MES Project report

Line Follower

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BE MECHATRONICS (Session BEMTS-F22-A)

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Chapter 1: Preliminaries

1.1 Proposal

We are aiming to developing a line-following robot equipped with various sensors and modules to navigate predefined paths autonomously, detect obstacles, and provide real-time feedback.

1.2 Initial Feasibility

Initial feasibility studies were conducted to assess the technical and financial viability of the project. The availability of components, feasibility of integration, and estimated costs were evaluated.

1.3 Comparison Table of at Least 2 Similar Products

A comparison table was created to analyse at least two existing line-following robot products, considering factors such as functionality, performance, and cost.

	Rahbar Robot	The Snake
Obstacle Avoidance	Yes	No
Line Following	Yes	Yes
Colour Detection	Yes	No
Slope	30 °	10°
Speed	7cm/s	4cm/s
Battery Timings	7 minutes	10 minutes
IoT Enabled	Yes	No
Cost	7000	4500

1.4 Technical Standards

Technical standards, such as speed requirements for the robot's movement and sensor accuracy, were established based on industry norms and project specifications.

1.5 Team Roles & Details

- Ashir Mumtaz (221746) - Assembling, PCB Soldering

- M. KHOBAIB (221665) - Lab Report Making, Components Balance

- M. Jamshed (221674) - Planning, PCB Designing, Coding

1.6 Work Breakdown Structure

A detailed breakdown of tasks and responsibilities assigned to each team member was created to ensure efficient project management and execution.

1)The pin maping was done to each and every sensor with micro controller

2)Specified pins ie: analogue inputs were put with care while mapping

Team Member Name	**Role**	**Word count that each has written in assigned color code in report**	**Signature**
M-Jamshed	**Code and PCB Designing**	**2500**	
M-Khobaib	**Report Formatting and Component Selection**	**3500**	
Ashir Mumtaz	**Robot Assembling, PCB Soldering**	**2500**	
Done in Team	**Final Testing**		

1.7 Gantt Chart

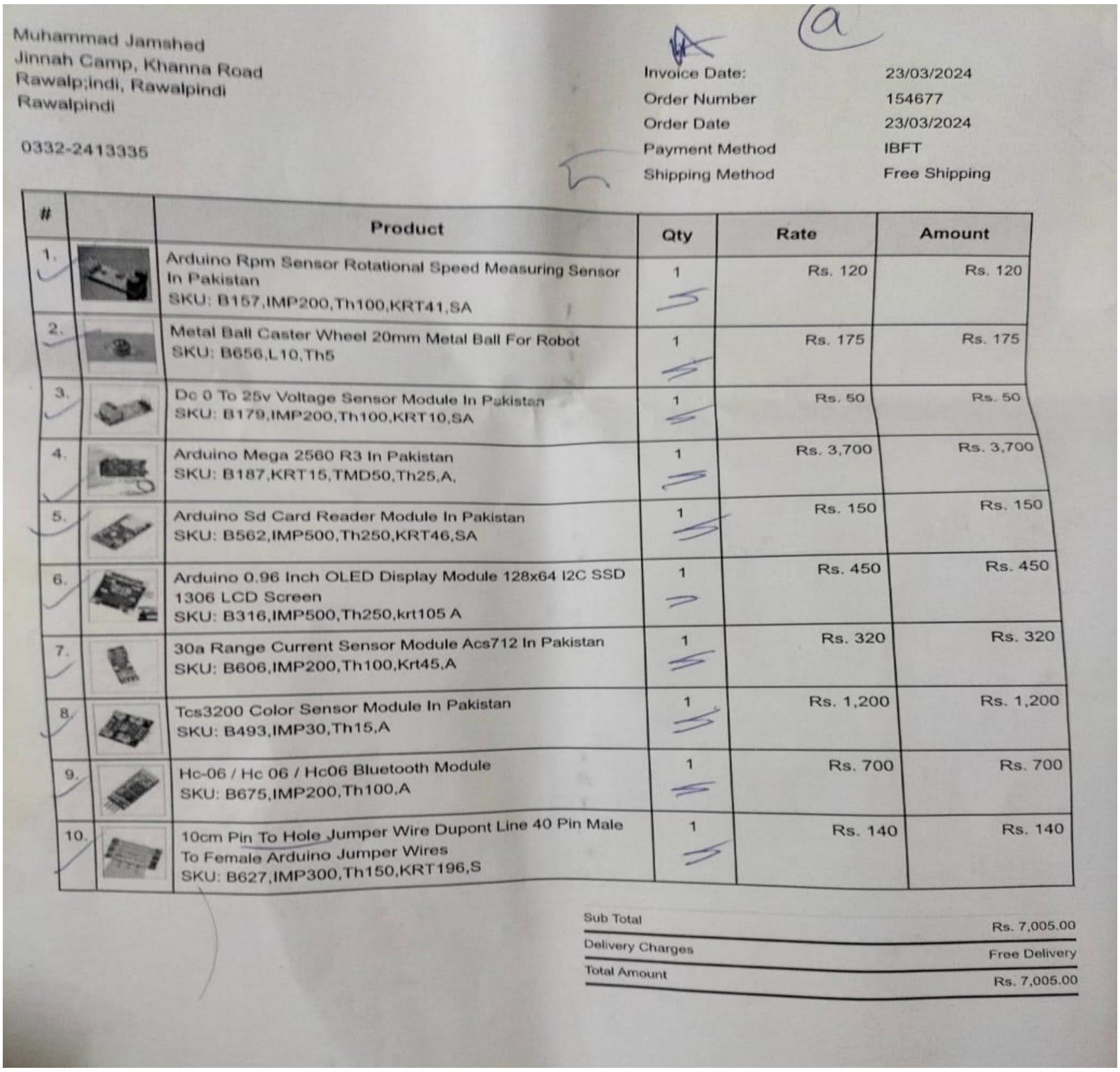
A Gantt chart was developed to visualize project timelines, milestones, and dependencies, facilitating project scheduling and tracking.

Task	Targeted Deadlines
Component Selection	20 April to 22 April
Pin Mappings	23 April
Schematic and PCB Designing	25 April to 02 May
Simole Line following Test	03 May to 05 May
Components Buying	06 May to 07 May
PCB Etchung and Soldering	09 May to 12 May
PCB Testing	13 May
Code Making	10 May to 17 May
Robot Assembling	14 May to 18 May

Testing	20 May to 22 May
Delivereable	24 May

1.8 Estimated Budgets

An estimated budget of 7,000 PKR was allocated for the project, covering expenses related to components, materials, and other resources.



Muhammad Jamshed
Jinnah Camp, Khanna Road
Rawalp;indi, Rawalpindi
Rawalpindi

0332-2413335

Invoice Date:	23/03/2024
Order Number	154677
Order Date	23/03/2024
Payment Method	IBFT
Shipping Method	Free Shipping

#	Product	Qty	Rate	Amount
1.	Arduino Rpm Sensor Rotational Speed Measuring Sensor In Pakistan SKU: B157,IMP200,Th100,KRT41,SA	1	Rs. 120	Rs. 120
2.	Metal Ball Caster Wheel 20mm Metal Ball For Robot SKU: B656,L10,Th5	1	Rs. 175	Rs. 175
3.	Dc 0 To 25v Voltage Sensor Module In Pakistan SKU: B179,IMP200,Th100,KRT10,SA	1	Rs. 50	Rs. 50
4.	Arduino Mega 2560 R3 In Pakistan SKU: B187,KRT15,TMD50,Th25,A,	1	Rs. 3,700	Rs. 3,700
5.	Arduino Sd Card Reader Module In Pakistan SKU: B562,IMP500,Th250,KRT46,SA	1	Rs. 150	Rs. 150
6.	Arduino 0.96 Inch OLED Display Module 128x64 I2C SSD 1306 LCD Screen SKU: B316,IMP500,Th250,krt105 A	1	Rs. 450	Rs. 450
7.	30a Range Current Sensor Module Acs712 In Pakistan SKU: B606,IMP200,Th100,Krt45,A	1	Rs. 320	Rs. 320
8.	Tcs3200 Color Sensor Module In Pakistan SKU: B493,IMP30,Th15,A	1	Rs. 1,200	Rs. 1,200
9.	Hc-06 / Hc 06 / Hc06 Bluetooth Module SKU: B675,IMP200,Th100,A	1	Rs. 700	Rs. 700
10.	10cm Pin To Hole Jumper Wire Dupont Line 40 Pin Male To Female Arduino Jumper Wires SKU: B627,IMP300,Th150,KRT196,S	1	Rs. 140	Rs. 140

Sub Total	Rs. 7,005.00
Delivery Charges	Free Delivery
Total Amount	Rs. 7,005.00

Chapter 2: Project Conception

2.1 Introduction

The introduction provides an overview of the project, outlining its objectives, scope, and significance in the field of robotics.

