Design of Smart Controller for Coconut Tree Climbing Robot

PROJECT REPORT

Submitted in the fulfilment of the requirements for

the award of the degree of

Bachelor of Technology

in

Electronics and Communication Engineering

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VIGNAN'S Foundation for Science, Technology & Research (Deemed to be University) -Estd. u/s 3 of UGC Act 1956

(ACCREDITED BY **NAAC** WITH **"A+"** GRADE)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
(ACCREDITED BY **NBA**)

VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY AND RESEARCH
(Deemed to be University)

Vadlamudi, Guntur, Andhra Pradesh, India -522213

MAY–2024

CERTIFICATE

This is to certify that the project report entitled **"Design of Smart Controller for Coconut Tree Climbing Robot"** that is being submitted by **Veeranki Gopinadh** (201FA05099), **Annam Akash** (201FA05105), **Madaraju Sri Krupa** (211LA05011) in fulfilment for the award of B.Tech degree in Electronics and Communication Engineering, Vignan's Foundation for Science Technology and Research University, is a record of bonafide work carried out by them under the guidance of Dr. N V R Vikram G of ECE Department.

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DECLARATION

We here by declare that the project work entitled **Design of Smart Controller For Coconut Tree Climbing Robot** is being submitted to Vignan's Foundation for Science, Technology and Research (Deemed to be University) in fulfilment for the award of B. Tech degree in Electronics and Communication Engineering**.** The work was originally designed and executed by us under the guidance of Dr. N V R VIKRAM G at Department of Electronics and Communication Engineering, Vignan's Foundation for Science Technology and Research (Deemed to be University) and was not a duplication of work done by someone else. We hold the responsibility of the originality of the work incorporated into this report.

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ABSTRACT

This work presents the design and implementation of a smart controller for a Coconut Tree Climbing Robot that focuses on ensuring functional safety and reliable Bluetooth connectivity. Coconut harvesting is a dangerous task, often performed manually by workers climbing tall trees. Automating this process through a smart controller can significantly improve safety and efficiency.

The proposed smart controller utilizes advanced control algorithms to adjust the harvester's movements and actions in order to optimize the coconut collection process. Crucially, the smart controller is designed with robust functional safety features to mitigate risks and prevent accidents. This includes redundant monitoring, fault detection, and emergency stop capabilities.

Additionally, the system leverages Bluetooth wireless communication to enable remote monitoring and control. Special attention has been paid to ensuring stable and reliable Bluetooth connectivity, even in challenging outdoor environments.

Field trials have demonstrated that this smart controller can improve coconut harvesting productivity by over 30% compared to manual methods. The modular design also enables easy integration with existing coconut harvester platforms. Overall, this smart controller for Coconut Tree Climbing Robot represents a significant technological advancement that enhances the safety, efficiency, and precision of a critical agricultural process.

Major Design (Final Year Project Work) Experience Information

Student Group	**V.GOPINADH (201FA05099)**	**A.AKASH (201FA05105)**	**M.SRI KRUPA (211LA05011)**
Project Title	DESIGN OF SMART CONTROLLER FOR COCONUT TREE CLIMBING ROBOT		
Program Concentration Area	Design and implementation of IoT based agriculture Product		
Constraints - Examples			
Economic	Fixed budget		
Environmental	Friendly		
Sustainability	By integrating functional safety measures and stable communication technologies, our smart controller for coconut tree climbing robots promotes sustainable and safer agricultural practices.		
Manufacturability	Yes		
Ethical	Followed the standard professional ethics		
Health and Safety	Guidelines are followed		
Social	Applicable for Agricultural Growth		
Political	None		
Other	-		
Standards			
1.IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems		
2. MISRA C	The guidelines for robust and reliable coding practices.		
3. IEEE 802.15.1	IEEE Standard for Bluetooth Connectivity		
4. IEEE 802.11	IEEE Standard for reliable and secure Wi-Fi connectivity		
Previous Course Required for the Major Design Experience	1.Microcontroller 2.Internet of Things 3.Basic Electrical and Electronic Engineering		

Supervisor Project Co-Ordinator Head of the department ECE 23/5/24.

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LIST OF ACRONYMS AND ABREVATIONS

AC	Alternating Current
CS	Current Sense
CMOS	Complementary Metal Oxide Semiconductor
DIR	Direction
DC	Direct Current
IEC	International Electro Technical Commision
IEEE	Institute of Electrical & Electronics Engineers
IoT	Internet of Things
LED	Light Emitting Diode
MISRA	Motor Industry Software Reliability Association
MOSFET	Metal Oxide Semi Conductor Field Effect Transistor
PWM	Pulse Width Modulation
RX	Receiver
SMPS	Switch Mode Power Supply
SPI	Serial Peripheral Interface
TX	Transmitter

CHAPTER 1

Introduction

Researchers around the world are actively developing climbing machines, with most designed to scale regular structures like poles and walls. However, very few are capable of climbing trees due to the irregular surface and varying diameters along the tree's length. Tree climbing requires greater agility and high maneuverability, making it a challenging task for conventional climbing machines. Additionally, the bark of some trees may not be strong enough to support the weight of these devices. For trees like coconut, arecanut, and palm, which can be quite tall, climbing becomes risky, complicating the tasks of harvesting fruits and nuts and maintaining the trees[3].

Labor scarcity has become a significant challenge in farming, especially affecting the coconut industry. Coconut trees can reach heights of 60-70 feet, necessitating at least five climbs per year for preventive spraying and harvesting. This labor-intensive task requires skilled workers who must rely on physical strength to climb the trees, a demanding job that is increasingly unappealing to younger generations. Consequently, there is an urgent need for a unique tree-climbing mechanism for maintenance and harvesting purposes[6].

Fig 1:Manual climbing

This project focuses on developing a safe, reliable, and efficient tree-climbing machine specifically for coconut trees with diameters between 220 and 320 mm. Key considerations include maintaining sufficient friction to handle the self-weight, ensuring structural stability during motion, reducing total weight, and achieving precise gripping. The machine must be able to adjust to the tree's varying cross-section during upward and downward movements and grab the tree firmly to maintain its position during operation. A powerful geared motor is essential to carry the payloads and the machine's weight[1].

In [2] author specifies that recent years have seen significant technological advancements in the coconut harvesting industry, aimed at overcoming the challenges and safety concerns of traditional manual methods. Automated or semi-automated coconut harvesting machines, employing various climbing methods from robotic manipulators to pneumatic systems, hold the promise of improving productivity and safety. The design of the control systems for these machines is critical to their overall effectiveness and reliability, necessitating rigorous adherence to safety and communication standards to ensure their success.

1.1: Motivation

The motivation behind the design of smart Controller for coconut tree climbing robot is driven by the pressing need to enhance safety, efficiency, and productivity in coconut harvesting. Traditional methods of coconut harvesting are labor-intensive, dangerous, and increasingly unsustainable due to a decline in the availability of skilled climbers. Harvesting coconuts manually involves significant physical risk, as workers must climb tall, often unstable trees, exposing them to falls and other injuries. Additionally, the shortage of skilled laborers has led to increased costs and delays in harvesting, impacting the coconut industry's profitability and supply chain.

The coconut tree climbing robot aims to address these challenges by leveraging advancements in robotics and automation. By integrating robust motor drivers like the RMCS-2305 for base motor control and the VNH2SP30 for arm control, the robot can navigate and operate efficiently in the demanding environment of coconut trees. The use of an Arduino Uno for central control, combined with a Bluetooth module for wireless communication, allows for flexible and remote operation, reducing the need for human presence in hazardous areas. Furthermore, the incorporation of a camera module provides real-time visual feedback, enabling precise control and execution of the coconut cutting process. Limit switches enhance the robot's operational safety by preventing overextension and ensuring accurate positioning. This integration of technologies not only mitigates the risks associated with manual harvesting but also significantly boosts operational efficiency and productivity. In a broader context, this project represents a step forward in the application of robotics in agriculture, demonstrating how modern technology can be harnessed to solve age-old problems.

By automating the coconut harvesting process, the robot contributes to a more sustainable and safe agricultural practice, potentially inspiring further innovations and adoption of robotics in other areas

1.2: Objectives

1. **To design Robot Arm base Control using Limit Switches**: Develop a control system for the robot arm base that utilizes limit switches to ensure precise and safe movement limits.
2. **To implement Wireless Connectivity through Bluetooth for Controlling the robot**: Establish a wireless communication system using Bluetooth to remotely control the robot's functions.
3. **To integrate the Camera Module for Visual Feedback**: Incorporate a camera module to provide real-time visual feedback for enhanced monitoring and navigation of the robot.

CHAPTER 2

Implementation of Robot Arm base Control using Limit Switches

2.1: Introduction

In the realm of robotic systems, precise control of movement is crucial for the successful execution of tasks, especially in complex environments. This chapter delves into the design and implementation of a robot arm base control mechanism utilizing limit switches. The primary objective is to regulate the movement of the arm base, ensuring both accuracy and safety. Limit switches will be strategically placed to detect the endpoints of motion, thus controlling the base arm's positioning with high precision. This approach is particularly significant for applications such as tree climbing operations, where exact movements are imperative.

IEC 61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems).This standard provides guidelines on designing and implementing safety-related systems to prevent hazardous situations. By integrating limit switches as part of the safety system, we ensure that the robot’s arm base control adheres to the safety integrity levels (SILs) defined by IEC 61508. This minimizes risks and ensures the operational safety of the robot during tree climbing activities.

2.1.1: Overview of Limit Switches

Fig 2.1:Micro Limit switch

The limit switches will be used to regulate the movement of the arm base. Limit switches will be strategically placed to detect the end points of motion, ensuring precise control over the base arm's positioning. By effectively integrating limit switches into the design, the aim is to enhance the safety and accuracy of the robot's movements during tree climbing operations. The use of limit switches will also contribute to the efficient operation of the robotic arm, ensuring that it does not exceed its range of motion and minimizing the risk of damage to the system.

