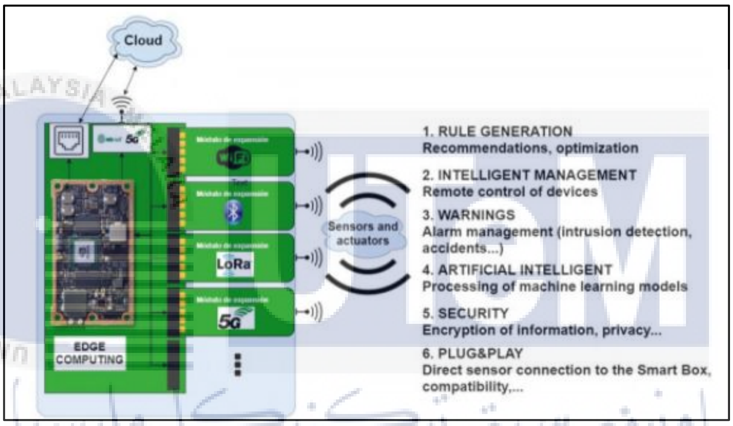


Figure 2.6: Gateway edge computing [15]

2.10 Low-Cost Embedded Vision for Industrial Robots: A modular End-of-Arm Concept

This study includes a prototype of a modular and universal platform (end-effector) for industrial robots, which includes an embedded low-cost microprocessor and a diverse set of sensors. The embedded computing unit is a Raspberry Pi 3 Model B+. Because of its dimensions, connectivity, and computing capacity, the single-board computer is ideal. A UR5 robot, a Robotic gripper, and an end-effector module make up the robot. The goal is to use object detection to pick up an industrial bearing and place it in a box [17].

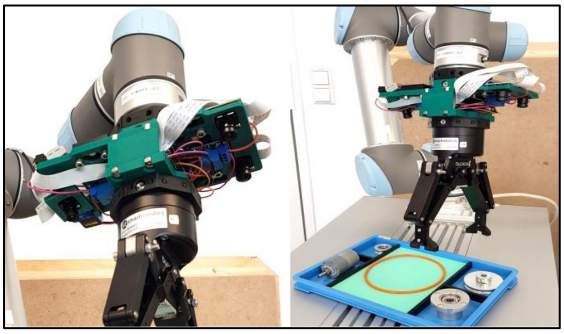


Figure 2.7: Prototype of a modular End-of-Arm [17]

2.11 Multi-Agent Modeling of Cyber-Physical Systems for IEC 61499 Based Distributed Automation

Modeling industrial CPS towards IEC 61499-based distributed automation using a two-layer design. It attempts to integrate system intelligence via high-level cyber modules' communication and processing cores, as well as real-time adaptability via distributed and intelligent control of low-level physical modules. Jetson Nano is used in the setup, which is developed in Python [18].

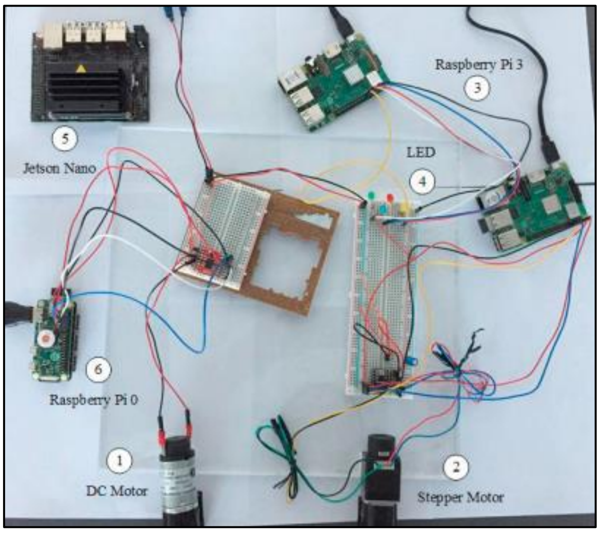


Figure 2.8: Two-layer modelling architecture [18]

2.12 Autonomous charging system for a three-wheel robot

A method for charging the robot autonomously is created, which is required for long-term autonomy. For perceiving the environment in which they work, the robots must use either sensors or cameras. It consists of a stationary docking station and a robot-mounted docking mechanism. The docking station is located using vision and a laser ranger-finder technology. The system responsible for running the Linux functions is an NVIDIA Jetson Nano. The custom robot was then equipped with an Arduino UNO compatible platform and an L298N motor driver to address the speed communication issue [19].

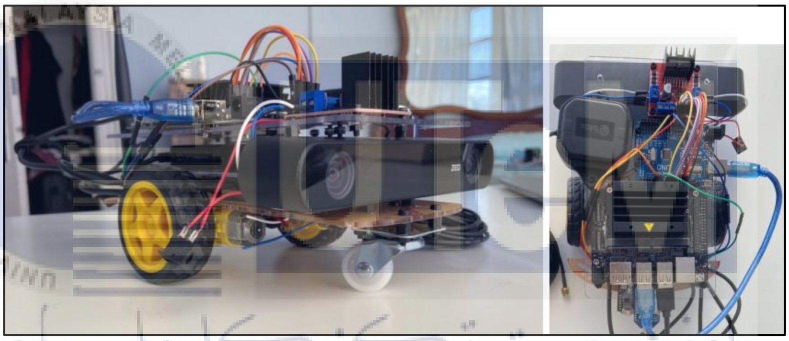


Figure 2.9: Front and the top view of the robot [19]

CHAPTER 3

METHODOLOGY

This chapter will cover the procedure that is required to complete the project. This chapter will explain more about the hardware involved in completing this project and their specifications.

3.1 Flowchart

The review of the specifications, requirements, and regulatory standards is the first step in this project. Drawings are made to outline the particular design of wiring, circuits, controls, and every other aspect of the final control panel once all considerations have been assessed. The drawings are including the functional diagram, input/output diagram, power distribution, control panel layout and materials. In order to ensure the outcome of this project is achieved, the process to developing the control panel is shown in Figure 3.1.

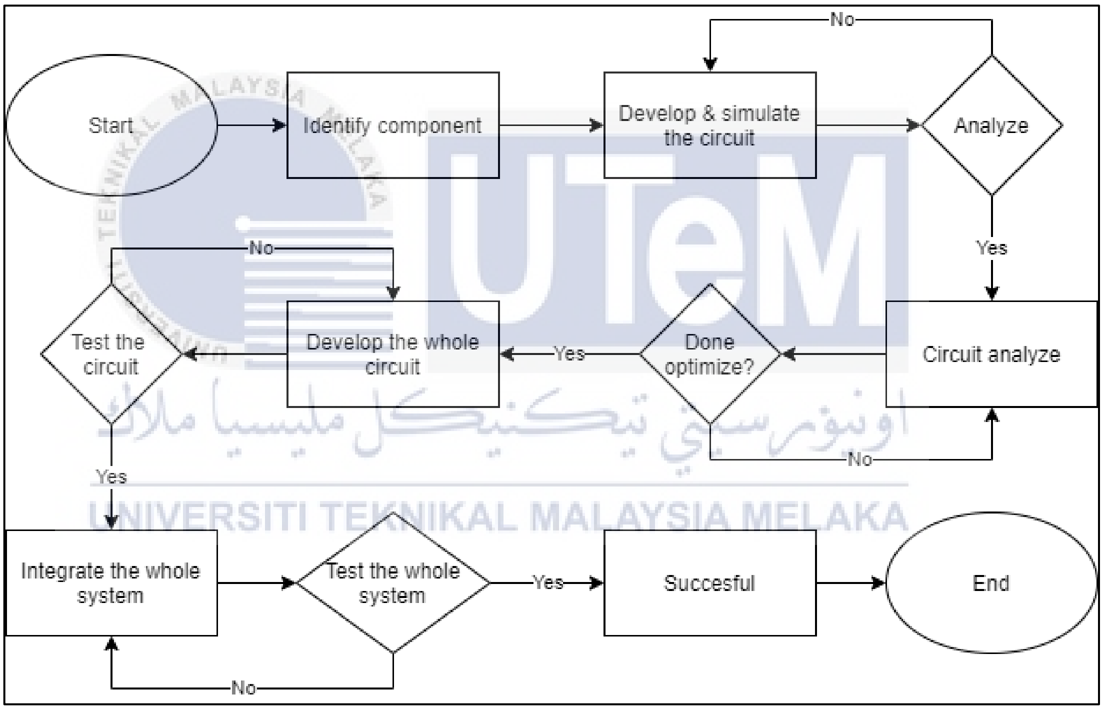


Figure 3.1: Flowchart of project

3.2 Detail Description the Methodology Flowchart

Stage 1

- Identify the component involved and used for the robot.

- Decide all the component that will be use include such as camera, arm and gripper and calculate all the measurement and dimension before developing the circuit

- Develop a conditioning circuit for fully automated robot arm mechanism for chili picking task.

- Simulate the design circuit by using Proteus 8 software.

- Validate the conditioning circuit of all actuator and sensor that is connected to the microcontroller.

Stage 2

- Pre available device or model is taken into the consideration of the circuit.

- Design the PCB circuit using SMT components.

- Fabricate the PCB board using Proteus 8 software.

- Implemented all the program in the Kinect distribution of the Robot Operating System.

Stage 3

- Develop the program to run the task by following the sequence.

- Develop an application using haptic concept for moving the mobile platform.

- Design a 2 layers PCB layout using Proteus 8 from LabCenter Electronics

- Optimize the circuit to achieve the minimal capacitive and inductive interference.

- Several sets of experiments were designed to evaluate both the individual subsystems and the complete system, including detection performance, gripper performance, and system localization accuracy, in order to assess the circuit's performance.

3.3 Hardware of Components

The component that used in the robot are taken into serious consideration in term of functionality, compatibility and etc.

3.3.1 The control system

The brain, also known as the controller board, resembles a small computer. It's essentially a microcontroller with sensors and actuators.

3.3.1.1 Arduino Mega

This project requires an Arduino Mega 2560 to control the stepper motor driver and sensors. In order to function properly, it must be powered by a suitable power supply. As a result, it is necessary to use a precise power source and make precise connections in order to achieve the best results.

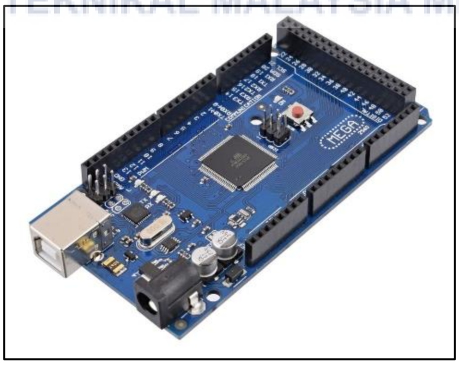


Figure 3.2: Arduino Mega

The ATmega2560 AVR microcontroller is used in the Arduino Mega 2560 microcontroller board. A 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button are among the 70-digital input/output pins (of which 15 can be used as PWM outputs and 16 as analog inputs). It comes with everything you'll need to get started with the microcontroller.

3.3.1.2 Nvidia Jetson-Nano

For this project, an Nvidia Jetson Nano is necessary to manage the localization and color camera modules in order to recognize the "Cili-padi" and interact with the Arduino Mega through USB enumeration protocol as soon as 5V is provided.

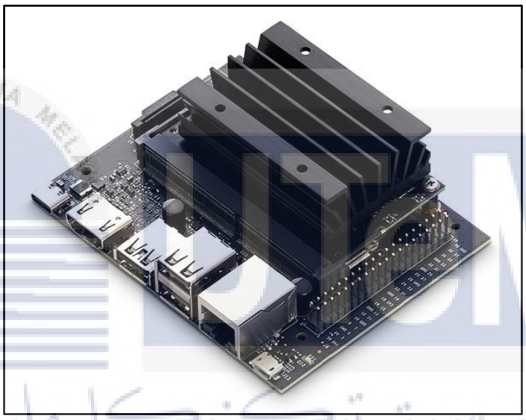


Figure 3.3: Nvidia Jetson-Nano [3]

The Jetson Nano Developer Kit comprises a Jetson Nano module with 4 GB RAM and a 128-core NVIDIA Maxwell GPU and 64-bit Quad-core Arm 157 CPU that gives 472 GFLOPS of computational capability. The included carrier board includes USB 3.0 and USB 2.0 ports for connecting peripherals such as USB cameras, one MIPI CSI-2 camera connector, a 40-pin header that is compatible out of the box with many peripherals and add-ons, an HDMI display interface, and a Gigabit Ethernet port, all of which are commonly used in edge and embedded project development. An 802.11ac wireless networking USB adapter is also included in the developer kit [3]. The Nvidia Jetson Nano is compatible with Linux.

When examining at existing solutions to similar challenges, it's worth noting how many platforms are used. One of them is the Raspberry PI, which comes in a variety of variants. This choice is very popular, and it has a large number of completed and effectively implemented projects. However, in terms of competitiveness, this board cannot handle visual tasks quickly enough, which are crucial in the competition's framework. Orange PI is a lesser-known alternative. In truth, this is a less expensive version of Raspberry, but it lacks the processing quality of the original. It was planned to employ a single-board computer, the Nvidia Jetson Nano, for implementation. This choice is more expensive than the previous one, but it is the cheapest of the entire Nvidia Jetson family. It has a smaller open-source database, but it has a fast speed in executing graphic tasks.