Objective:

The line-following robot, equipped with infrared and color sensors, SD card modules, OLED screen, Bluetooth, ultrasonic sensor, and current/voltage sensors, aims to autonomously navigate predefined paths, detect obstacles, and provide real-time feedback. Integrated sensors enable it to follow lines accurately, differentiate surfaces, store data for analysis, and communicate wirelessly. With ultrasonic sensors for obstacle detection and current/voltage sensors for performance monitoring, the robot ensures efficient and safe operation, fulfilling its objective of adaptive navigation in varied environments.

2.2 Literature Review

A literature review was conducted, analysing research papers, commercial products, and patents related to line-following robots to gather insights and identify existing technologies and trends.

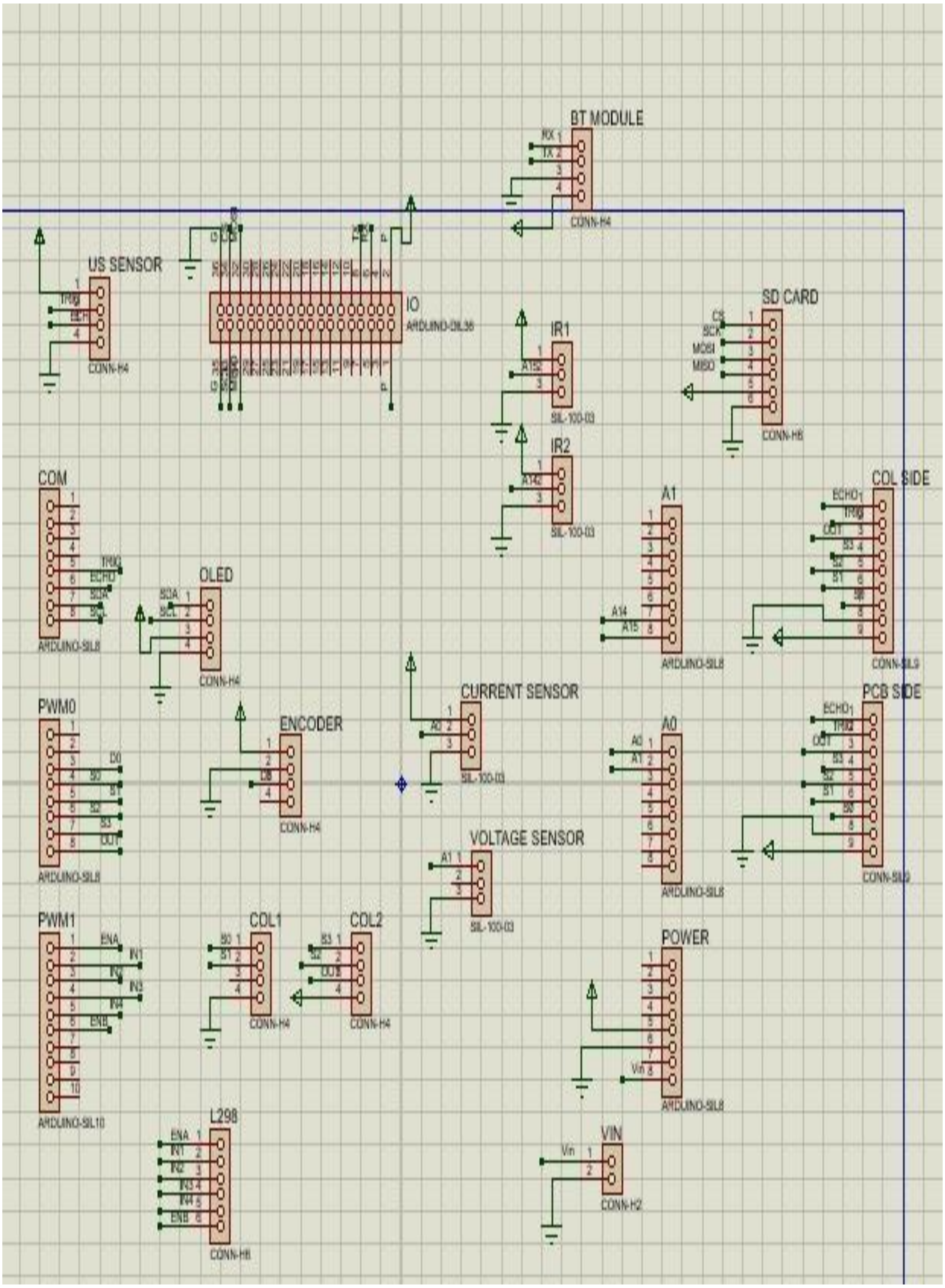
2.3 List of Features and Operational Specification

The preliminary product specification was established, outlining the features and operational requirements of the line-following robot.

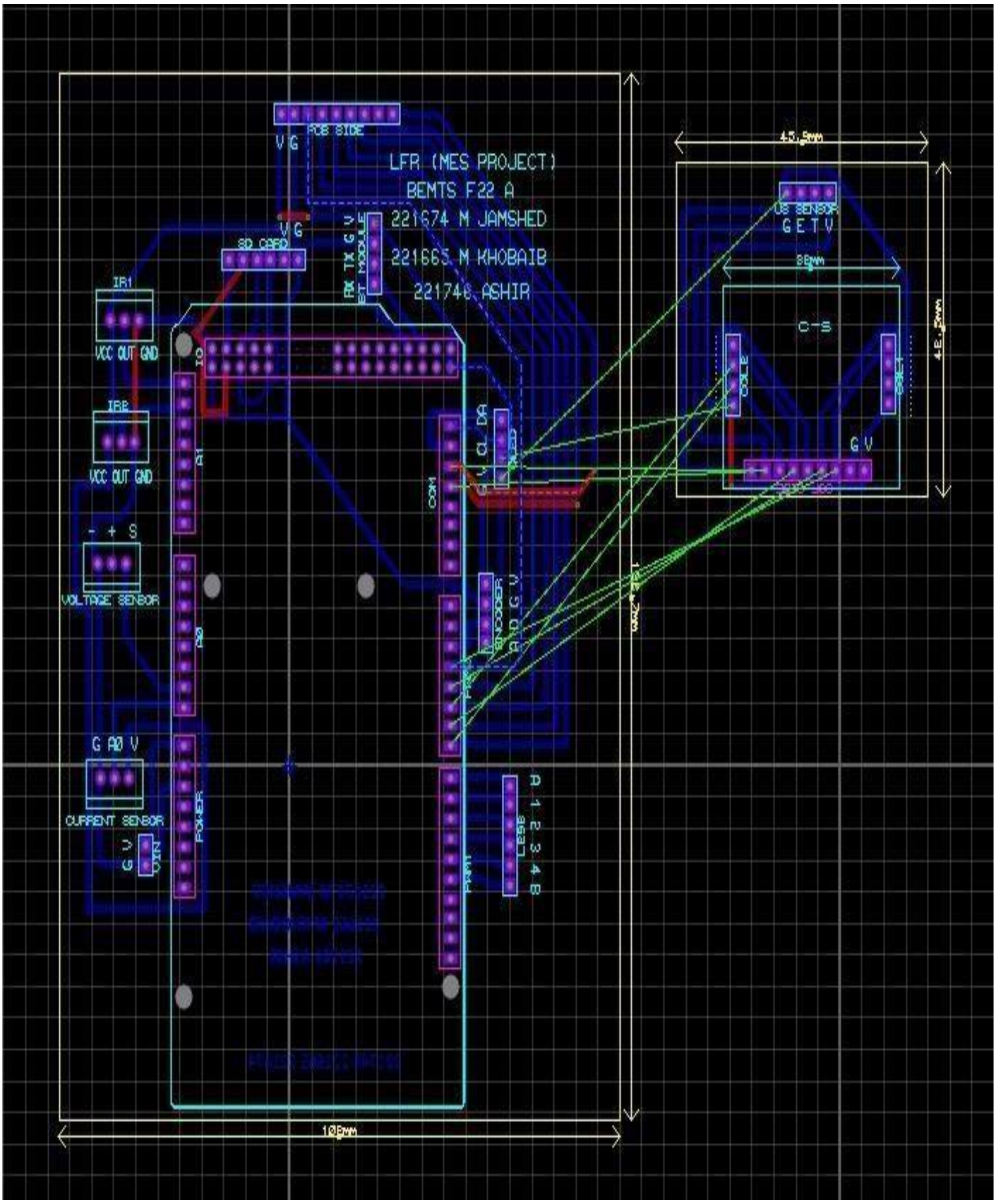
2.4 Project Development Process

The design process of the mechatronics system, including conceptualization, design, prototyping, and testing, was discussed in this section.