2.1.2: Safety Mechanisms

Incorporating limit switches enhances the safety of the robotic system by preventing the arm from moving beyond its mechanical limits. This helps in avoiding potential damage to the system and ensures the safety of the operational environment.

2.1.3: Environmental Considerations

Since the robotic arm may be used in varying environmental conditions, the limit switches must be chosen based on their ability to withstand such conditions. Factors such as temperature, humidity, and potential exposure to dust or water should be considered.

2.2: Hardware Implementation

2.2.1: Hardware Setup

The hardware setup involves mounting the limit switches at the designated endpoints of the arm base. Wiring must be done meticulously to ensure reliable signal transmission. The switches should be tested individually to confirm proper functioning before integrating them into the control system.

Fig 2.2: Installation of Limit switches

2.2.2: Software Integration

The control software must be programmed to respond to the signals from the limit switches. This involves writing code ,we have followed MISRA C guidelines for robust and reliable coding practices for that interprets the signals and commands the robotic arm to stop or change direction upon activation of a limit switch. The software should also include routines for calibrating the arm's range of motion during the initial setup.

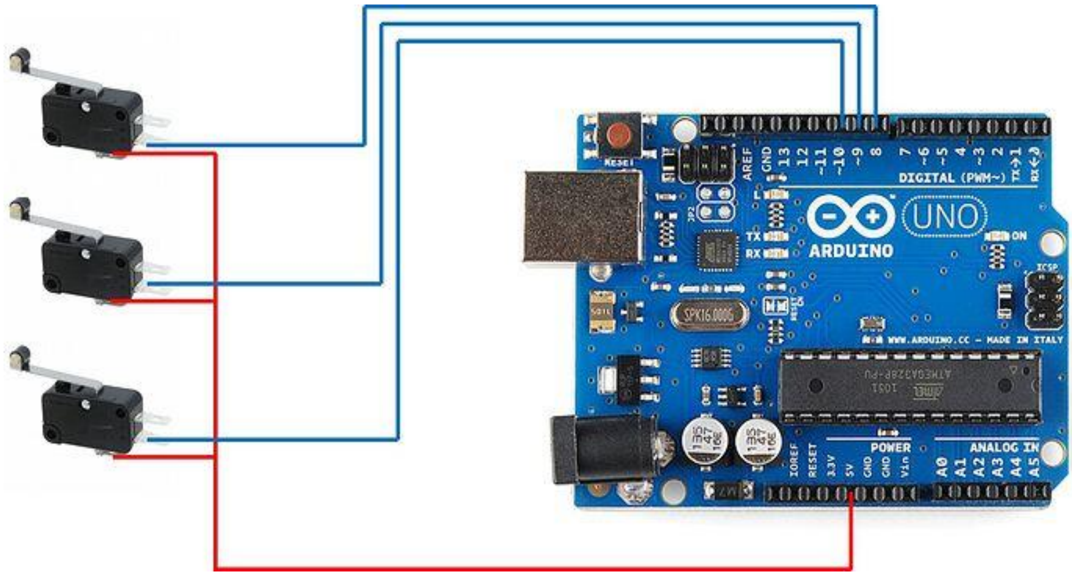

Fig 2.3: Arduino uno with limit switches

CHAPTER 3

Implementation of Wireless Connectivity through Bluetooth for Controlling the Robot

3.1: Introduction

Wireless connectivity is a critical feature in modern robotic systems, offering enhanced flexibility, ease of control, and the ability to operate remotely. This chapter focuses on implementing wireless connectivity using Bluetooth technology to control a robot. The goal is to enable seamless communication between the robot and a remote controller, such as a smartphone or a computer, facilitating efficient and intuitive control.

By adhering to IEEE 802.15.1, the robot's Bluetooth connectivity will ensure robust and stable wireless communication. This standard supports the necessary data rates and reliability required for real-time monitoring and control, which is crucial for the effective operation of the robot in dynamic environments.

3.2: Overview of Bluetooth Technology

Bluetooth is a wireless communication technology that allows the exchange of data over short distances using radio waves. It is widely used in various applications due to its reliability, low power consumption, and ease of integration.

3.2.1: Specifications

- Frequency Range: 2.4 GHz ISM band
- Range: Typically up to 10 meters (Class 2), extendable with Class 1 devices
- Data Rate: Up to 3 Mbps (Bluetooth 2.0 + EDR)
- Power Consumption: Low, suitable for battery-operated devices
- Profiles: Various profiles available for different types of data exchange (e.g., SPP, A2DP, HID)

3.2.2: Advantages

- Low Power Consumption: Ideal for battery-powered devices.
- Ease of Use: Simple pairing process and widely supported across devices.
- Cost-Effective: Inexpensive modules and widespread availability.
- Interoperability: Compatible with numerous devices and operating systems.

3.3: Components and Tools

3.3.1: Hardware Components

- Bluetooth Module: HC-05 or HC-06 Bluetooth module
- Microcontroller: Arduino Uno or similar
- Robot Base: The robotic platform that requires wireless control
- Power Supply: Batteries or power adapters for the robot and microcontroller

3.3.2: Software Tools

- Arduino IDE: For programming the microcontroller
- Bluetooth Terminal App: For sending commands from a smartphone or computer
- Custom Control App: Optional, for creating a more user-friendly interface

3.4: Hardware Integration

3.4.1: Connecting the Bluetooth Module

The HC-05/HC-06 Bluetooth module typically has 6 pins: EN, VCC, GND, TXD, RXD, and STATE. For basic operation, the EN and STATE pins can be left unconnected.

- VCC: Connect to the 5V pin of the Arduino.
- GND: Connect to the GND pin of the Arduino.
- TXD: Connect to the RX pin (pin 0) of the Arduino.
- RXD: Connect to the TX pin (pin 1) of the Arduino.

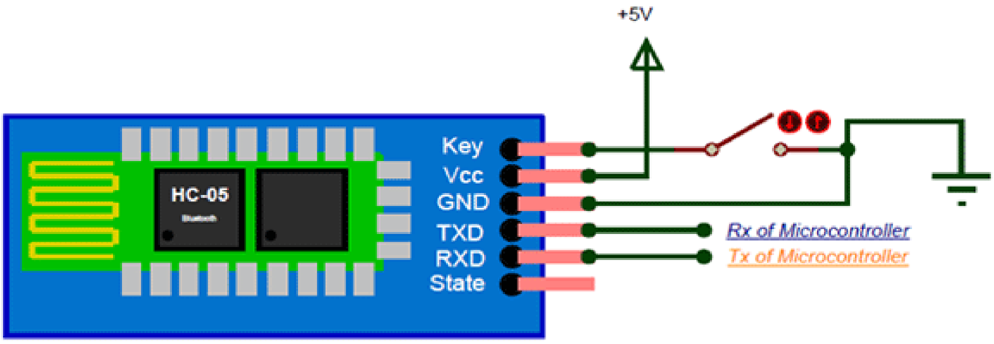

Fig 3.1: Pin configuration of bluetooth

CHAPTER 4

Integration of a Camera Module for Visual Feedback in Robotic Systems

4.1: Introduction

Visual feedback is a vital component in modern robotics, enhancing the robot's ability to perceive its environment and make informed decisions. This chapter explores the integration of a camera module into a robotic system to provide real-time visual feedback. The objective is to enable the robot to capture and process images or video streams, facilitating tasks such as navigation, object recognition, and environmental monitoring.

IEEE 802.11 (Wi-Fi): This standard governs the protocols for wireless LAN communication, which the ESP32 camera module uses for transmitting visual data. Ensuring compliance with IEEE 802.11 guarantees reliable and secure Wi-Fi connectivity, essential for real-time video streaming and remote monitoring. This enhances the robot's situational awareness and operational efficiency.

4.2: Overview of Camera Modules

Camera modules are compact devices that capture images and videos, which can be processed for various applications. In robotics, these modules are used to provide the robot with vision capabilities, allowing it to interact more intelligently with its surroundings.

4.2.1: Types of Camera Modules

- CCD Cameras: Known for high image quality and low noise, suitable for applications requiring detailed images.
- CMOS Cameras: More power-efficient and faster than CCDs, commonly used in many consumer electronics.
- USB Cameras: Easy to interface with microcontrollers and computers, often plug-and-play.
- Wireless Cameras: Provide flexibility in placement, eliminating the need for wired connections.

4.2.2: Key Features

- Resolution: Determines the clarity of the images captured, measured in pixels.
- Frame Rate: The number of frames captured per second, important for video and real-time applications.
- Field of View (FOV): The extent of the observable world seen at any given moment.

- Connectivity: Methods of connecting to other devices, such as USB, Wi-Fi, or direct pin connections.

4.3: Components and Tools

4.3.1: Hardware Components

- Camera Module: For example, the OV7670 or Raspberry Pi Camera Module.
- Microcontroller: Such as Arduino for basic control, or Raspberry Pi for more advanced processing.
- Robot Base: The robotic platform that will use the visual feedback.
- Power Supply: Batteries or power adapters to power the camera and microcontroller.

4.3.2: Software Tools

- Arduino IDE: For programming the microcontroller.
- OpenCV: A powerful library for image processing and computer vision tasks.
- Python: Often used with Raspberry Pi for advanced processing and control.
- Libraries: Specific libraries for interfacing with the camera module (e.g., PiCamera library for Raspberry Pi).

4. 4: Hardware Integration

4.4.1: Connecting the Camera Module

Example with OV7670 and Arduino

1. Power Connections: Connect the VCC and GND pins of the camera module to the 5V and GND pins on the Arduino.
2. Data Connections: Connect the camera module’s data pins (SDA and SCL) to the corresponding pins on the Arduino for I2C communication.

Ensuring compliance with IEEE 802.11 guarantees reliable and secure Wi-Fi connectivity, essential for real-time video streaming and remote monitoring. This enhances the robot's situational awareness and operational efficiency.