3.3.1.3 Stepper Motor Driver

Stepper motor drivers convert pulse signals from the controller into motor motion to achieve precise positioning. A pulse generator generated by the microcontroller can be used to control the motor.

Figure 3.4: Stepper motor driver

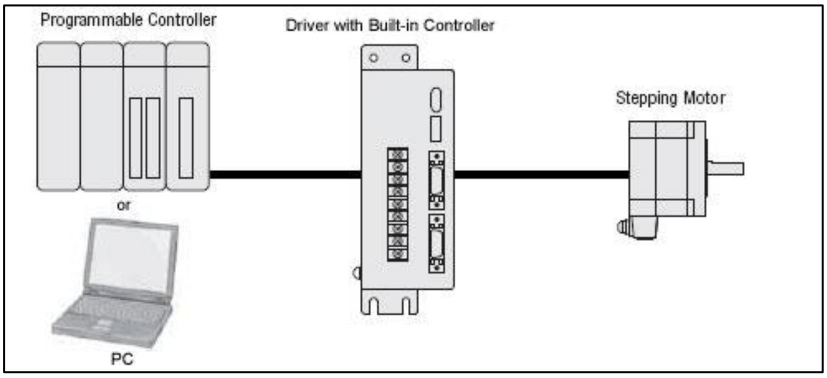


Figure 3.5: Stepper motor driver connection

3.3.2 Actuators

An actuator is an electronic component that has the power to move on its surroundings. It is responsible for moving and controlling a mechanism or system [8].

3.3.2.1 Stepper Motor

Stepper motors make precise positioning easy. They're utilized in a variety of machines to control rotation angle and speed utilizing pulse signals. Stepper motors have a small size and provide a lot of torque, making them excellent for quick acceleration and responsiveness. Because of their mechanical construction, stepper motors also maintain their position when stopped. A driver (which receives pulse signals and translates them to motor action) and a stepper motor make up a stepper motor solution.

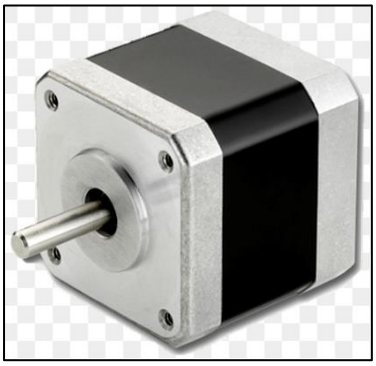


Figure 3.6: Stepper motor

This project is using 6 units of stepper motor, 3 of it is used to control the delta arm movement, the other 2 is responsible for the movement of the right and left wheels and last stepper motor were used to control the movement of the grabbing mechanism.

3.3.2.2 Servo Motor

Servo motors are self-contained electric devices that precisely rotate or push machine elements. It's a type of little motor that's used to maneuver radio-controlled vehicles. They're particularly handy for robotics and animatronics because the position is easily controllable. The servo motor in this project is in charge of controlling the gripper mechanism's movement.

Figure 3.7 Servo motor

3.3.3 Sensors

A sensor is a simple electrical component that sends a lesser or bigger amount of energy in response to a physical element such as light, sound, or distance. It's necessary to determine whether a sensor is digital or analogue before connecting it to the board [8].

3.3.3.1 Intel® RealSense™ Tracking Camera T265

The Intel® RealSenseTM Tracking Camera T265 is a visual and inertial sensor fusion-based tracking peripheral device. Fisheye cameras, an IMU module, and a processing ASIC (Intel® MovidiusTM MyriadTM 2 MA215x) with USB 3.0 interface to the host CPU SoC make up the assembly (System on Chip) [7].

Figure 3.8: Tracking Camera T265 [7]

3.3.3.2 Intel® RealSense™ LiDAR Camera L515

An IR laser, a MEMS, an IR photodiode, an RGB imager, a MEMS controller, and a vision ASIC are all used in the Intel® RealSenseTM LiDAR Camera L515. The MEMS scans the infrared laser beam throughout the whole field of view (FOV). The data from the reflected beam acquired by the photodiode will be processed by the L515 vision ASIC, which will output a depth point representing the correct distance of a given point in the picture from the camera. The depth points will be combined to create a point cloud depth data that represents the entire scene [9].

Figure 3.9: LiDAR Camera L515 [9]

3.3.3.3 500g Resistance-type Thin Film Pressure Sensor Force

Ultra-thin films with good mechanical properties, conductive materials, and nanoscale pressure-sensitive layers are used to make Thin Film Pressure Sensors. These sensors are built to last and are designed to detect static and dynamic pressure with a fast reaction time. The upper layer of the sensors has a thin film and a pressure-sensitive layer, while the lower layer has a thin film and a conductive circuit. The sensors transform pressure into resistance by connecting the lower layer's disconnected circuit to the upper layer's pressure-sensitive layer. The sensor is in responsible for driving the mobile platform.

Figure 3.10: Thin Film Pressure Sensor

3.3.3.4 Ultrasonic Sensor

An ultrasonic sensor is an electronic device that uses ultrasonic sound waves to detect the distance between a target item and converts the reflected sound into an electrical signal. The transmitter and receiver are the two primary components of ultrasonic sensors. The sensor measures the time between the transmitter's sound emission and its contact with the receiver in order to compute the distance between the sensor and the item. D=1/2 T C (where D is the distance, T is the time, and C is the sound speed of 343 meters per second) is the formula for this computation. The Ultrasonic sensor is responsible for sensing the polybag for grabbing process.

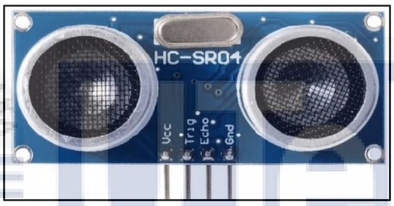


Figure 3.11: Ultrasonic Sensor

3.3.3.5 Limit Switch

A limit switch is an electromechanical device that uses a physical interaction to convey an electrical signal. Limit switches detect the presence of items, allowing the system to take the appropriate action. Limit switch were attached to the grabber arm for commanding the arm to stop grabbing after detecting the polybag.

Figure 3.12: Limit Switch

3.3.4 12v 100Ah Lithium Polymer Battery

The lithium iron phosphate deep cycle battery has a voltage of 12V and a capacity of 100Ah. It weighs only 20 pounds but has the power of a 140-pound lead-acid battery and lasts ten times longer. 100-amp continuous output with a 200-amp surge output – 30 seconds ½ second surge output for higher loads.

Figure 3.13: 12V 100Ah Lithium Polymer Battery

3.3.5 Charger controller

The power from the solar array that goes into the battery bank is managed by a solar charge controller. It prevents the deep cycle batteries from being overcharged during the day and prevents power from flowing backwards to the solar panels overnight, draining the batteries.

Figure 3.14: Charger controller

3.3.6 Charging station (xw-20 intelligent battery charger)

An intelligent charger keeps track of the battery's voltage, temperature, and time under charge in order to calculate the best charge current and stop charging.

Figure 3.15: Charging station

3.3.7 Voltage Regulator

The voltage regulator generate higher ouput voltage from low input voltages. They are switching regulator (DC-to-DC converters) and have a typical efficiency between 80% to 95%. The voltage regulator is required in this project is because the systems is powered by the 12V battery and the stepper motor driver need 24V to operate. For maintaining the efficiency of the converter, its decided that the systems use 3 voltage regulators.

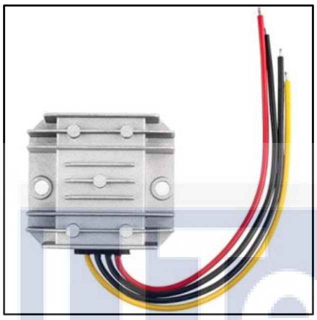


Figure 3.16: Voltage regulator

3.3.8 Fuse Block

A fuse block provides multiple fuse circuits. These circuits can be standalone, with their own input and output wires, or they can be ganged, with power shared across all circuits. It's utilized in vehicle electrical systems to distribute electricity. The fuse is a type of early-warning mechanism that detects overloads before the circuit wires themselves overheat, potentially causing fire.

Figure 3.17: Fuse block

3.3.9 LCD Display

The LCD Display is responsible for monitoring the cili-padi picking robot interfaces. It’s connected to Nvidia Jetson Nano through HDMI cable and power by 5v.

Figure 3.18: LCD Display

3.4 Software

The software that is used in completing this robot is taken into serious consideration in term of functionality, feature and etc.

3.4.1 Solidworks

SolidWorks is computer-aided design (CAD) software owned by Dassault Systèmes. It employs the parametric design method to build three types of interrelated files: the part, the assembly, and the drawing. SolidWorks were used to design the robot platform and switch box.

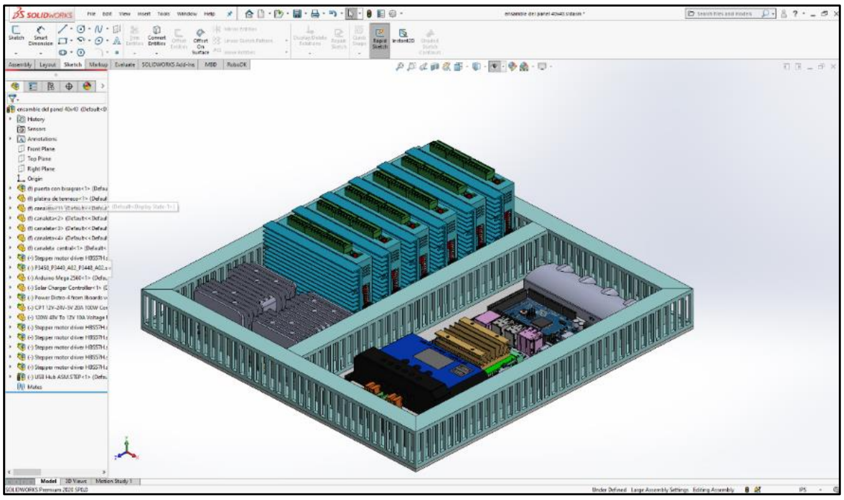
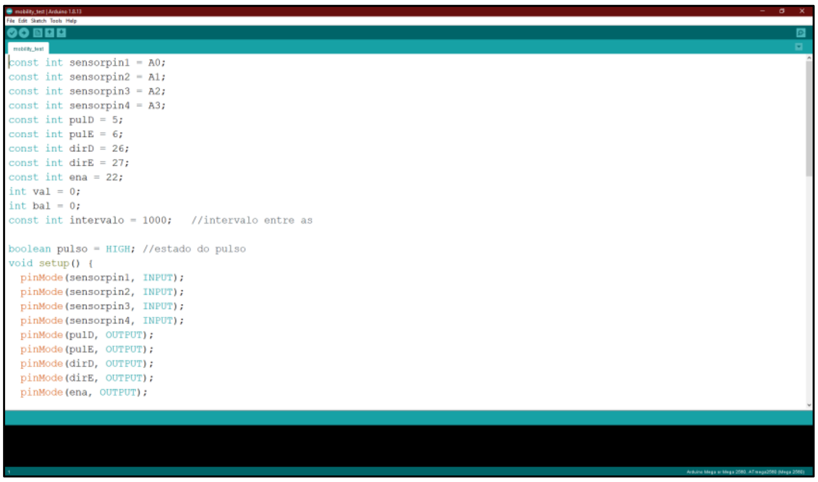


Figure 3.19 SolidWorks Interfaces

3.4.2 Arduino IDE

The Arduino IDE (Integrated Development Environment) is an official software developed by Arduino.cc that is primarily used for authoring, compiling, and uploading code to an Arduino device. Almost all Arduino modules are compatible with this open-source software, which is simple to install and begin compiling code on the fly. On the board of Arduino is a microcontroller that is programmed and accepts information in the form of code. [16] The Arduino IDE is a flexible cross-platform software sketchbook that runs on Windows, Macintosh OS X, and Linux.



```
const int sensorpin1 = A0;
const int sensorpin2 = A1;
const int sensorpin3 = A2;
const int sensorpin4 = A3;
const int pulD = 5;
const int pulE = 6;
const int dirD = 26;
const int dirE = 27;
const int ena = 22;
int val = 0;
int bal = 0;
const int intervalo = 1000;   //intervalo entre as

boolean pulso = HIGH; //estado do pulso
void setup() {
  pinMode(sensorpin1, INPUT);
  pinMode(sensorpin2, INPUT);
  pinMode(sensorpin3, INPUT);
  pinMode(sensorpin4, INPUT);
  pinMode(pulD, OUTPUT);
  pinMode(pulE, OUTPUT);
  pinMode(dirD, OUTPUT);
  pinMode(dirE, OUTPUT);
  pinMode(ena, OUTPUT);
```

Figure 3.20: Arduino IDE Interfaces

3.4.3 Proteus 8

Proteus 8 Professional is a software that allows you to draw schematics, plan PCBs, code, and even simulate schematics. It is capable of simulating the project and finishing the task at hand with greater efficiency. Proteus 8 in this project is used to design and simulate the schematic circuit and double layer PCB boards.