Schematic:

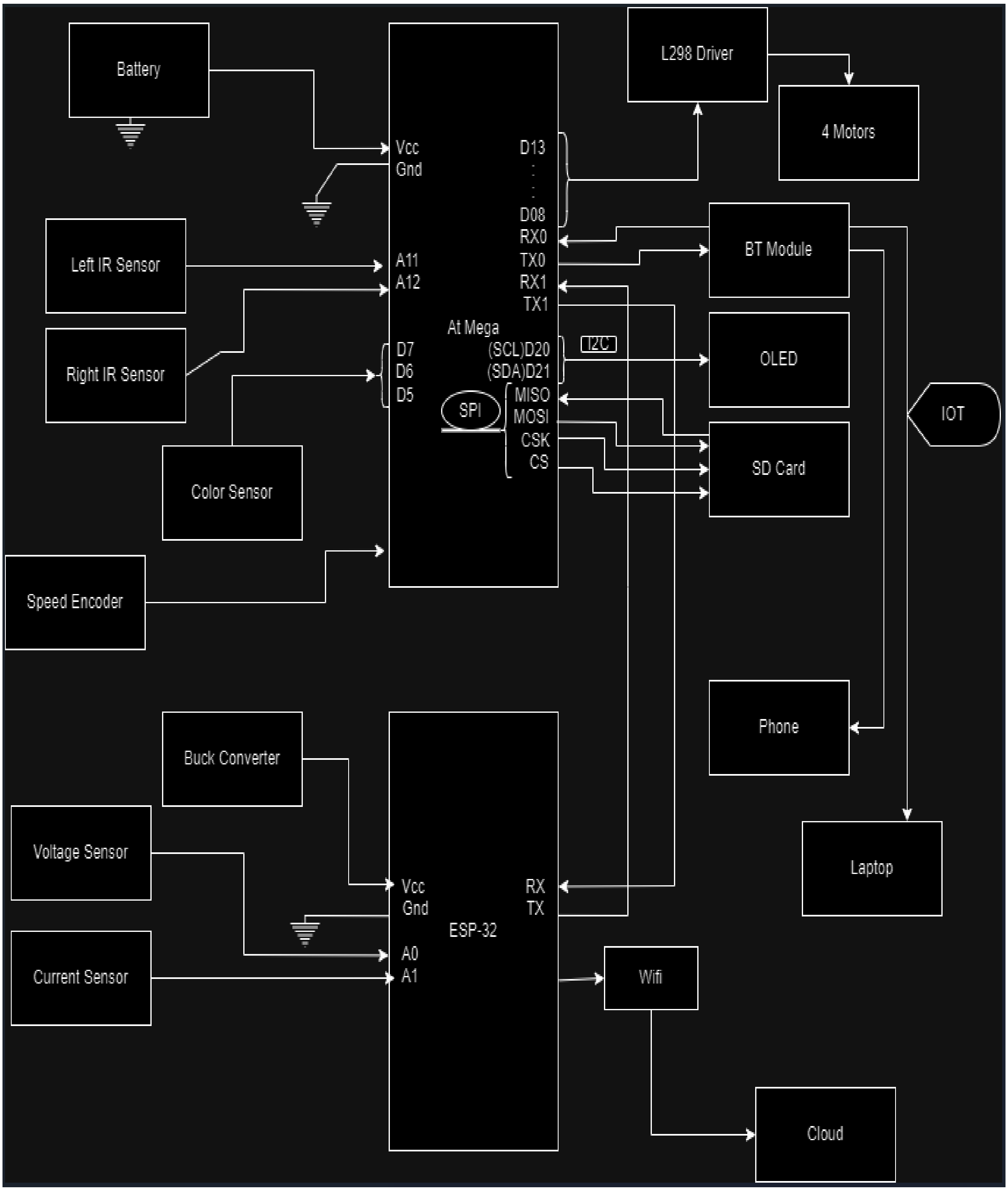

BT MODULE
US SENSOR
IO
SD CARD
IR1
IR2
COM
OLED
A1
COL SIDE
PWM0
ENCODER
CURRENT SENSOR
A0
PCB SIDE
VOLTAGE SENSOR
PWM1
COL1
COL2
POWER
L298
VIN

PCB Design:


PCB SIDE
V G
LFR (MES PROJECT)
BEMTS F22 A
221674 M JAMSHED
221665 M KHOBAIB
221746 ASHIR
SD CARD
IR1
VCC OUT GND
IR2
VCC OUT GND
- + S
VOLTAGE SENSOR
G A0 V
CURRENT SENSOR
45.5mm
US SENSOR
G E T V
38mm
G V
108mm

2.5 Basic Block Diagrams:

Basic block diagrams of the entire system and its subcomponents were created using tools like Draw.io, providing a visual representation of the system architecture.



2.6 Deliverables with Complete Specification Sheet

Detailed deliverables, including specification sheets for components and subsystems, were compiled to ensure clarity and alignment with project goals.

Speed	70 cm /s (depends of battery)
Elevation	30°
Width of Path	1.9 cm – 3.15 cm
Battery Voltage	9V – 12V
Colour Avoidance	Red
Obstacle Avoiding Range	10 cm
Weight	750 – 800 gram
Loading Capacity	1.1 Kg
Body Type	Plastic
Drive	4 WD
Motor Type	TT Motors

Chapter 3: Product Design

3.1 System Consideration for the Design

The product design process involved careful consideration of various system requirements to ensure that the final design would meet all functional and performance criteria. Factors such as the size, weight, and power requirements of the robot were analyzed to ensure compatibility with the chosen chassis and components. Additionally, considerations were made for the environmental conditions in which the robot would operate, ensuring that the design would be robust and reliable in a range of scenarios.

3.2 Criteria for Component Selection

The selection of components for the robot was based on the final approved project specification, which outlined the required performance metrics and functionality. Criteria such as performance, durability, and cost-effectiveness were considered when choosing components to ensure that the final design would meet the project's goals within the allocated budget. Compatibility with other system components and ease of integration were also key factors in the selection process.

3.3 Free Body Diagrams

Free body diagrams were created to illustrate the forces acting on the robot and to determine the center of gravity. These diagrams were essential for ensuring the stability and balance of the robot during operation, as they helped to identify areas where additional support or counterbalancing may be required. By carefully analyzing these diagrams, the design team was able to optimize the placement of components to achieve the desired performance and stability.

3.4 Design Calculation

Dynamic and static calculations were performed to determine the forces and torques experienced by the robot during operation. These calculations were essential for selecting suitable actuators and motors that could provide the necessary power and torque to drive the robot's movement. By accurately calculating these values, the design team was able to ensure that the chosen components would be able to meet the performance requirements of the robot.

3.5 Compute Forces and Torques

Forces and torques were computed in SI units, and equations were provided to highlight the calculations and their relevance to the design process. These calculations were used to determine the required specifications for components such as motors, gears, and structural supports. By accurately calculating these values, the design team was able to ensure that the robot would be able to perform its intended tasks with precision and efficiency.

3.6 Committed Accuracy and Resolution System

The design aimed for a high level of accuracy and resolution in sensor readings and actuator movements to ensure precise navigation and control. This required careful selection of sensors and actuators that could provide the necessary performance while remaining within the project's budget constraints. By prioritizing accuracy and resolution in the design process, the team was able to develop a robot that could meet the project's requirements with a high degree of precision.

The width of the path was to be specifically calibrated.