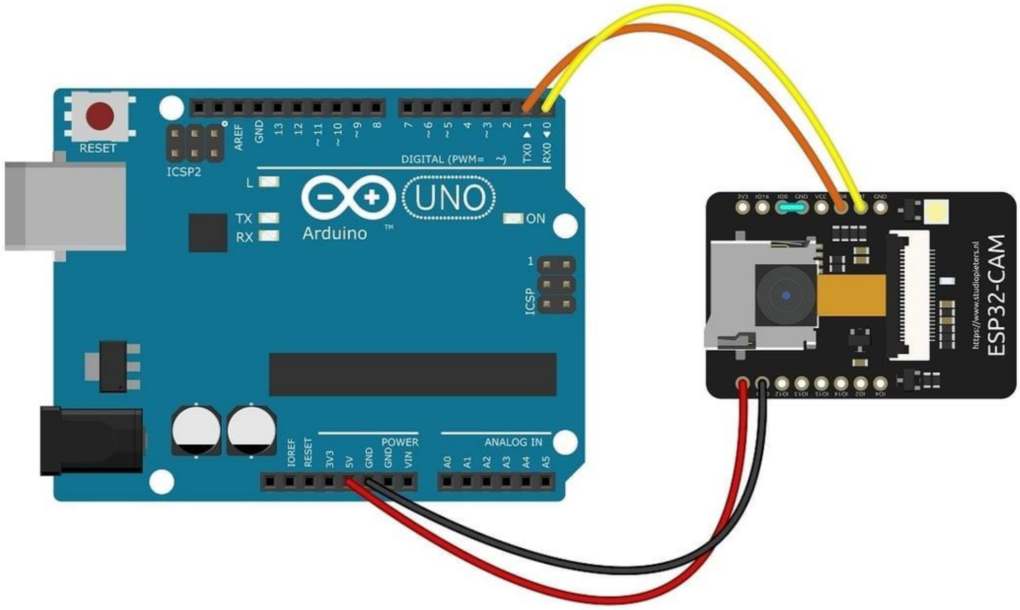

Fig 4.1: Arduino UNO with Camera Module

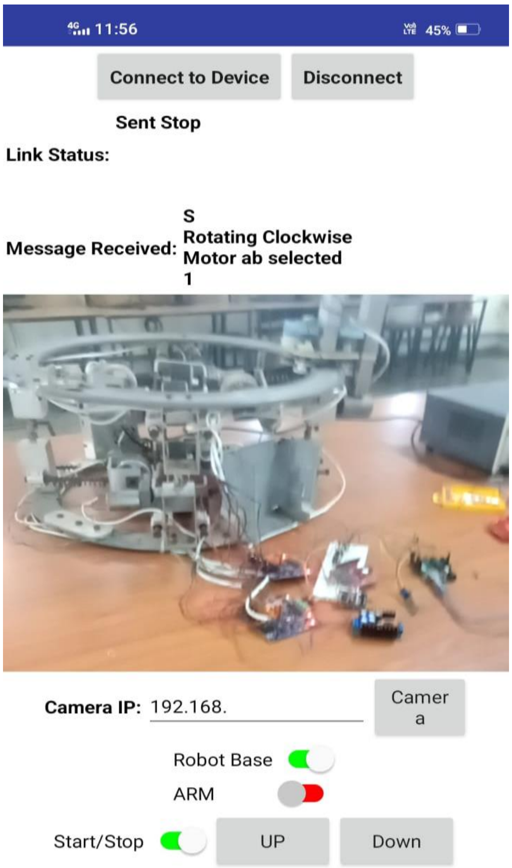

Fig 4.2: Camera Visibily in MIT application

CHAPTER 5

COMPONENTS REQUIRED

Description of Components:-

5.1: Arduino Uno:

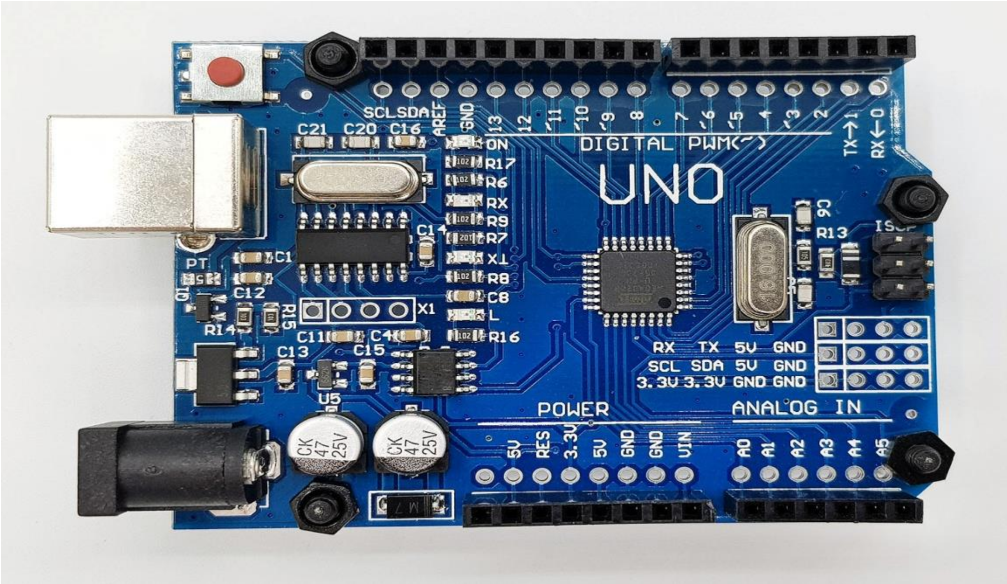

Fig 5.1:Arduino UNO Board

5.1.1: Arduino UNO Board Description:

The Arduino Uno board is the most popular board and mostly referred for the beginners as they are super easy to begin with, it does not requires any specific arduino uno software instead of that all you need is to select the arduino uno in the device option before uploading your program. There are plenty of arduino uno boards look different from the one as shown. But they all have plenty of the same components given below.

5.1.2: Voltage Regulator:

The Arduino Uno can be powered by USB cable or directly supplying 9-12v from the barrel jack. The circuitry operates at 5v dc which in case input more than that is regulated with the help of 7805 voltage regulator. The 7805 voltage regulator IC used regulate the voltage supplied to the arduino board and manage it through processor and other elements.

5.1.3: Crystal Oscillator:

There are certain case when the processor has to deal with time-signal issues, in order to balance it the crystal oscillator is used. The crystal oscillator is the only way the arduino is able to calculate the time. There is a number printed on the top of the crystal. The number indicates the frequency of the crystal, in most of them the frequency is 16 MHZ or 16,000,000 hertz, indicates the frequency of the crystal, in most of them the frequency is 16 MHZ or 16,000,000 hertz.

5.1.4: Reset Button:

There is a reset button given which is used to restart the program running in the Arduino uno. There are two ways to restart the whole program. By using the default reset button(or)You can connect your own reset button at the pin labelled as reset.

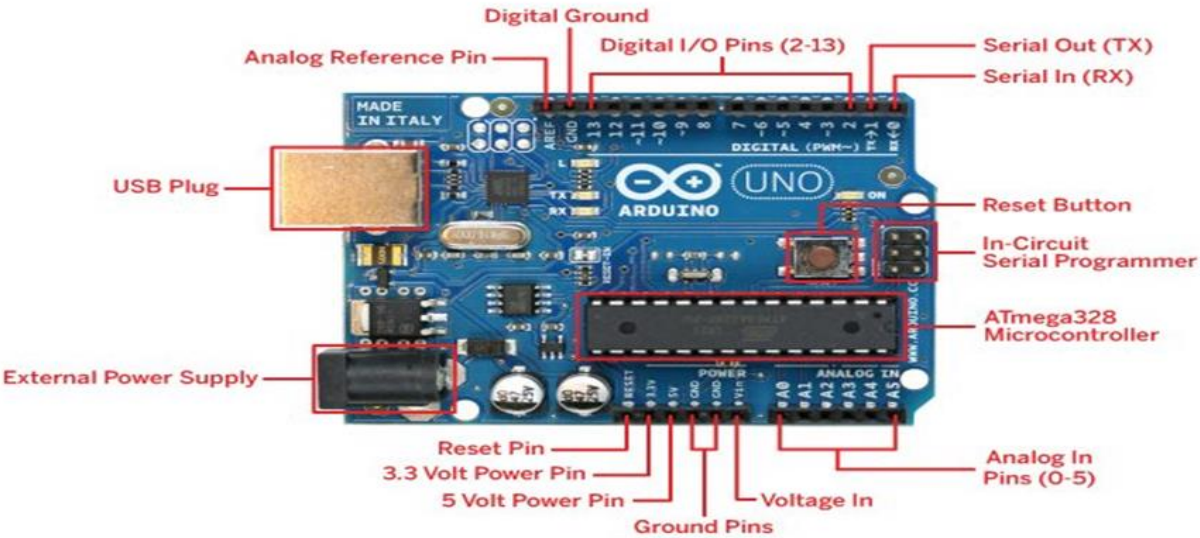

Fig 5.2: Pin configuration of Arduino

5.1.5: Arduino Uno Board General Voltage Pins:

There are following output voltage pins.

- 3v output pin
- 5v output pin
- GND (ground)

Most of the arduino components operate at 5v or 3.3v and so can be powered with these pins. There are several ground ports which can be used to give ground to your circuit and components. There is a Vin pin which can be used to power the arduino uno from an external source.

5.1.6: Analog I/O Pins:

The Arduino uno board has 6 analog input and output pins from A0 to A5. The pins are best used in case of the analog sensors. The analog pins can read the analog signals from them like temperature, proximity, humidity etc and converts them into digital values that can be read and processed by the microcontroller.

5.1.7: Microcontroller In Arduino Uno Board:

Different Arduino boards have different microcontrollers. It can be said that is the main component in the overall Arduino board. The main IC is a bit different in different arduino uno boards. The microcontrollers used basically are of ATMEL Company and it is necessary for you to know what IC you are using in order to load your program in it. You can easily read the information on the top of the IC and select the corresponding from the option given in the arduino software. For more information about the IC you can refer to the corresponding datasheet.