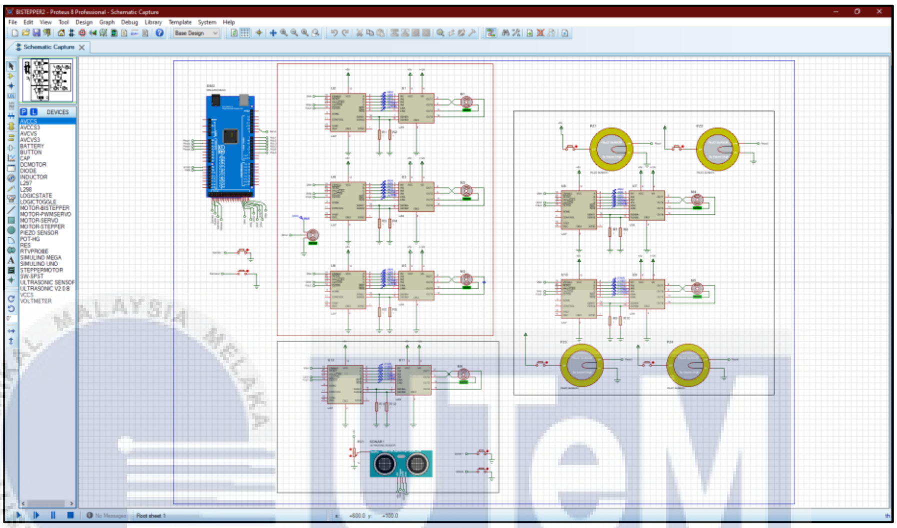
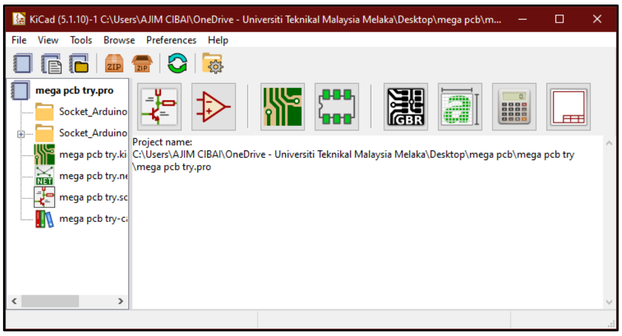


Figure 3.21: Proteus 8 Professional Interfaces

3.4.4 KiCAD EDA

The KiCAD EDA software suite is used to design the shields. Electronic Design Automation (EDA) is a term that refers to the process of creating electronic designs. KiCad, which manages the entire project of a board design, Eeschema, which builds and edits schematics, and Pcbnew, which builds and edits PCB layouts, are the three components.

The primary project management tool is KiCad. It may archive and open projects, as well as be used to launch all other programs.



Project name:
C:\Users\AJIM CIBAI\OneDrive - Universiti Teknikal Malaysia Melaka\Desktop\mega pcb\mega pcb try
\mega pcb try.pro

Figure 3.22 KiCad Project Manager

Eeschema is the schematics editing program. The design of the schematics must be fully connected, annotated and then performed the ERC, electric rules check before generating the net list.

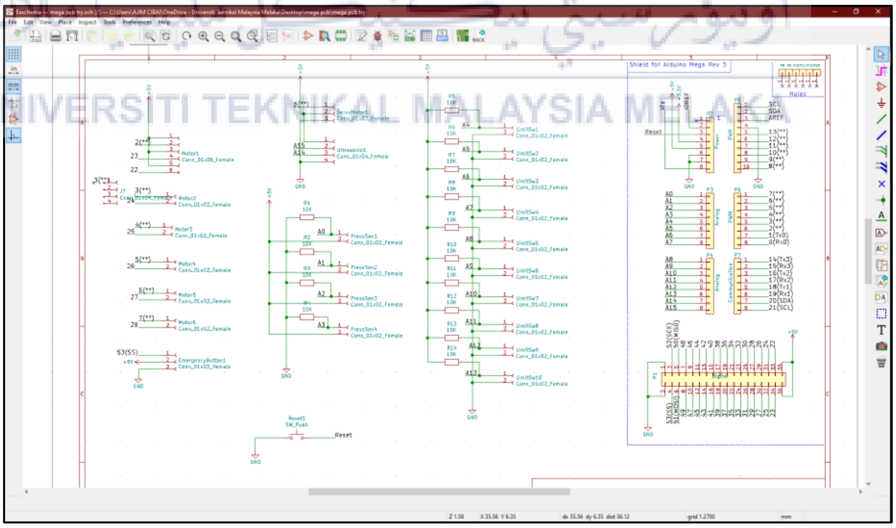


Figure 3.23: Eeschematic View

Pcbnew is the main PCB layout editor. All of the components are positioned according to the imported net list, and then tracks and vias are created to connect all of the components. Finally, the edge layer is used to draw the board edge.

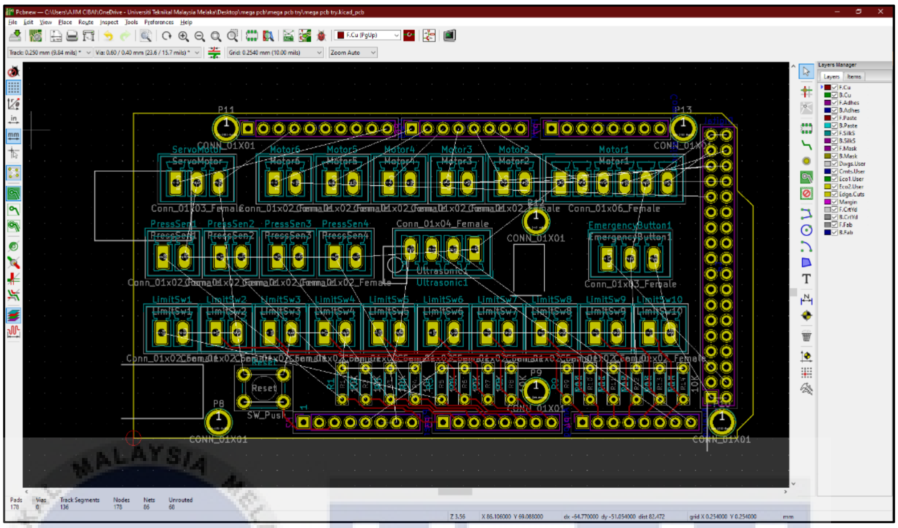


Figure 3.24: Pcbnew View

3.5 Block Diagram

Based on the requirement, the control panel circuit is decided to separate into three node sub-system with specific task; mobility, picking mechanism and localization and color as illustrated in Figure 3.25**.** The mobility node is to control the mobile platform movement. Localization and color node is to detect cili-padi and picking mechanism is for picking cili-padi.

The localization and color node consists of a LiDAR and tracking camera for receiving video pictures, as well as an Nvidia Jetson CPU for analyzing video data and sending commands to the executive node. The main goal of this website is to help people form gun teams, fire autonomously, and work with video.

The mobility and picking mechanism nodes consist an Arduino Mega microcontroller for processing commands from the operator, as well as a localization and color node for transmitting commands to motor drivers that control stepper and direct current motors, respectively.

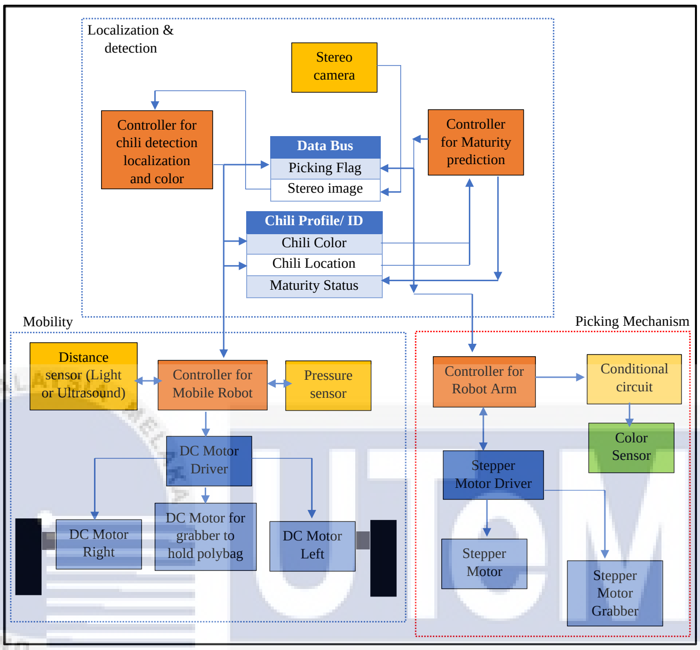


Figure 3.25: Block Diagram of Cili-padi Picking Robot

3.6 Technical Design

The evaluation of the specifications, requirements, and regulatory standards is the first step in the process. Following the evaluation of these factors, drawings are made to detail the particular wiring, circuits, controls, and other aspects of the final control panel. Both electrical and physical requirements are addressed in good design. The designs comprise a functional diagram, an input/output diagram, a power distribution diagram, and a layout of the control panel.

3.6.1 Circuit Connectivity

The proposed system is a vehicle that equipped with thin film pressure sensor to control the movement of the robot. Nvidia Jetson Nano is also equipped with LiDAR and tracking camera to picks cili-padi using picking mechanism and Nvidia Jetson Nano is connected to the Arduino mega through USB enumeration protocol.

3.6.1.1 Signal and Power Distribution Overview

The robot's signal distribution and power distribution schematics are presented in Figure 3.26.

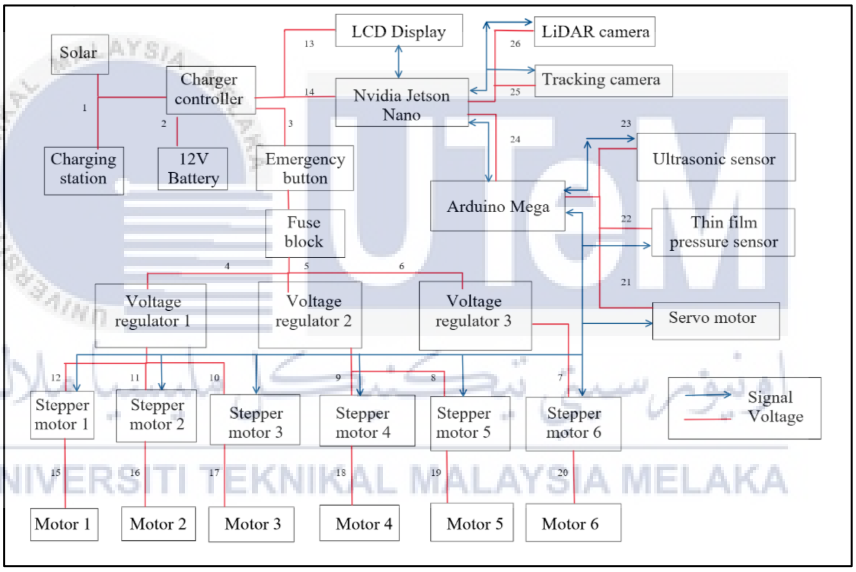


Figure 3.26: Signal and Power Distribution

3.6.1.2 Circuit Connection Overview

Mobility, Picking Mechanism, Localization, and Color are the three major sub-systems of the system. Figure 3.27 shows the relationships between these three subsystems.

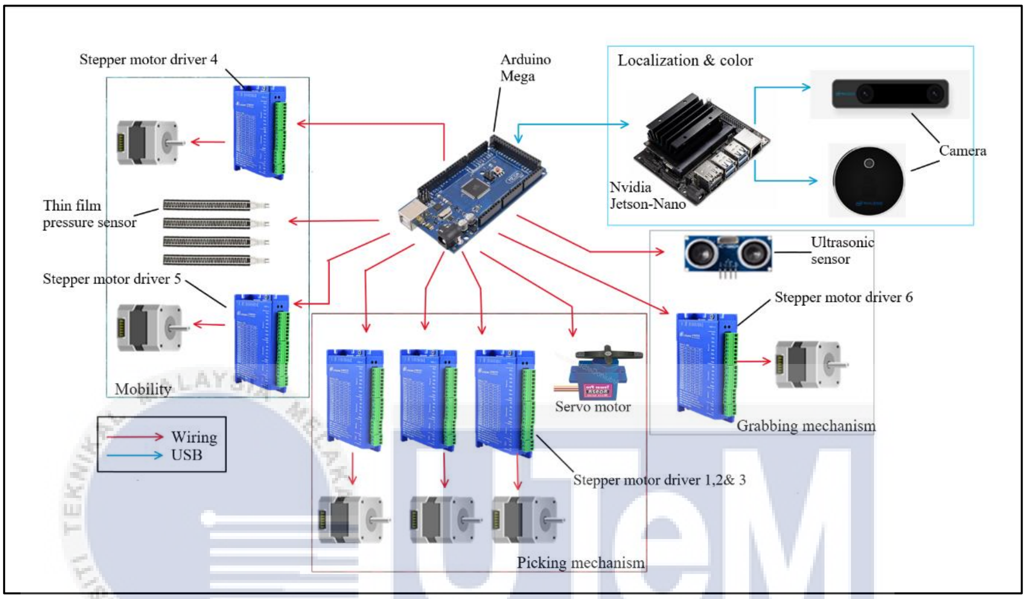


Figure 3.27: Circuit connection overview

The Arduino Mega is the robot's main microcontroller; it receives data from a variety of sensors and processes it to make decisions. The Localization and Color sub-system is responsible for identifying and recognizing ripe cili-padi and sending the information to the main controller for the harvesting process. The mobility picking mechanism sub-system is responsible for controlling the robot's actuators and supplying electricity to the rest of the robot's components.