3.7 Deliverables with Calculated Values

The deliverables included calculated values of forces for the actuator section, along with a discussion of trade-offs and considerations in the final choice of actuators. These calculations were essential for ensuring that the chosen actuators would be able to provide the necessary power and torque to drive the robot's movement. By carefully considering these values, the design team was able to select actuators that could meet the performance requirements of the robot while remaining within the project's budget constraints.

Chapter 4: Mechanical Design

4.1 Mechanism Selection

The selection of mechanisms for the robot was based on a detailed analysis of the requirements and constraints of the project. Factors such as speed, torque, and precision were considered when choosing mechanisms such as rack and pinion, pulleys, and gears. Each mechanism was selected based on its ability to meet the specific performance requirements of the robot while ensuring smooth and reliable operation.

4W Driver:

A 4-wire driver typically controls devices like stepper motors or resistive touchscreens, utilizing four connections to manage power, ground, and two signal lines for precise operation. For stepper motors, a 4-wire driver sequentially energizes coils to control movement, while for touchscreens, it applies and measures voltages across X and Y layers to detect touch positions, ensuring accurate and synchronized functionality.

4.2 Platform Design

The design of the robot's platform was crucial for ensuring stability, durability, and ease of assembly. The platform was designed to accommodate all the required components, including the chassis, motors, sensors, and electronics. Special attention was paid to the placement of components to ensure optimal weight distribution and balance, which are critical for the robot's overall performance.

4.3 Material Selection and Choices

The choice of materials for the robot's construction was based on a thorough analysis of the mechanical properties and cost of various materials. Factors such as strength, weight, and durability were considered when selecting materials for the chassis, platform, and other structural components. The final choice of materials was made to ensure that the robot would be able to withstand the rigors of its intended use while remaining within the project's budget constraints.

4.4 3D CAD Design and Analysis

The mechanical design of the robot was developed using 3D CAD software to create detailed models of all components and assemblies. These models were used to conduct stress analysis and simulate the robot's performance under various conditions. The CAD models were also used to create detailed drawings and specifications for manufacturing the robot's components.

4.5 Factor of Safety and Maximum Stress Analysis

Factor of safety and maximum stress analysis were conducted to ensure that the robot's components would be able to withstand the expected loads and forces during operation. These analyses helped to identify areas of potential weakness in the design and allowed for modifications to be made to improve the overall strength and reliability of the robot.

4.6 Actuators with Specification and Datasheet

The selection of actuators for the robot was based on their ability to provide the required torque, speed, and precision for the robot's movement. The specifications and datasheets of selected actuators were carefully reviewed to ensure that they met the project's requirements and were compatible with the rest of the robot's components.

4.7 Deliverable of Complete CAD with Discussion

The deliverable for this chapter included a complete CAD model of the robot, along with a discussion of the design process and considerations that went into the selection of components and materials. The CAD model was used as a reference for manufacturing the robot and served as a visual aid for understanding the overall design and layout of the robot.

4.8 Additional Information

Any additional information or details relevant to the mechanical design phase of the project would be included here. This could include discussions of design iterations, challenges encountered during the design process, and any innovative solutions developed to overcome these challenges.

Chapter 5: Electronics Design and Sensor Selections

5.1 Component Selection

The selection of components for the robot's electronics was based on the project's requirements for performance, reliability, and cost. Components such as microcontrollers, sensors, motor drivers, and communication modules were chosen for their compatibility with the rest of the system and their ability to meet the project's specifications.

- Arduino mega
- IR sensors
- Ultrasonic sensor
- Colour sensor
- Voltage and current sensor
- SD card module
- L298 motor driver
- Motors
- OLED
- Bluetooth module
- Encoder
- ESP-32 Wroom

5.2 Sensors Along with Specification and Features

Various sensors were selected for the robot, including IR sensors, ultrasonic sensors, and color sensors, each chosen for its ability to provide the necessary input for the robot's control system. The specifications and features of each sensor were carefully reviewed to ensure they met the project's requirements for accuracy, range, and sensitivity.

5.3 Power Requirements and Power Supply Design

The power requirements for the robot were calculated based on the power consumption of each component and the expected operating conditions. A power supply system was designed to provide the necessary voltages and currents to all components, taking into account factors such as efficiency, reliability, and safety.

5.4 Motor Selection Current/Voltage/Speed/Torque

Motors were selected based on their ability to provide the required torque and speed for the robot's movement. The specifications of each motor, including current, voltage, speed, and torque, were carefully considered to ensure they met the project's requirements for performance and efficiency.

5.5 Feedback Mechanism Positional Sensors

Positional sensors were included in the design to provide feedback on the robot's position and orientation. These sensors were selected based on their accuracy, resolution, and compatibility with the rest of the system, ensuring they could provide the necessary feedback for precise control of the robot.

5.6 Deliverable of Complete Electronics Design with A4 Size Schematic and PCB with Discussion

The deliverable for this chapter included a complete electronics design for the robot, including schematics and PCB layouts. The design was accompanied by a detailed discussion of the design process, component selection criteria, and considerations for PCB layout and routing.

5.7 Components and their Working

Arduino mega:

The **Arduino Mega 2560** is a powerful microcontroller board designed for projects that require an abundance of **I/O pins**, ample sketch memory, and more RAM. Here's how it works:

Hardware Overview:

The Mega 2560 boasts **54 digital I/O pins** and **16 analogue inputs**, making it suitable for complex projects.

It's a recommended board for applications like **3D printers** and **robotics** due to its extensive capabilities.

The board can draw power either from the **USB connection** or an external power supply.

Programming:

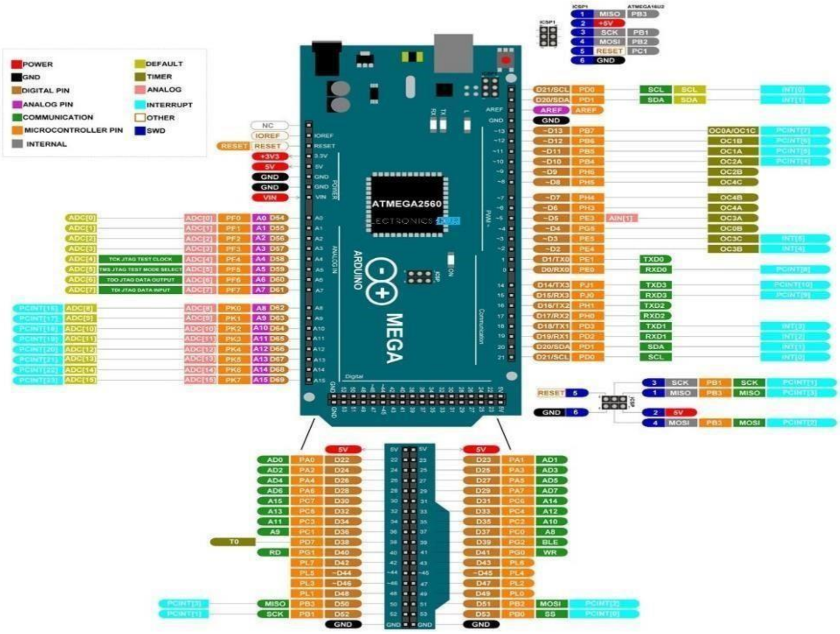
The Mega 2560 is programmed using the **Arduino Software (IDE)**, which is a common development environment for all Arduino boards. ◦ You can use the **Arduino Web Editor** (online) or the **Arduino Desktop IDE** (offline) to write and upload your sketches. ◦ To get started, connect your Mega2560 board to your computer via a **USB cable**.

Open the **LED blink example sketch** (File > Examples >

01.Basics > Blink) to test your setup.

Selecting Board Type and Port:

Choose the appropriate board type in the **Tools** > **Board menu** (Mega2560 with ATmega2560 microcontroller) ◦ Select the correct **serial port** (likely COM3 or higher) from the **Tools** > **Serial Port menu**.



IR sensors:

Certainly! **Infrared (IR) sensors** operate based on the principle that all objects with a temperature above absolute zero emit heat energy in the form of **infrared radiation**. These sensors detect this radiation and convert it into a form that can be interpreted or measured. Here's how they work:

Emitter and Receiver:
An IR sensor consists of two essential components: an **IR LED (emitter)** and an **IR photodiode (receiver)**. ◦ The IR LED emits infrared light, which is invisible to the human eye. The IR photodiode is sensitive to this emitted light and acts as the receiver.