5.1.8: SPI Ports:

The SPI (Serial Peripheral Interface) is considered for an expansion of the output. In most of the cases the ICSP Pin as an small programming header in Arduino Uno consist of RESET, SCK, MOSI, MISO, VCC and GND.

5.1.9: Power Indicator LED:

There are certain case when the processor has to deal with time-signal issues, in order to balance it the crystal oscillator is used. The crystal oscillator is the only way the arduino is able to calculate the time. There is a number printed on the top of the crystal. The number indicates the frequency of the crystal, in most of them the frequency is 16 MHZ or 16,000,000 hertz,indicates the frequency of the crystal, in most of them the frequency is 16 MHZ or 16,000,000 hertz.

5.1.10: TX And RX Pins:

In the Arduino Uno board there are two LED's labeled as TX (transmitter) and RX (Receiver), Same are labelled on the pin 0 and 1 respectively. These pins are used for serial communication and the corresponding LED glowing indicated the data is being sent by TX and if the data is being received by RX. The TX LED flashes at the different frequency which depends on the baud rate being used by the arduino board to transmit.

5.1.11: Digital I/O Pins:

Arduino uno board does have 14 digital i/o pins (input/output pins) out of which contains 6 PWM output (Pulse width modulation). The digital pins can be configured to read logic values such as 0 and 1 or can give logic (0 and 1) output for different modules such as LEDs, Relays, etc. there is a symbol "~" corresponding to the PWM pins. Additionally there is AREF which is used to set an external reference voltage as the upper limit to the analog input pins. The external reference voltage is usually in between 0 to 5 volts.

5.2: RMCS2305:

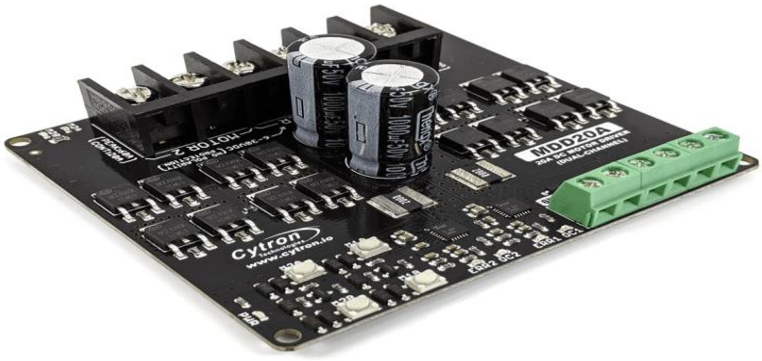

Fig 5.3:RMCS2305

The RMCS2305 enables bidirectional control of two high-power brushed DC motors from 6V to 30V. With full discrete NMOS H-Bridge design, this motor driver is able to support 20Amp continuously for each motor without any heat sink.
This motor driver can be controlled with PWM and DIR inputs. With input logic voltage range from 1.8V to 12V, it's compatible with wide variety of host controller (e.g. Arduino, Raspberry Pi, PLC). Over current protection prevents the motor driver from damage when the motor stalls or an oversized motor is hooked up. When the motor is trying to draw current more than what the motor driver can support, the motor current will be limited at the maximum threshold.

Assisted by temperature protection, the maximum current limiting threshold is determined by the board temperature. The higher the board temperature, the lower the current limiting threshold.

5.2.2:Features:

- Bidirectional control for two brushed DC motors.
- Operating Voltage: DC 6V to 30V
- Maximum Motor Current (Each Channel): 20A continuous, 60A peak
- Buttons for quick testing.
- LEDs for motors output state.
- PWM and DIR inputs.

- Inputs compatible with 1.8V, 3.3V, 5V and 12V logic (Arduino, Raspberry Pi, PLC, etc).
- PWM frequency up to 20kHz (Output frequency is same as input frequency).
- Compatible with sign-magnitude and locked-antiphase PWM operation.
- Overcurrent protection with active current limiting.
- Temperature protection

5.2.3:Technical Specifications:

Table 5.1: Technical Specifications of RMCS2305

Specifications	Min	Max	Units	Comments
Supply Voltage	6	30	Volts DC	Between +vcc and GND
Phase Current (Continuous)	-	20	Amps	Peak 20 Amps per phase
Phase current (peak)	-	60	Amps	Max 60amps capacity for fluctuation
LogicInput Voltage (PWM & DIR)	0	5	volts	Can be given through pulse generator or some microcontroller.
PWM Frequency	0	20	KHZ	Output frequency will be same as input frequency

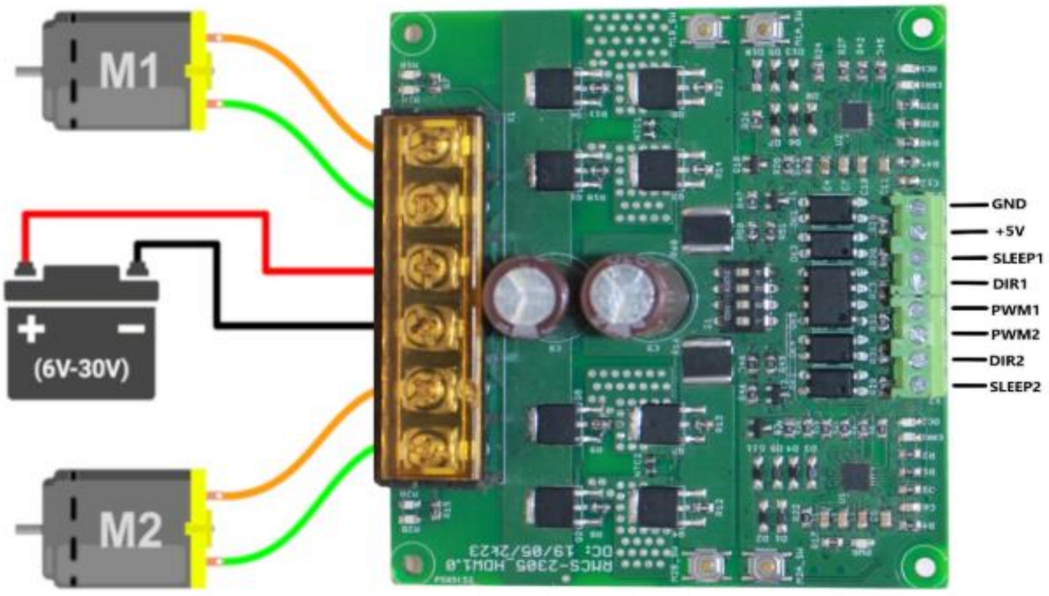

Fig 5.4: Hardware Connection

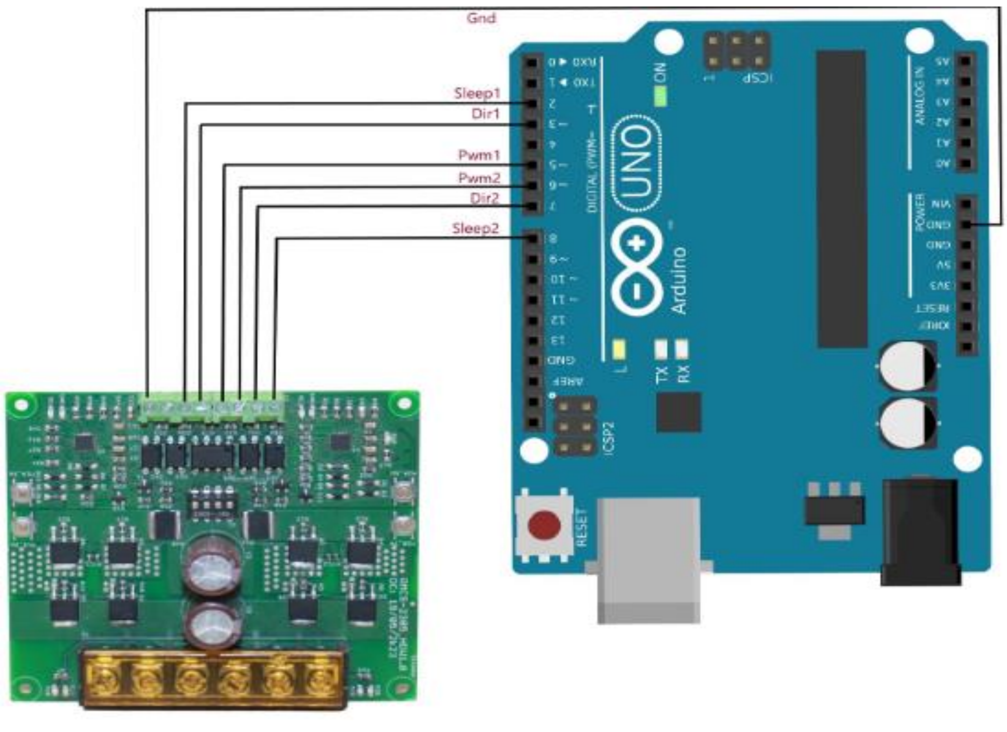

Fig 5.5: Motor Control Using Microcontroller

The motors can be easily controlled using any microcontroller equipped with 5V pins. By providing PWM signals to the PWM pins of the drive (PWM1 and PWM2), the motor speed can be adjusted accordingly. To change the direction of the motors, a signal from any digital 5V pin can be directed to the corresponding direction pins (DIR1 and DIR2).

5.3:VNH2SP30

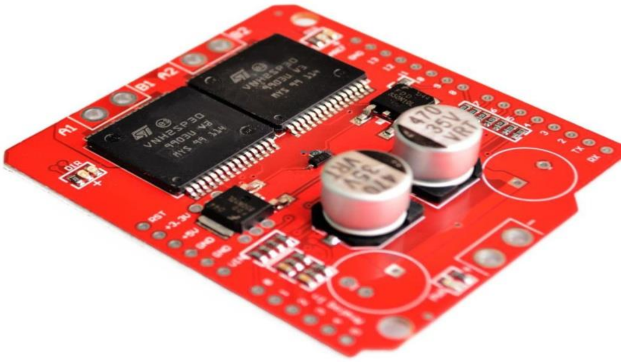

Fig 5.6: VNH2SP30

The VNH2SP30 is a full-bridge motor driver that is designed for a wide range of automotive applications. It incorporates a dual monolithic high-side driver and two low-side switches, with the high-side driver switch designed using ST Microelectronic's VI Power M0 technology. This technology allows for efficient integration of a true Power MOSFET with intelligent signal/protection circuitry on the same die. The device has a voltage range of 5.5V to 16V and a maximum current rating of 30A, with a practical continuous current of 14A. The current sense (CS) pins output approximately 0.13 volts per amp of output current. The MOSFET on-resistance is 19 mΩ per leg, and the maximum PWM frequency is 20 kHz.