3.6.1.3 Power Distribution

The system is powered by the 12V 100Ah Lithium Polymer Battery and connected to the charger controller for managing the power going to the systems.

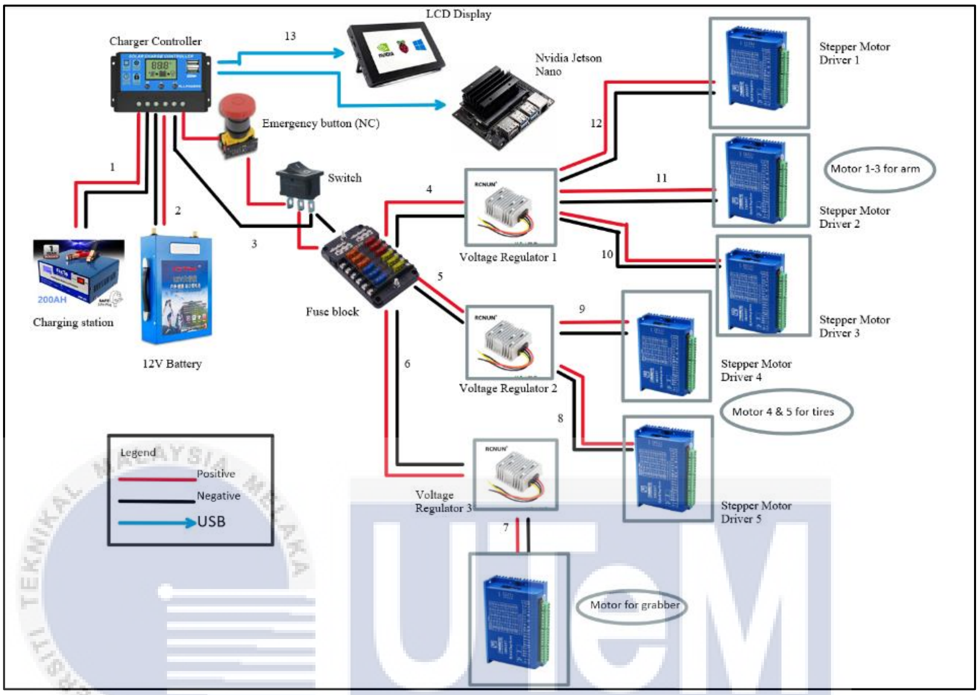


Figure 3.28: Power Distribution

The charger controller also manages the electricity from the solar array that goes into the battery bank, ensuring that the deep cycle batteries are not overloaded and that the power does not go backwards, draining the batteries. The voltage from the batteries is stepped up using voltage regulator from 12V to 24V as needed by each of the stepper motor driver. The system uses 3 voltage regulators to efficiently distribute the voltage to each stepper motor driver.

3.6.1.4 Nvidia Jetson Nano Connectivity

The Nvidia Jetson Nano includes USB 3.0 and USB 2.0 ports for connecting peripherals via USB cable, which are commonly utilized in edge and embedded project development.

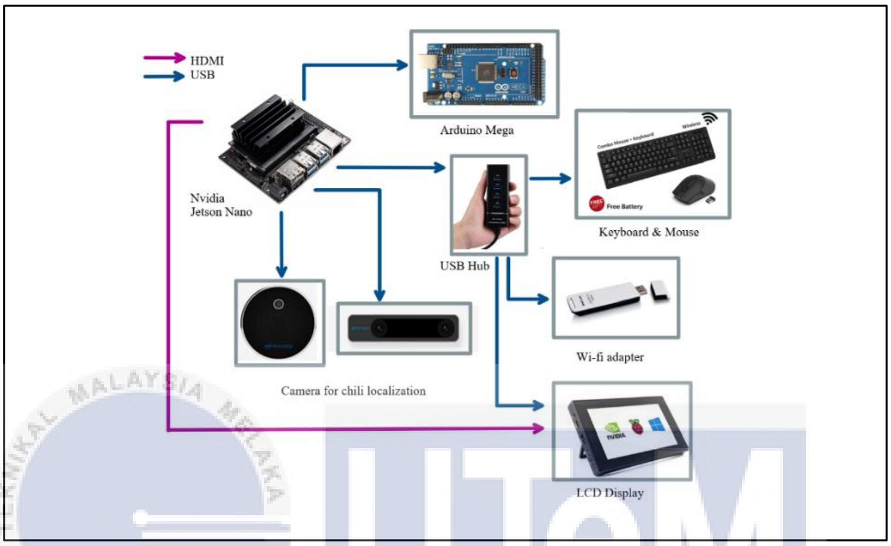


Figure 3.29: Nvidia Jetson-Nano connection

The microcontroller is directly connected to the Arduino mega, LiDAR and tracking camera as it is critical and important component and needed minimum interference in data trafficking. Nvidia Jetson Nano and Arduino Mega is communicate via USB enumeration protocol. Lastly, the LCD Display is connected to the Nvidia Jetson Nano through HDMI cable for monitoring purpose.

3.6.2 Schematic Diagram

As a main controller on this robot system, Arduino Mega is responsible to control the mobility and picking mechanism sub-system and process the receive inputs from various sensors.

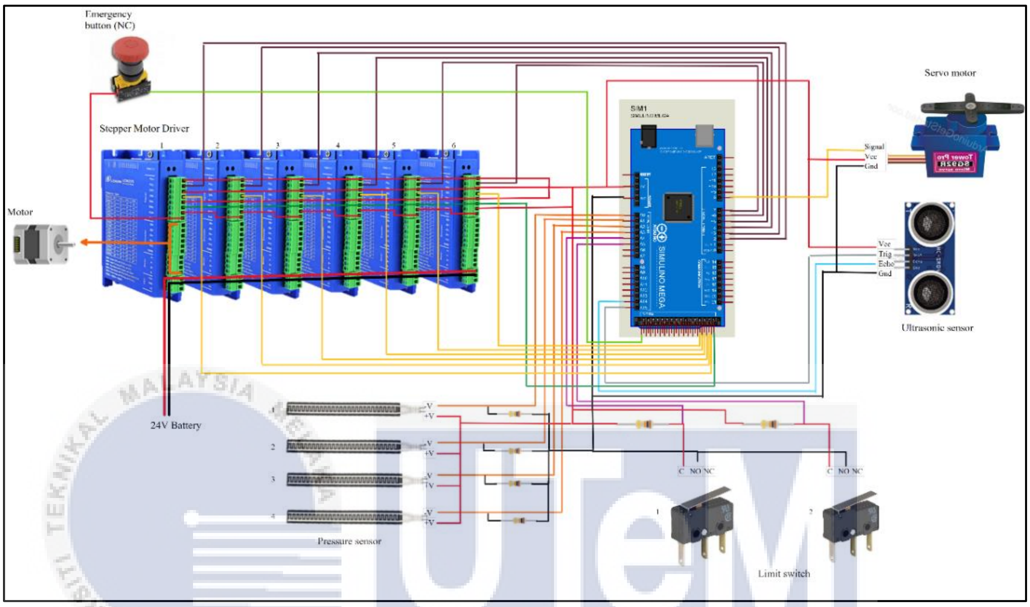


Figure 3.30: Circuit connection diagram

The circuit diagram for the system is show above, Figure 3.30. Arduino Mega microcontroller provides fast and reliable control operations and able to synchronized control multiple numbers of stepper motor. It provides to set the position of the stepper motor angle. The microcontroller is programmed to control the motor by sending the pulse through PWM pinout (pin 2-7).

The control signal is carried on the third pin of the servo connector and is connected to the Arduino Mega PWM pinout (pin 8) to direct the motor where to go. This control signal is an instance of a pulse train of a specific type.

The thin film pressure sensor is non-polarized, just like normal resistors. Either one of the leads are connected to the 5V and the other lead are connected to analog pinout (pin A0 – A3) and the 10KΩ pulldown resistor gets connected between GND and analog pinout.

Ground, VCC, Trig, and Echo are the four pins on the ultrasonic sensor. The module's Ground and VCC pins must be connected to ground and 5 volts, respectively. The Trig and echo pins are connected to analog pinout (pin A14 – A15).

Finally, a 10K pullup resistor is connected in series with the limit switch. The Arduino is normally connected to 5 volts, but when the limit switch is pressed, the Arduino's analog pinout (pin A4 – A13) is connected to ground.

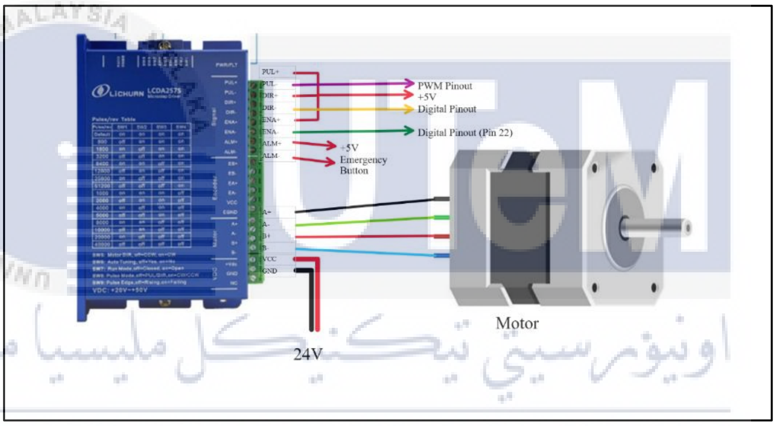


Figure 3.31: Stepper motor driver connection

The stepper motor is capable of independent control as well as synchronized control. A stepper motor driver is a four-switch circuit that can securely operate a stepper motor. The stepper motor driver can assist prevent the motor from frying the microcontroller. Inductors are motors that store electrical energy in magnetic fields. When power is no longer supplied to the motors, magnetic energy reverts to electrical energy, which might cause damage to the components. The stepper motor driver assists with the isolation of the Arduino Mega.

3.6.3 Conditioning Circuit

Embedded systems require sensors and actuators to function properly. A malfunction in the sensors or actuators in these complex embedded systems might cause catastrophic events to occur. Detecting sensor and actuator problems is challenging and has a significant impact on system performance. Before connecting the actuator and sensor to the microcontroller, the signal from the sensor and actuator needs to be conditioning to meet the requirement of the input pin of the microcontroller.

3.6.3.1 Schematic Drawing

The main objective of designing the conditioning circuit is to organized circuit connectivity and replicate the Arduino’s pinout and functionality and act as Arduino shield. Another purpose of the condition circuit is to ease in maintaining the systems. The conditioning circuit is a small circuit boards that attached on top of Arduino Mega boards and contain additional components to boost the capabilities of the system. The schematics drawing of the condition circuit is shown below, Figure 3.32.

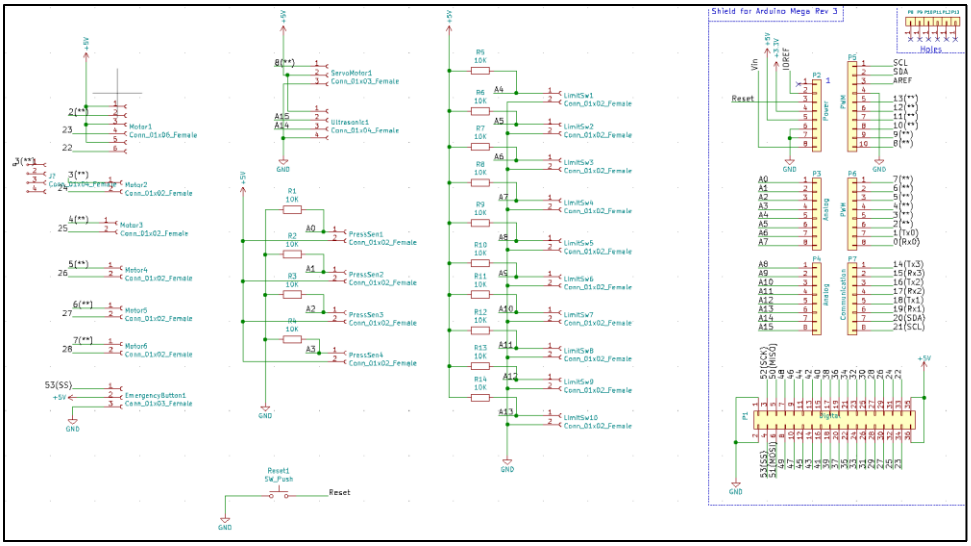


Figure 3.32: Conditioning Circuit Schematic Diagram

3.6.3.2 PCB Sketch

The layout of the conditioning circuit is compatible with the Arduino Mega and can be plugged in straight away. The layout of the conditioning circuit is shown below, Figure 3.33. The copper track width for the 5V voltage and ground is set on 0.6 mm for carrying high current and the copper track for signal routing is set on 0.25 mm.