Detection Mechanism:
When an object comes within the sensor's range, it reflects or emits IR radiation. ◦ The IR light from the LED strikes the surface of the object and interacts with it. ◦ The photodiode detects the altered intensity of IR light due to this interaction. ◦ As a result, the photodiode's **resistance** and **output voltage** change proportionally to the received IR light.

Applications:

IR sensors are commonly used for:

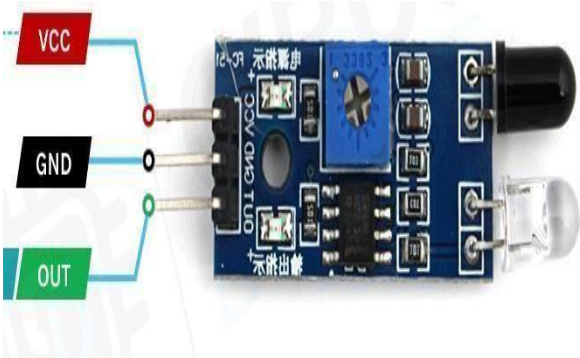
Proximity sensing: Detecting the presence or absence of an object.

Heat sensing: Measuring the temperature of a surface.

Motion detection: Identifying movement in security systems, automatic doors, and robotics.

Indirect and Direct Types:

In the **direct type**, the IR LED and photodiode are aligned directly, without any obstacles. ｡ In the **indirect type**, a solid object is placed between them. The IR light reflects off the object and reaches the photodiode.



Ultrasonic sensor:

Certainly! The **Ultrasonic Sensor** is an electronic device that calculates distance by emitting sound waves and collecting their echoes. Here's how it works:

Hardware Overview:

The Ultrasonic Sensor features an **adjustable pulse width** and can measure objects from up to **4.5 meters away**. ｡ It's versatile for measuring both short and long distances without making physical contact with the target object. ｡ Common applications include **obstacle avoidance systems in robotics**, **autonomous cars**, and **parking technologies**.

Working Principle:

The sensor uses **ultrasound**, which travels faster than audible sound. ｡ It consists of two major components:

Transmitter: Generates sound waves using a piezoelectric crystal.

Receiver: Detects the reflected ultrasonic waves.

When the transmitter emits ultrasonic sound, it travels through the air. ｡ If an object is present, the sound waves reflect off it and return to the receiver. ｡ The time taken for the sound waves to travel and return is used to calculate the distance.

Applications:

Ultrasonic sensors are widely used as **proximity sensors**.

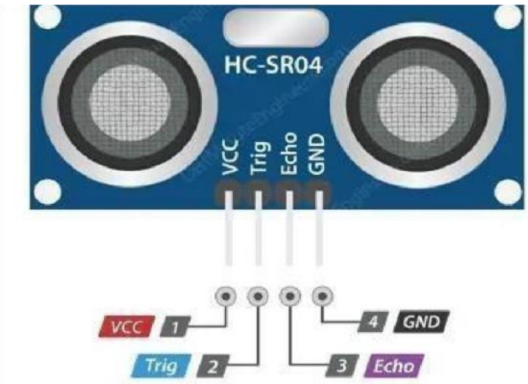
They play a crucial role in **anti-collision safety systems**, **automated obstacle detection**, and **factory engineering**.

Unlike infrared (IR) sensors, ultrasonic sensors are less affected by smoke, gases, and airborne particles.

Beyond Distance Measurement:

Ultrasonic sensors are multitasking experts:

They measure liquid levels in containers.



Colour Sensors:

Certainly! A **colour sensor** operates based on the principle of **light reflection**.

Here's how it works:

Illumination:

The sensor emits **white light**, which contains all colours, toward the object whose colour needs to be determined. ◦ Depending on the colour of the object, a specific part of the light spectrum is **reflected back** to the sensor.

Detection Mechanism:

The sensor contains a **receiver** that detects the reflected light. ◦ When the white light hits the object, certain wavelengths corresponding to the object's colour are reflected. ◦ By analysing the intensity of these reflected wavelengths, the sensor determines the **colour of the target object**.

RGB Scale:

Colour sensors typically work in the **RGB (Red, Green, Blue)** scale. ◦ They categorize colors based on the activation of filters sensitive to wavelengths at 580nm (red), 540nm (green), and 450nm (blue). ◦ A **light-to-voltage converter** in the sensor generates a voltage proportional to the detected colour.

Applications:

Colour sensors find applications in various fields:

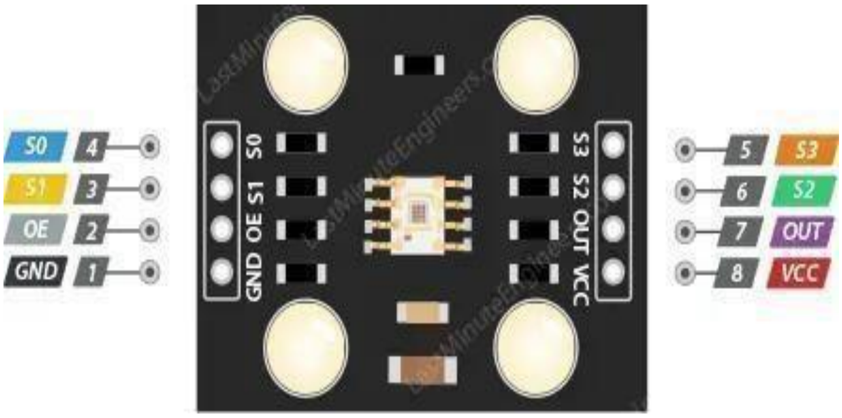
Industrial automation: For quality control, sorting, and identifying products.

Medical devices: In diagnostics and monitoring.

Security systems: Detecting coloured objects or markings.

Filtering IR and UV:

To determine accurate colours, colour sensors filter out **infrared (IR)** and **ultraviolet (UV)** radiations. ｡ These sensors are thin, easily interfaced with microcontrollers, and popular for **Arduino projects**.



Voltage and Current sensor:

Certainly! Let's delve into the working principles of **voltage sensors** and **current sensors**:

Voltage Sensors:

A **voltage sensor** calculates and monitors the amount of voltage in an object. ｡ It can determine both **AC voltage** and **DC voltage** levels. ｡ The input to the voltage sensor is the voltage itself, and the output can take various forms:

Analog voltage signals: Representing the voltage level.

Switches: Triggered based on voltage thresholds.

Audible signals: Such as buzzers or alarms.

Current signals: Indicating the voltage level.

One common implementation uses a **voltage divider** circuit. ｡ Two main types of voltage sensors are:

Capacitive type voltage sensor: Utilizes the voltage division principle based on capacitors.

Resistive type voltage sensor: Relies on resistors for voltage measurement. ｡ Capacitive voltage sensors work by exploiting the voltage distribution across capacitors in series. When the sensor's tip is placed near a live conductor, the voltage accumulates across the sensing circuit, triggering indicators like lights or buzzers1.

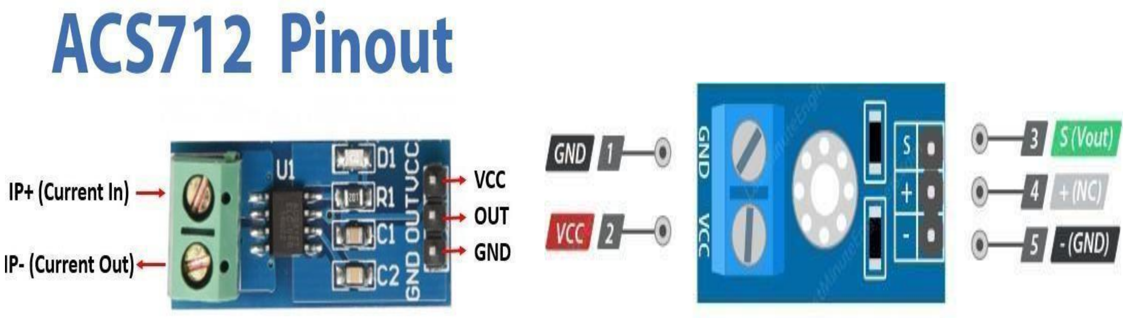
Current Sensors:

A **current sensor** measures the flow of electric current in a circuit. ｡ One common type is the **air-core coil current sensor**:

It consists of an air-core coil wound around the conductor being measured.