The VNH2SP30 is designed for use with a single DC motor, and the INA and INB pins control the direction of the motor, while the PWM pin turns the motor on or off. The current sense (CS) pins provide a voltage output proportional to the motor current.

5.3.1:Features:

- Overvoltage clamp
- Under voltage and overvoltage shut-down
- Cross-conduction protection
- PWM operation up to 20 kHz
- Thermal shut down
- Very low stand-by power consumption
- Linear current limiter
- 5V logic level compatible inputs

5.3.2:Pin Description

Table 5.2: Pin Description of VNH2sp30

Name	Description
Vcc	Battery connection
GNDA, GNDB	Power grounds; must always be externally connected together
OUTA, OUTB	Power connections to the motor
INA, INB	Voltage controlled input pins with hysteresis, CMOS compatible. These two pins control the state of the bridge in normal operation according to the truth table (brake to Vcc. brake to GND, clockwise and counterclockwise).
PWM	Voltage controlled input pin with hysteresis, CMOS compatible. Gates of low side FETs are modulated by the PWM signal during their ON phase allowing speed control of the motor.
ENA/DIAGA , ENB/DIAGB	Open drain bidirectional logic pins. These pins must be connected to an external pull up resistor. When externally pulled low, they disable half-bridge A or B. In case of fault detection (thermal shutdown of a high side FET or excessive ON state voltage drop across a low side FET), these pins are pulled low by the device (see truth table in fault condition).
CS	Analog current sense output. This output sources a current proportional to the motor current. The information can be read back as an analog voltage across an external resistor

5.3.3: Specifications:

- Voltage Range: 5.5V - 16V
- Maximum Current rating: 30A
- Practical Continuous Current: 14 A
- Current sense output proportional to motor current
- MOSFET on-resistance: 19 mΩ (per leg)
- Maximum PWM frequency: 20 kHz

5.4:ESP32 -CAM

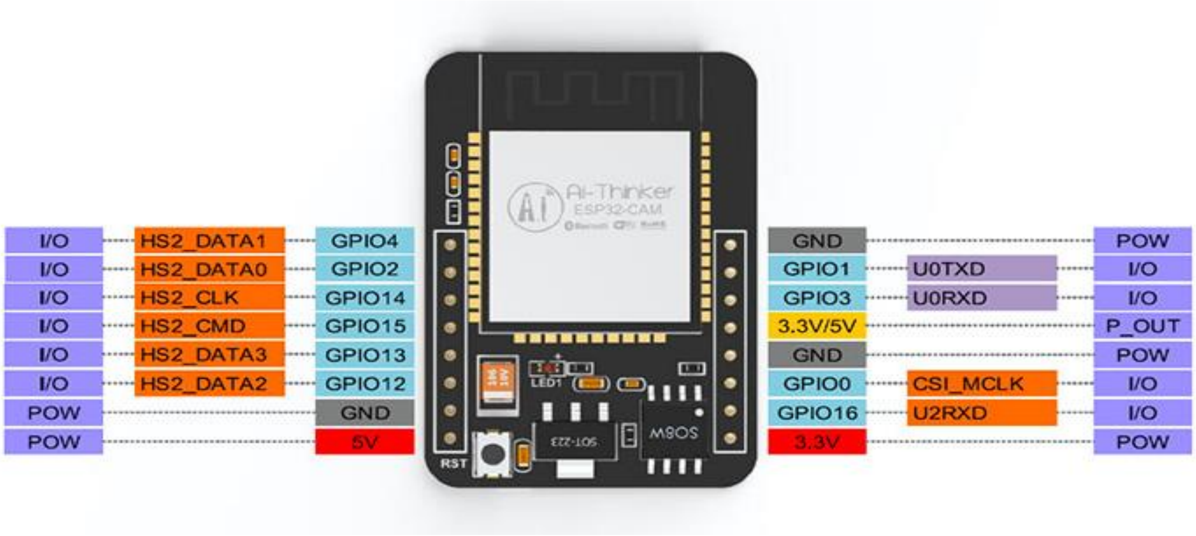

Fig 5.7: ESP32 CAM

The ESP32-CAM is a small-size, low-power camera module based on **ESP32**. It comes with an **OV2640 camera** and provides an onboard TF card slot. This board has **4MB PSRAM** which is used for buffering images from the camera into video streaming or other tasks and allows you to use higher quality in your pictures without crashing the ESP32. It also comes with an onboard LED for flash and several GPIOs to connect peripherals.

5.4.1: Specifications

- WIFI module: ESP-32S
- Processor: ESP32-D0WD
- Built-in Flash: 32Mbit
- RAM: Internal 512KB + External 4M PSRAM
- Antenna: Onboard PCB antenna
- WiFi protocol: IEEE 802.11 b/g/n/e/i
- Bluetooth: Bluetooth 4.2 BR/EDR and BLE
- WIFI mode: Station / SoftAP / SoftAP+Station
- Security: WPA/WPA2/WPA2-Enterprise/WPS
- Output image format: JPEG (OV2640 support only), BMP, GRAYSCALE
- Supported TF card: up to 4G
- Peripheral interface: UART/SPI/I2C/PWM
- IO port: 9
- UART baudrate rate: default 115200bps

5.4.2: Features

- Onboard ESP32-S module, supports WiFi + Bluetooth
- OV2640 camera with flash
- Onboard TF card slot, supports up to 4G TF card for data storage
- Supports WiFi video monitoring and WiFi image upload
- Supports multi sleep modes, deep sleep current as low as 6mA
- Control interface is accessible via pin-header, easy to be integrated and embedded into user products

5.5: HC-05 Bluetooth

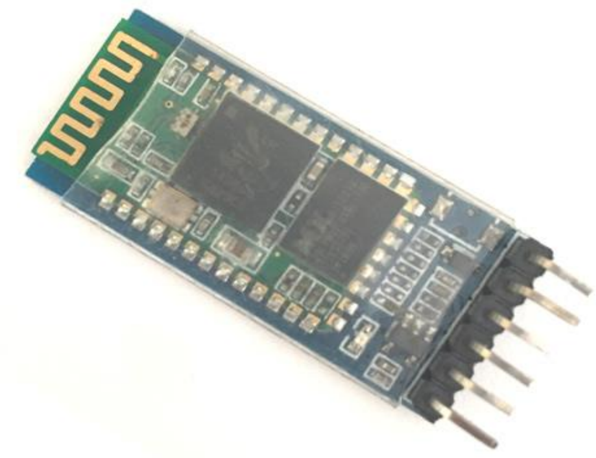

Fig 5.8: HC-05 Bluetooth Module

The **HC-05** is a popular module which can add two-way (full-duplex) wireless functionality to your projects. You can use this module to communicate between two microcontrollers like Arduino or communicate with any device with Bluetooth functionality like a Phone or Laptop. There are many android applications that are already available which makes this process a lot easier.

The module communicates with the help of USART at 9600 baud rate hence it is easy to interface with any microcontroller that supports USART. We can also configure the default values of the module by using the command mode. So if you looking for a Wireless module that could transfer data from your computer or mobile phone to microcontroller or vice versa then this module might be the right choice for you.

The **HC-05** has two operating modes, one is the Data mode in which it can send and receive data from other Bluetooth devices and the other is the AT Command mode where the default device settings can be changed. We can operate the device in either of these two modes by using the key pin as explained in the pin description.

It is very easy to pair the HC-05 module with microcontrollers because it operates using the Serial Port Protocol (SPP). Simply power the module with +5V and connect the Rx pin of the module to the Tx of MCU and Tx pin of module to Rx of MCU as shown in the figure below

During power up the key pin can be grounded to enter into Command mode, if left free it will by default enter into the data mode. As soon as the module is powered you should be able to discover the Bluetooth device as “HC-05” then connect with it using the default password 1234 and start communicating with it.

5.5.1:Specifications:

- Serial Bluetooth module for Arduino and other microcontrollers
- Operating Voltage: 4V to 6V (Typically +5V)
- Operating Current: 30mA
- Range: <100m
- Works with Serial communication (USART) and TTL compatible
- Follows IEEE 802.15.1 standardized protocol
- Uses Frequency-Hopping Spread spectrum (FHSS)
- Can operate in Master, Slave or Master/Slave mode

5.6: Switching Mode Power Supply

A switching regulator is included in an electronic power supply called a switched-mode power supply (SMPS) to facilitate effective electrical power conversion. An SMPS converts voltage and current while transferring power to **DC loads** via a DC or AC source, just like other suppliers.

Fig 5.10: Switching Mode Power Supply

5.6.1: Working Principle of SMPS

Switching regulators are employed in SMPS devices to maintain & regulate the output voltage by turning on or off the load current. The mean value between on and off is the appropriate power output for a system. The SMPS reduces depletion strength because, in contrast to the linear power supply, it carries transistor switches between low dissipation, full-on as well as full-off phases and spends significantly fewer seconds in high dissipation cycles.