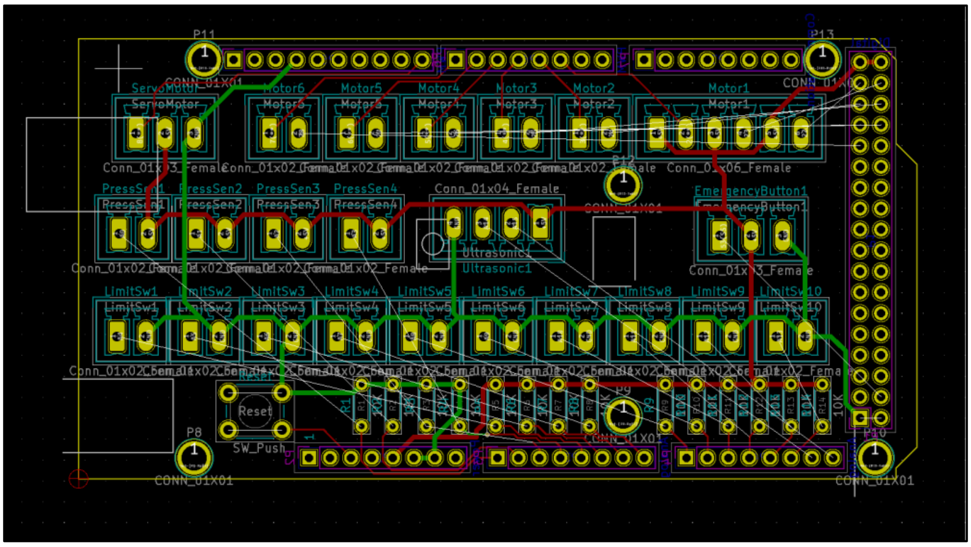


Figure 3.33: Conditioning Circuit PCB Layout

The routing path on the PCB board for the conditioning circuit is almost impossible to executed on a single layer. However, the routing path can be routed on an additional layer, and then via stitching can be done between the two layers. It effectively doubles the current carrying capacity when both traces on different layers have the same width. The routing path on both layers via stitching is shown below, Figure 3.34 & Figure 3.35.

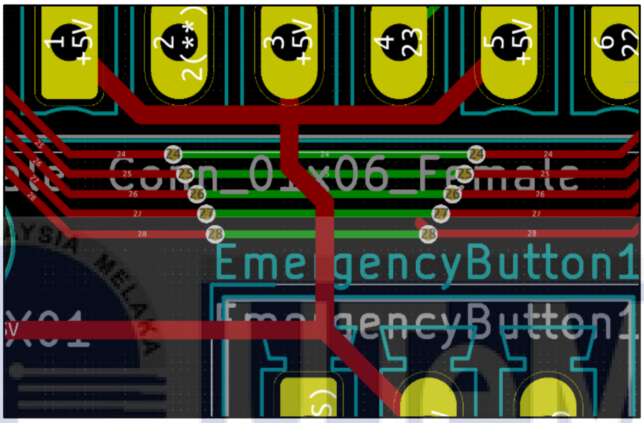


Figure 3.34: PCB Stitching Layout

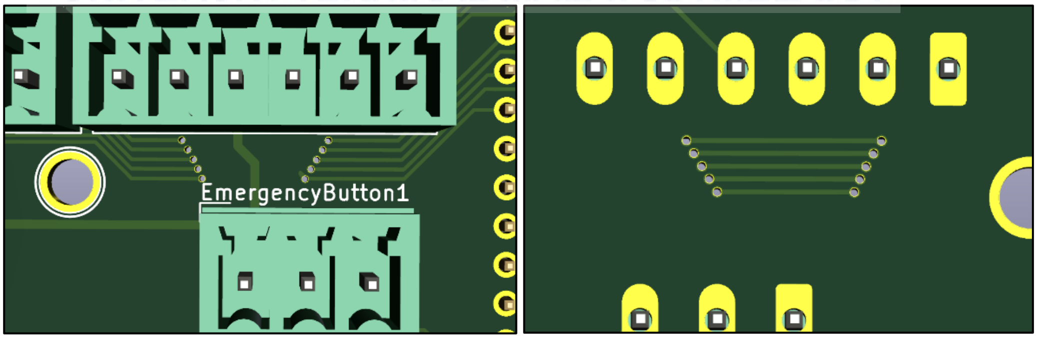


Figure 3.35: Front & Back Panel View of Stitching

3.6.4 Robot Design

The 3D design of the Cili-padi picking robot were developed in SolidWorks.

3.6.4.1 Sketches of Cili-Padi Picking Robot

Figure 3.36 depicts the earliest concept designs. The cili-padi picking robot teams propose the initial sketches.

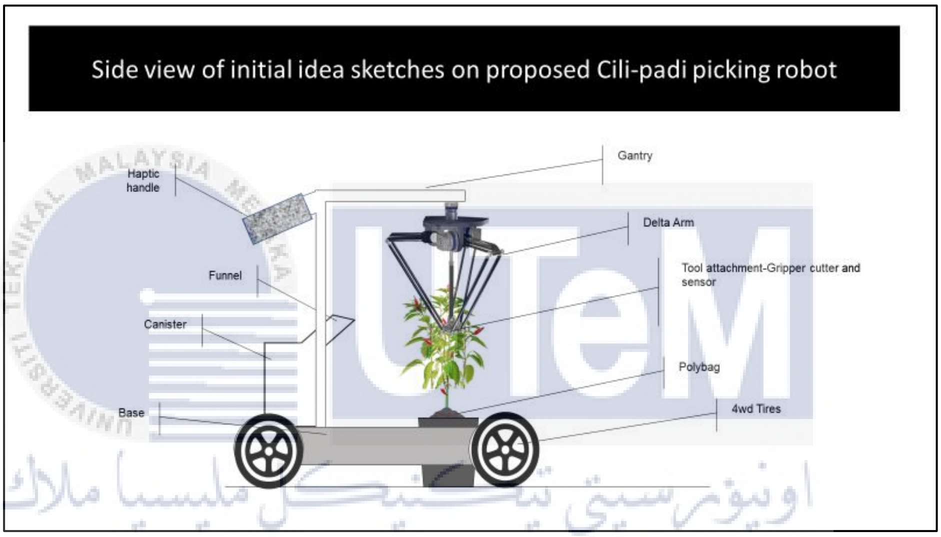


Figure 3.36: Initial Idea Sketches of Cili-padi Picking Robot

A conditioning circuit is connected to an Nvidia Jetson-Nano, and the robot is equipped with a gripper mounted on a mobile platform, as well as a stereo vision camera for picking cili-padi. The control panels will be placed at the central of the robot.

3.6.4.2 Picking mechanism

The picking mechanism consist of Delta Arm and attached with RC Robot Gripper.

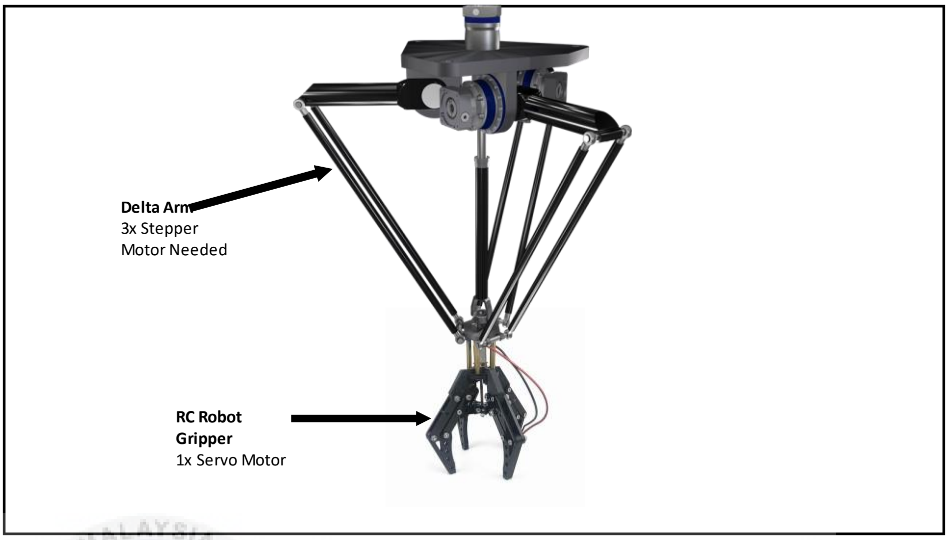


Figure 3.37: Picking Mechanism

The Delta Arm is responsible for move the arm from its current position to a specified position. The Delta Arm are controlled by 3 Stepper motor and each of the stepper motor are controlling each of the arm. Simultaneously, the robot gripper starts closes on the fruit and rotates it in such way that the stem is bent, thus breaking the stem appropriately. The RC Robot Gripper is controlled by single servo motor.

3.6.4.3 Mobility

The mobile platform is driven by 2 stepper motors to control left and right wheels of the robot, the left and right stepper motor are being navigated by the thin film pressure sensor input that attached to the robot's handle.

3.6.5 Control Panel Design

The design of the individual parts associated with Control panel for the robot was first studied and analyzed. Then, the 3D models for control panel with the associated parts were developed in SolidWorks. Fits & Tolerance details were added wherever it was necessary.

3.6.5.1 Control Panel Dimension

The wiring must be drawn as a reference in future use. Control panel wiring diagrams are used to outline each component in a control panel, as well as the connections between them. The control panels are containing with microcontroller, stepper motor driver and etc. Layout and component placement in any control panel, components or "component groups" must be laid out in a logical-functional manner.

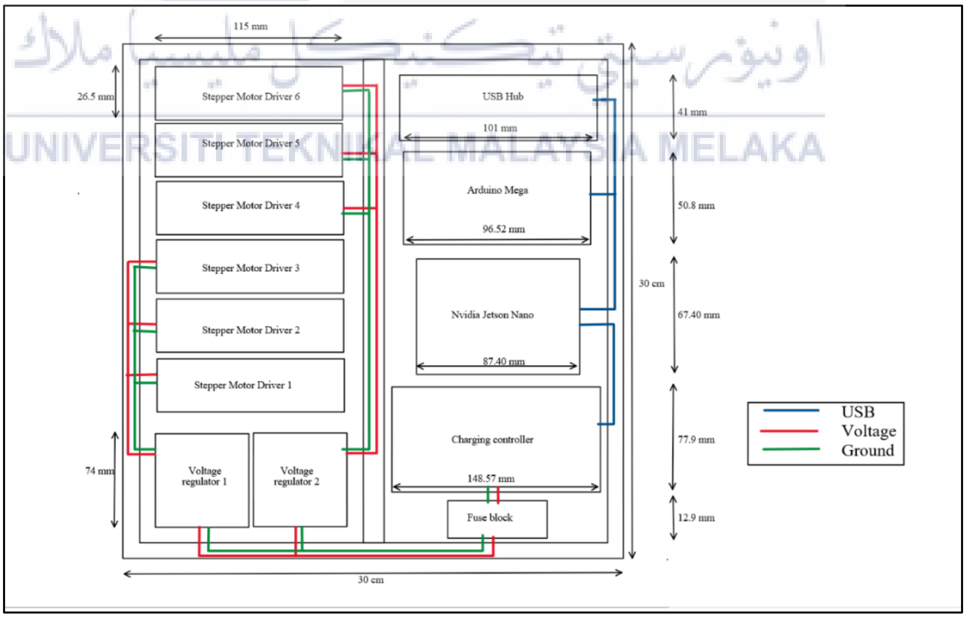


Figure 3.38: Control Panel Design and Dimensions

3.6.6 Wiring Schedule

The right method and amount of wireway are included in a decent control panel design. The aim is to provide enough space for both internal panels wiring and I/O wiring to be routed. Wires are rated for temperature and voltage. Selecting the wires sized for the correct temperature and voltage levels will ensure a durable, high-performing end product. The wiring circuit layout is shown in Figure 3.38.