When AC current flows through the conductor, it generates a magnetic field.

The output voltage represents the **time derivative** of the measured current. ◦ Current sensors are crucial for applications like power quality monitoring, energy management, and motor control2.



3. SD card module:

Certainly! An **SD Card Module** is a circuit board equipped with an SD card slot and a set of pins. These modules allow microcontrollers, such as **Arduino** or **Raspberry Pi**, to interact with SD cards by reading and writing data. Here's how they work:

Intermediary Role: The SD Card Module acts as an intermediary between the microcontroller and the SD card. It translates commands from the microcontroller into a format that the SD card can understand and vice versa.

Communication Protocol: These modules primarily operate using the **SPI (Serial Peripheral Interface)** communication protocol. SPI is a synchronous serial data link that allows simultaneous data transmission and reception. The four essential logic signals in SPI are:

SCLK (SerialClock): Output from the master (microcontroller).

MISO (Master In Slave Out): Output from the slave (SD card).

MOSI (Master Out Slave In): Output from the master (microcontroller).

SS (Slave Select): Output from the master, unique for each device.

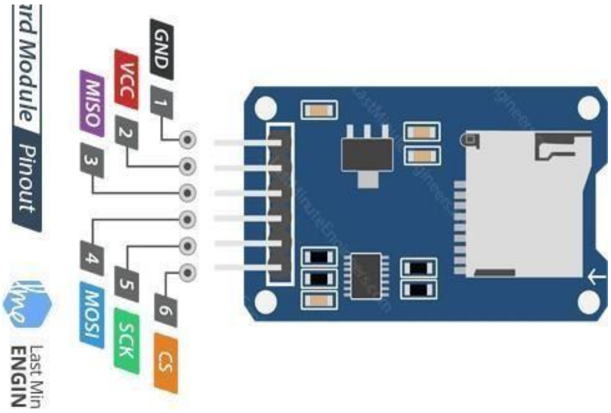
Applications:

Data Logging: SD Card Modules are commonly used for data logging. With a microcontroller and an SD Card Module, you can collect data from sensors or other input devices, process it, and store it on an SD card. This is useful for long-term data collection, such as monitoring temperature or humidity in a greenhouse. ◦ **Additional Storage**: Microcontrollers often have limited onboard flash memory. SD Card Modules provide gigabytes of extra storage, essential for projects dealing with large data files like audio or video.

Choosing the Right Module:

Compatibility: Ensure the module is compatible with your microcontroller (most work with 3.3V logic levels).

SD Card Size: Check the maximum SD card size supported by the module (SD, SDHC, or SDXC).



4. L298 motor driver:

Certainly! The **L298N Motor Driver** is a versatile module used to control DC motors and stepper motors. Let's delve into how it works:

L298 Motor Driver IC:

The heart of the L298N module is the **L298 dual-channel HBridge motor driver IC**. ◦ It accepts standard TTL logic levels (control signals) and can handle inductive loads like relays, solenoids, DC motors, and stepper motors. ◦ The L298N operates within an operating voltage range of **+5V to +46V** and allows a maximum current of **3A** per output. ◦ It features two enable inputs that independently enable or disable the device based on input signals. ◦ A heat sink is attached to the L298 IC to dissipate heat generated during operation.

Functionality:

The L298N module combines two essential techniques for motor control:

PWM (Pulse Width Modulation): Used to control motor speed. By adjusting the average input voltage through a series of ON-OFF pulses, the motor's speed can be varied.

H-Bridge Configuration: Used to control motor rotation direction. The H-bridge allows the motor to rotate clockwise or counterclockwise. ◦ These modules can simultaneously control two DC motors or one stepper motor.

Hardware Overview:

The L298N module consists of two main components:

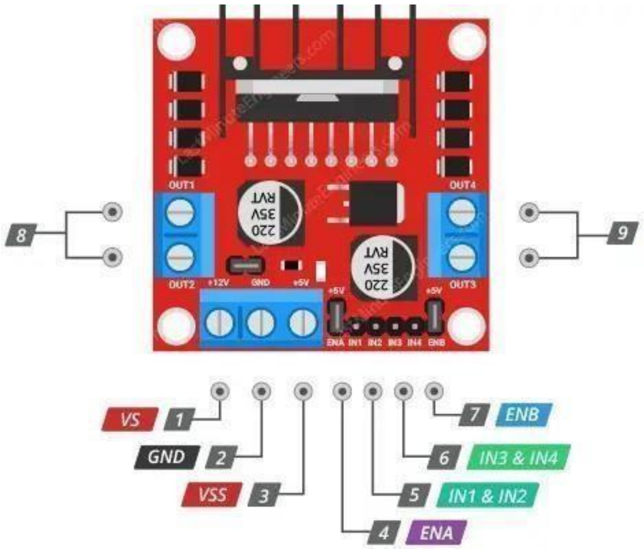
L298 motor driver IC: Handles motor control.

78M05 5V regulator: Provides regulated 5V power.

When the power supply is less than or equal to 12V, the internal circuitry is powered by the voltage regulator. Above 12V, a separate 5V supply is needed for the internal circuitry.

Applications:

Robotics: Ideal for building two-wheeled robotic platforms due to its dual motor control capability. ◦ **Data Logging**: Used in projects where data from sensors or other devices needs to be logged onto an SD card. ◦ **Additional Storage**: Provides extra storage for projects dealing with large data files (audio, video, etc.).



OLED Screen:

Certainly! Let's delve into the fascinating world of **OLED (Organic LightEmitting Diode)** screens and understand how they work: 1. **What is an OLED?**

An OLED is a type of display technology that produces light directly from organic molecules. ◦ Unlike traditional LEDs (lightemitting diodes), which use inorganic semiconductors, OLEDs utilize organic materials based on carbon atoms.

Basic Structure:

An OLED display consists of several layers sandwiched together:

Emissive Layer: This layer contains organic molecules that emit light when an electric current passes through them.

Cathode: The cathode injects electrons into the emissive layer.

Anode: The anode removes electrons from the emissive layer. ◦ When electricity flows from the cathode to the anode, it excites the organic molecules, causing them to emit colored light.

Color Production:

The primary OLED materials emit light in specific colors:

Yellow: One of the primary colors produced by OLEDs.

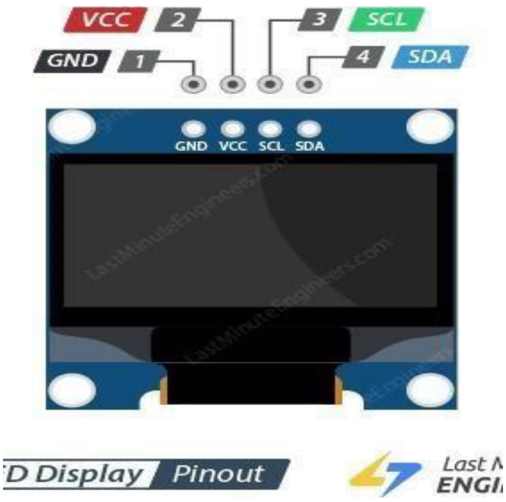
Blue: Another essential color.

To create a full-color display, color filters are used to combine yellow and blue emissions into red, green, and other colors.

Advantages of OLEDs:

Self-Emitting: OLEDs emit their own light, eliminating the need for a separate backlight. This results in deep black levels and thinner displays. ○ **Thin and Flexible**: OLED screens are incredibly thin and lightweight, making them suitable for curved displays and flexible applications. ○ **Vivid Colors**: OLEDs produce vibrant and accurate colors due to their direct emission properties.

Applications:
TVs: OLED TVs offer stunning picture quality with true blacks and rich colors. **Smartphones**: Many high-end smartphones use OLED displays for their vivid visuals.



Bluetooth module:

Certainly! Let's explore the fascinating world of **Bluetooth modules** and understand how they work:

Introduction to Bluetooth Modules:
A **Bluetooth module** is a specialized chip designed to wirelessly connect two compatible devices for communication. ○ These modules act as an interface between microcontrollers (such as Arduino or Raspberry Pi) and various devices. ○ Bluetooth technology operates using low-energy waves, allowing seamless data transfer between devices.