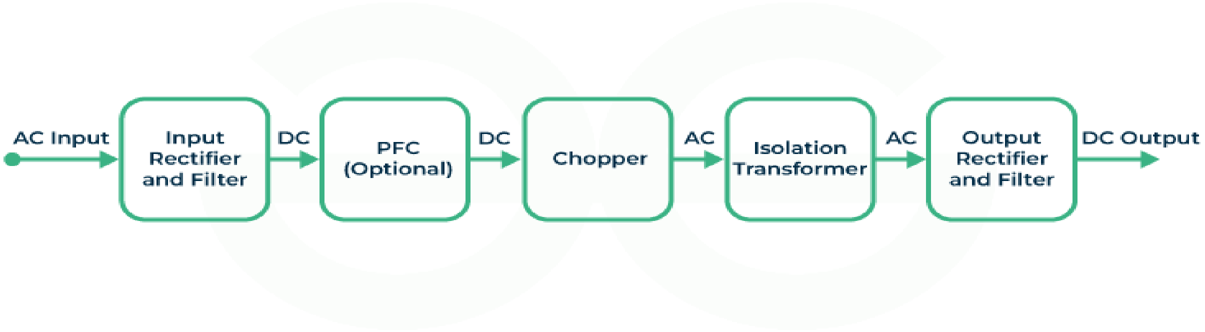

Fig 5.11: Block Diagram of SMPS

- In the initial stage, a rectifier and filter are used to process the AC power that comes in into DC.
- Because the SMPS operates at high frequencies, the DC signal is processed by a high-frequency switch to produce a medium-frequency pulsating DC signal.
- A power transformer reduces the high-voltage DC output to the proper level of DC signal.
- Reversing and filtering the stepped-down DC signal results in a constant steady DV output.
- To guarantee a constant output stream of the intended voltage, the control circuitry continuously monitors the generated voltage and modifies the high-frequency switch.

5.6.2: AC-DC Converter SMPS Working

The input supply in this sort of SMPS is AC, and the output is DC. This AC power is converted to DC using rectifiers and filters. This erratic DC voltage is applied to the impacted circuits for power factor correction. This is due to a low current pulse that occurs near the voltage peak inside the rectifier.

5.6.3: DC-DC Converter SMPS Working

This power source's input supply comes straight from a DC power source, which provides high-voltage DC power. Next, the frequency of this high-voltage DC power supply is lowered to 15KHz–5KHz. A 50 Hz steps-down transformer unit receives it after that. This transformer's output serves as the rectifier’s input, and the **rectifier’s** output provides the power that loads are drawn from. A closed-loop regulation is created when the oscillator is regulated on time. The transformer transfers its maximum power when its duty cycle is 50%. If its duty cycle is lowered, the transformer’s power is likewise decreased by lowering the interruption.

5.6.4: Fly-Back Converter Type SMPS Working

A fly-back converters SMPS is any SMPS with an output power of less than 100W. The circuit for these SMPS is easy to understand and less complicated than that of other SMPS. Low power consumption is the purpose of this kind of SMPS. Using a MOSFET, the unregulated voltage that is input of constant intensity switches at a frequency of about 100 kHz to the desired output voltage. A transformer is used to achieve voltage separation. A workable fly-back converter can be operated while the switch is controlled via PWM.The two windings that make up the fly-back transformer function as magnetically coupled inductors. To improve filtering, capacitors and diodes are used to spread the transformer’s output.

5.7: Buck Converter

A buck converter steps down the applied DC input voltage level directly. By directly means that buck converter is non-isolated DC converter. Non-isolated converters are ideal for all board level circuits where local conversion is required. Fax machines, scanners, Cellphones, PDAs, computers, copiers are all examples of board level circuits where conversion may require at any level inside the circuit. Hence, a buck converter converts the DC level of input voltage into other required levels.

Fig 5.12: Buck Converter

Buck converter is having a wide range of use in **low voltage low power** applications. **Multiphase version** of buck converters can provide high current with low voltage. Therefore, it can be used for low voltage high power applications. This article will discuss both low voltage low power converter and low voltage high power converter.

The efficiency of the converter can be improved using **synchronous version** and **resonant derivatives**. The other method of improving efficiency is to use Multiphase version of buck converters. The improvement of efficiency with multiphase inverter is discussed at the end of the article.

5.8: DC Gear Motors

DC gear motors are widely used in various applications requiring precise control of torque and speed. They combine a DC motor with a gearbox to reduce speed and increase torque, making them suitable for robotics, conveyor systems, and automotive applications.

Fig 5.13: DC Gear Motor

5.8.1: Components of a DC Gear Motor

1. **DC Motor:**
    - **Armature (Rotor):** The rotating part of the motor which includes windings where current flows, creating a magnetic field.
    - **Stator:** The stationary part of the motor that provides a magnetic field through either permanent magnets or electromagnets.
    - **Commutator and Brushes:** The commutator is a rotary switch that reverses the direction of current flow through the rotor windings, while the brushes maintain electrical contact with the rotating commutator.

2. **Gearbox:**
    - **Gears:** The gearbox contains a series of gears (spur, helical, worm, or planetary) that reduce the motor's speed and increase its torque. The gear ratio determines the amount of speed reduction and torque multiplication.
    - **Output Shaft:** The shaft that delivers the torque and speed from the gearbox to the load.

5.9: Limit Switches:

A **limit switch** is a switch operated by the motion of a machine part or the presence of an object. A limit switch can be used for controlling machinery as part of a control system, as a safety interlock, or as a counter enumerating objects passing a point.

Fig 5.10: Micro limit Switch

Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence, passing, positioning, and end of travel of an object.

5.10: MIT App Inventor

MIT App Inventor is a visual programming environment that allows users to create fully functional applications for Android devices. It is particularly useful for those without extensive programming experience, as it employs a drag-and-drop interface to build apps quickly and efficiently.

It's a blocks-based tool that facilitates the creation of complex, high-impact apps in significantly less time than traditional programming environments.

The MIT App Inventor is used to develop a mobile application that interfaces with the coconut tree climbing robot. The application enables users to control and monitor the robot remotely via Bluetooth or

Wi-Fi. Key functionalities of the app include:

- **Real-time Video Streaming:** Viewing live footage from the robot's camera module.
- **Control Interface:** Sending commands to control the movement and operations of the robot.
- **Status Monitoring:** Displaying sensor data and status updates from the robot, ensuring efficient and safe operation.

By using the MIT App Inventor, the project benefits from a user-friendly and customizable interface, allowing for rapid development and deployment of the control application.

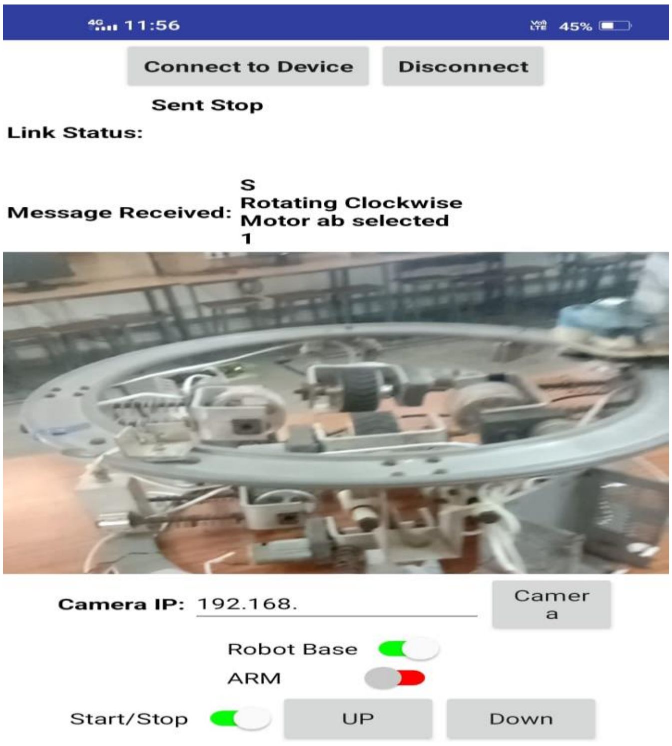

Fig 5.11: MIT Application

CHAPTER-6

BLOCK DIAGRAM

6.1:Block Diagram

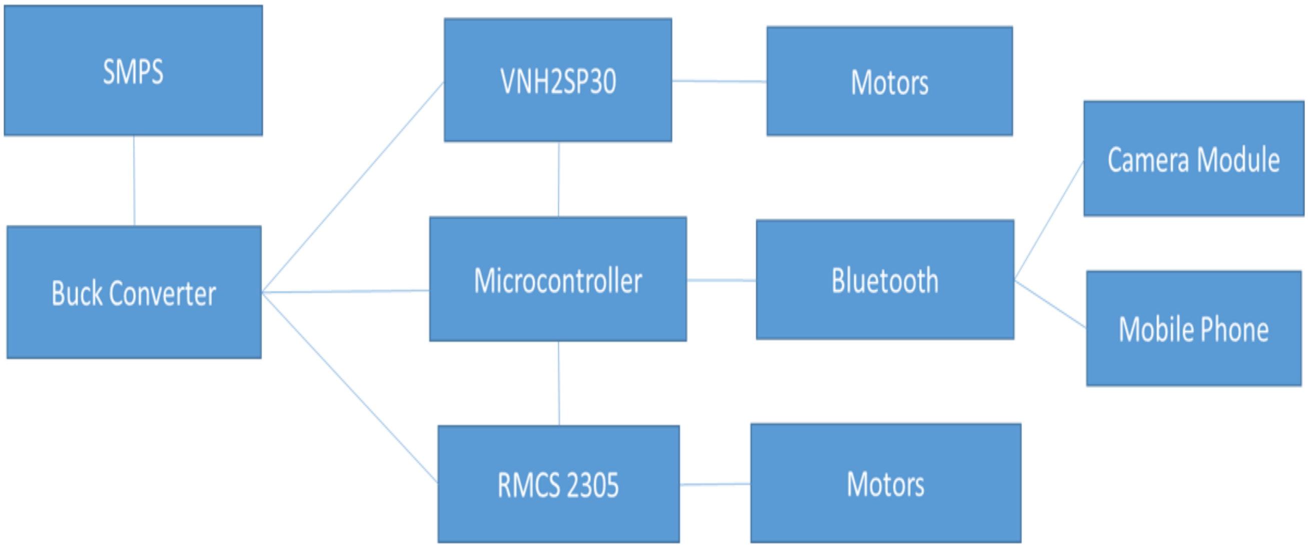

Fig 6.1:Block Diagram

6.1.1 : Working:

1. **Power Supply:** The system starts with the 230V AC input from the wall outlet. The SMPS (Switched-Mode Power Supply) converts this high AC voltage to a lower, regulated DC voltage that can be used by the various components in the system.
2. **Buck Converter:** The output of the SMPS is then fed into a buck converter, which further steps down the voltage to a level that is suitable for the Arduino Uno microcontroller and other low-voltage components.
3. **Arduino Uno:** The Arduino Uno is the central processing unit of the system. It receives input from the various sensors and peripherals, processes the data, and sends control signals to the motor drivers to operate the robotic arm.
4. **Motor Drivers:** The system has two motor driver modules: the MDD20A and the VNH2SP30.
   - The MDD20A motor driver is connected to the Arduino Uno and controls the direction of the motors in the robotic arm.