Table 3.1: Wiring Schedule

No.	From	To	Wire type	Connector
1	Charging station	Charger controller	10 gauge	MC4 Connector
2	Charger controller	12V Battery	12 gauge	Ring copper terminal
3	Charger controller	Fuse block	12 gauge	Crimp terminal conn
4	Fuse block	Voltage regulator 1	12 gauge	Crimp terminal conn
5	Fuse block	Voltage regulator 2	12 gauge	Crimp terminal conn
6	Fuse block	Voltage regulator 3	12 gauge	Crimp terminal conn
7	Voltage regulator 3	Stepper motor driver 6	10 gauge	M/F terminal block
8	Voltage regulator 2	Stepper motor driver 5	10 gauge	M/F terminal block
9	Voltage regulator 2	Stepper motor driver 4	10 gauge	M/F terminal block
10	Voltage regulator 1	Stepper motor driver 3	10 gauge	M/F terminal block
11	Voltage regulator 1	Stepper motor driver 2	10 gauge	M/F terminal block
12	Voltage regulator 1	Stepper motor driver 1	10 gauge	M/F terminal block
13	Charger controller	LCD Display	USB	USB
14	Charger controller	Nvidia Jetson Nano	USB	USB

15	Stepper motor driver 1	Motor 1	10 gauge	M/F terminal block
16	Stepper motor driver 2	Motor 2	10 gauge	M/F terminal block
17	Stepper motor driver 3	Motor 3	10 gauge	M/F terminal block
18	Stepper motor driver 4	Motor 4	10 gauge	M/F terminal block
19	Stepper motor driver 5	Motor 5	10 gauge	M/F terminal block
20	Stepper motor driver 6	Motor 6	10 gauge	M/F terminal block
21	Arduino Mega	Servo motor	16 gauge	Male phoenix block
22	Arduino Mega	Thin film sensor	16 gauge	Male phoenix block
23	Arduino Mega	Ultrasonic sensor	16 gauge	Male phoenix block
24	Nvidia Jetson Nano	Arduino Mega	USB	USB
25	Nvidia Jetson Nano	Tracking camera	USB	USB
26	Nvidia Jetson Nano	LiDAR camera	USB	USB

3.6.7 Safety

Power devices within a control panel are used to deliver the current required to each device and to protect them from overcurrent situations. A fuse is a static device that were used in this project, refers Figure 3.28, that will protect equipment and personnel from current surges. When a fuse is triggered, it must be replaced before resuming operation. Other than that, emergency push button is connected to the circuit, refers Figure 3.28 & 3.30. Emergency stop button switch are critical system component that protect the machinery in a variety of emergency shut down situations.

3.6.8 Charging systems

Rechargeable batteries often only give a few hours of peak usage.

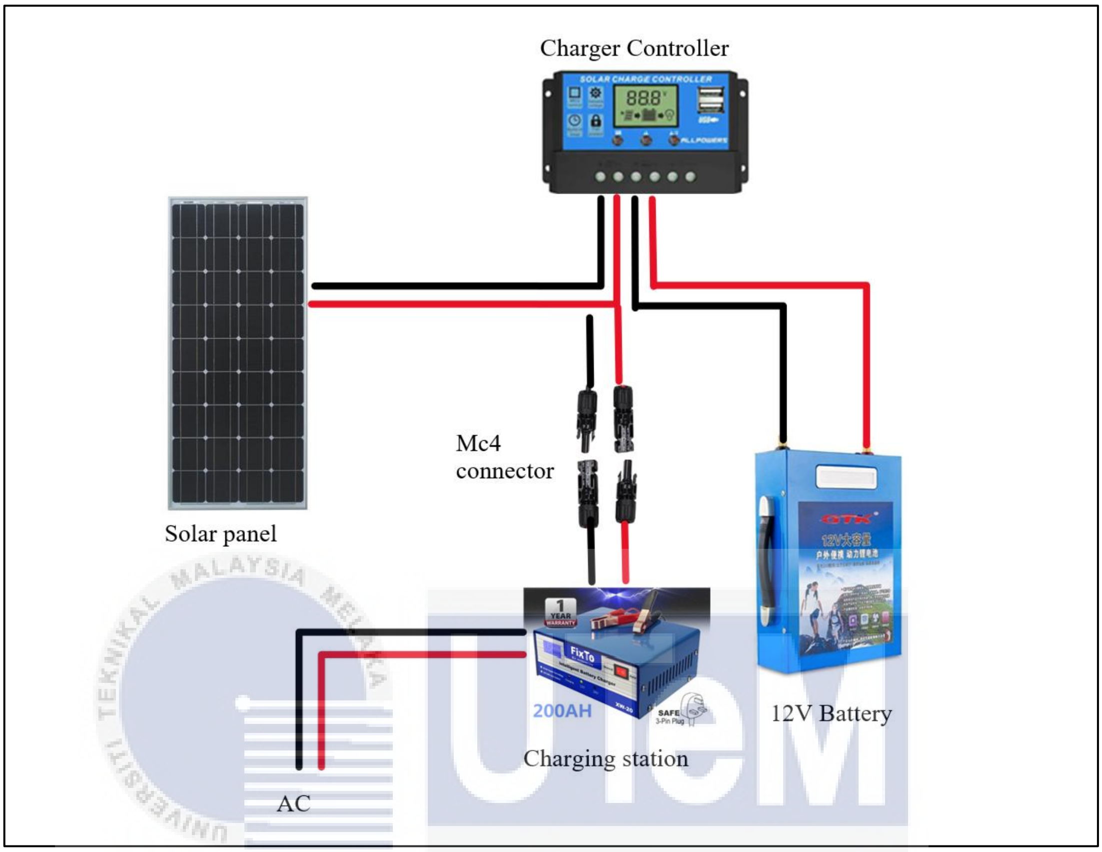


Figure 3.39: Battery charging connectivity

The connection for the battery charging is shown on Figure 3.39. The amount of time for mobile robots can spend to perform tasks and the level of autonomy can exert in their remaining operation time, however it will affect on their performance. Mobile robots can only do a certain amount of work in a single charging cycle, which is defined by their battery capacity. Before the robot's power becomes insufficient, it must be recharged.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will discuss about the results obtained from the experiment. The results have been recorded in order to analyse and determine the objective mentioned previously are achieved. All the data and figures presented in this chapter were discussion and explain in details.

4.1 The Conditioning Circuit

The Arduino board are used to connects the power source to the stepper motors. As a result, it's critical to comprehend the microcontroller's input/output pins.

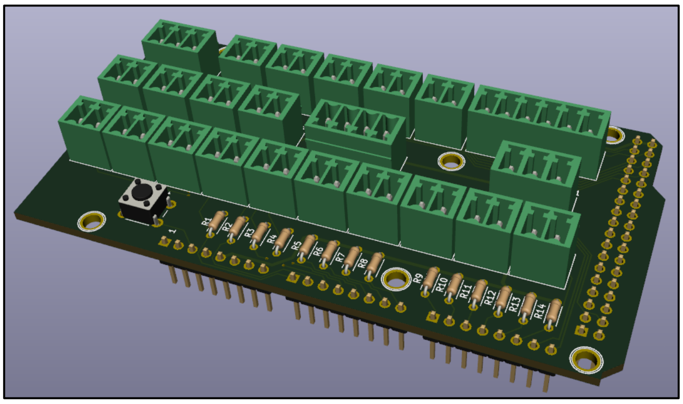


Figure 4.1: 3D View of Conditioning Circuit Board

In order to solve the problem that mention in the problem statement, which is the interconnection between the components is made through number current carrying wires and circuit from actuator and sensor is not within the voltage specification of microcontroller. The conditioning circuit that acts as shields is needed. The actuator and sensor are connected to the extruder connection for solving the interconnection problem. The conditioning circuit is shown above in Figure 4.1. The conditioning circuit and Arduino Mega are plugged together, then the actuator and sensor are connected to the conditioning circuit through extruder connection.

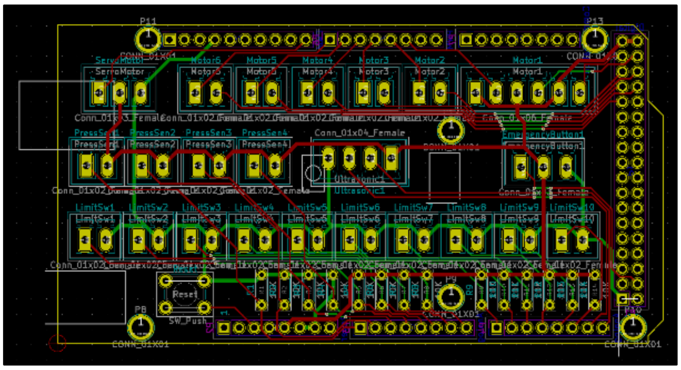


Figure 4.2: PCB Layout

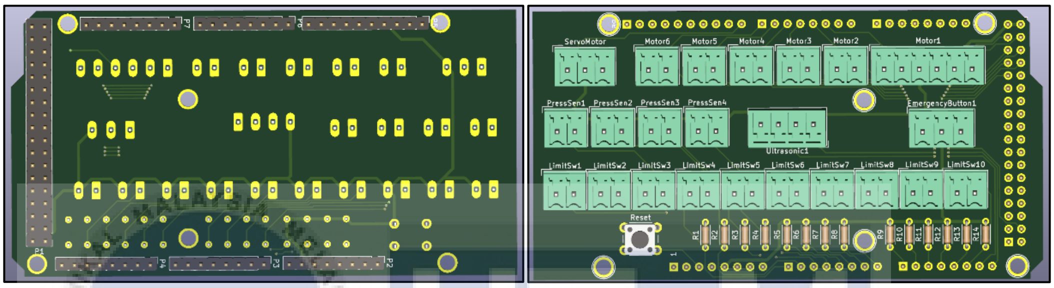


Figure 4.3: Back & Front View of Conditioning Circuit Board

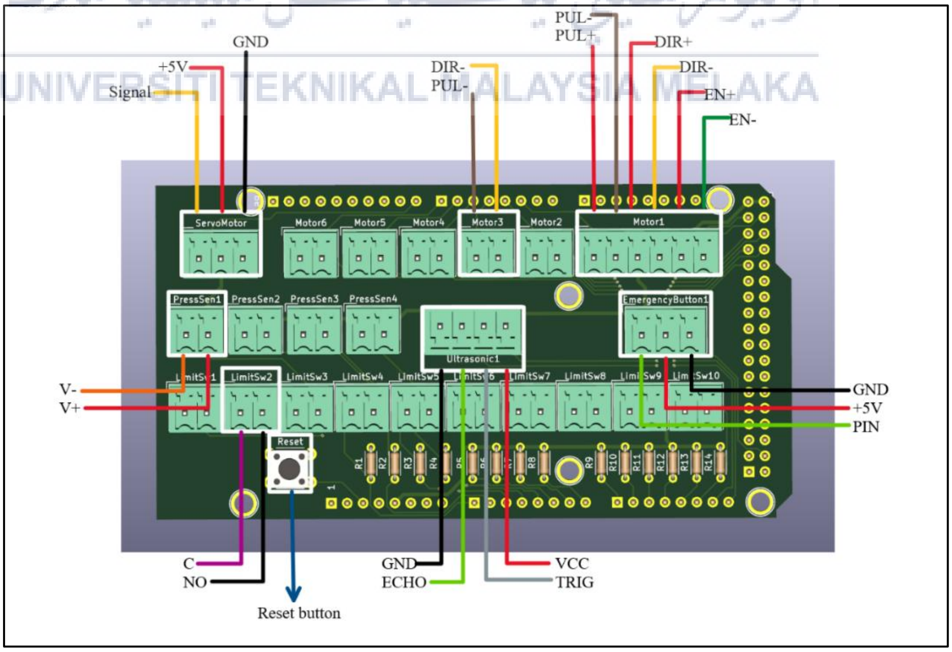
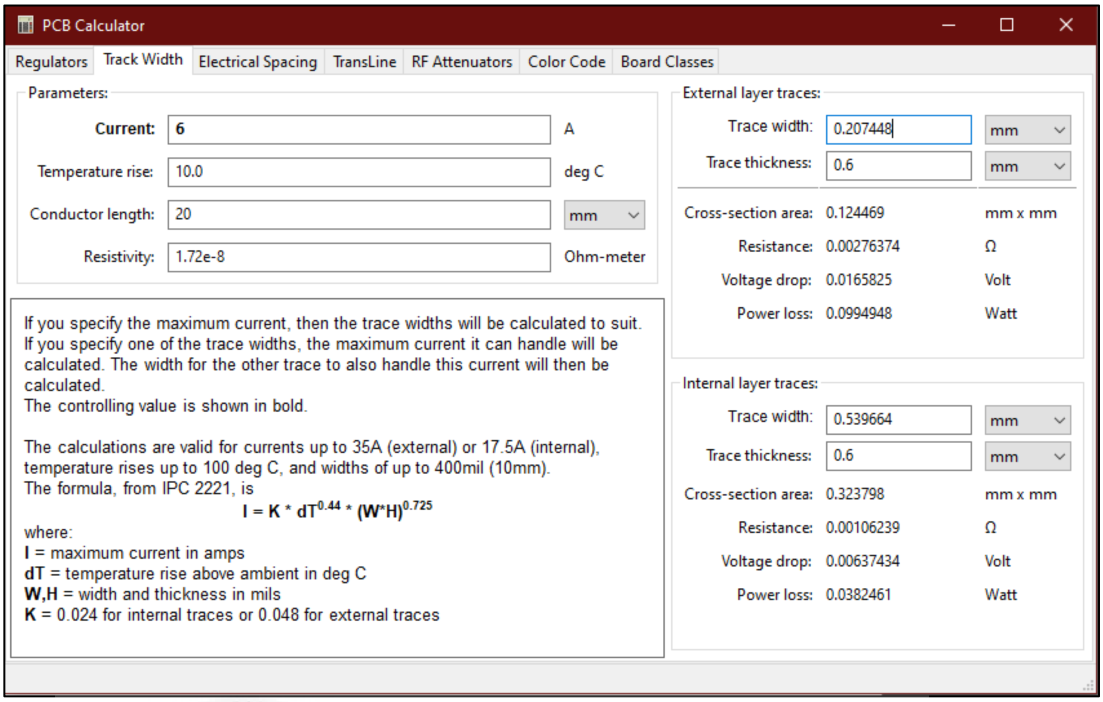


Figure 4.4: Conditioning Circuit Extruder Connection



Parameters:

Current: 6 A

Temperature rise: 10.0 deg C

Conductor length: 20 mm

Resistivity: 1.72e-8 Ohm-meter

If you specify the maximum current, then the trace widths will be calculated to suit.
If you specify one of the trace widths, the maximum current it can handle will be calculated. The width for the other trace to also handle this current will then be calculated.
The controlling value is shown in bold.

The calculations are valid for currents up to 35A (external) or 17.5A (internal), temperature rises up to 100 deg C, and widths of up to 400mil (10mm).
The formula, from IPC 2221, is

$$I = K * dT^{0.44} * (W*H)^{0.725}$$

where:
I = maximum current in amps
dT = temperature rise above ambient in deg C
W,H = width and thickness in mils
K = 0.024 for internal traces or 0.048 for external traces

External layer traces:

Trace width: 0.207448 mm

Trace thickness: 0.6 mm

Cross-section area: 0.124469 mm x mm

Resistance: 0.00276374 Ω

Voltage drop: 0.0165825 Volt

Power loss: 0.0994948 Watt

Internal layer traces:

Trace width: 0.539664 mm

Trace thickness: 0.6 mm

Cross-section area: 0.323798 mm x mm

Resistance: 0.00106239 Ω

Voltage drop: 0.00637434 Volt

Power loss: 0.0382461 Watt

Figure 4.5: PCB Calculator

From the documentation in the methodology, the stepper motor driver, that at peak will draw 6 Amps of power. The PCB Calculator, refer Figure 4.5 will automatically be calculating the trace width, thickness and others characteristics. The minimum width and thickness as calculated by the PCB Calculator is 0.539664 mm, however bigger track widths are better. After calculating, it’s decided to set the trace with 0.6mm width and thickness with 0.00095 resistance, 0.006V voltage drop and 0.040 power loss.

4.2 Cili-padi Picking Robot

The design of the Cili-padi picking robot is attached below, Figure 4.6.

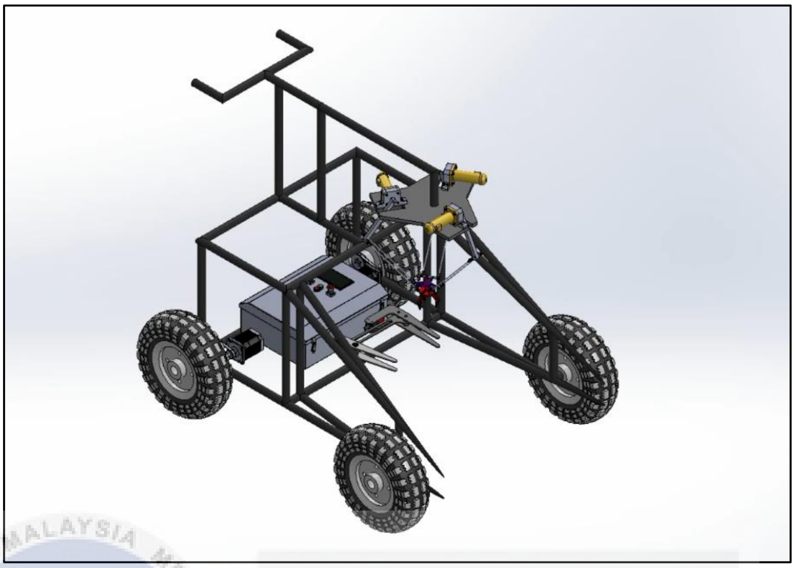


Figure 4.6: Cili-padi Picking Robot

The Cili-padi picking robot is designed based on a study of original concepts and important design elements. However, not all factors have been taken into account. The features of design, software architecture, and handling in everyday use, in particular, will be examined further. In the future, this platform will be expanded.

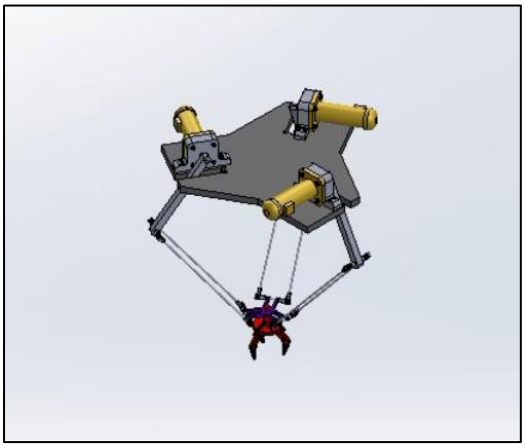


Figure 4.7: Picking Mechanism

4.3 The Control Panel

The final design of the control panel is attached in Figure 4.8 and Figure 4.9.

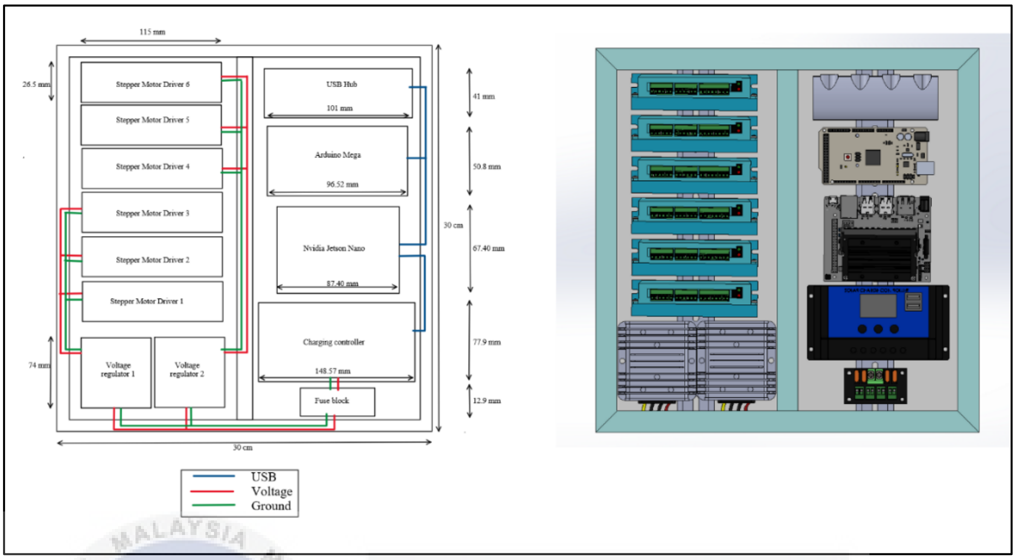


Figure 4.8: Control Panel Design

Control panel consist of power and control circuits which provide signals that direct the performance of equipment. The control panel is mounted in an enclosure, refer Figure 4.10. All the component specification and standard requirement are arranging accordingly.

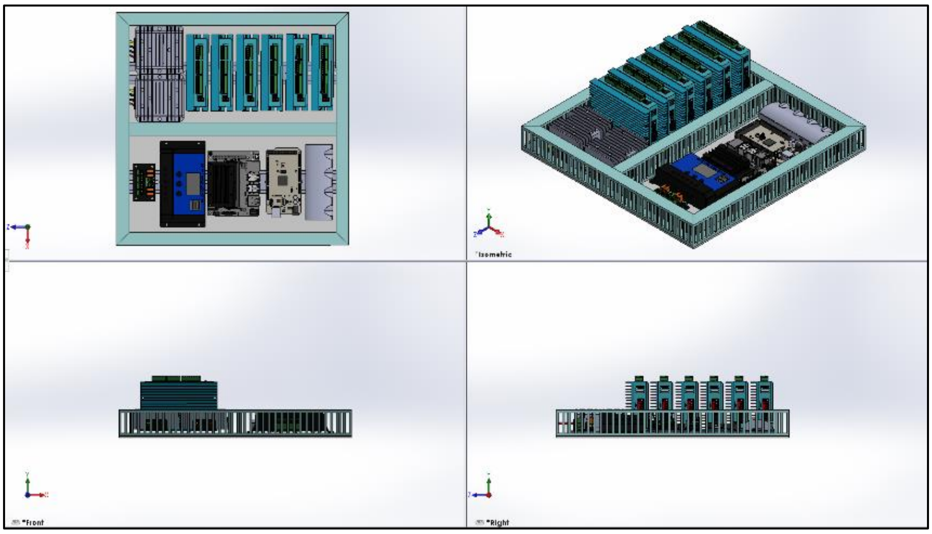


Figure 4.9: Control Panel in Isometric View

4.4 Enclosure

The control panel of a well-designed control panel is scaled to allow for "generous" component placement.

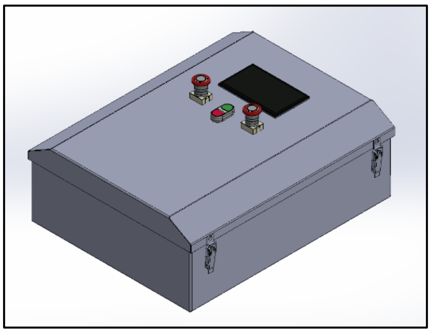


Figure 4.10: Control Panel Enclosure

Ample horizontal room will enable for the addition/expansion of components such as power distribution and terminals, i/o terminals, and so on, as well as proper power dissipation. Ample vertical area will provide much-needed space for neatly landing wiring into connections, avoiding crowding. Power components will be able to dissipate heat more effectively if they have enough vertical space. Furthermore, enough space should be allowed at the bottom of the control panel to coil up spare cabling.

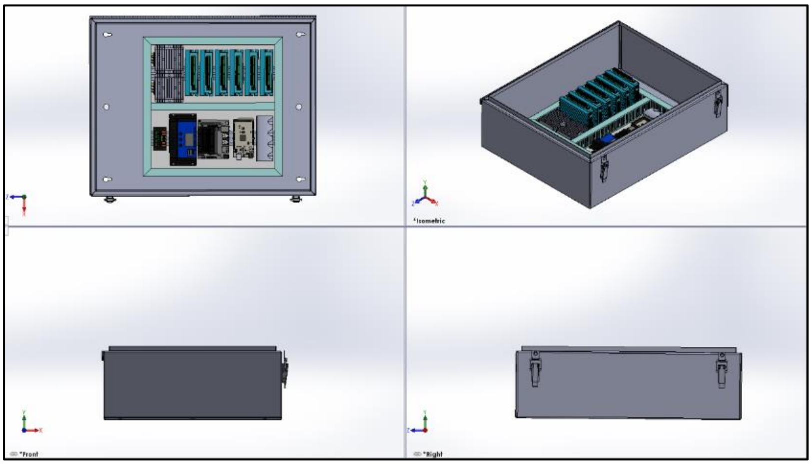


Figure 4.11: Enclosure in Isometric View

4.5 Analysis

The Cili-padi Picking Robot is expected to operated long hour and during midday at 38°C in Malaysia weather. As an addition when the system is powered up, the components themselves generate heat, and the heat produce by the system is trapped inside the enclosure. At this point, if the ambient temperature and humidity are not taken into the account, it may damage the system. To avoid the damaged of the system, heat analysis is conducted.

The control panel has 6 stepper motor drivers operate at the same time. Each of the driver will generate about 0°C ~ 55°C. The maximum outside temperature expected is 35°C ~ 38°C during midday. The temperature difference between outside and inside of the enclosure is about 18°C. The acceptable temperature inside the enclosure during the operation is at range of 38°C ~ 48°C.

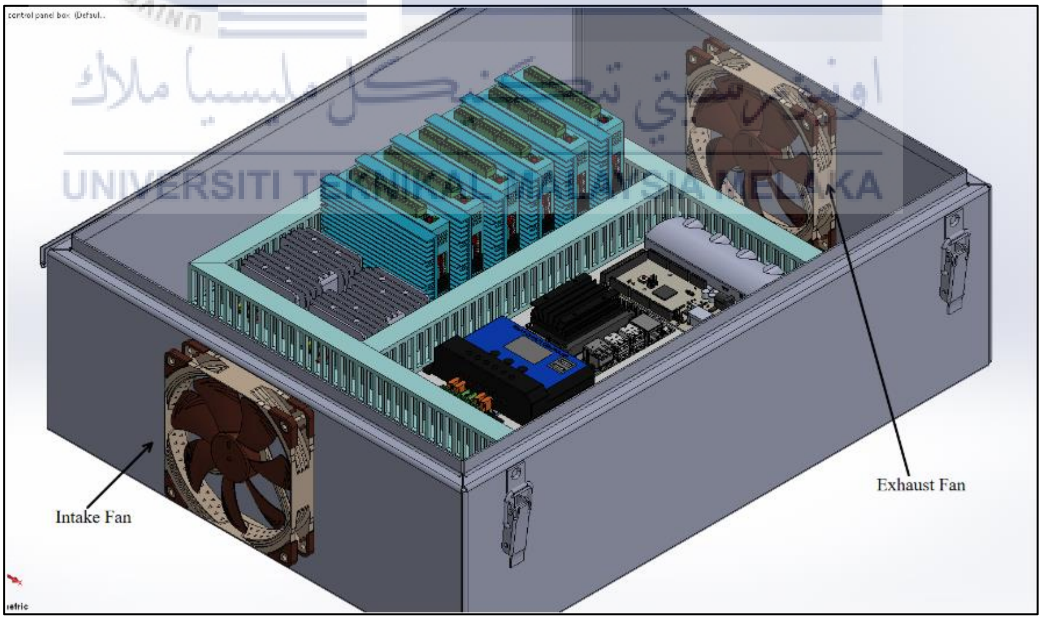


Figure 4.12: Enclosure with Intake & Exhaust Fan

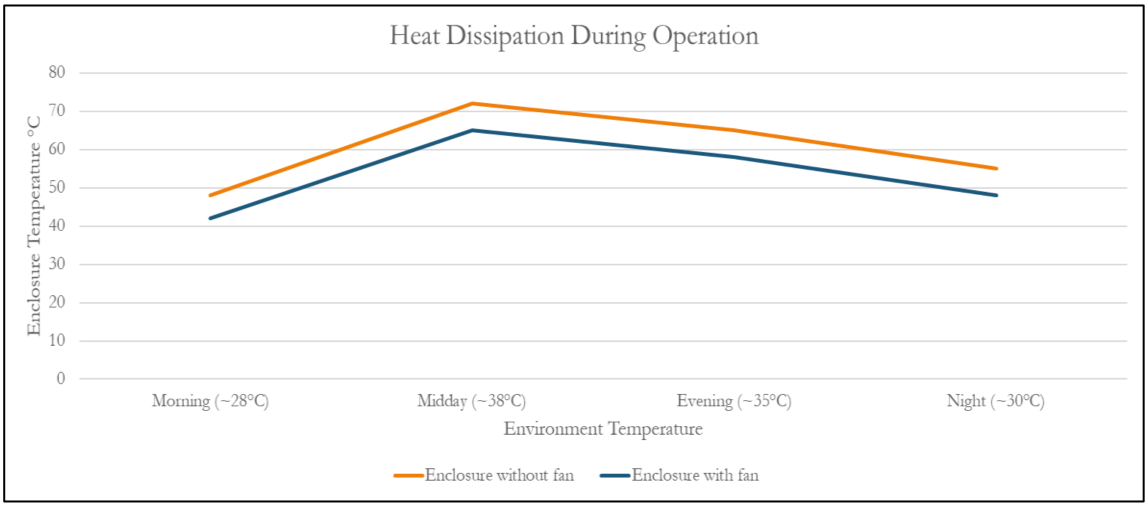


Figure 4.13: Graph of Heat Dissipation During Operation in a day

After the heat analysis is conducted, two 5” high speed fan with rated of 3000 RPM were attached to the enclosure as shown in Figure 4.12. The panel cooling system works by drawing in the relatively cool air from outside into the enclosure through Intake fan to lower the temperature inside the enclosure while the exhaust fan, will expelling the hot air in the system back to outside of the enclosure.

The result is, temperature during the operation throughout the day is decreasing in about 10 degrees with the cooling system installed as refers in Figure 4.13. The analysis on heat dissipation on enclosure has shown the positive benefits of installing the cooling system. Cooling system has been found to be an effective, low-cost method of reducing heat in control panel enclosure.

4.6 Simulation

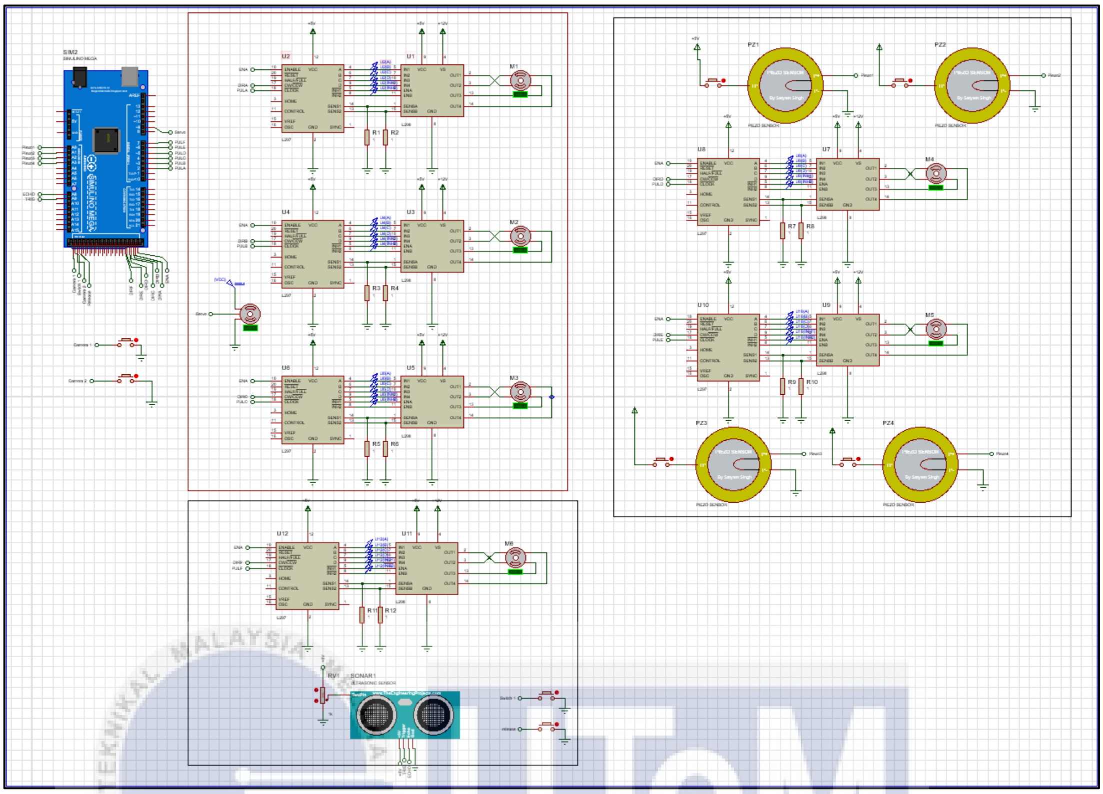


Figure 4.14: Schematic Circuit Diagram

All the component specification and standard requirement are arranging accordingly. The functionality and connectivity are validating through a Proteus8 simulation as shown in Figure 4.12, whereby the system is successfully function without problem. However, the prototype of the control panel cannot be implemented due to purchasing problem and grant receiving. As the same time, the device functionality and connectivity also cannot be achieved.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

In this chapter, the sustainability of this project and future works and improvements are discussed. The overall result of this project is also concluded in this chapter.

5.1 Conclusion

A Cili-padi Picking Robot control system was developed as a result of the effort. A low-level controller (Arduino Mega) and a single-board computer are the system's major components (Nvidia Jetson Nano). The separation of the control system into different sub-systems with specialized tasks, such as mobility, picking mechanism, localization and color, as shown in Figure 3.25, has a positive influence on the system's speed and stability. The proposed solutions to the problems encountered throughout the project's completion improve the robot's efficiency levels. The microcontroller was programmed to executed the task given via Arduino IDE for Arduino MEGA and Linux terminal for Nvidia Jetson-Nano.

The control panel optimization to control the actuator and sensors that connected to the microcontroller is successfully design and simulated. The control panel and control panel enclosure design are developed via SolidWorks and other supported software. The control panel enclosure is then undergoing a heat analysis, where two 5” high speed fan rated at 3000 RPM were attached to the enclosure as intake and exhaust fan to lower the temperature inside the enclosure and expelling the hot air back to outside of the enclosure after heat analysis is conducted.

Unfortunately, the prototype of the control panel was not yet assembled due to the availability of the component and were not able to field tested the functionality and connectivity. However, the functionality and connectivity are simulated via Proteus 8.

5.2 Future works

This project can be expanded as necessary in the future and developed with real component, measurement and testing. Next, the control systems should be fully assembled accordingly to the documented. After completing of this project, another Cili-padi picking robot teams should continue the project in working on ROS architecture and MatLAB Library before deployed into the systems. Moreover, this project is collaborating with several industrial partners and have higher chance to be commercial.

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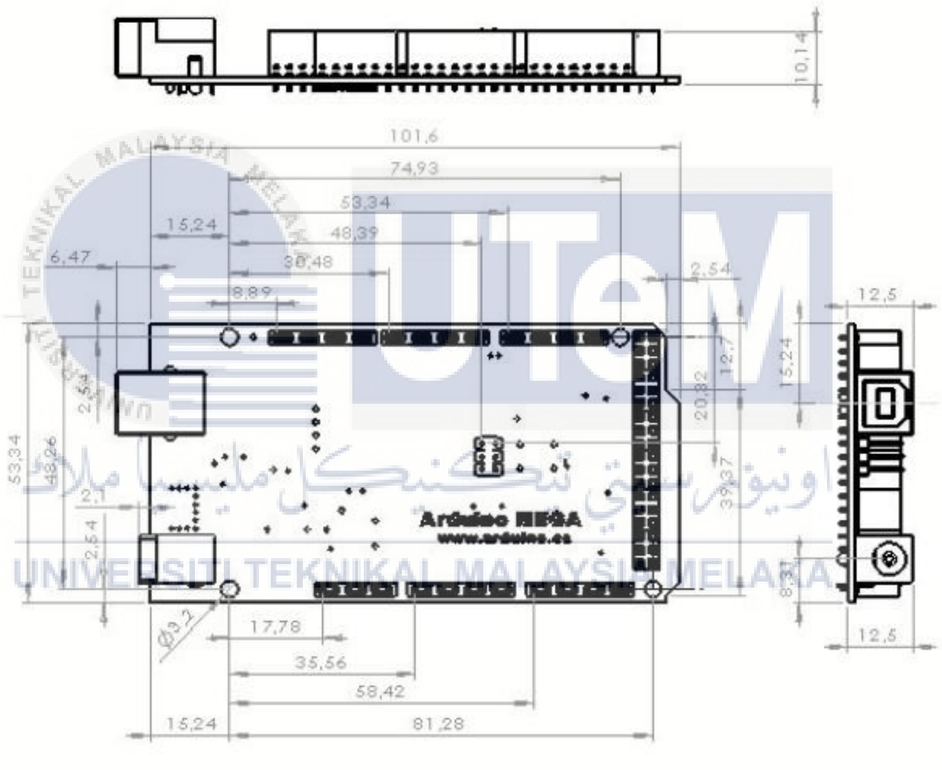
LIST OF PUBLICATIONS AND PAPERS PRESENTED

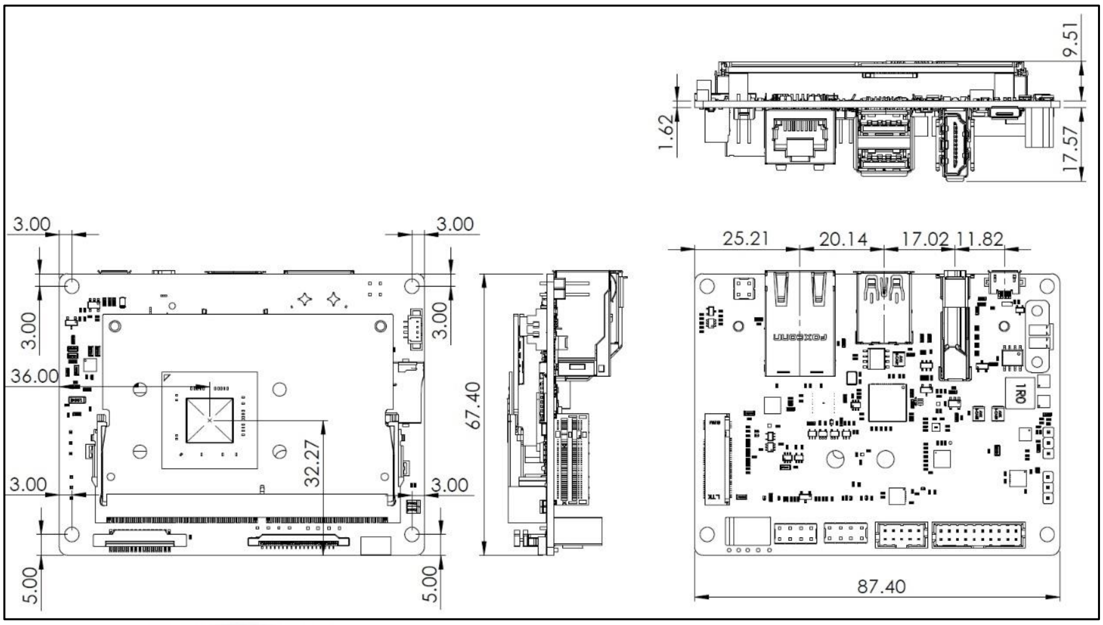
Published works as well as papers presented at conferences, seminars, symposiums etc. pertaining to the research topic of the research report/ dissertation/ thesis are suggested be included in this section. The first page of the article may also be appended as reference.

APPENDICES

Appendix A: Arduino Mega 2560 Dimensions



Appendix B: Nvidia Jetson-Nano Dimensions



Appendix C: Stepper Driver Dimensions