Working Mechanism:
Bluetooth Protocol: Bluetooth modules work based on the **Bluetooth wireless technology** protocol.

Frequency and Band: They operate in the **2.4GHz ISM (Industrial, Scientific, and Medical)** band.

Spread Spectrum: Bluetooth uses **frequency hopping** to avoid interference and ensure reliable communication. ○ **Full-Duplex Communication**: It enables simultaneous data transmission and reception.

Applications:

Audio Streaming: Bluetooth modules are commonly used for audio streaming between devices like headphones, speakers, and car stereos. ◦ **Data Transfer**: They facilitate data exchange between smartphones, laptops, and other gadgets. ◦ **Gaming**: Bluetooth controllers and accessories enhance gaming experiences.

Examples of Bluetooth Modules:

HC-05: A classic module used for audio streaming, data transfer, and file sharing. ◦

HC-06: Similar to HC-05 but with additional features.

HM-10: Known for its low energy consumption, ideal for IoT applications.

Encoder:

Certainly! An **optocoupler**, also known as an **optoisolator**, is a fascinating electronic component that bridges the gap between two electrically isolated sections of a circuit. Let's explore how it works:

Basic Structure:

An optocoupler consists of two primary components:

LED (Light-Emitting Diode): The input side of the optocoupler contains an LED. When current flows through the LED, it emits infrared light.

Phototransistor or Photodiode: The output side of the optocoupler contains a phototransistor or photodiode. These components detect light and respond accordingly.

Working Mechanism:

When an electrical signal (voltage or current) is applied to the LED, it emits infrared light. ◦ The emitted light falls onto the photosensitive component (phototransistor or photodiode) on the output side. ◦ The photosensitive component responds to the incoming light by either conducting current (in the case of a phototransistor) or changing its resistance (in the case ofa photodiode). ◦ This interaction allows signals to pass from the input side to the output side without any direct electrical connection.

Applications:

Isolation: Optocouplers provide electrical isolation between different parts of a circuit. For example:

In power supplies, they separate the high-voltage primary side from the low-voltage secondary side.

In motor control circuits, they protect sensitive microcontrollers from high-voltage spikes. ◦ **Signal Transmission**: Optocouplers transmit signals across isolation barriers:

- In digital communication interfaces (RS-232, RS-485), they prevent ground loops and noise.
- In audio equipment, they isolate audio signals to reduce interference. ◦ **Switching and Control**: Optocouplers can control switching elements (transistors, relays) without direct physical contact:
- When the LED is activated, the phototransistor conducts, allowing current to flow through an external load.
- This feature is useful for applications like solid-state relays and motor control.

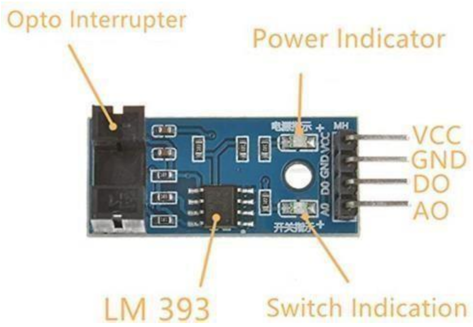
4. **Variants**:

Phototransistor Optocouplers: These have a phototransistor on the output side.

Photodiode Optocouplers: These use a photodiode for detection.

Triad Output Optocouplers: Designed for AC switching applications.

Linear Optocouplers: Used for analogue signal transmission.



Chapter 6: Software/Firmware Design

6.1 Input Output Pinouts

The input and output pinouts of the microcontroller were carefully selected to ensure compatibility with the rest of the system and to facilitate the connection of sensors, actuators, and other peripherals. Each pin was assigned a specific function based on the requirements of the system.

6.2 Controller Selections with Features

The microcontroller was selected based on its features, including processing power, memory, and available peripherals. The selected microcontroller met the project's requirements for performance and compatibility with the rest of the system.

6.3 Software Design Details & User Requirements

The software design for the robot's control system was developed based on the requirements specified in the project brief. The design included details of the software architecture, algorithms used for control and navigation, and user interface design.

6.4 State Machine & System Flow Diagram

A state machine was developed to model the behavior of the robot and to define its states and transitions. The system flow diagram illustrated how data and control signals flowed through the system, including inputs from sensors, outputs to actuators, and communication with external devices.

6.5 Flowchart for Each Circle of State Machine

Flowcharts were created to illustrate the logic and decision-making process for each state of the state machine. These flowcharts helped to clarify the control logic of the robot and ensure that all possible states and transitions were accounted for.

6.6 User Cases for Running Your System (Test Cases)

User cases were developed to define the various scenarios in which the robot would operate and to specify the expected behavior of the system in each scenario. These test cases were used to validate the software design and ensure that it met the project's requirements.

6.7 Deliverable of Complete Commented Code as per State Machine and Discussion

The deliverable for this chapter included the complete commented code for the robot's control system, organized according to the state machine. The code was accompanied by a discussion of the design decisions, challenges faced during implementation, and any optimizations made to improve performance.

6.8 Additional Information

Any additional information or details relevant to the software/firmware design phase of the project would be included here. This could include discussions of software testing methodologies, debugging techniques, and integration with the rest of the system.

Chapter 7: Simulations and Final Integrations (Test Definition Phase)

7.1 Integrations and Testing of All Hardware and Software Components Separately

Before final integration, each hardware and software component was tested separately to ensure that they functioned correctly. This included testing sensors, actuators, and the microcontroller individually to verify their performance.

7.2 Simulations (Proteus with State Machines)

Simulations were conducted using Proteus to simulate the behavior of the robot's control system. The simulations were based on the state machine developed earlier and helped to validate the design before actual implementation.

7.3 Simulation PCB (3D Diagram with Connector and Power Interface)

A simulation PCB was designed to simulate the connections and interactions between components on the actual PCB. This helped to identify any potential issues with the PCB layout and design before fabrication.

7.4 Simulation CAD, etc.

In addition to PCB simulation, other aspects of the robot's design, such as the mechanical structure and overall system layout, were simulated using CAD software. These simulations helped to ensure that the design was robust and met the project's requirements.

7.5 Actual Wiring Plan with Color Codes (Wires External to System from Sensor, Power Supply, Actuator, etc.)

An actual wiring plan was developed to guide the physical assembly of the robot. The plan included color codes for wires to indicate their function (e.g., power, ground, signal) and connections to external components such as sensors, power supplies, and actuators.

7.6 Discussion on Simulations with Possible Challenges

The simulations revealed several challenges, including issues with sensor calibration, motor control algorithms, and communication between components. These challenges were addressed through iterative testing and refinement of the design.

7.7 Additional Information

Any additional information or details relevant to the simulation and final integration phase of the project would be included here. This could include discussions of simulation results, lessons learned, and recommendations for future projects.

Chapter 8: System Test Phase

8.1 Final Testing

The final testing phase involved comprehensive testing of the entire robot system to ensure that it met all design specifications and performance requirements. This included testing the robot's ability to follow a line accurately, detect obstacles using the ultrasonic sensor, and recognize colors using the color sensor.

8.2 Identified Challenges and Solutions
During the final testing phase, several challenges were identified, such as issues with sensor calibration, motor control stability, and communication reliability. These challenges were addressed through software adjustments, hardware modifications, and sensor recalibration.

8.3 Project Actual Pictures
Pictures of the completed robot were taken during the final testing phase to document the physical appearance and components of the robot. These pictures were used in the project report to provide a visual representation of the final product.

8.4 Final Observations and Performance Evaluation
The robot's performance was evaluated based on its ability to follow a line accurately, avoid obstacles, and respond to commands from the user interface (Bluetooth and WiFi modules). The evaluation included measuring the robot's speed, accuracy, and responsiveness to various stimuli.

8.5 Any Other Relevant Information
Any additional information or details relevant to the system test phase, such as unexpected findings, last-minute modifications, or final thoughts on the project's outcome, would be included here.

Chapter 9: Project Management

9.1 Individual Contributions
Each team member contributed significantly to the project's success. Responsibilities were divided based on individual strengths, with each member taking on specific roles such as hardware design, software development, testing, and documentation.

9.2 Project Success and Challenges
The project was largely successful, meeting most of its objectives and design requirements. However, several challenges were encountered along the way, including technical difficulties, time constraints, and communication issues. These challenges were overcome through teamwork, perseverance, and creative problem-solving.