   - The VNH2SP30 motor driver is connected to the top of the arm base and controls the speed and motion of the motors responsible for the arm's movement.

5. **Limit Switches:** Limit switches are placed at the starting and ending positions of the robotic arm's range of motion. These switches provide feedback to the Arduino Uno, allowing the system to stop the motors and ensure the arm doesn't exceed its designated limits.
6. **Camera Module:** The camera module is positioned at the cutter position of the robotic arm. It is used to detect the position of the coconuts, enabling the system to precisely locate and interact with the targets.
7. **Bluetooth Module:** The Bluetooth module allows for wireless communication between the robotic system and a mobile phone or other control device. This enables the user to remotely control and monitor the operation of the robotic arm.
8. **MIT APP Inventor**: The MIT App Inventor is used to develop a mobile application that interfaces with the coconut tree climbing robot. The application enables users to control and monitor the robot remotely via Bluetooth or Wi-Fi. Key functionalities of the app include:

   Real-time Video Streaming: Viewing live footage from the robot's camera module.

   Control Interface: Sending commands to control the movement and operations of the robot.

   Status Monitoring: Displaying sensor data and status updates from the robot, ensuring efficient and safe operation.

The working of the system can be summarized as follows:

1. The 230V AC input is converted to a lower DC voltage by the SMPS.
2. The buck converter further steps down the voltage to a level suitable for the Arduino Uno and other low-voltage components.
3. The Arduino Uno receives input from the various sensors and peripherals, processes the data, and sends control signals to the motor drivers.
4. The motor drivers, MDD20A and VNH2SP30, control the direction and speed of the motors in the robotic arm.
5. The limit switches provide feedback to the Arduino Uno, ensuring the arm doesn't exceed its designated limits.
6. The camera module detects the position of the coconuts, allowing the system to precisely locate and interact with the targets.
7. The Bluetooth module enables wireless communication between the robotic system and a mobile phone or other control device, allowing for remote control and monitoring.

This integrated system allows for the autonomous detection and interaction with coconuts, making it a versatile and effective robotic arm solution

"In the event of a Bluetooth disconnection, the system should have a failsafe mechanism in place to ensure the safe operation and control of the robotic arm, adhering to the principles outlined in the **IEC 61508 standard for functional safety**. This entails implementing robust safety measures to mitigate potential hazards arising from communication failures, thereby safeguarding the integrity of the overall system and preventing any compromise in operational safety.

"Here's how the system would work in such a scenario:

1. **Bluetooth Disconnection Detection**: The Arduino Uno should continuously monitor the Bluetooth connection status. If the connection is lost, the Arduino will detect the disconnection event.
2. **Autonomous Control Mode**: When the Bluetooth connection is interrupted, the system should automatically switch to an autonomous control mode. In this mode, the Arduino Uno will take full control of the robotic arm's operation without relying on the remote control from the mobile device.
3. **Limit Switch Monitoring**: The limit switches placed at the starting and ending positions of the robotic arm's range of motion will play a crucial role. The Arduino Uno will closely monitor the state of these limit switches to determine the current position of the arm.
4. **Controlled Descent**: Upon detecting the Bluetooth disconnection, the Arduino Uno will initiate a controlled descent of the robotic arm. Using the motor drivers (MDD20A and VNH2SP30), the Arduino will gradually slow down and lower the arm until it reaches the starting or home position, as determined by the limit switches.
5. **Safe Landing**: As the arm reaches the home or starting position, the Arduino Uno will command the motors to stop, ensuring a safe and controlled landing of the robotic arm.
6. **Standby Mode**: Once the arm is safely in the home position, the system will enter a standby mode, waiting for the Bluetooth connection to be re-established before resuming normal operation.

This failsafe mechanism ensures that in the event of a Bluetooth disconnection, the robotic arm will safely and autonomously return to its starting position, minimizing the risk of damage or injury. The limit switches play a crucial role in providing the necessary feedback to the Arduino Uno, allowing it to precisely control the arm's movement during the descent.

CHAPTER-7

RESULTS & DISCUSSIONS

7.1: Circuit diagram

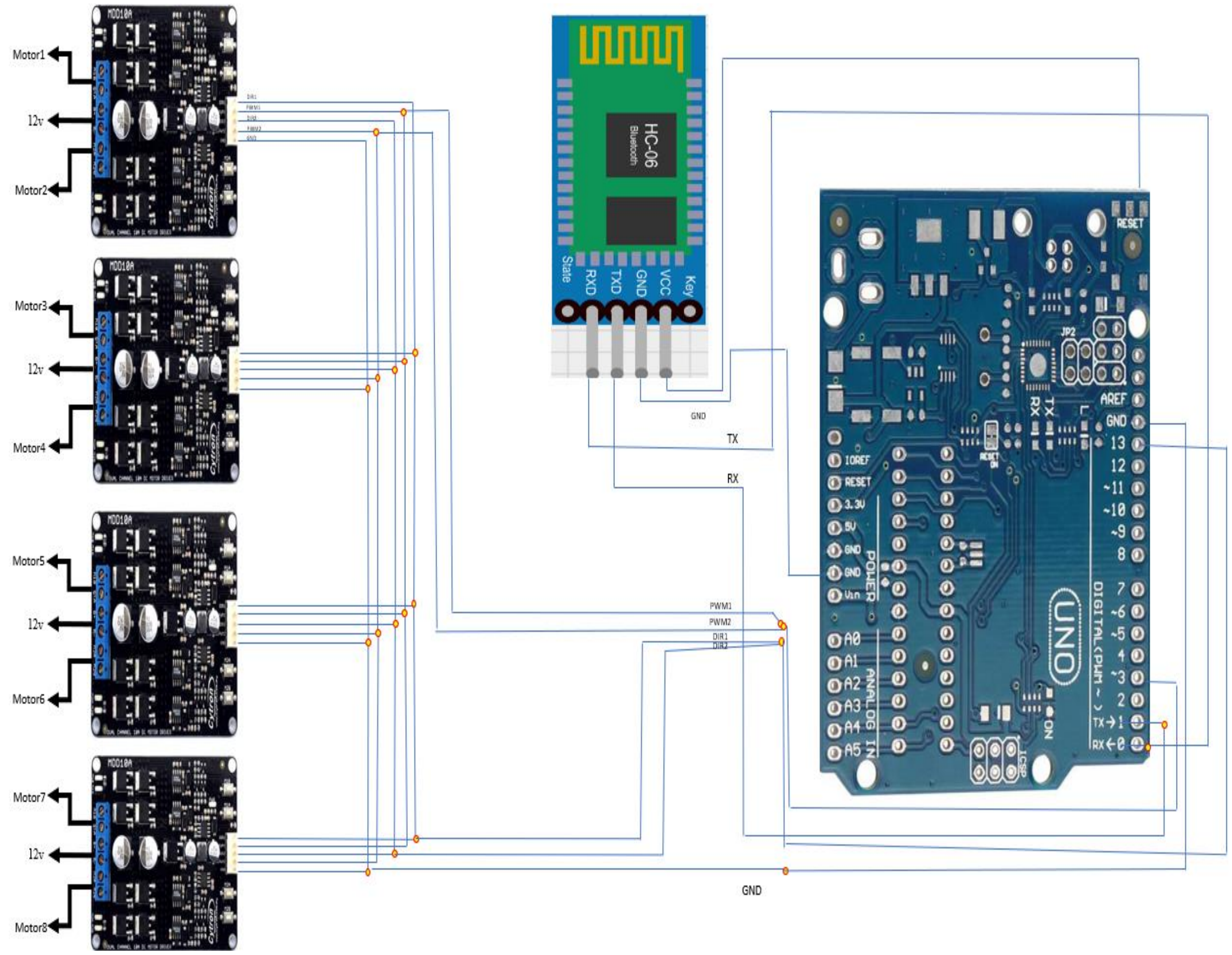

Fig 7.1: Connection of Base motors with Bluetooth Module

In this project, an RMCS-2305 motor driver was connected to an Arduino Uno and controlled via a Bluetooth module to operate the base motors of a coconut tree climbing robot. The Arduino's digital pins were linked to the input pins of the RMCS-2305, with the 5V and GND pins providing power to both the Bluetooth module and the motor driver. The Bluetooth module, an HC-05, was interfaced by connecting its TXD to the Arduino's RX pin (pin 0) and its RXD to the Arduino's TX pin (pin 1), with VCC and GND connected to the 5V and GND pins of the Arduino.

The motor driver's IN1 and IN2 were connected to digital output pins on the Arduino (pins 3 and 4) to control the first base motor, and IN3 and IN4 to additional digital output pins (pins 5 and 6) for the second base motor.

Motor outputs OUT1 and OUT2 were connected to the first motor, and OUT3 and OUT4 to the second motor. An appropriate power supply was connected to the motor driver, ensuring compatibility with the motors' voltage requirements.

An Arduino sketch was developed to receive Bluetooth commands, enabling wireless control of the base motors, thus facilitating the movement and operation of the coconut tree climbing robot.

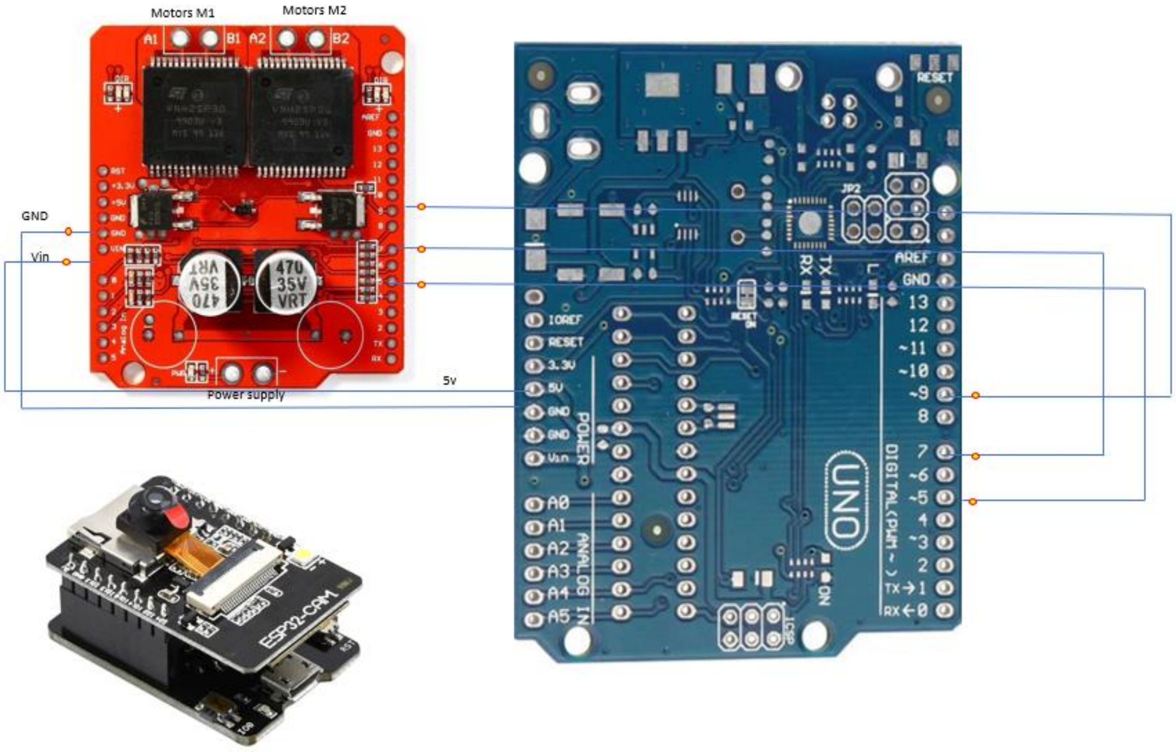

Fig 7.2: Connection of Arm Base Motors With Camera Module

For the arm base, the VNH2SP30 motor driver was connected to additional digital output pins on the Arduino to control its movement. The camera module was connected to the Arduino to provide visual feedback for precise control and operation during the coconut cutting process. An appropriate power supply was connected to both motor drivers, ensuring compatibility with the motors' voltage requirements.

An Arduino sketch was developed to receive Bluetooth commands, enabling wireless control of the base motors, the arm base, and the camera module, thereby facilitating the movement, positioning, and operation of the coconut tree climbing robot to cut coconuts effectively.

7.2: Results of the Project

7.2.1. Design and Implementation of Robot Arm Base Control Using Limit Switches

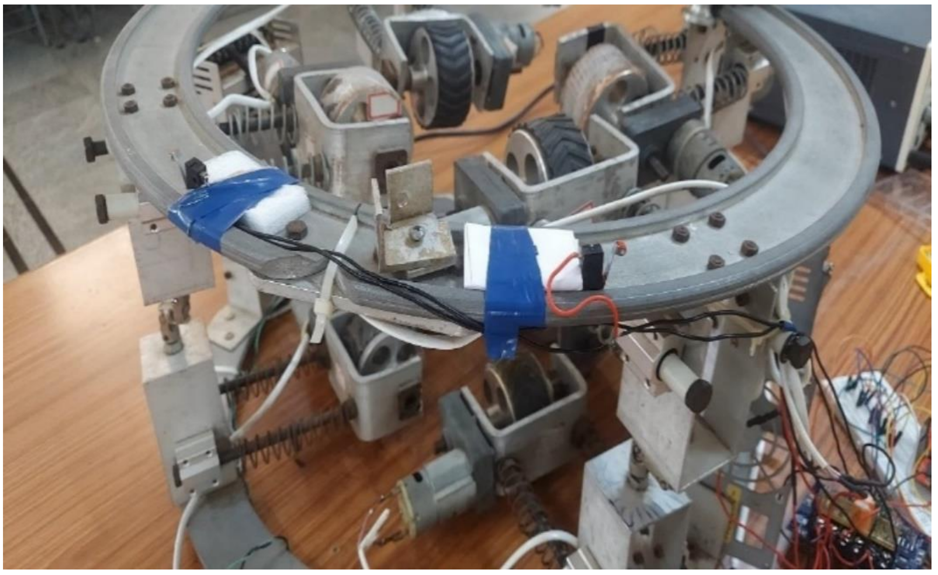

Fig 7.3: Installation of limit switches

Fig 7.4: Controlling the Arm base motors with Limit Switches

Limit switches were placed at the starting and ending positions of the robotic arm's range of motion. These switches play a crucial role in ensuring the safe and accurate operation of the robotic arm. The Arduino Uno continuously monitors the state of these limit switches to determine the current position of the arm.

Table 7.1: Limit Switch Activation Data

Test Number	Starting Position Switch (Activated/Deactivated	Ending Position Switch (Activated/Deactivated)	Arm Position Status
1	Activated	Deactivated	Start Position
2	Deactivated	Activated	End Position
3	Activated	Deactivated	Start Position

7.2.2. Implementation of Wireless Connectivity through Bluetooth for Controlling the Robot

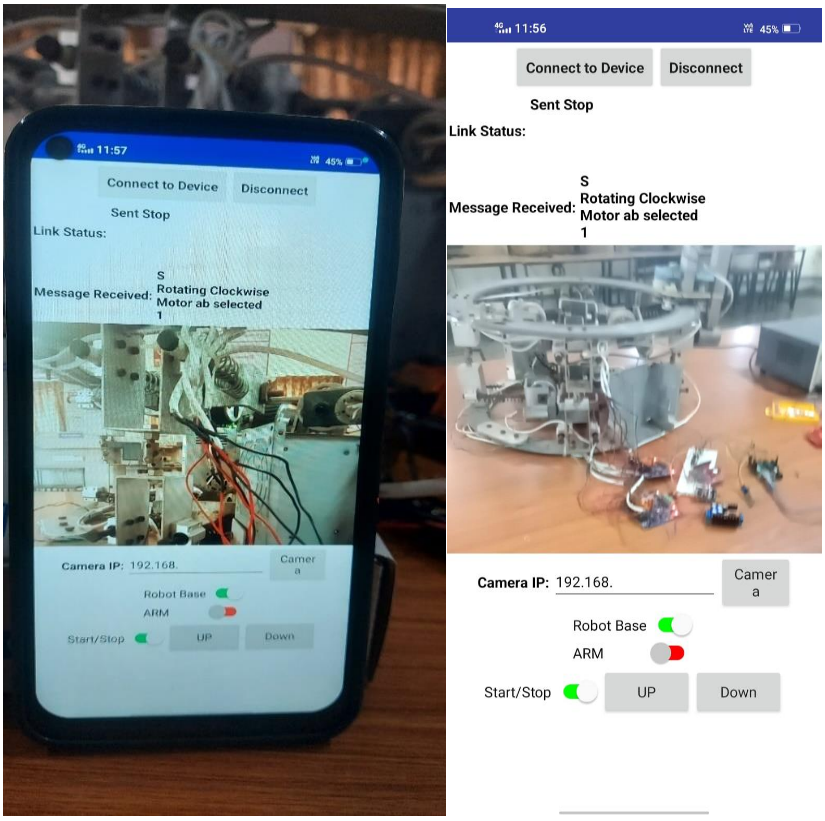

Fig 7.5: Controlling of Motors with Bluetooth through the MIT APP

The successful integration of Bluetooth with the MIT App Inventor app demonstrated the feasibility and benefits of wireless control for the robotic arm. This setup not only met the project's objectives of enhancing usability and control but also provided a foundation for future improvements and applications**.**

7.2.3.Verifing the prototype of coconut tree climbing robot

Fig 7.6: Coconut tree Climbing robot

7.3 : Advantages:

1. Improved Safety: The integration of functional safety measures enhances worker safety by reducing the risks associated with manual coconut tree climbing.

2. Enhanced Efficiency: Utilizing stable communication technologies and advanced camera modules can improve the efficiency and accuracy of coconut harvesting operations.

3. Labor Savings: By automating coconut tree climbing, the project reduces reliance on manual labor, addressing labor scarcity issues and potentially reducing labor-related costs.

4. Environmental Impact: Automation can lead to more sustainable agricultural practices by reducing the carbon footprint associated with manual labor and optimizing resource use.

5. Scalability: The smart controller can be adapted for use in various agricultural settings beyond coconut tree climbing, increasing its applicability and scalability.

6. Data Collection: The incorporation of camera modules enables data collection during operations, providing valuable insights for optimizing harvesting techniques and overall farm management.

+

7.4: CONCLUSION:

In conclusion, the Design of Smart Controller For Coconut Tree Climbing Robot, incorporating RMCS-2305 and VNH2SP30 motor drivers for controlling the base and arm motors respectively, represents a significant innovation in agricultural automation. The integration of an Arduino Uno, a Bluetooth module for wireless communication, and a camera module for precise visual feedback ensures efficient and accurate operation in the coconut cutting process. Additionally, the inclusion of limit switches enhances the safety and reliability of the robot by preventing overextension and ensuring precise movements. This system not only mitigates the physical risks and demands on human workers but also significantly boosts productivity and operational safety in coconut harvesting. The project showcases the effective use of robotics and modern communication technologies to solve practical challenges in agriculture, highlighting the potential for further advancements in the field.

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