9.3 Team Member Feedback
Team members provided constructive feedback on each other's performance, highlighting areas of improvement and acknowledging strengths. This feedback was crucial in fostering a positive team dynamic and improving overall project efficiency.

9.4 Final Bill of Materials and Budget Allocation
A detailed bill of materials was compiled, including all components used in the project and their associated costs. The project budget was allocated judiciously, with funds allocated based on the criticality and priority of each component.

9.5 Word Count and Contribution Analysis
Each team member's contribution to the final report was analyzed based on word count, highlighting the individual effort put into the documentation process. This analysis helped ensure equitable distribution of workload and accountability.

9.6 Risk Management Lessons Learned

The project provided valuable lessons in risk management, highlighting the importance of identifying potential risks early, developing mitigation strategies, and being adaptable in the face of unforeseen challenges.

9.7 Any Other Relevant Information

Any additional information or reflections on the project management process, such as lessons learned, best practices identified, or suggestions for future improvements, would be included here.

Chapter 10: Feedback for Project and Course

10.1 Project Feedback

The project received positive feedback from both team members and external stakeholders. The functionality and performance of the line follower robot were praised, particularly its ability to navigate complex paths and adapt to changing conditions.

10.2 Course Feedback

The mechatronics engineering course provided a solid foundation for the project, equipping team members with the necessary knowledge and skills to design and implement complex mechatronic systems. Feedback on the course content, delivery, and assessment methods was generally positive, with suggestions for minor improvements.

10.3 Lessons Learned

The project provided valuable lessons in project management, teamwork, and technical skills. Team members gained hands-on experience in designing, building, and testing a mechatronic system, which will be invaluable in their future careers.

10.4 Future Improvements

Based on the feedback received, several areas for improvement were identified. These include enhancing the robot's speed and agility, improving its ability to navigate sharp turns and obstacles, and optimizing its power consumption for longer operation.

10.5 Applications

Here are five applications for the line-following robot (LFR):

1. **Industrial Automation:** In manufacturing plants, the LFR can transport materials between workstations, optimizing production efficiency and reducing labour costs.

2. **Warehousing and Logistics:** It can navigate warehouse shelves to locate and retrieve items for order fulfilment, streamlining inventory management processes.

3. **Education and STEM Learning:** The LFR serves as an educational tool for teaching robotics principles, programming, and sensor integration to students, fostering hands-on learning experiences.

4. **Home Assistance:** Adapted for household tasks, the robot can autonomously vacuum floors or deliver items within homes, offering convenience and assistance to occupants.

5. **Retail Guidance and Customer Service:** In retail environments, the LFR can guide customers to specific products or provide information about promotions, enhancing the shopping experience and reducing staff workload.

Chapter 11: Conclusion

11.1 Project Summary

The project involved the design and implementation of a line follower robot with various sensors and modules for navigation and communication. The robot was able to follow a predefined path, avoid obstacles, and communicate its status using OLED and Bluetooth modules.

11.2 Achievements

The project successfully met its objectives, demonstrating the team's ability to design and build a complex mechatronic system. The robot's performance exceeded expectations, showcasing its reliability and functionality in real-world scenarios.

11.3 Challenges

Throughout the project, the team faced several challenges, including sensor calibration, motor control, and communication issues. These challenges were overcome through collaboration, research, and iterative testing.

11.4 Future Work

There is potential for future enhancements to the robot, such as implementing more advanced navigation algorithms, integrating additional sensors for improved obstacle detection, and enhancing its communication capabilities.

11.5 Conclusion

In conclusion, the project was a valuable learning experience that allowed the team to apply theoretical knowledge to practical problems. The robot's successful development demonstrates the effectiveness of the mechatronics engineering curriculum at preparing students for real-world challenges.

Chapter 12: Recommendations

12.1 Recommendations for Future Projects

Based on our experience, we recommend future projects in mechatronics engineering to focus on interdisciplinary collaboration, thorough feasibility studies, and regular project updates to stakeholders.

12.2 Recommendations for Project Management

For effective project management, we suggest utilizing agile methodologies, maintaining clear communication channels, and conducting regular reviews to ensure project milestones are met.

12.3 Recommendations for Technical Improvements

In terms of technical aspects, we recommend exploring advanced sensor technologies, improving power management systems for longer operational durations, and integrating more robust communication protocols for enhanced data transfer rates.

12.4 Recommendations for Educational Enhancement

To enhance the educational experience, we propose incorporating more hands-on projects, real-world case studies, and industry collaborations to bridge the gap between academia and industry.

12.5 Final Thoughts

In conclusion, we believe that the successful completion of this project has not only enriched our understanding of mechatronics engineering but also provided valuable insights and lessons that will guide our future endeavours in this field.

Appendix:

Data sheet of AT MEGA:

Features

- High-performance, Low-power AVR® 8-bit Microcontroller
- RISC Architecture
  - 130 Powerful Instructions – Most Single Clock Cycle Execution
  - 32 x 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16 MHz
  - On-chip 2-cycle Multiplier
- Nonvolatile Program and Data Memories
  - 8K Bytes of In-System Self-programmable Flash
    Endurance: 1,000 Write/Erase Cycles
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - 512 Bytes EEPROM
    Endurance: 100,000 Write/Erase Cycles
  - 512 Bytes Internal SRAM
  - Up to 64K Bytes Optional External Memory Space
  - Programming Lock for Software Security
- Peripheral Features
  - One 8-bit Timer/Counter with Separate Prescaler and Compare Mode
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Three PWM Channels
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Three Sleep Modes: Idle, Power-down and Standby
- I/O and Packages
  - 35 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, 44-lead PLCC, and 44-pad MLF
- Operating Voltages
  - 2.7 - 5.5V for ATmega8515L
  - 4.5 - 5.5V for ATmega8515
- Speed Grades
  - 0 - 8 MHz for ATmega8515L
  - 0 - 16 MHz for ATmega8515

8-bit AVR® Microcontroller with 8K Bytes In-System Programmable Flash

ATmega8515
ATmega8515L

Preliminary

Data sheet of ESP-32:

ESP32 FEATURES & SPECS

ESP32 TECHNICAL SPECIFICATIONS

No.	Parameter Name	Parameter Value
1	Microprocessor	Tensilica Xtensa single-/dual-core 32-bit LX6 microprocessor(s)
2	CoreMark® score	1 core at 240 MHz: 504.85 CoreMark; 2.10 CoreMark/MHz
		2 cores at 240 MHz: 994.26 CoreMark; 4.14 CoreMark/MHz
3	Operating Voltage	3.3V
4	DC Current on 3.3V Pin	50 mA
5	DC Current on I/O Pins	40 mA
6	Maximum Operating Frequency	240MHz
7	Frequency Oscillators	8MHz (Internal Oscillator)
		Internal RC Oscillatoror
		2MHz ~ 60MHz External Crystal Oscillator(40MHz required for WiFi/BT)
		32kHz External Crystal Oscillator(For RTC)
8	Timers	2 x 64-bit Timers, 1 RTC Timer,

ESP32 PINOUT

1	DAC	2 Channels (8-bit, digital to analog converter)
2	ADC	2 Channels (8-bit, digital to analog converter)
3	Capacitive Touch Sensors	10
4	LED PWM	16 Channels

ESP32 COMMUNICATION PROTOCOLS

1	Wi-Fi	802.11 b/g/n (Speed upto 150Mbps)
2	Bluetooth	Supports Classic Bluetooth v4.2 BR/EDR & Bluetooth Low Energy(BLE)
3	Bluetooth Low Energy	Supports BLE
4	UART Protocol	3 Channels
5	SPI Protocol	4 Channels
6	I2C Protocol	2 Channels
7	I2S Protocol	2 Channels (for digital audio)
8	CAN Protocol	1 Channels

Data sheet of color sensor:

Pin	Name	Details
1.	S0	Output frequency scaling selection inputs.
2.	S1	Output frequency scaling selection inputs.
3.	OE	Enable for fo (active low).
4.	GND	Power supply ground.
5.	S3	Photodiode type selection inputs
6.	S2	Photodiode type selection inputs
7.	OUT	Output frequency (fo).
8.	V_{DD}	Supply Voltage

Inspired From: