Mansoura University
Faculty of Engineering
Mechatronics Department

Outdoor Self Driving and Mapping Robot

UNDER THE SUPERVISION OF:
Dr. Aber Twakol Khalil
Eng. Ahmed Ramadan Abdo

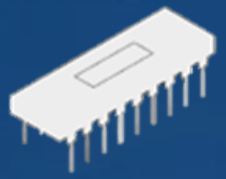
About our Project:

- Our project is a self-guided mobile robot that is used in Outdoor environment using ROS technology, used in autonomous and contactless delivery.
- The main function is to transport objects to a selected destination in dimensions specified campus.

Project Aim:


Dangerous Atmosphere
Deliver orders
Avoid Contact
Protect people
Contactless Robot Delivery

Technical Content



Hardware

Business

Mechanical

Software


Mechanical

Mechanical

Shape of the whole design

Manufacturing process

Parts & Sub-assemblies

Movement

Design

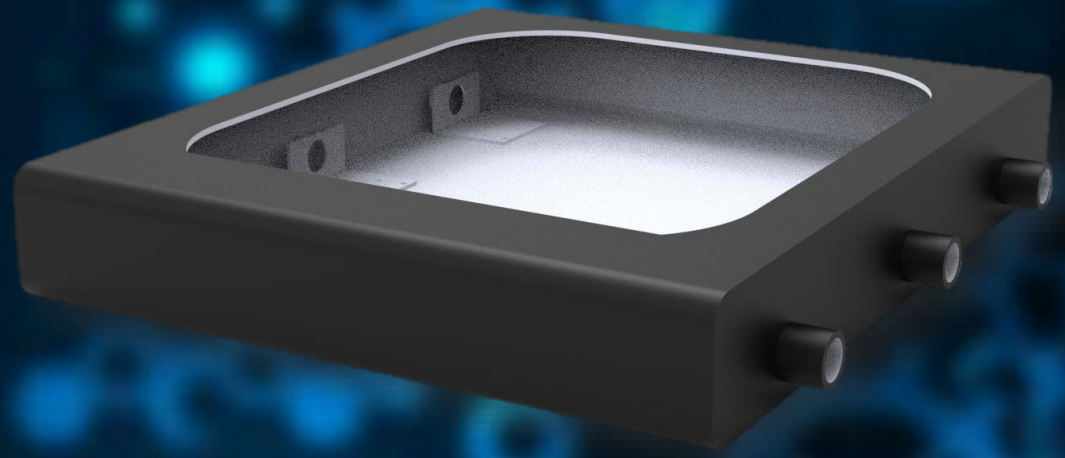
Challenges

CAD Design

SOLIDWORKS

Base

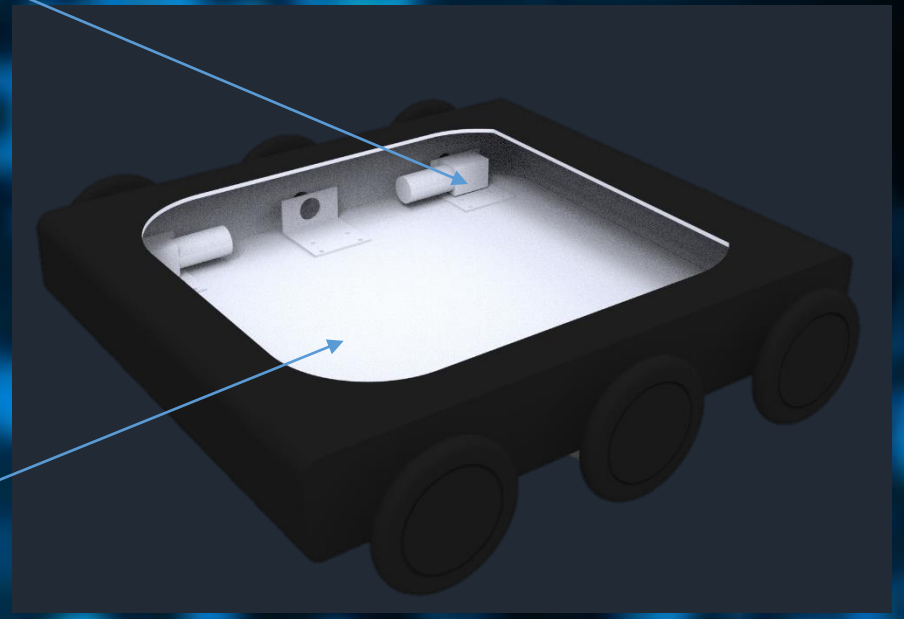
- Size 580 * 680
- Thickness 5mm



Base

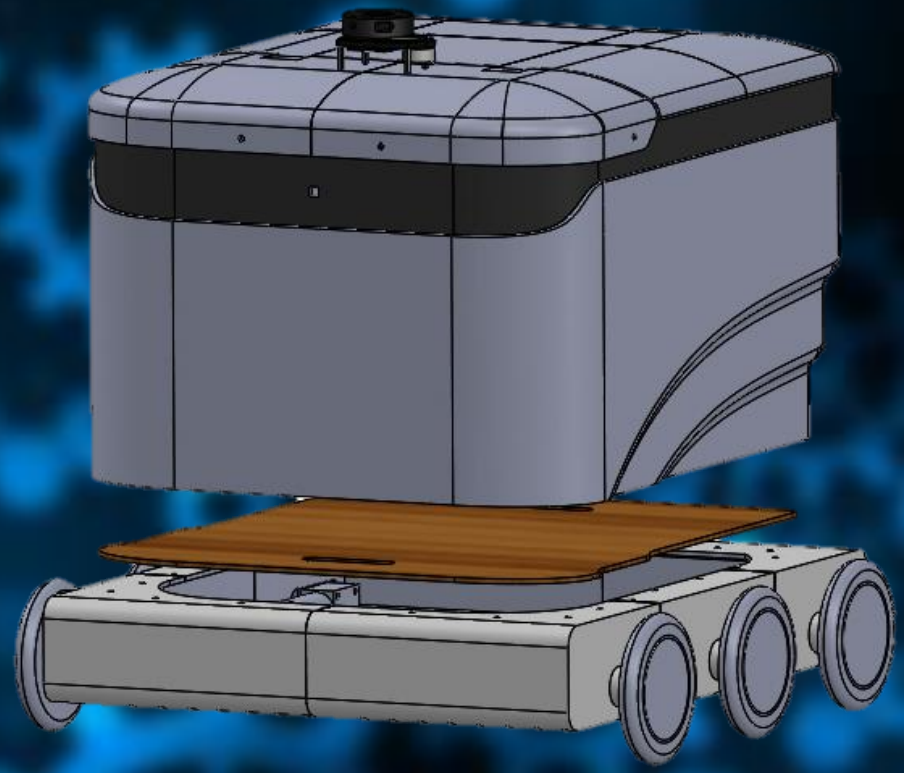
Motors Holder

Fixing Plate
6mm



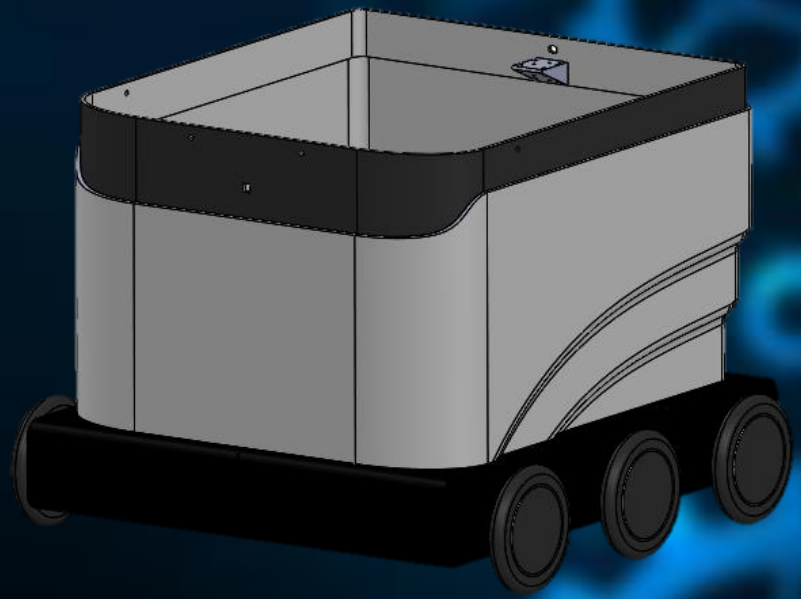
Separation plate

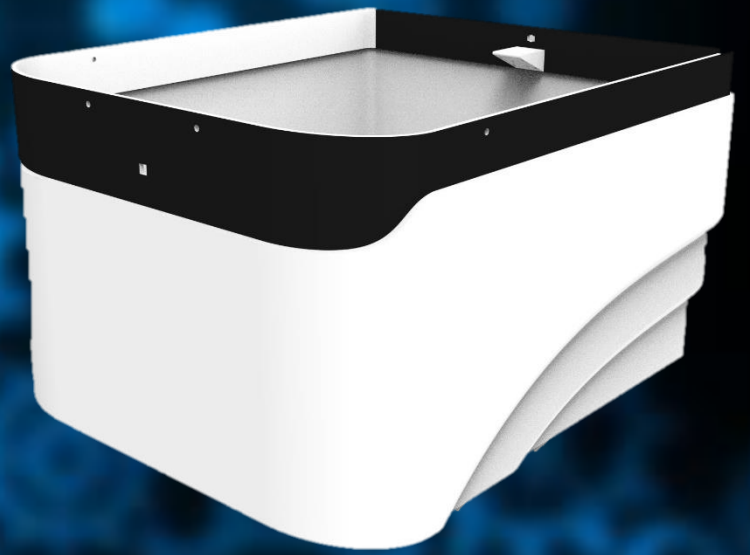
- Thickness 5mm



Body

- Size 560 * 640
- Thickness 5mm



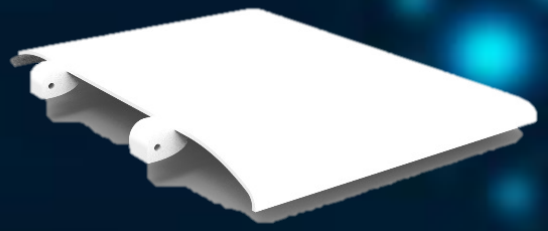


Cover

- Thickness 5mm

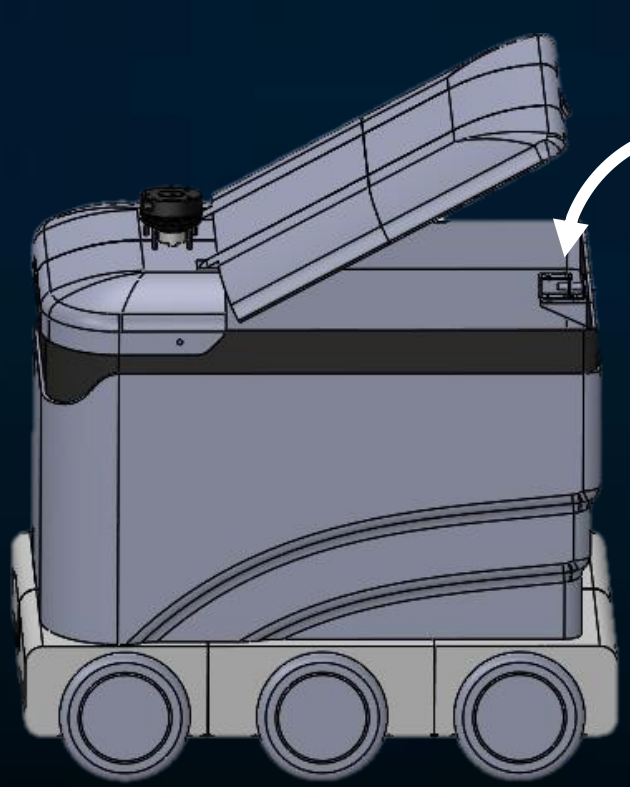
Cover Parts

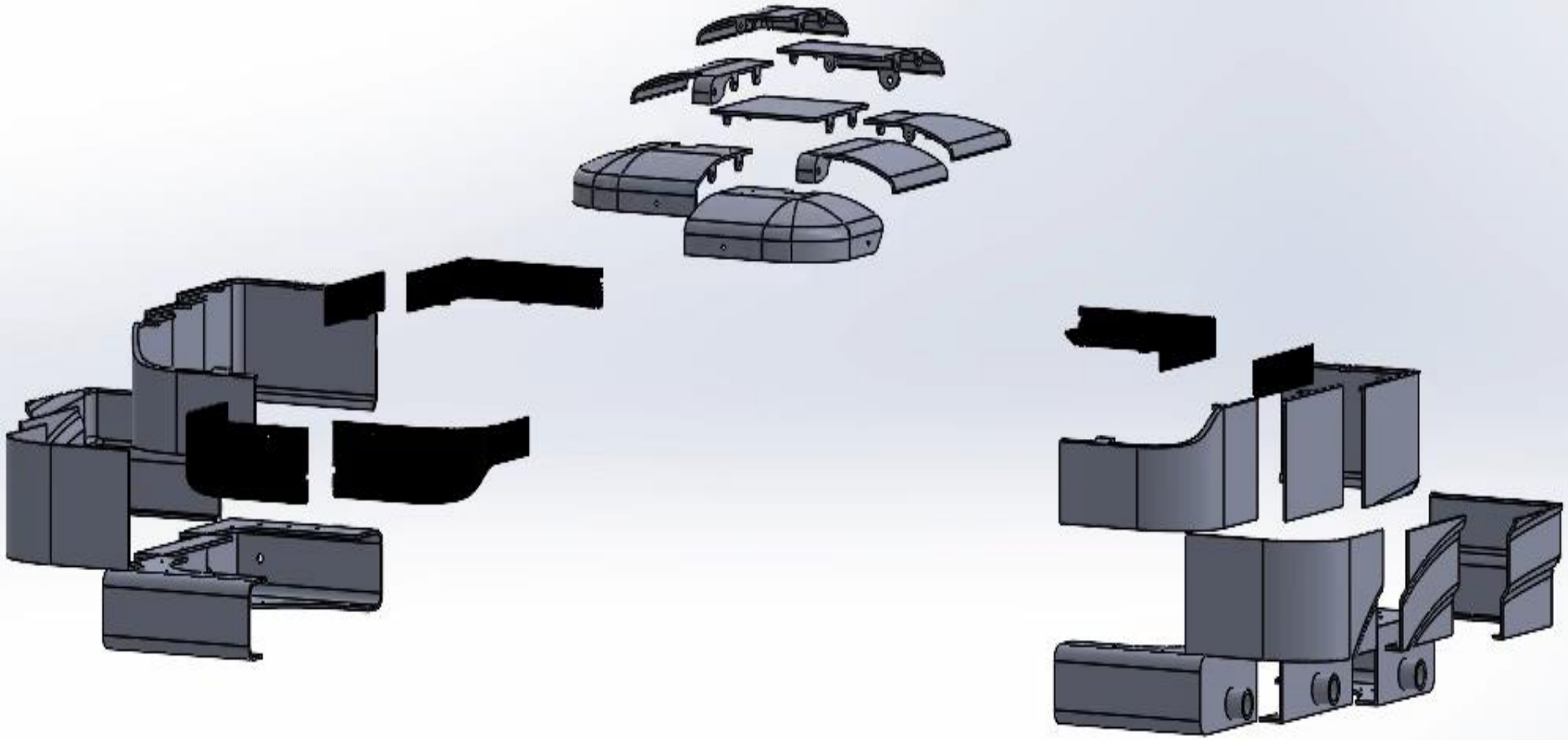
Fixed Part



Moving Part

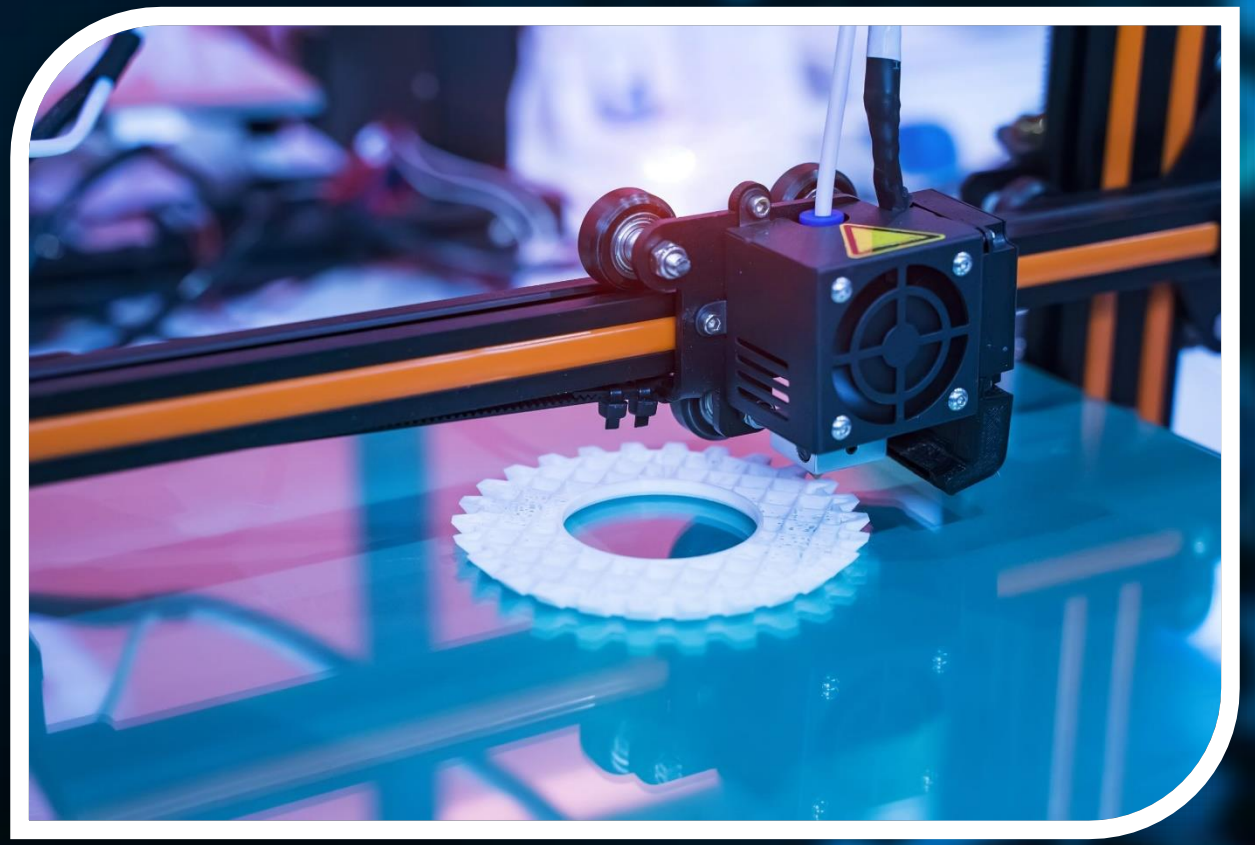
Cover Lock





Manufacturing process

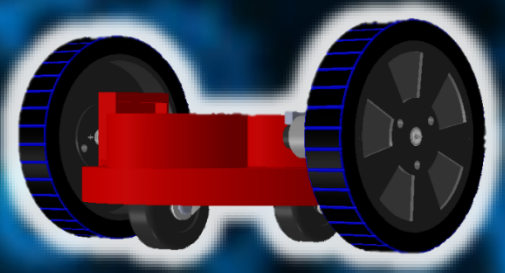
Manufacturing process



Movement

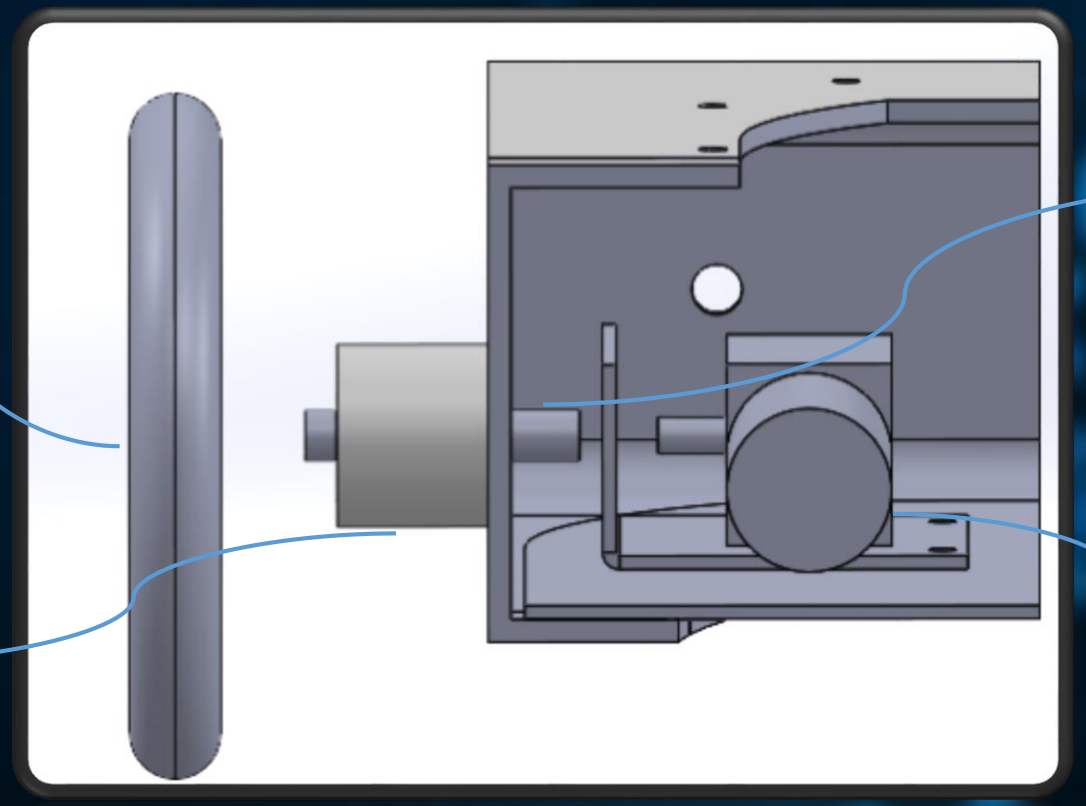
- Three-Wheeled Robots

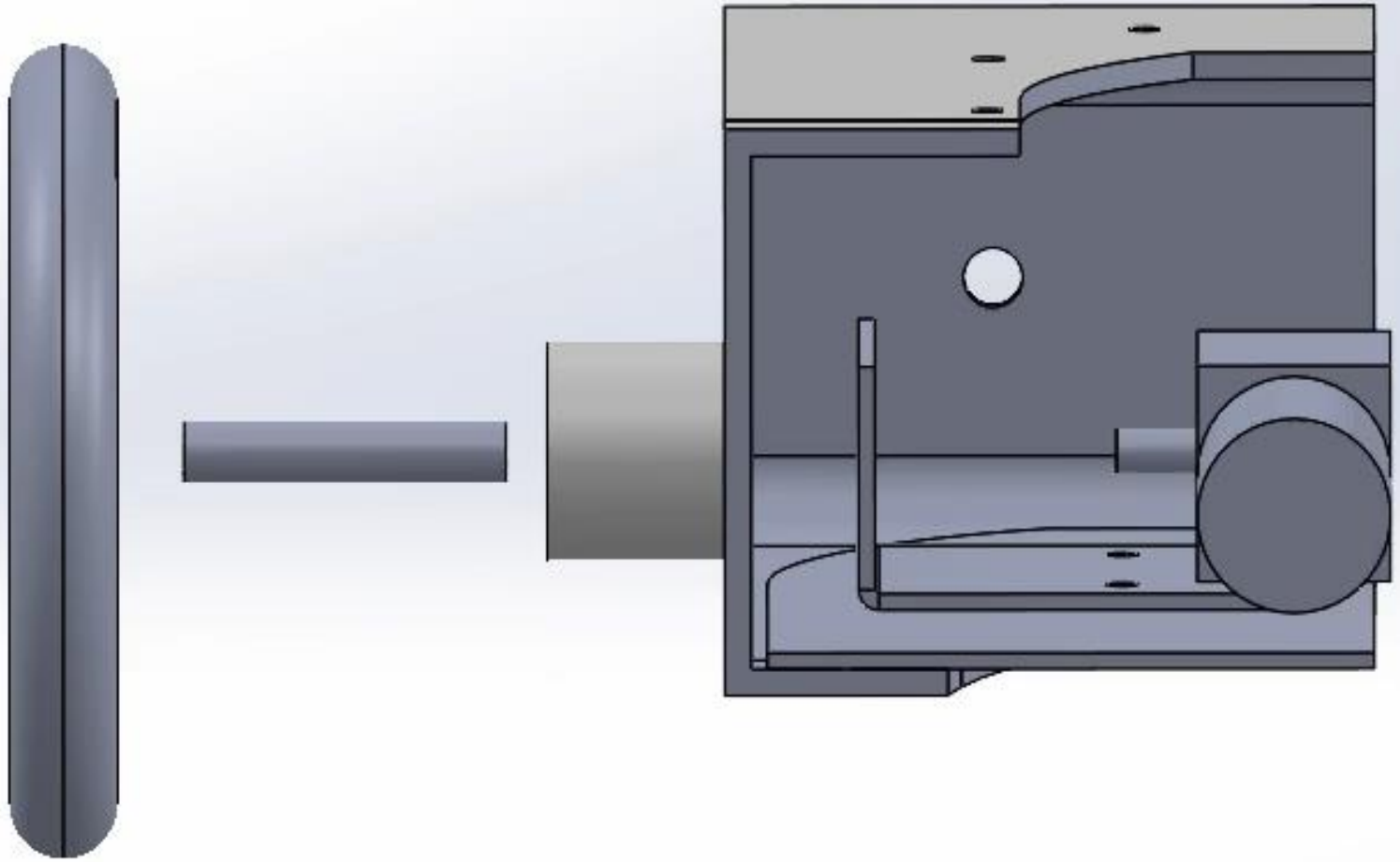
- Four-Wheeled Robot



- Six-Wheeled Robot
  (The base plate)

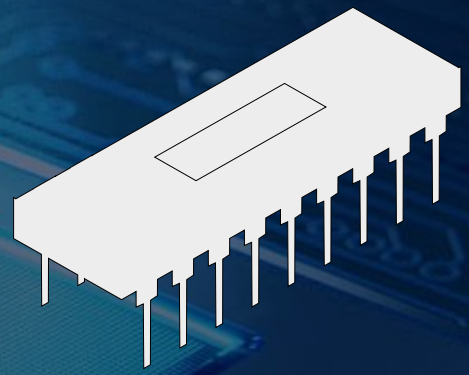
Wheel



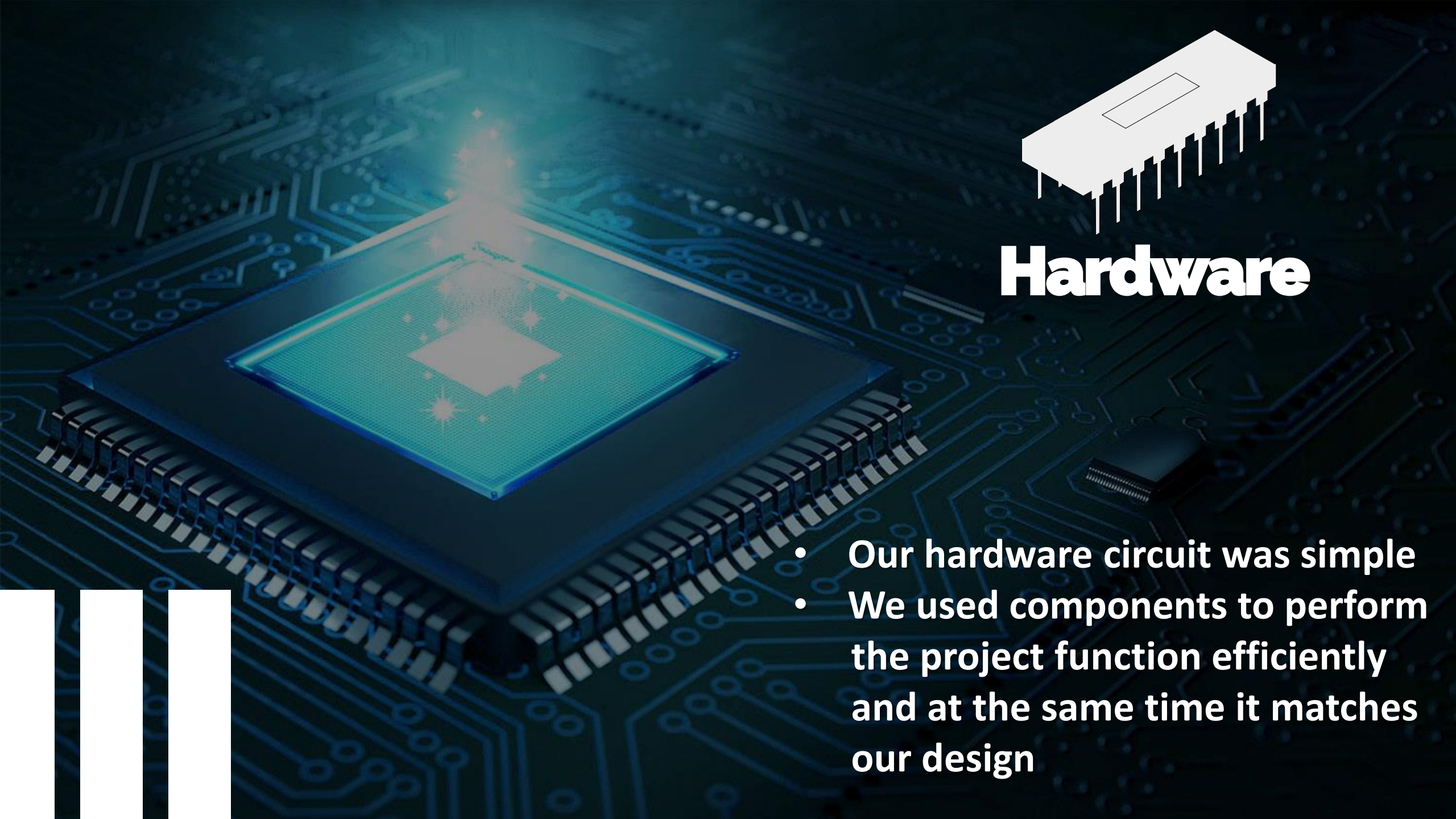


Challenges

Challenges

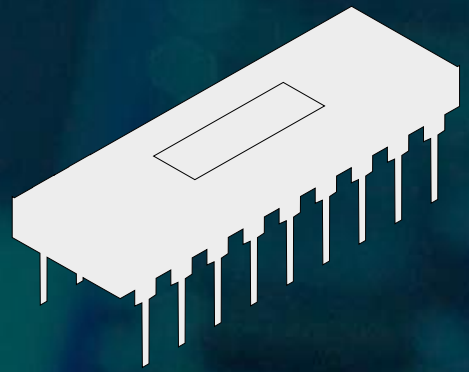


Hardware



Hardware

- Our hardware circuit was simple
- We used components to perform the project function efficiently and at the same time it matches our design



Hardware

HIGH VOLTAGE
24V

MEDIUM VOLTAGE
12V

LOW VOLTAGE
5V

SYSTEM
OVERVIEW

HIGH VOLTAGE 24V

XT60

MAIN SWITCH

MOTORS & DRIVERS

MEDIUM VOLTAGE 12V

BUCK CONVERTER 12V

LOCK MECHANISM

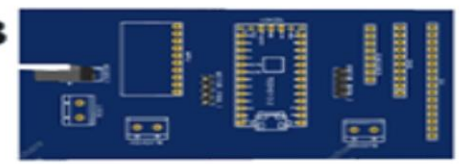
LIGHTENING SYSTEM

LOW VOLTAGE 5V

BUCK CONVERTER 5V

RASPBERRY PI

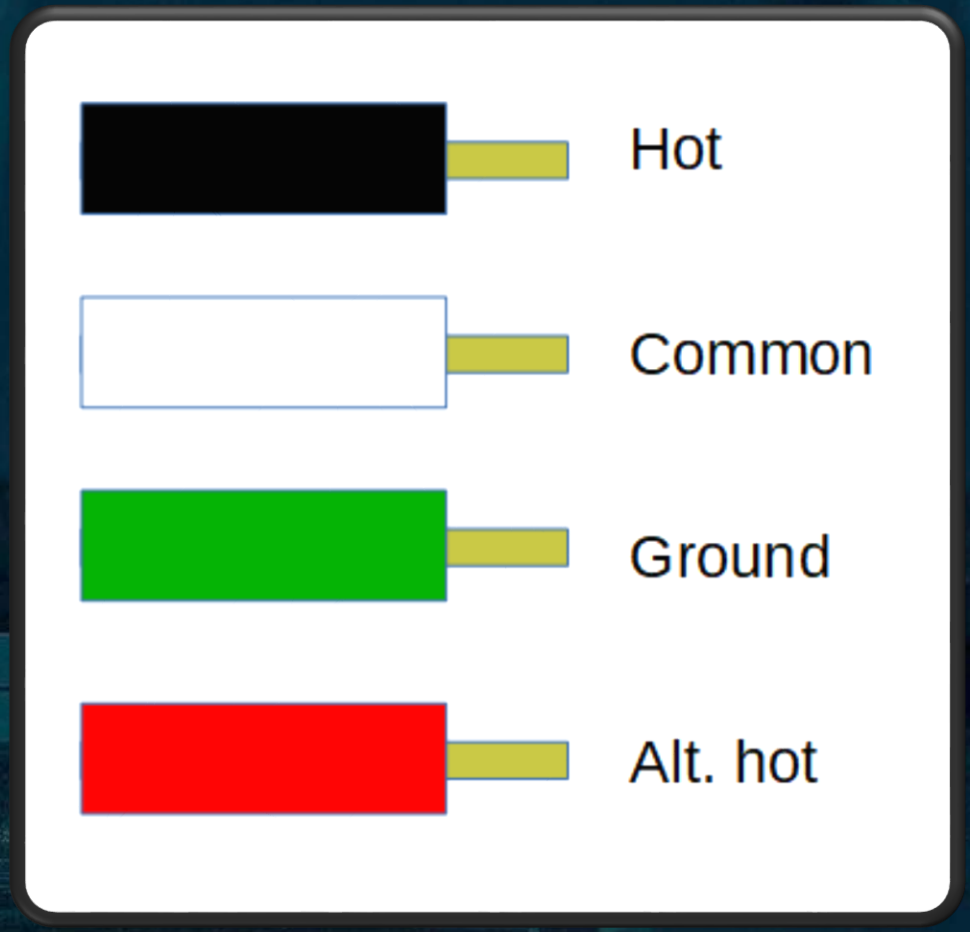
PCB



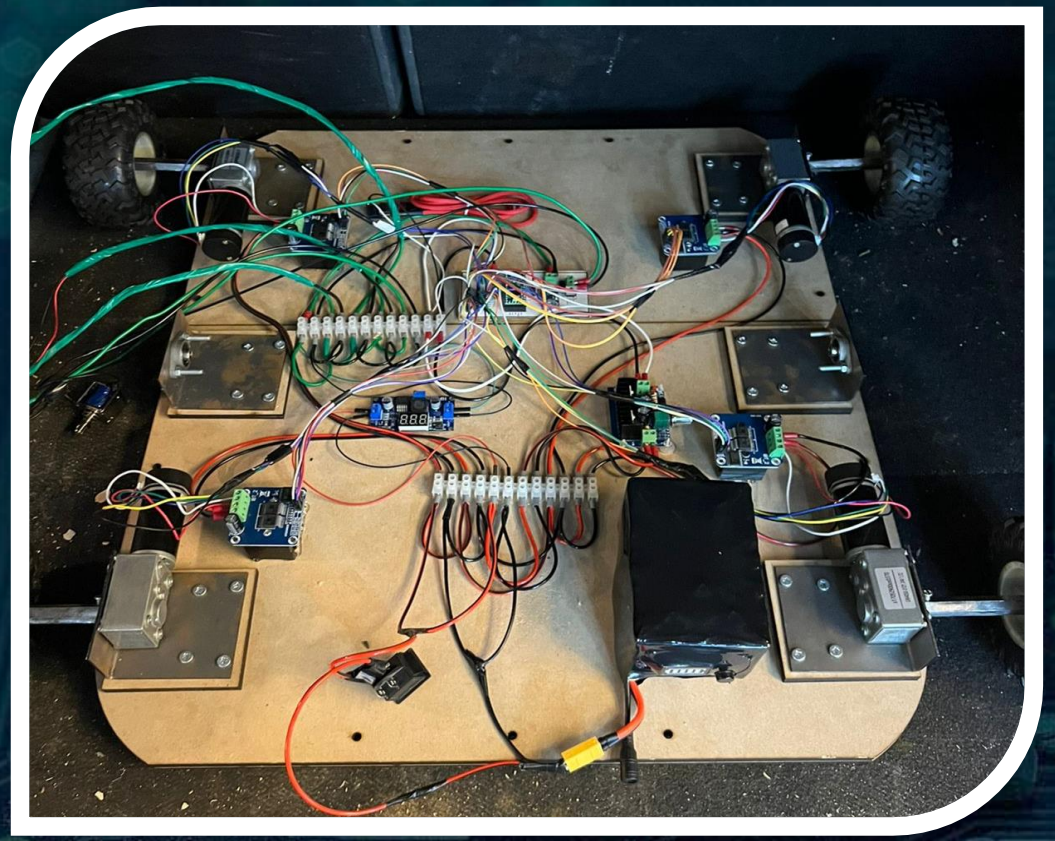
TEENSY 3.2

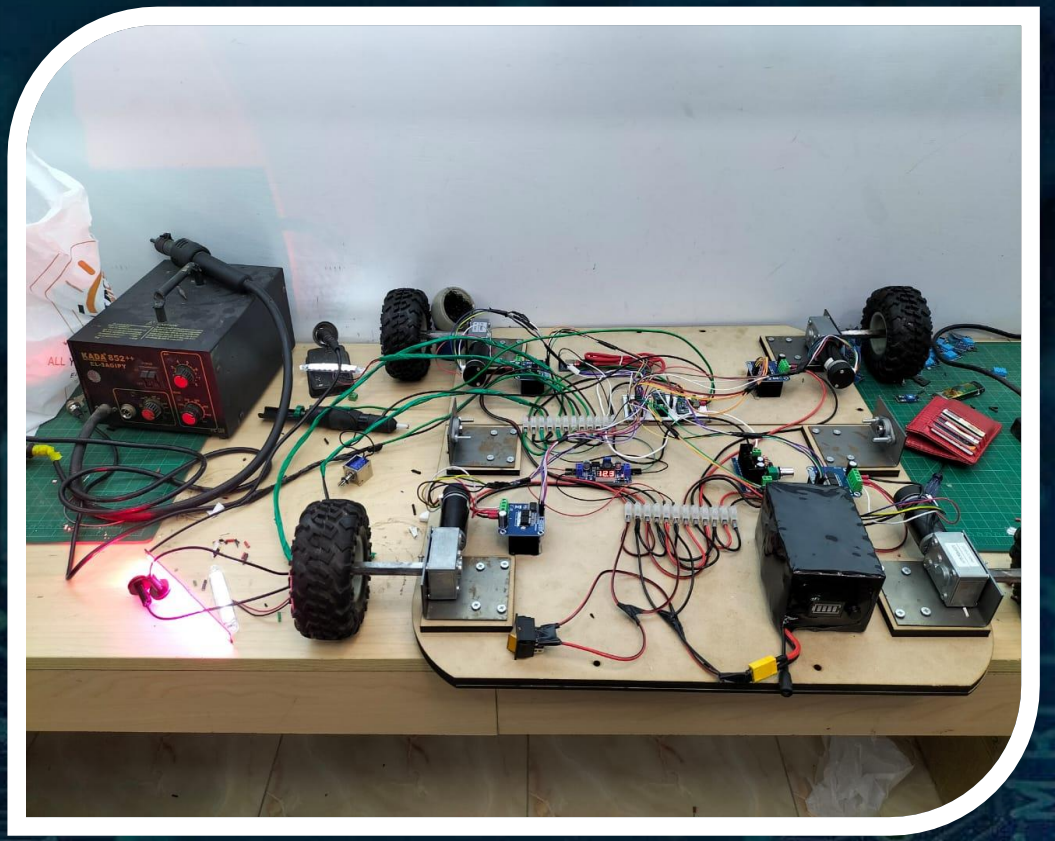
IMU

WIRING COLOR CODING

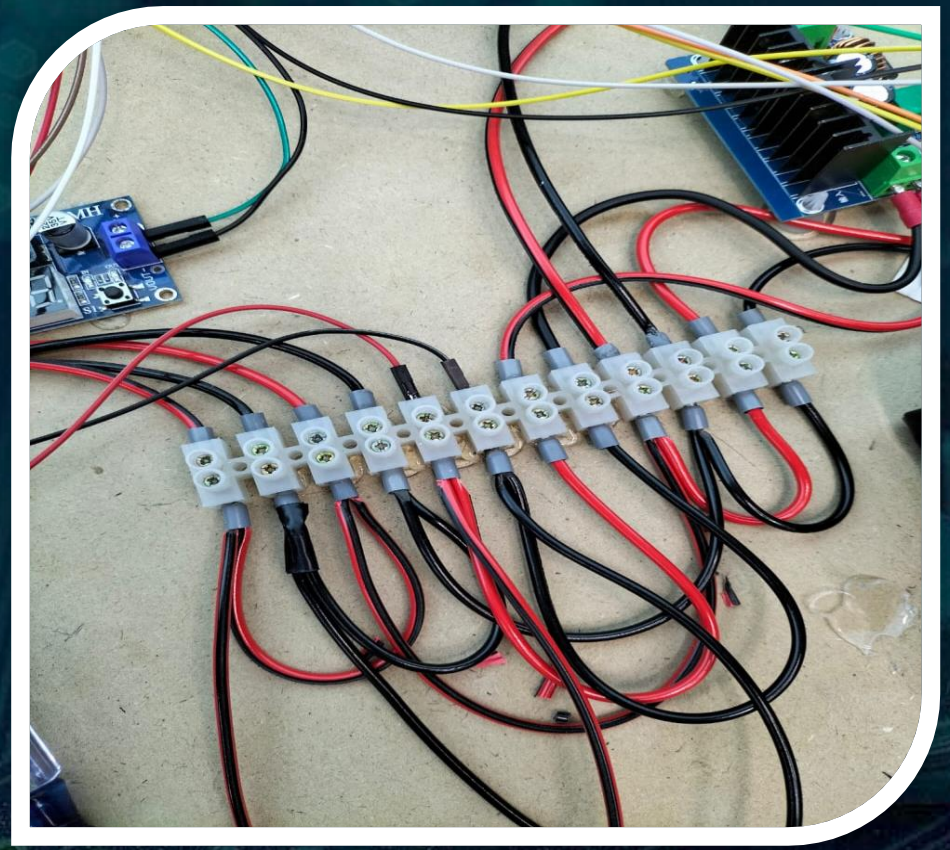


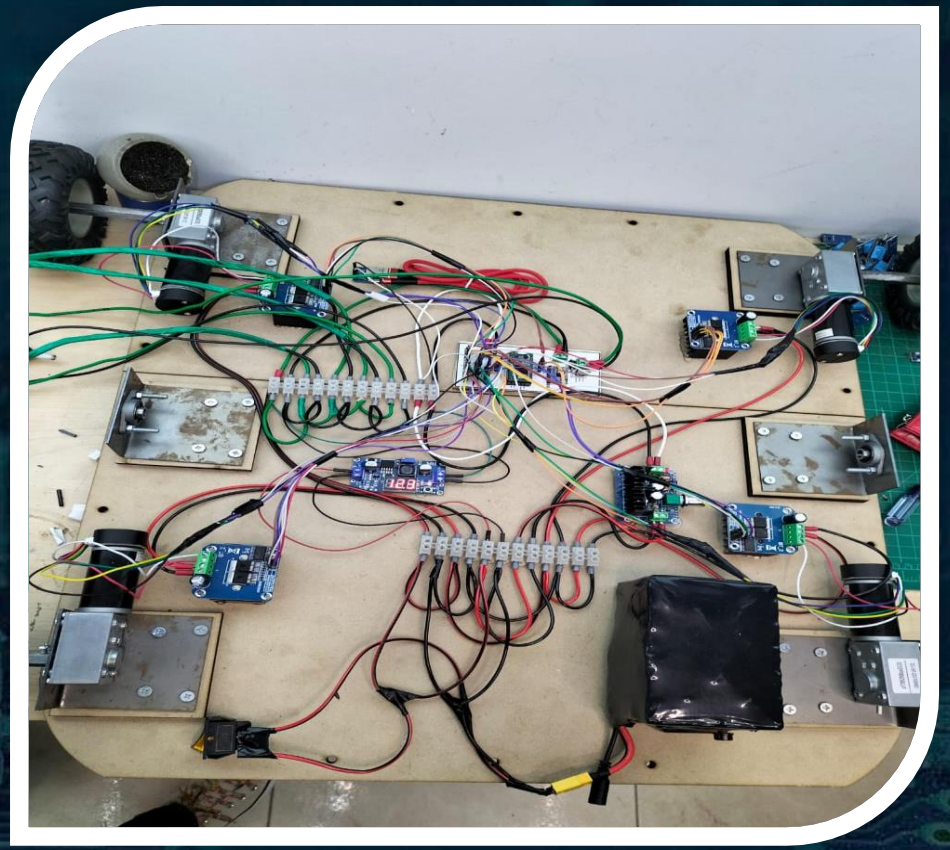
WIRING

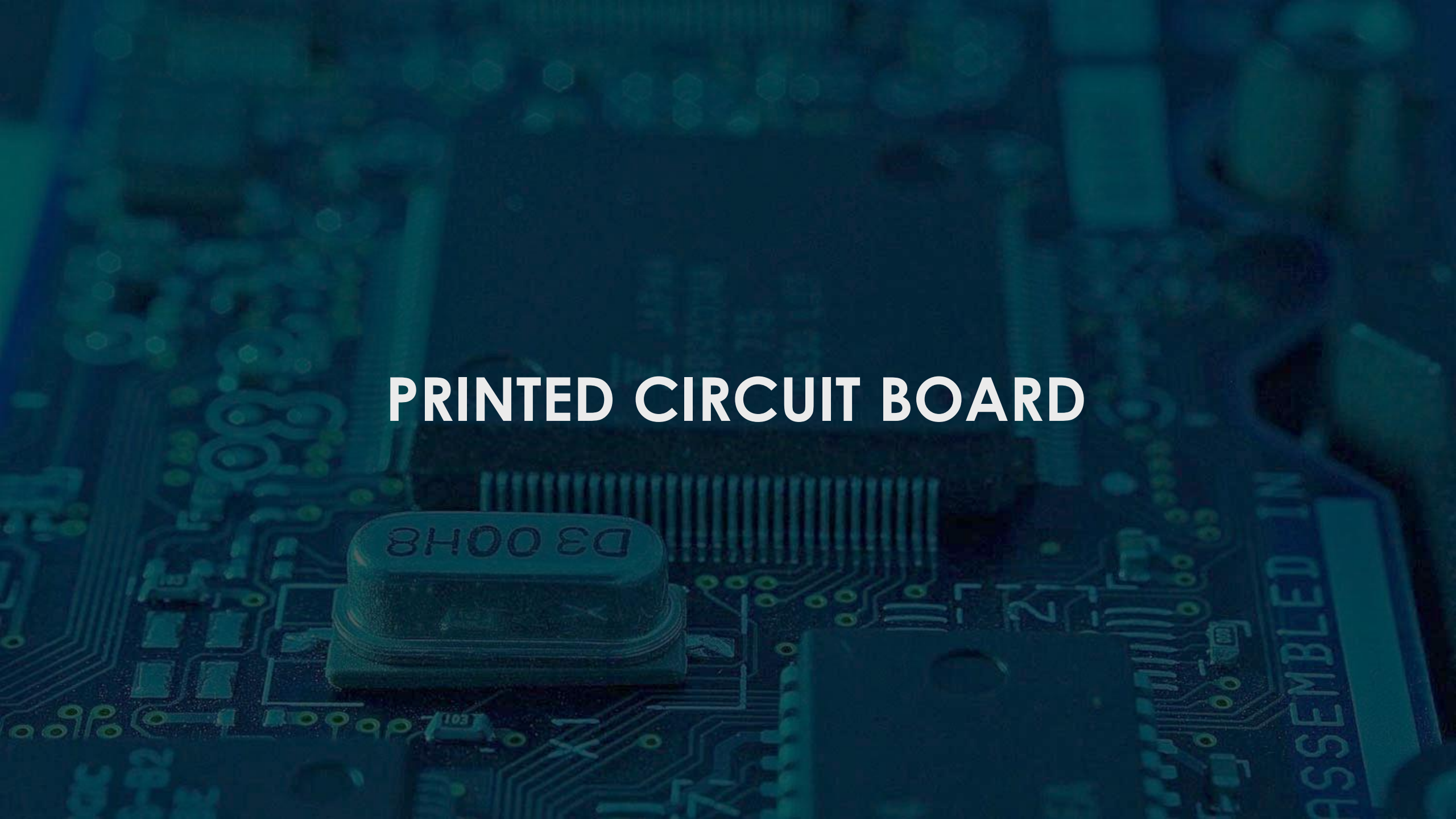




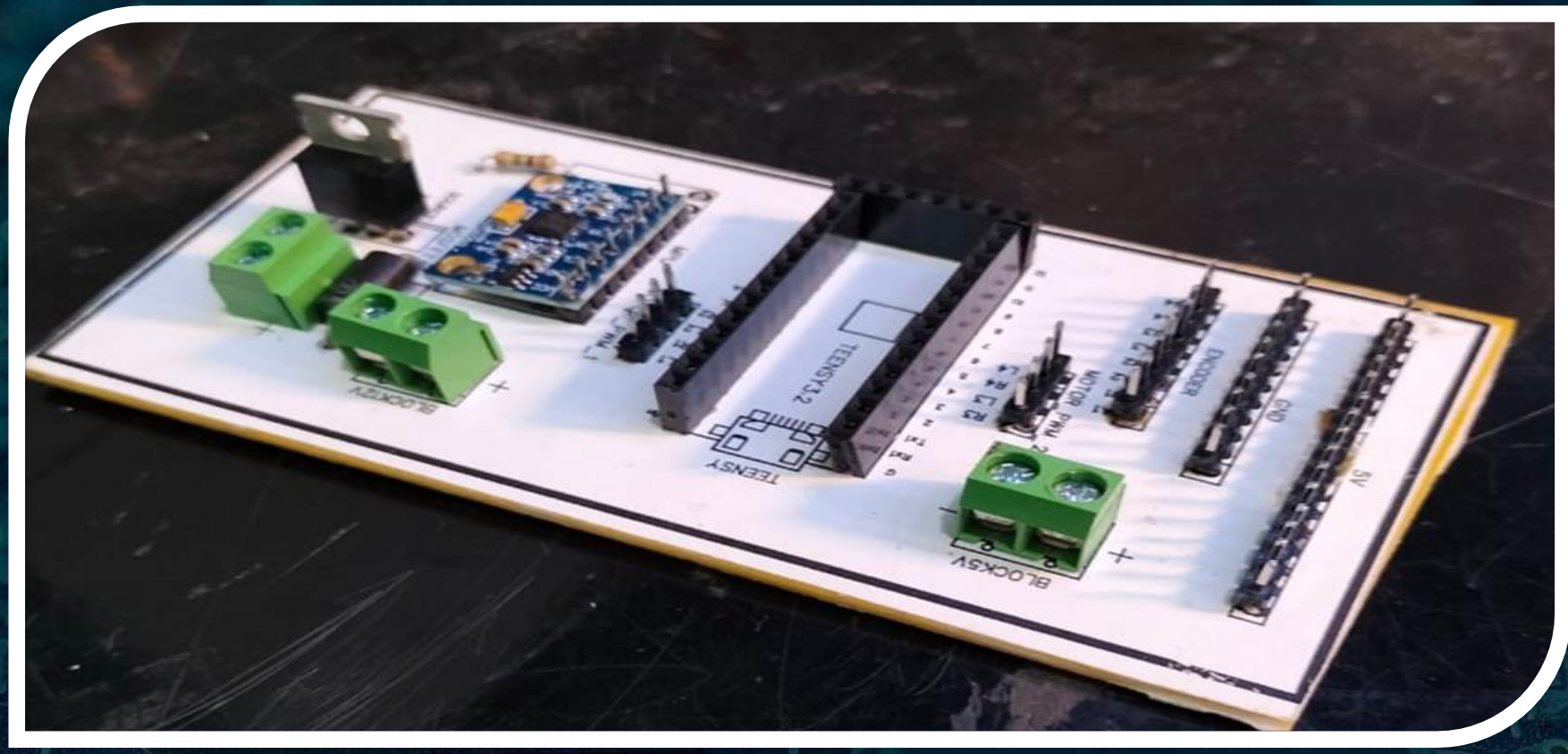
WIRING



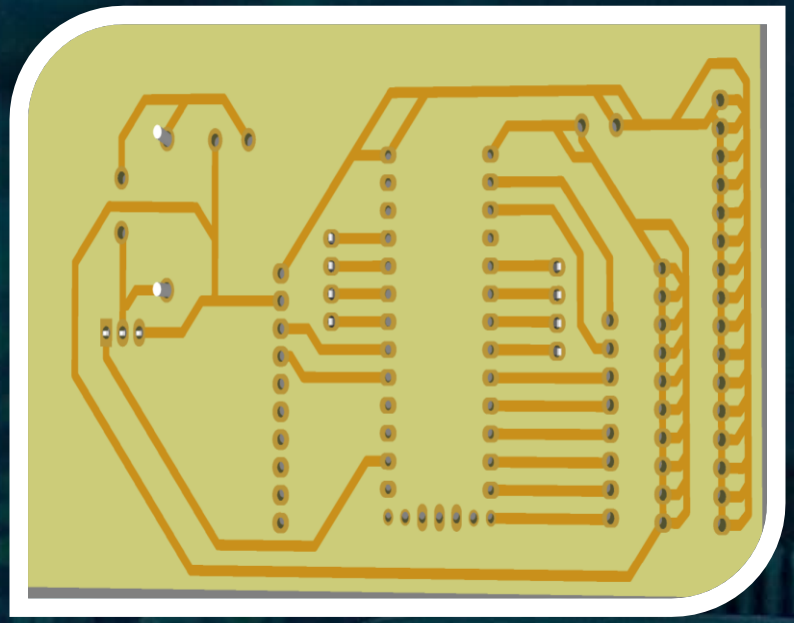


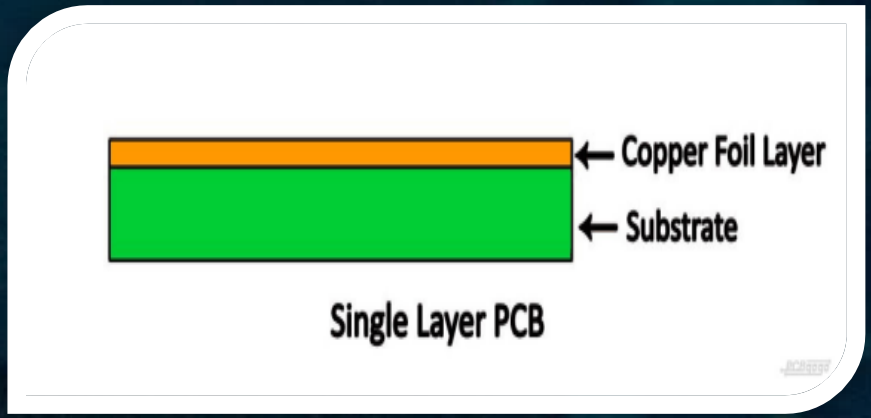

PRINTED CIRCUIT BOARD

Single Layer PCB



Construction of Single Layer PCB





Single layer PCB, also known as single-sided PCB, which is a type of PCB which comes with only one layer of conducting material on one side of the board and other side is used for incorporating different electronic components on the board

Why single layer ?

Advantages of single layer PCB

it is an ideal choice for low density components

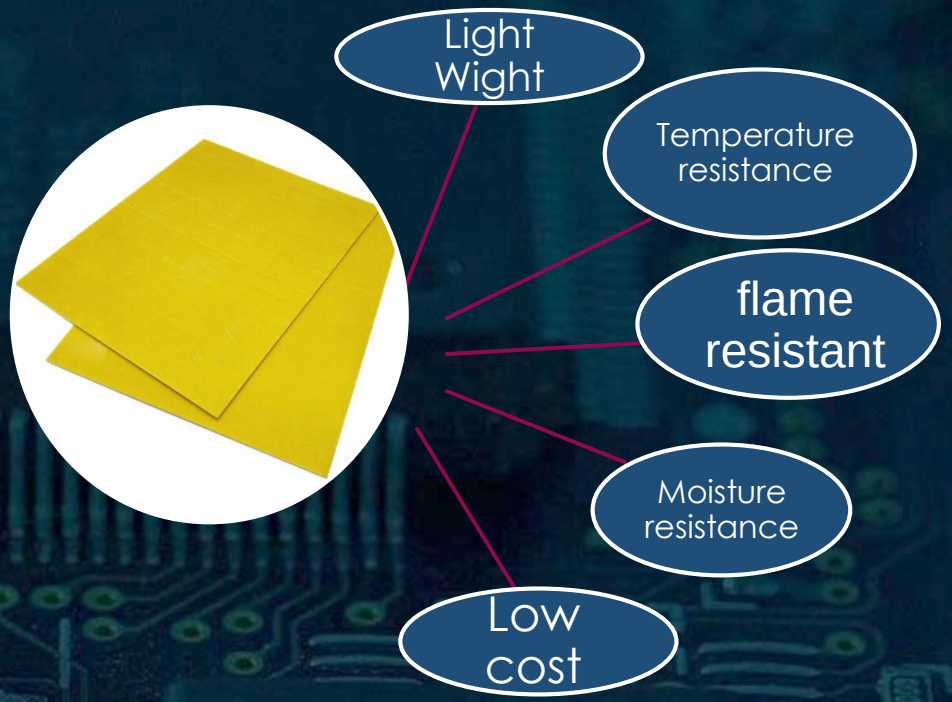
simple manufacturing process

Lower cost

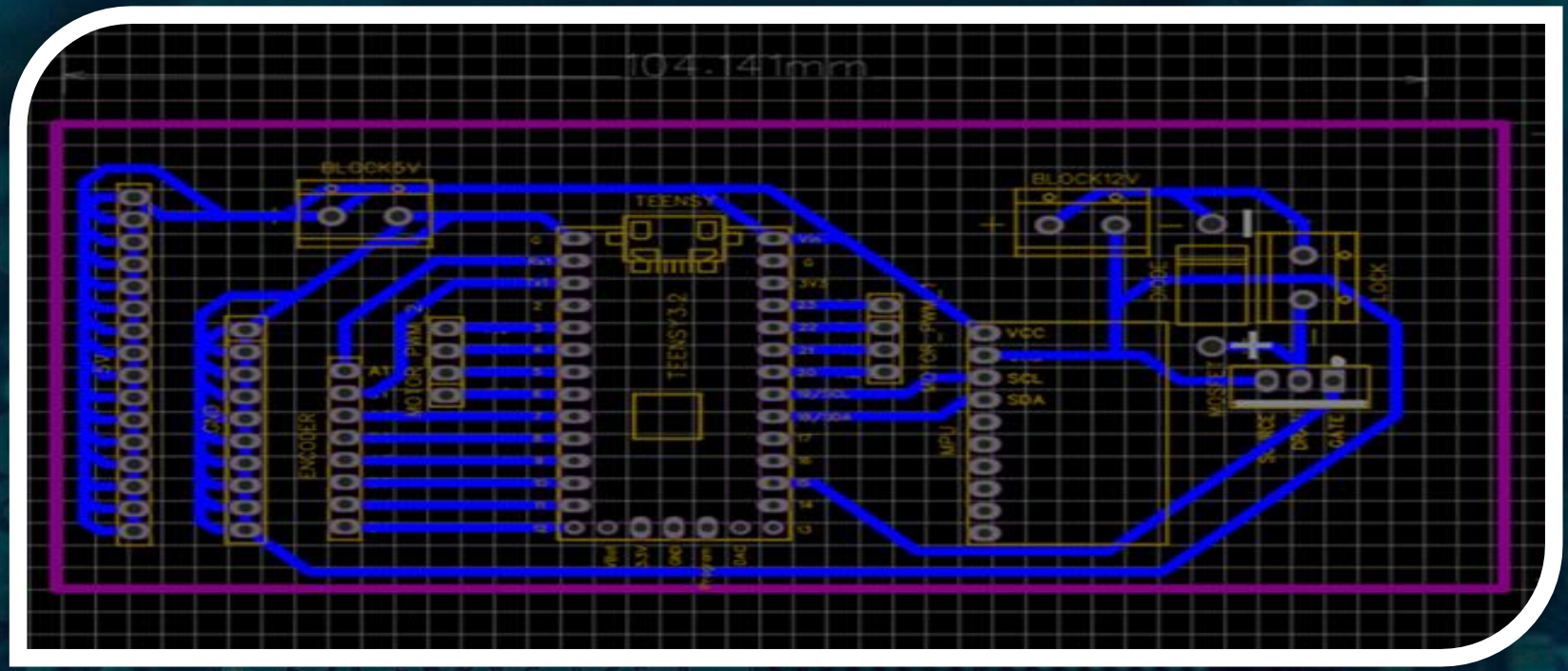
Substrate FR-4

-FR-4 is a composite material composed of woven fiberglass cloth with an epoxy binder that is flame resistant

-FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength



PCB design

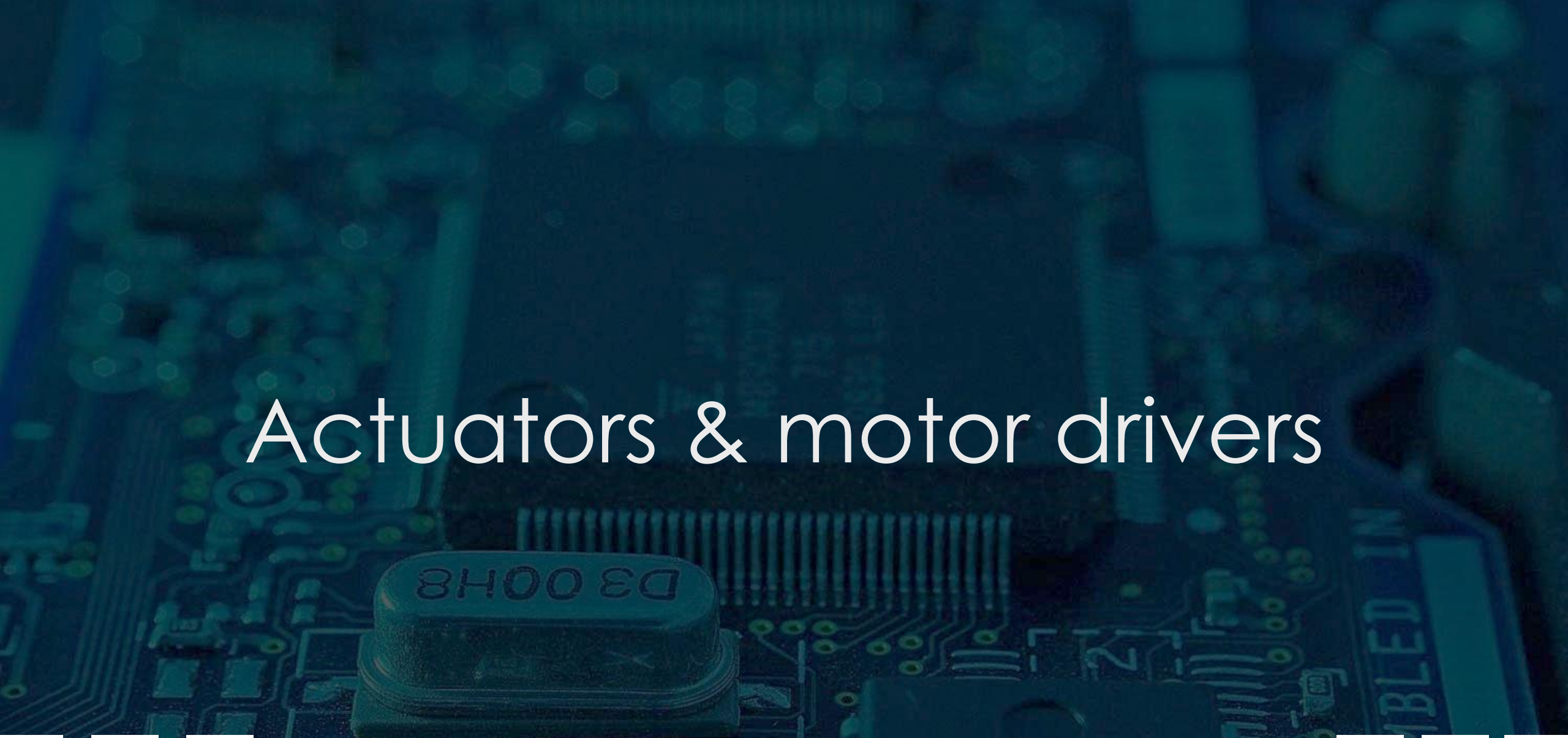


For manufacturing considerations

trace width 1 mm

conductor clearance 0.5 mm

Actuators & motor drivers



Actuators & motor drivers

Specifications :

Rated Voltage: 24V

Load Torque Current (With Load): 800mA

Output Power: 2.3 W

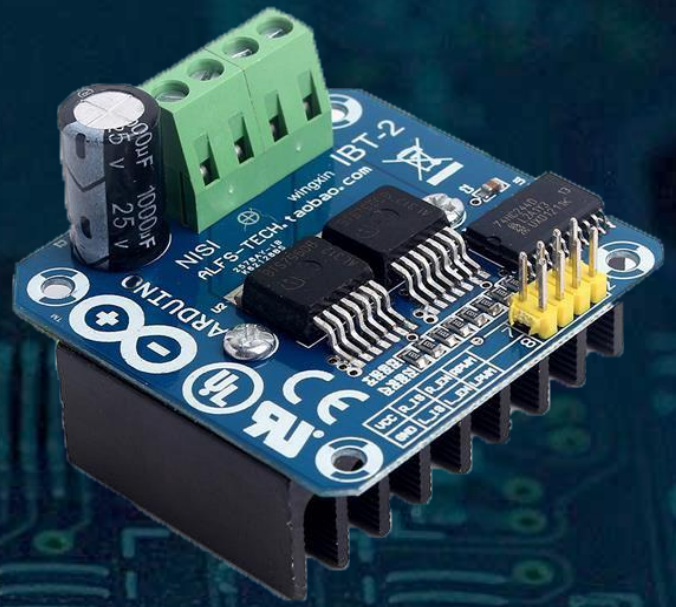
BTS7960 High Current 43A H-Bridge

Specifications :

Input Voltage: 6 ~ 27Vdc.

Peak current: 43-Amp.

Control Input Level: 3.3~5V.



Solenoid (Linear Motion) 12V-5N Force

Specifications :

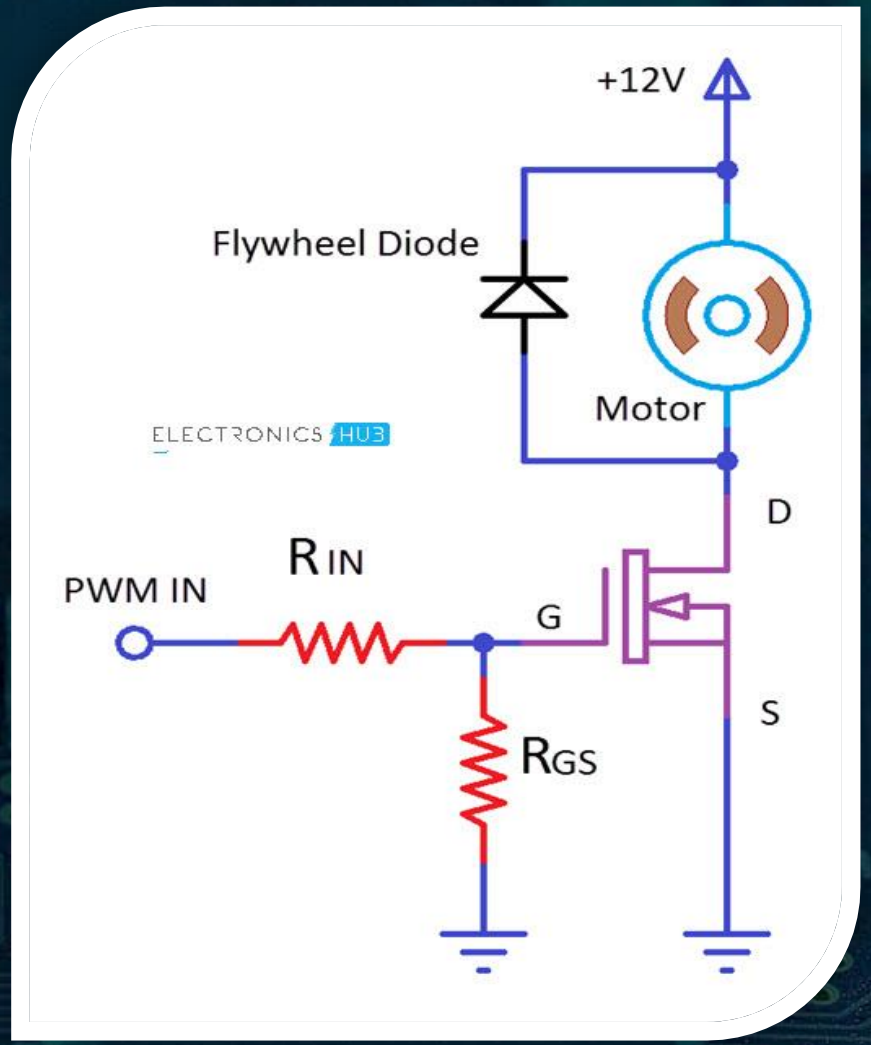
- Rated Voltage: DC 12V
- Current: 1A

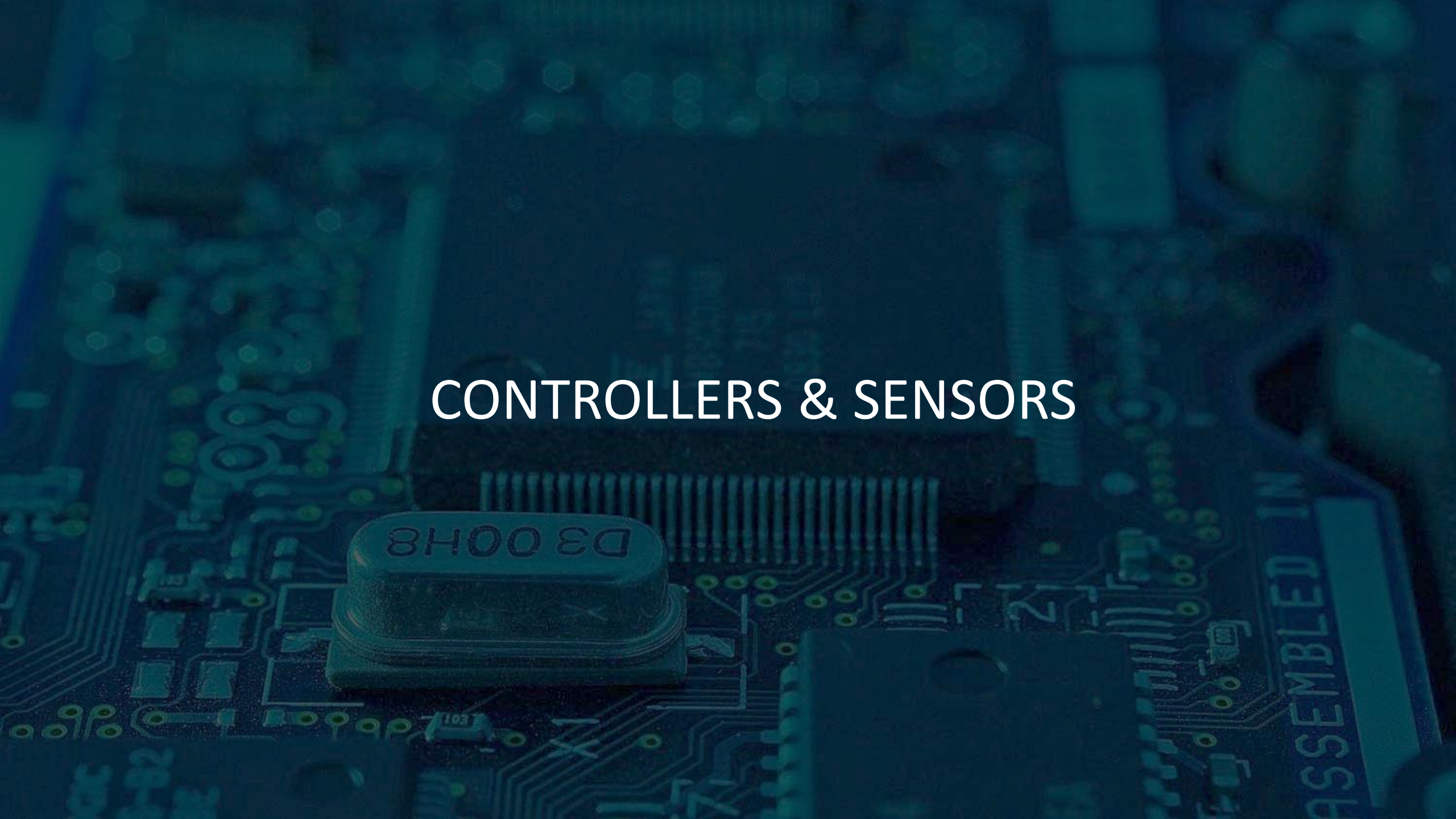
Solenoid driver

Mosfet transistor work as a switch

Fly wheel Diode for protection

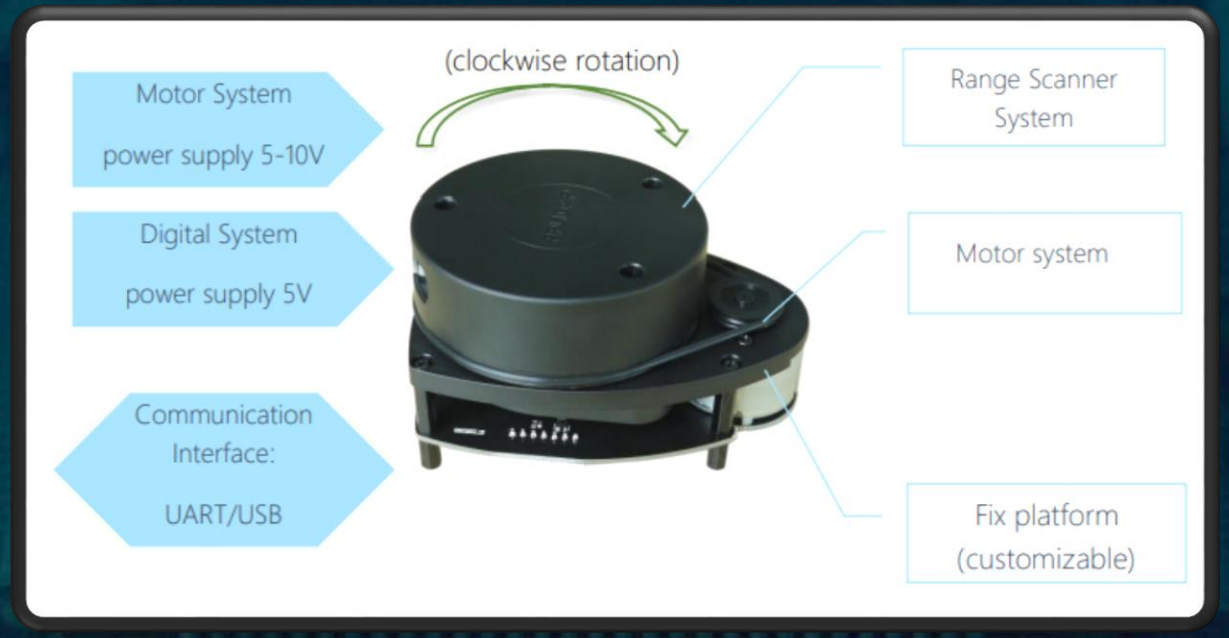
RGS to discharge and turn off the transistor





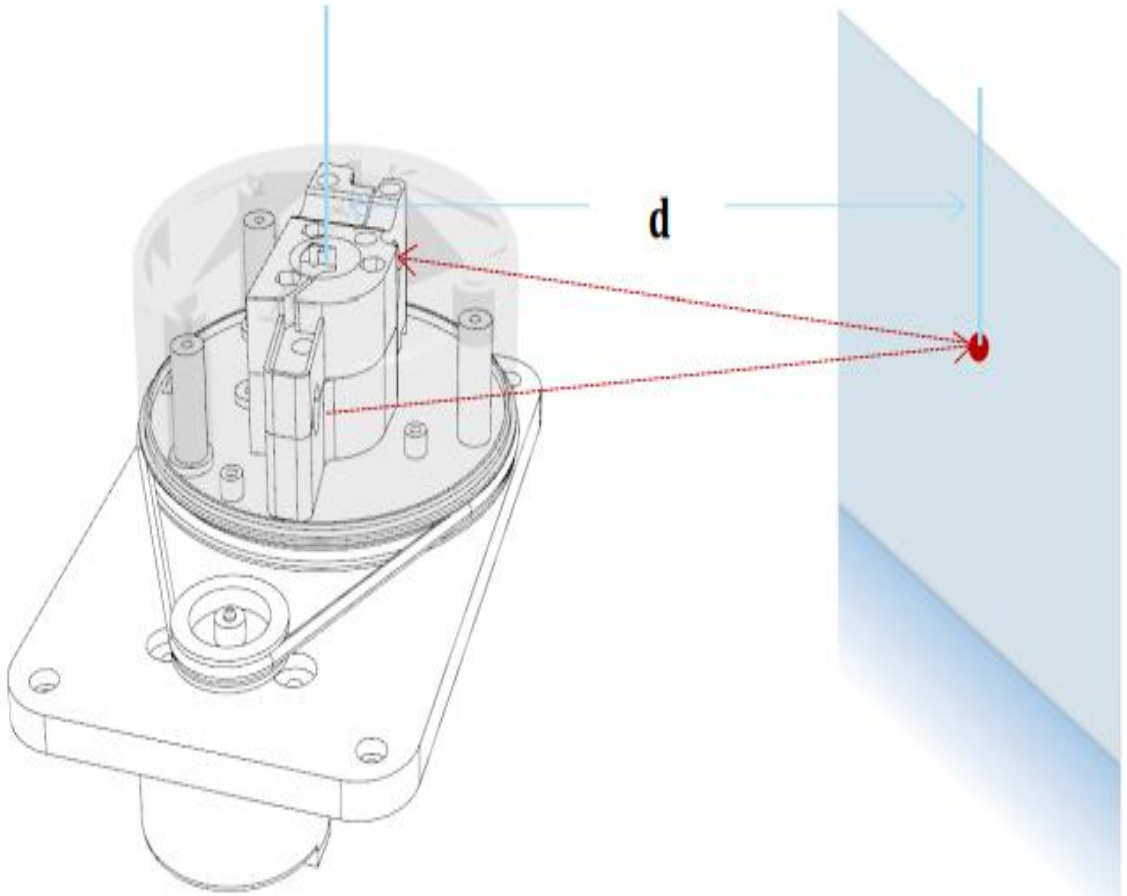
CONTROLLERS & SENSORS

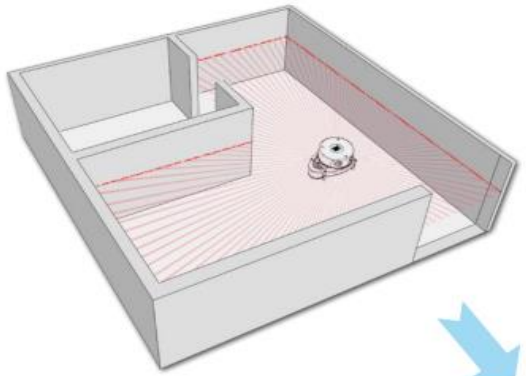
RPLIDAR A1M8



1. The system can perform 360 degree scan within 12 meter range
2. During the working process, the RPLIDAR A1 will output the sampling data via the communication interface
3. RPLIDAR A1 uses 3.3V-TTL serial port (UART) as the communication interface.

Schematic





*Note：The LIDAR scan image is not
relative to the environment showed
Illustrative purpose only.

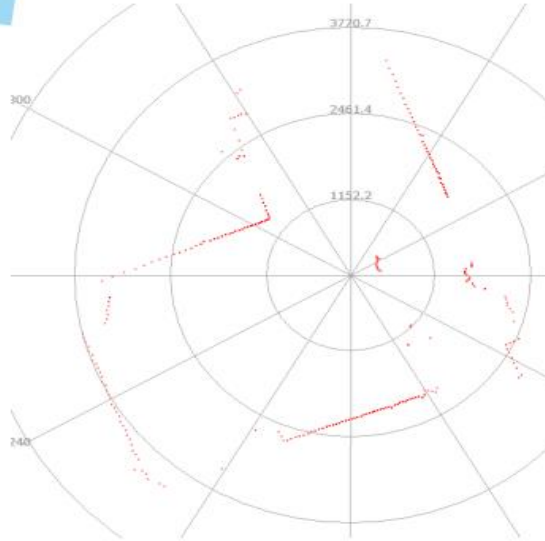
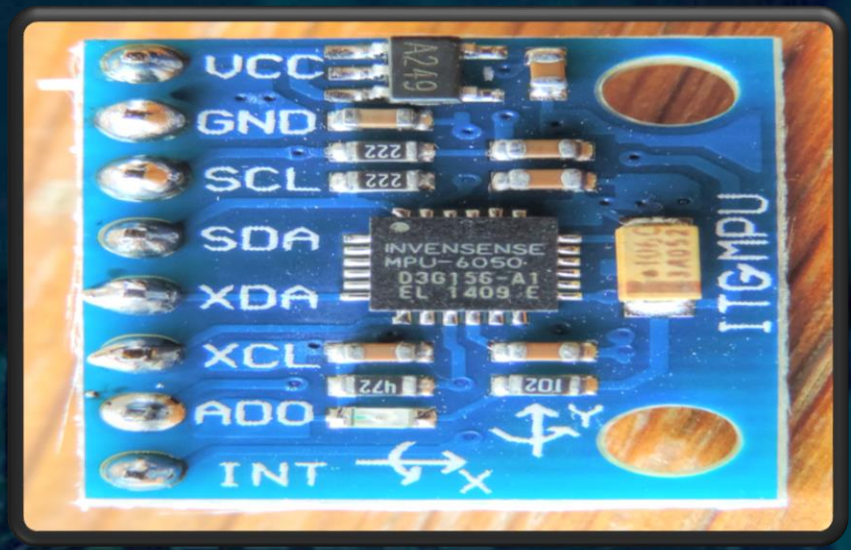


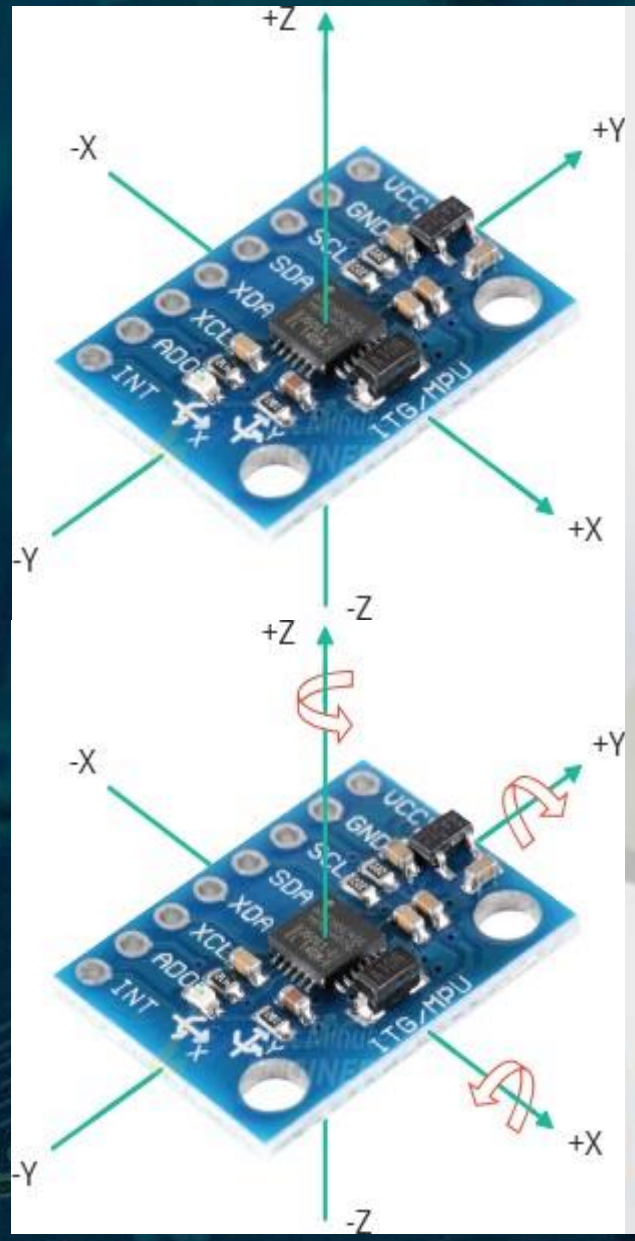
Figure 1-3 The Obtained Environment Map from RPLIDAR A1 Scannin

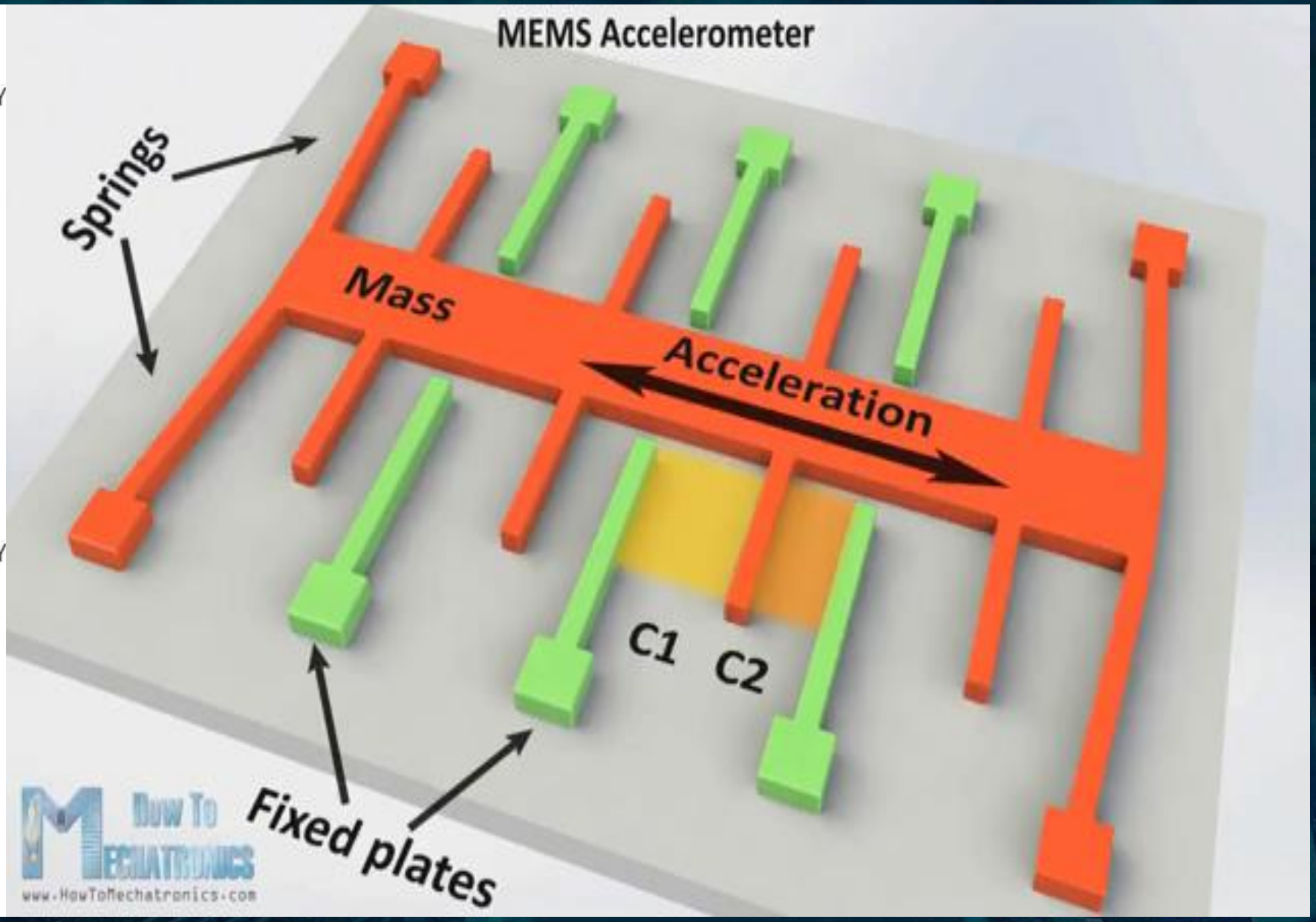
IMU (MPU6050)

Features/Specifications

- MEMS 3-aixs accelerometer and 3-axis gyroscope values combined
- Power Supply: 3-5V
- Communication : I2C protocol
- Built-in 16-bit ADC provides high accuracy
- Built-in DMP provides high computational power
- Can be used to interface with other IIC devices like magnetometer
- Configurable IIC Address
- In-built Temperature sensor



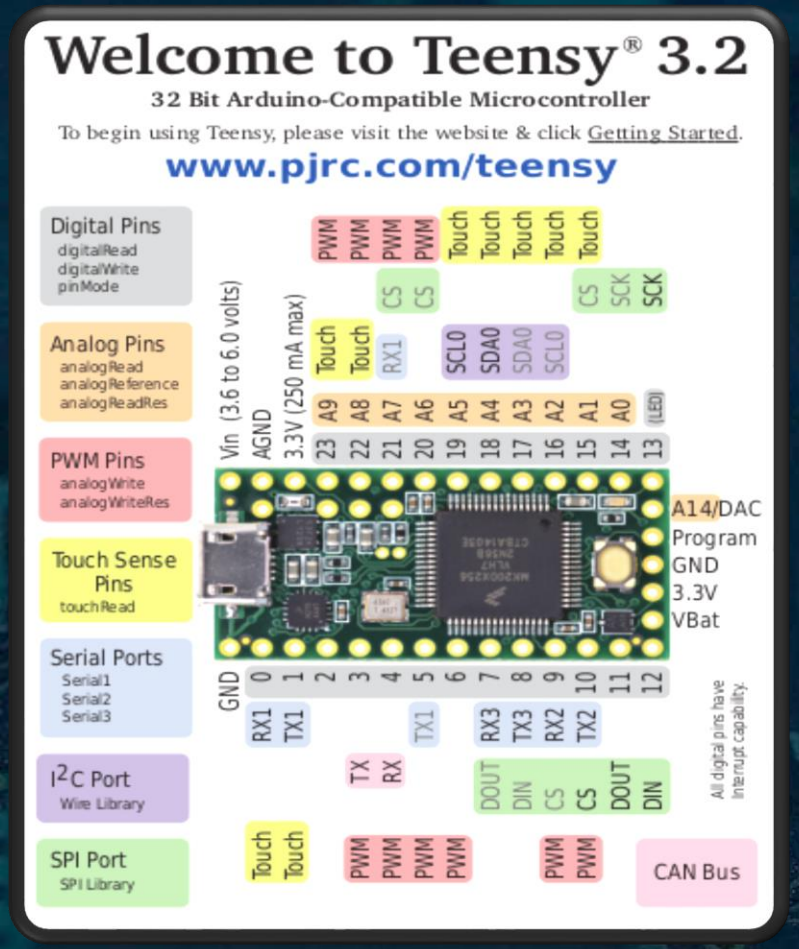

+Z
-X
+Y
-Y
+X
-Z
+Z
-X
+Y
-Y
+X
-Z


MEMS Accelerometer
Springs
Mass
Acceleration
C1
C2
Fixed plates
How To Mechatronics
www.HowToMechatronics.com

Teensy 3.2
Development Board

Features/specifications

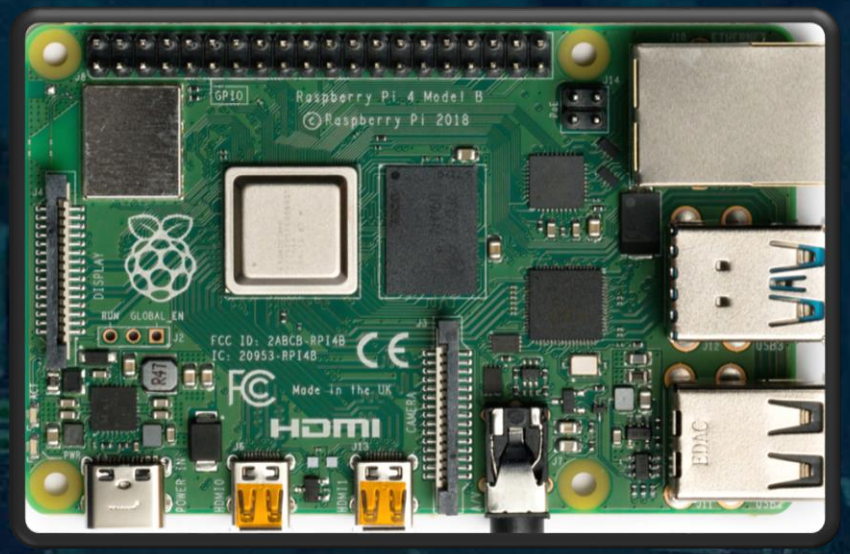
- ARM Cortex-M4 at 72 MHz
- 256K Flash, 64K RAM, 2K EEPROM
- USB device 12 Mbit/sec
- 34 digital input/output pins, 12 PWM output pins
- 21 analog input pins, 1 analog output pin, 12 capacitive sense pins
- 3 serial, 1 SPI, 2 I2C ports
- 1 I2S/TDM digital audio port
- 1 CAN bus
- 16 general purpose DMA channels
- RTC for date/time

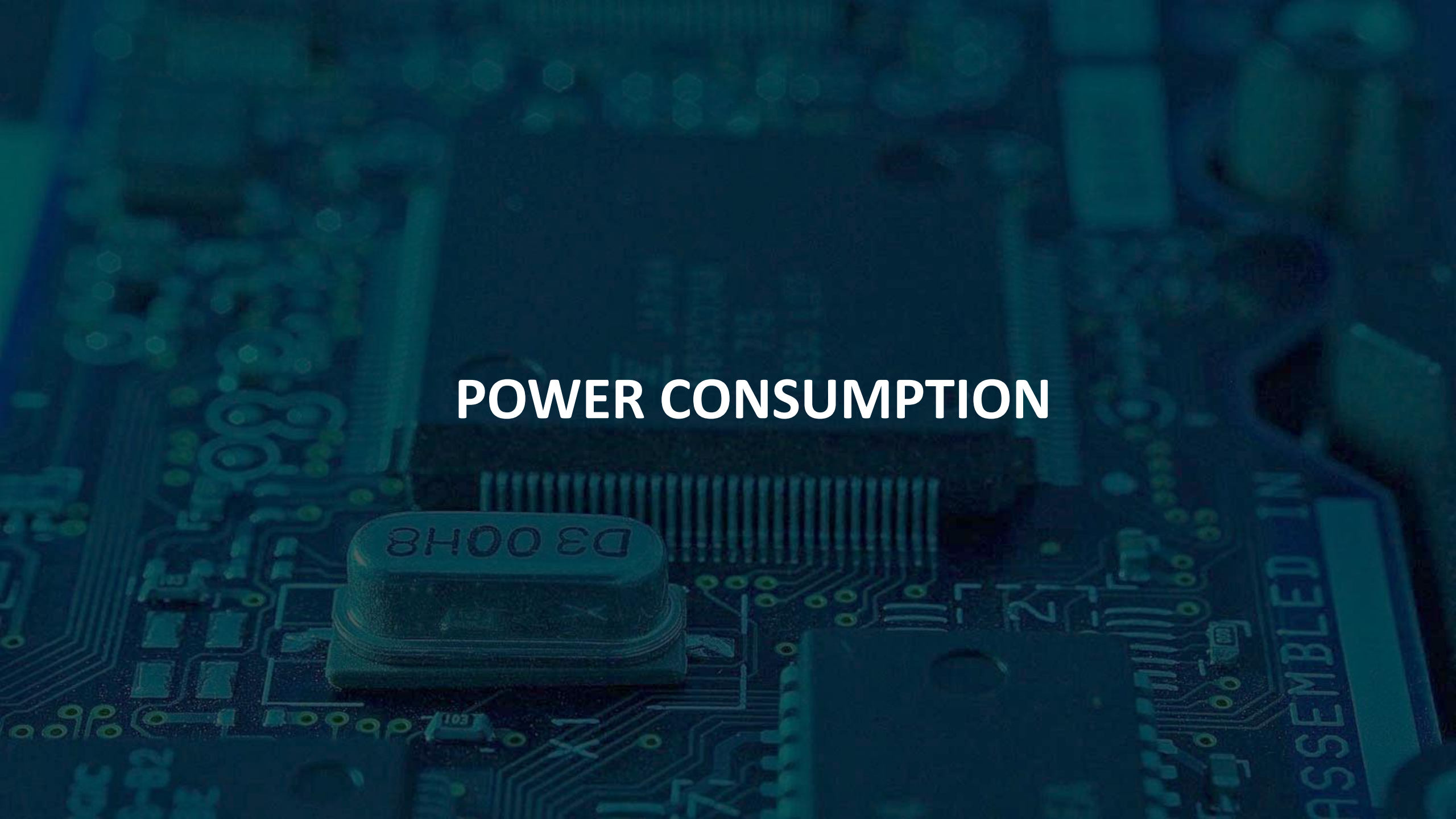


Rasberry pi 4 model B

Features/Specification

- Quad-core Cortex-A72 1.5GHz CPU
- Broadcom Video Core VI @ 500MHz GPU
- 4GB RAM
- 2 x USB 2.0 ports
- 2 x USB 3.0 ports
- 5mm TRRS a/v port
- 2 x Micro-HDMI ports
- Gigabit Ethernet port
- b/g/n/ac dual band 2.4/5GHz Wi-Fi
- Bluetooth 5.0
- USB-C power connection
- Weighs 46 grams





POWER CONSUMPTION

Power Consumption

component	max amps	voltage	power
4 * DC Motor	4 * 2 A	24 V	48 W
Raspberry pi	3 A	5 V	15 W
4 * Motor Driver	4 * 50 mA	24 V	4.8 W
Teensy 3.2	40 mA	5 V	0.2 W
LIDAR	100 mA	5 V	0.5 W
Lighting	800 mA	12 V	9.6 W
Total	12.14 A		78.1 W

Capacity Calculations

- System power consumption for 1 hour = 78.1 W
- For 2 hours = 2 x 78.1 = 156.2 W
- Battery power = 24 * 7.2 = 172.8 Wh
- So the battery can power up the system for up to 2.5 hours continuously at max power .

Battery System

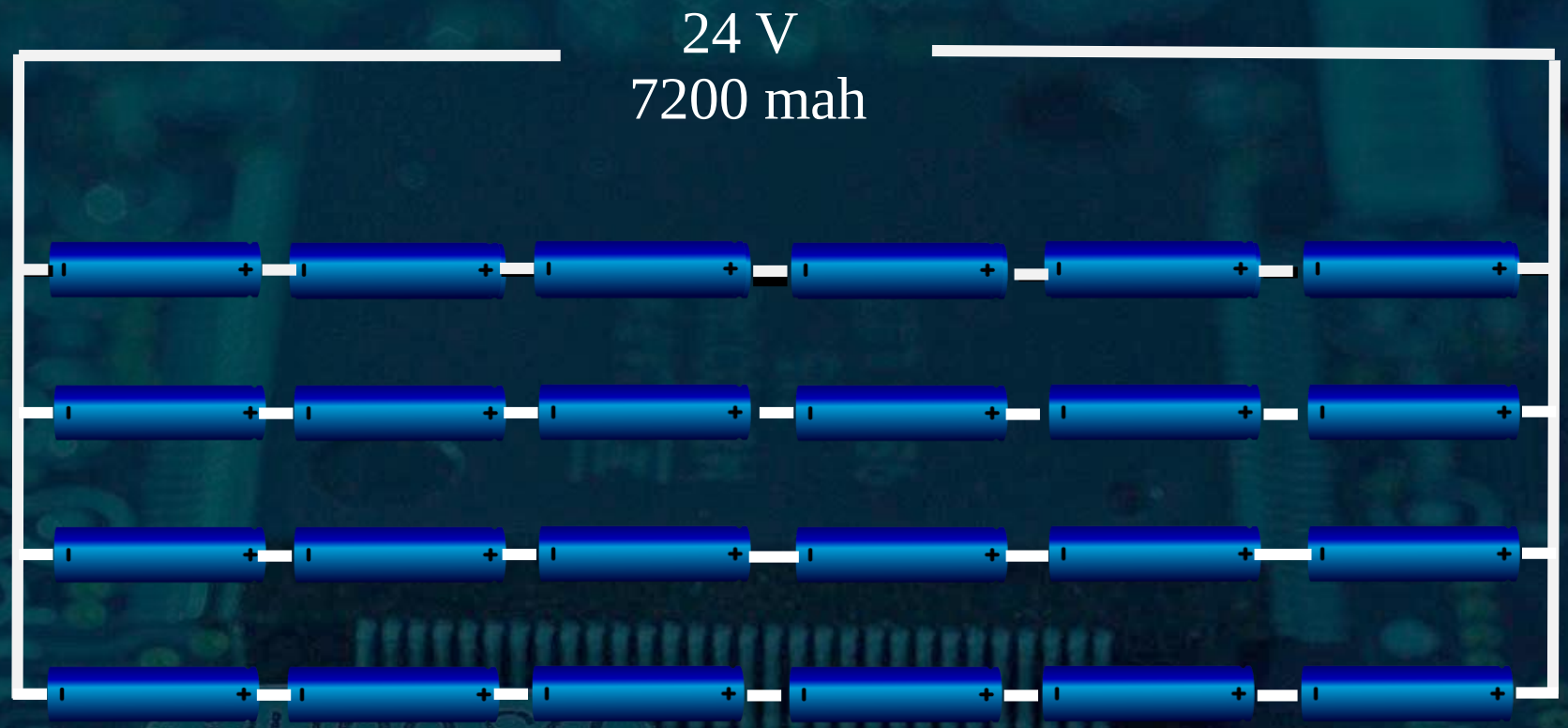
Lithium ion Cells

Rechargeable

Light Weight

Up to 20 A load

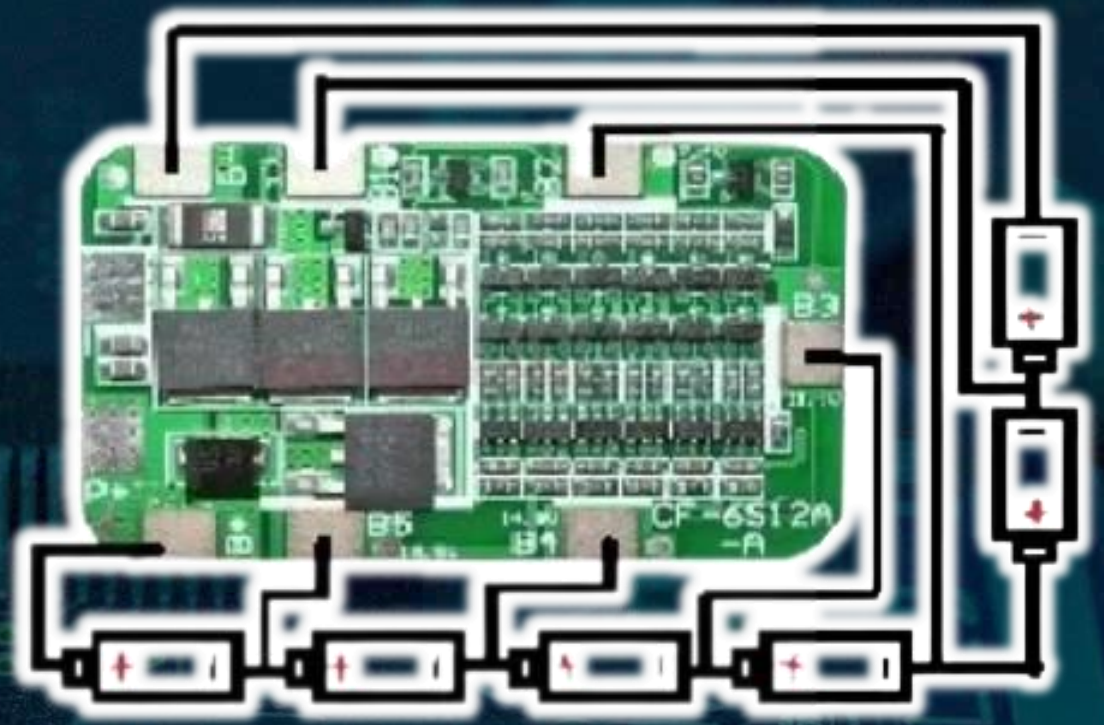
24 volt connection



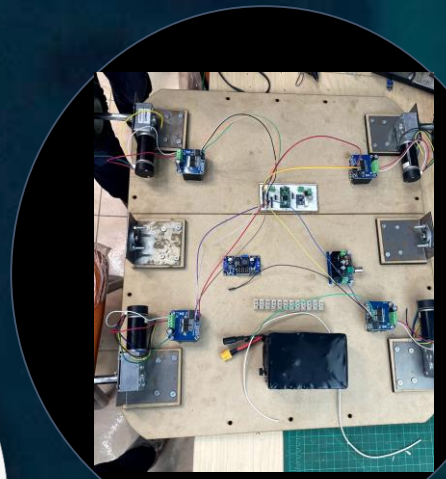
- Total Voltage = 6 x 4 = 24 V
- Total Capacity = 4 x 1800 = 7200 mah

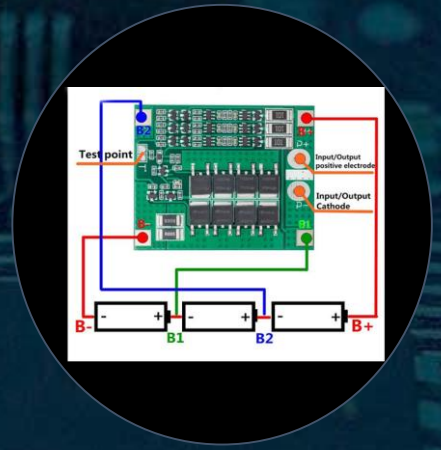
Battery Management System (BMS)

- Short circuit protection
- High current protection : 20 A max
- Over Temperature protection
- Over charge / Over discharge protection



SAFETY MEASURMENTS





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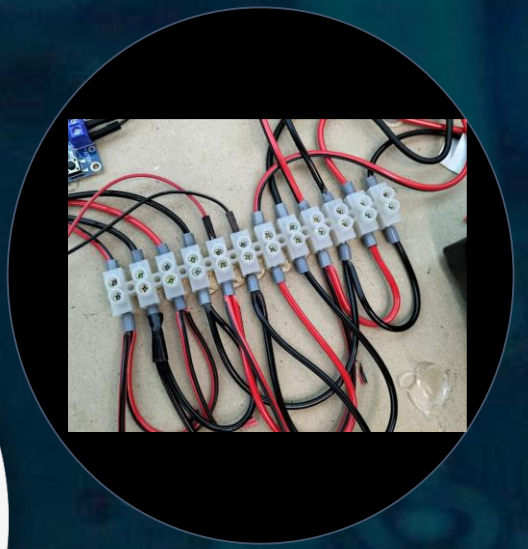

THINK
SAFETY
FIRST

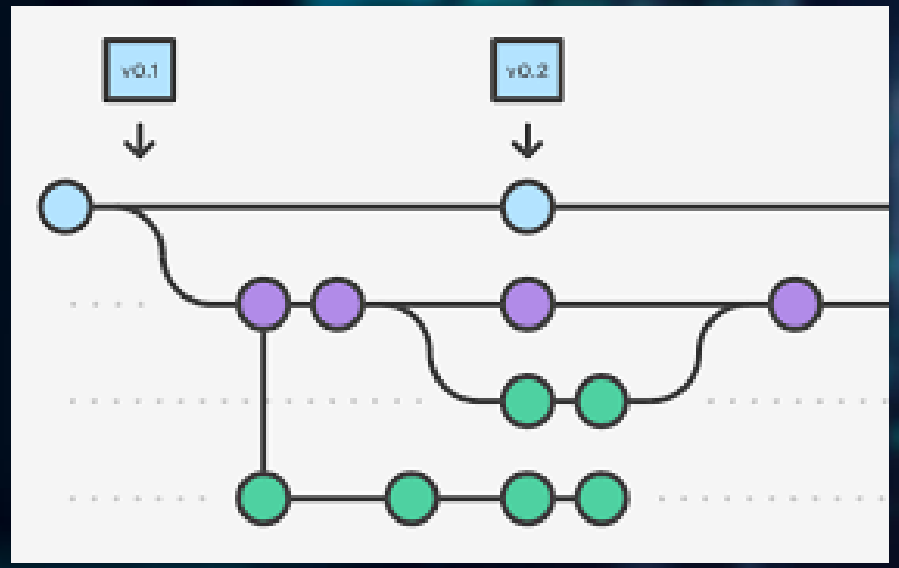

Software

Software

- Workspace
- What is ROS?
- Operating system of ROS
- Advantage of ROS
- Basic components of ROS
- Mapping – SLAM
- Odometry
- Robot transforms (TF)
- Navigation stack & AMCL
- Algorithms

Workspace

Code Source Control



git

GitHub

What is ROS?

- The Robot Operating System (ROS) is a set of software libraries and tools that help you build robot applications.
- From drivers to state-of-the-art algorithms, and with powerful developer tools. It is all open source.

ROS

Operating system of ROS

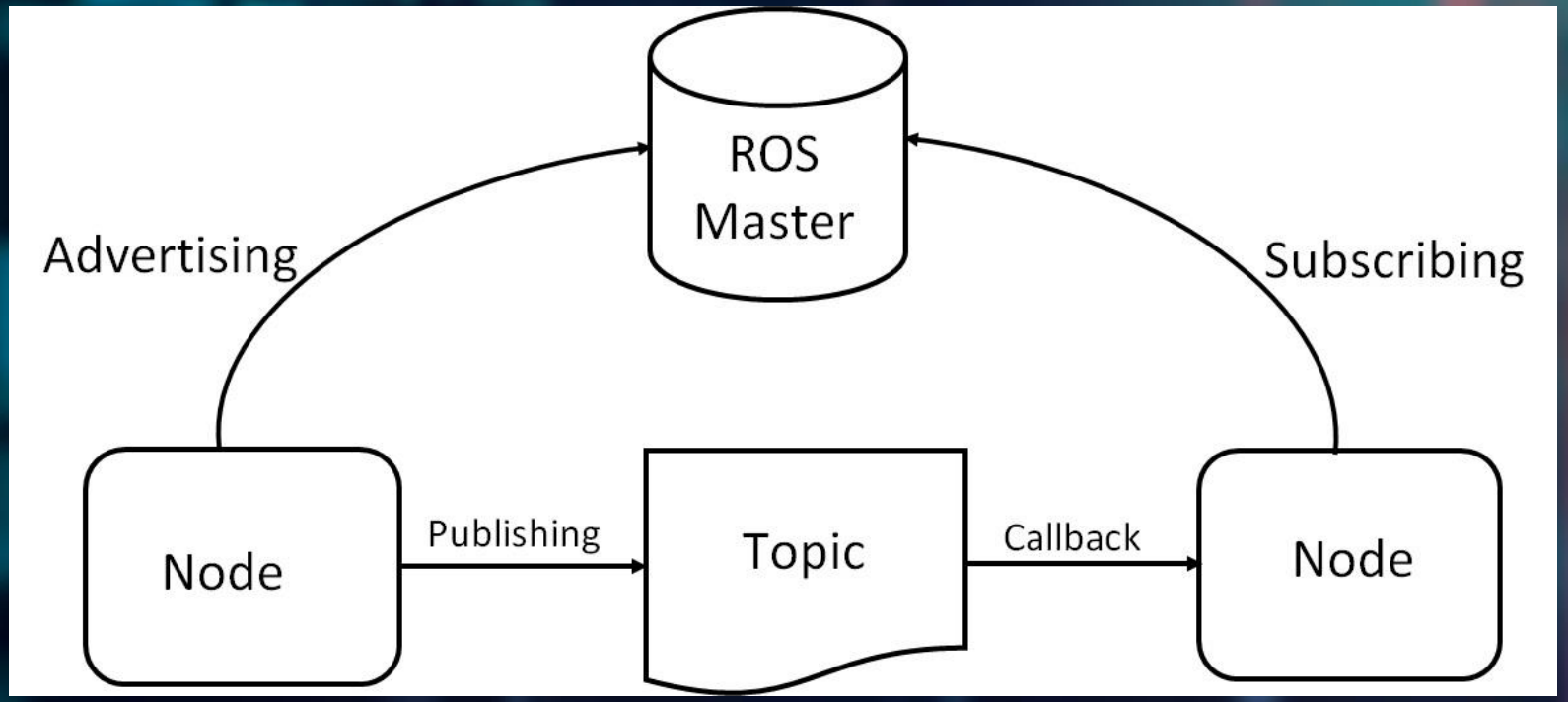
- Ubuntu is a Linux distribution based on Debian and composed mostly of free and open-source software.

Advantages

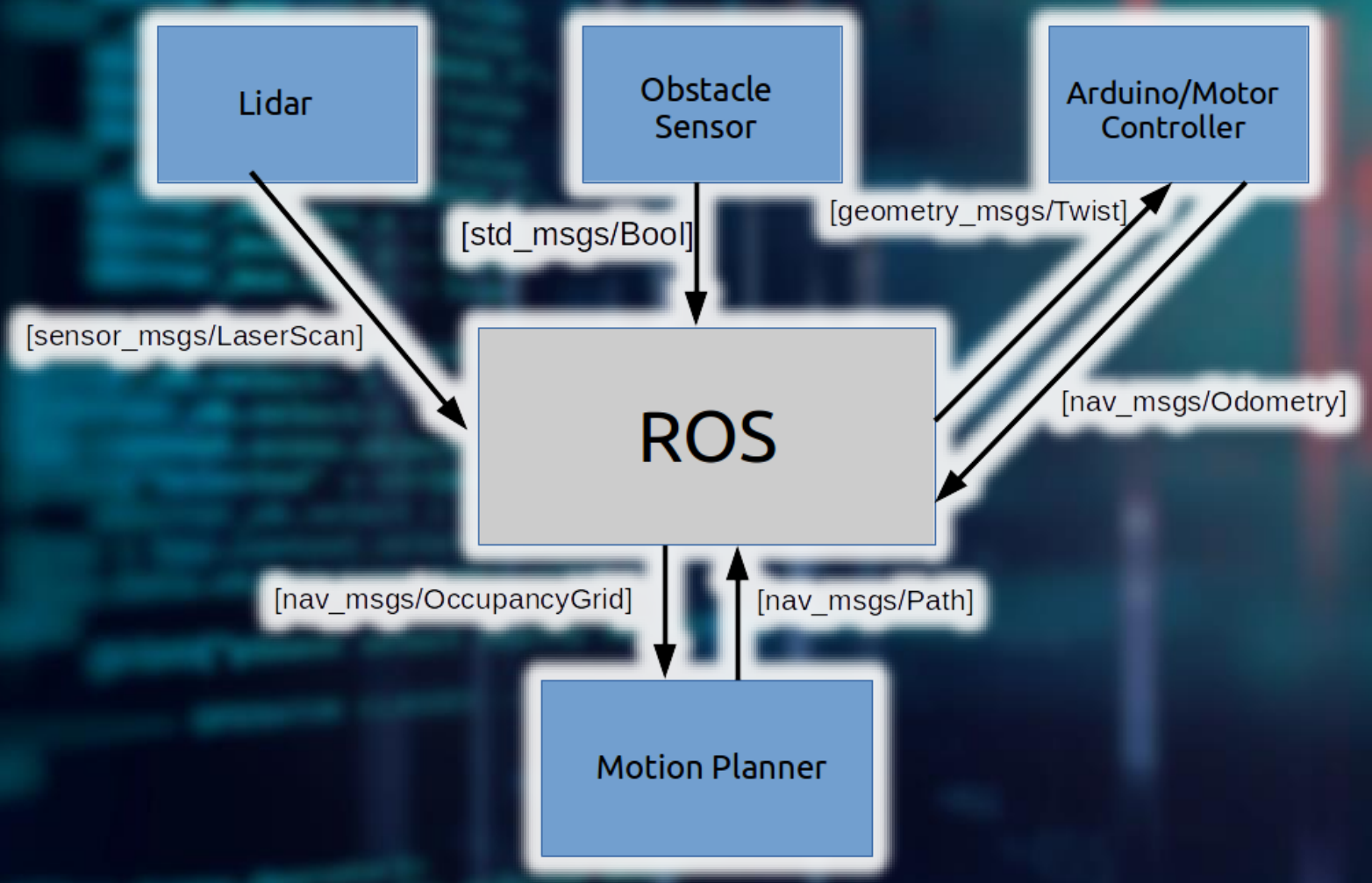
- Process management
- inter process communication
- Tools
- Community


Tools
Simulation
Visualization
Data login

Basic components of ROS



Basic components of ROS

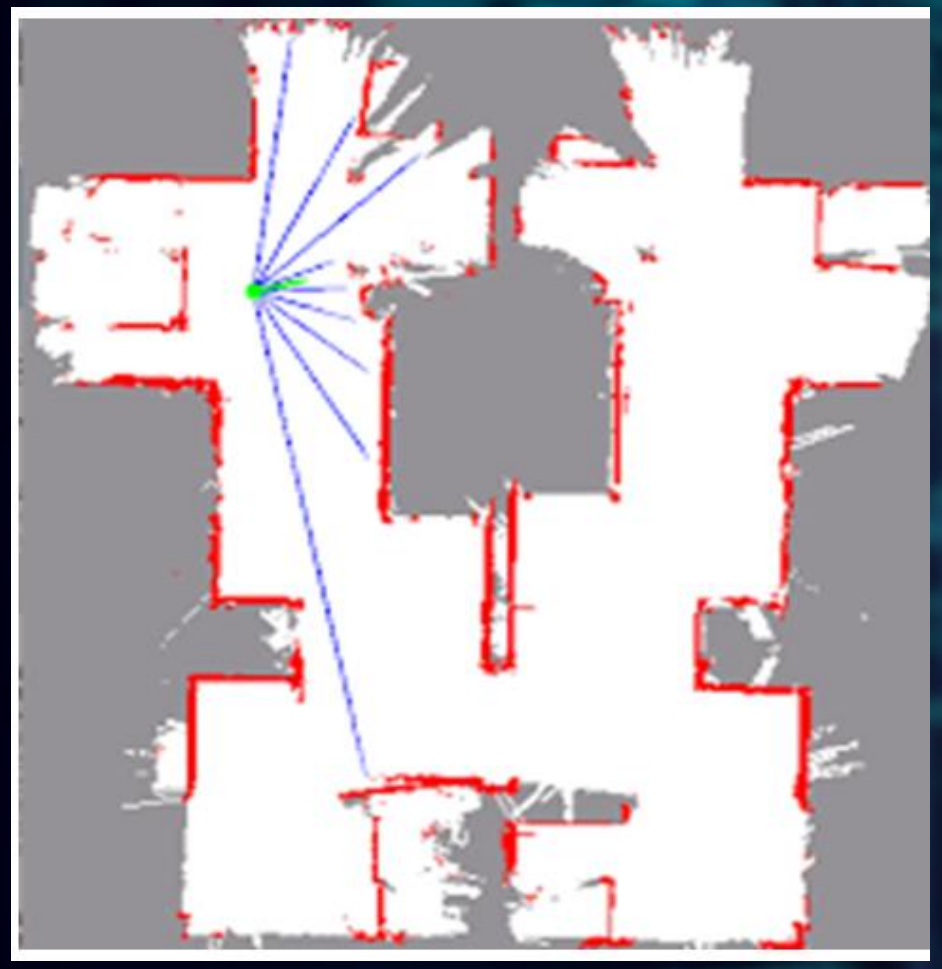


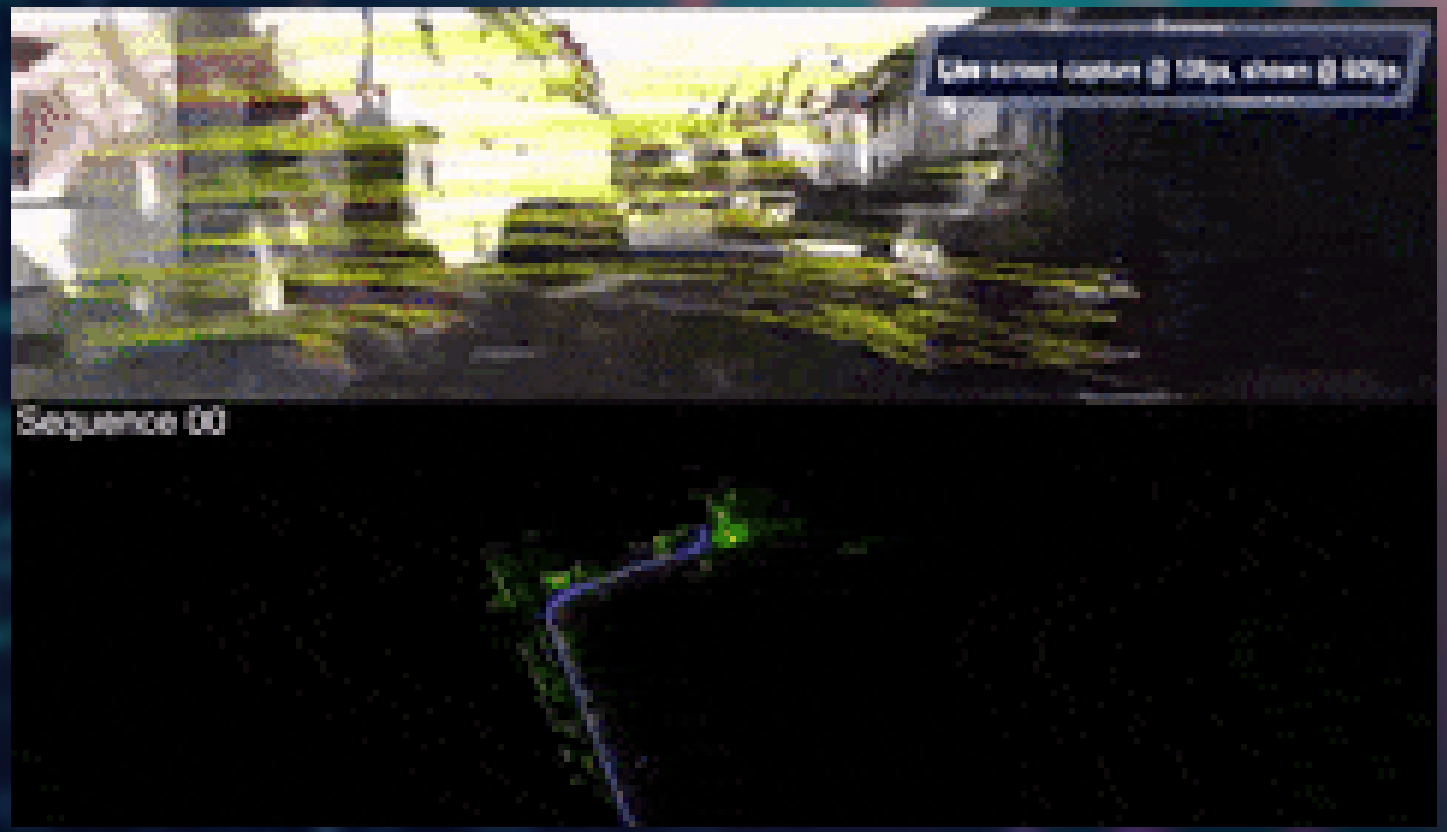
Mapping – SLAM

- SLAM (simultaneous localization and mapping) is a method used for autonomous vehicles that lets you build a map and localize your vehicle in that map at the same time.

- SLAM algorithms allow the vehicle to map out unknown environments. Engineers use the map information to carry out tasks such as path planning and obstacle avoidance.

Mapping – SLAM

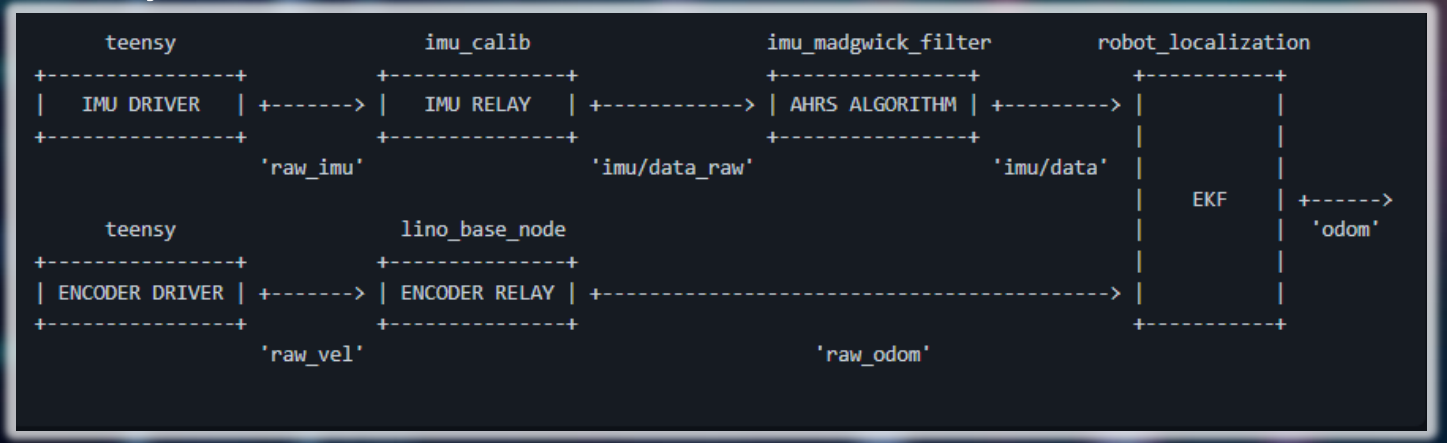




Odometry

- Odometry information is used to estimate the robot's position relative to its origin. Primarily, Linorobot's linear and angular velocity found in the odometry data is calculated by counting the change in number of ticks over time.

- Dead-reckoning that is solely based on motor encoders could be prone to errors due to system noise and wheel slippage.

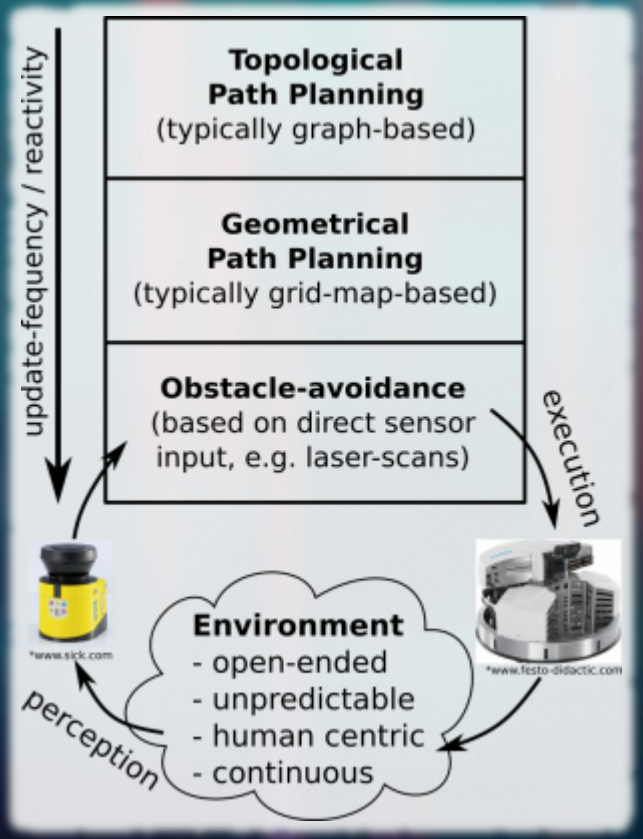


Robot transforms (TF)

- TF is ROS's way of determining the robot's location and relationships between coordinate frames.
- ROS packages require the transform tree of a robot to be published using the tf software library.
- At an abstract level, a transform tree defines offsets in terms of both translation and rotation between different coordinate frames.

Navigation stack & amcl

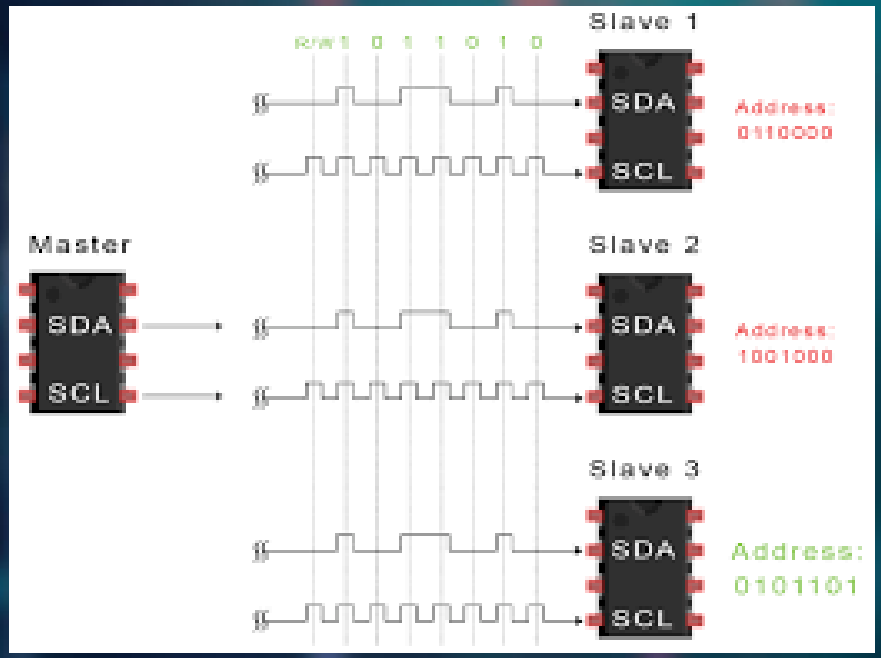
The flexible navigation stack is a set of components that realize specific navigation services to provide a flexibly applicable navigation capability for a service robot.



Embedded Systems Communication

In embedded systems, the communication means the exchange of data between two microcontrollers in the form of bits.

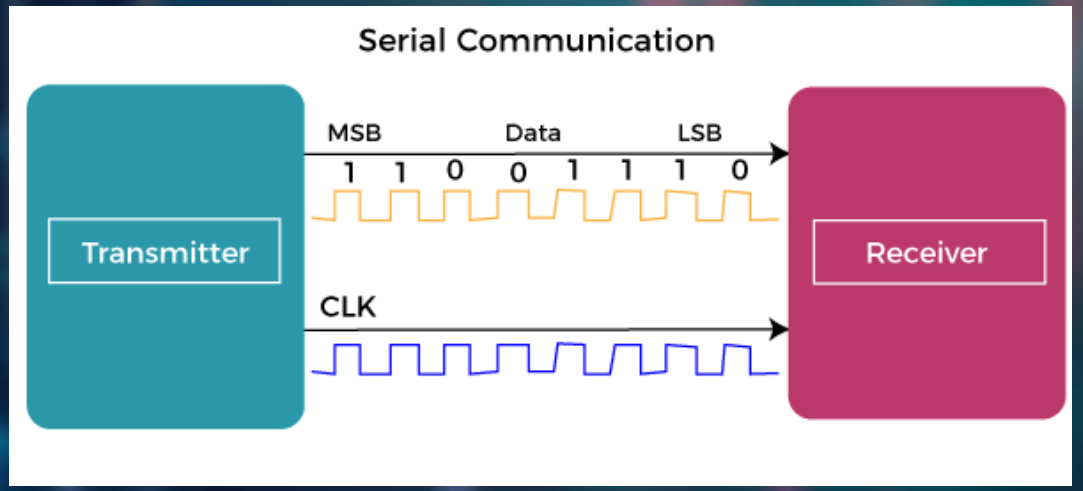
low-voltage wiring network is used for telecommunication equipment or voice and data cabling, which typically requires 50 volts or less electricity to function.



Communication Protocols

This exchange of data bits in microcontroller is done by some set of defined rules known as communication protocols.

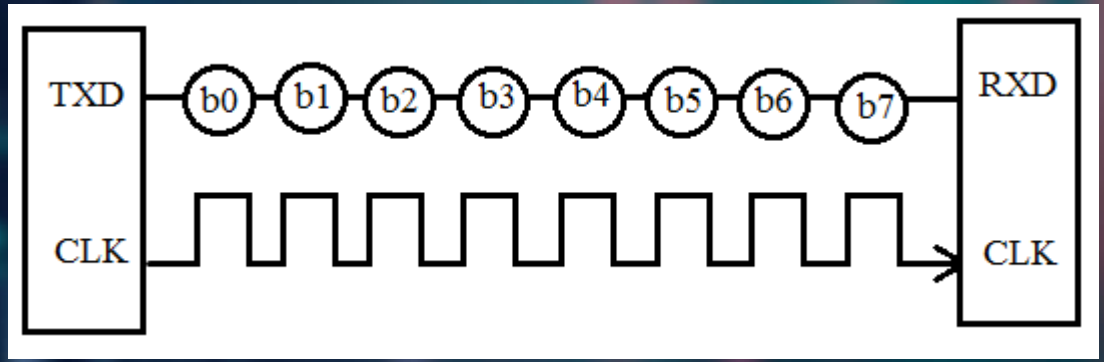
There are different types of data transfer available in the digital electronics such as serial communication and parallel communication. Similarly the protocols are divided into two types such as Serial Communication Protocol and Parallel Communication Protocols.



Serial Communication Protocol

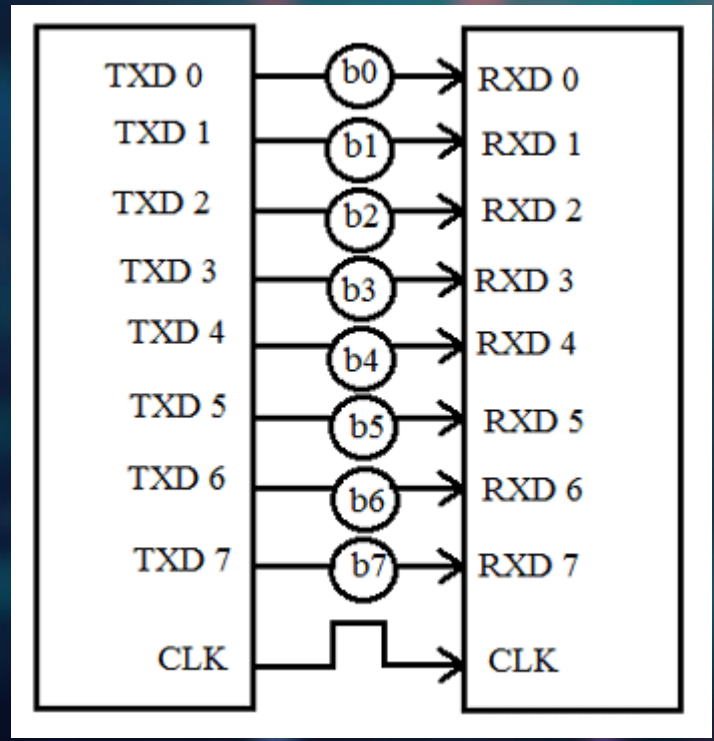
Now if the data is sent in series i.e. one after the other then the communication protocol is known as Serial Communication Protocol.

More specifically, the data bits are transmitted one at a time in sequential manner over the data bus or communication channel in Serial Communication



Parallel Communication

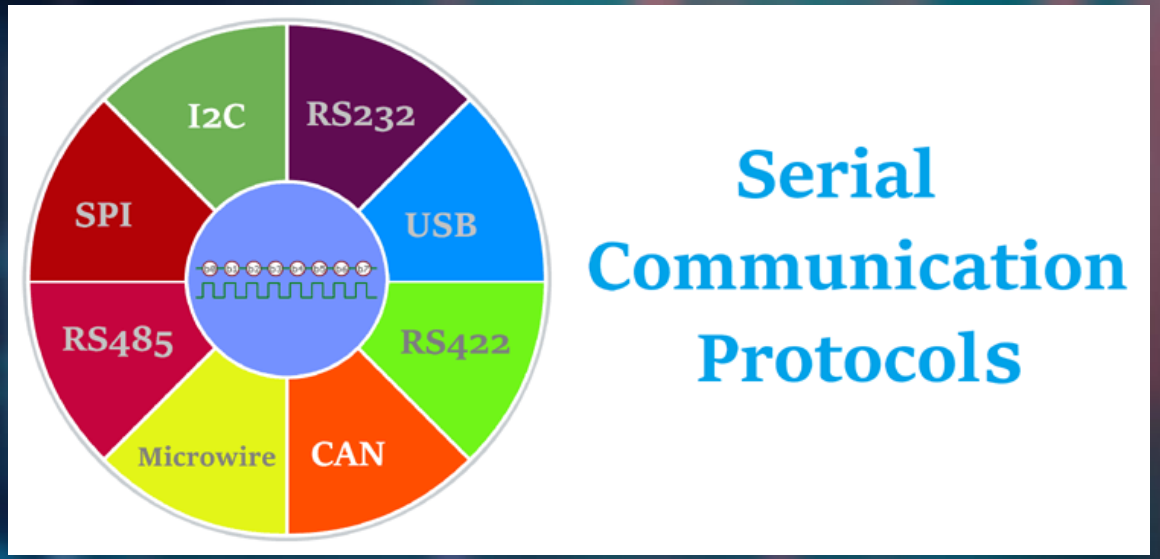
Examples of Parallel Communication Protocols are ISA, ATA, SCSI, PCI and IEEE-488.



Serial Communication Protocols

Similarly there are several examples of Serial Communication Protocols such as CAN, ETHERNET, I2C, SPI, RS232, USB, 1-Wire, and SATA etc.

Serial communication is the most widely used approach to transfer information between data processing peripherals.
Every electronics device whether it is Personal Computer (PC) or Mobile runs on serial communication.

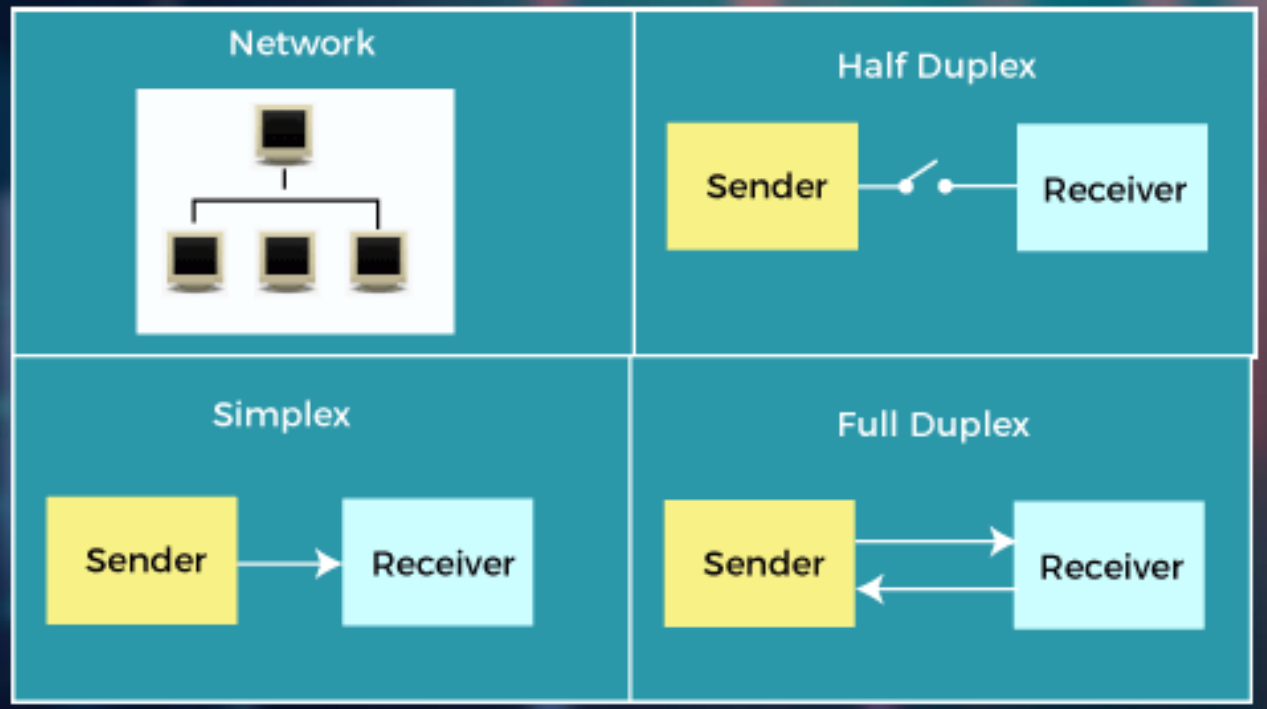


Transmission Modes in Serial Communication

The well-known examples of simplex method are Television and Radio.

The well-known examples of the half duplex is the internet where the user sends a request for a data and the gets it from server.

The well-known example is mobile phone.

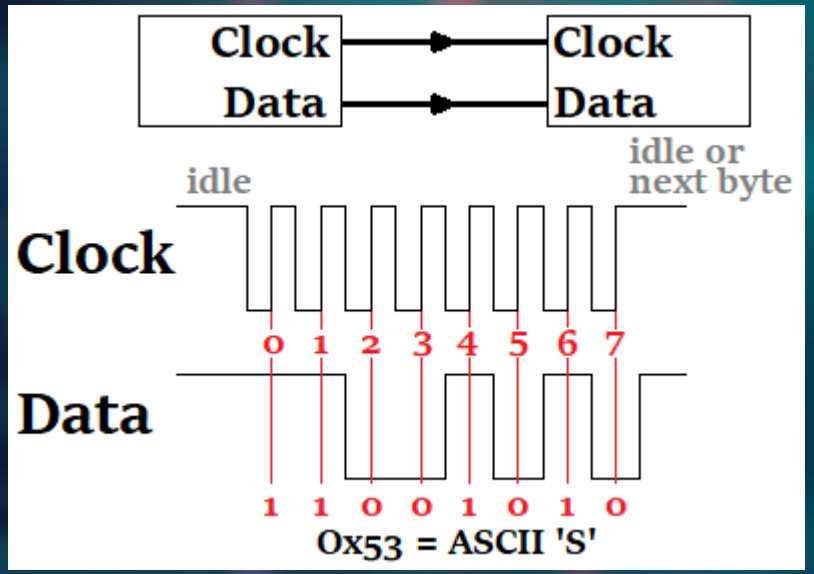


Clock Synchronization

Apart from this, for appropriate data transmission, the clock plays important role and it is one of the primary source. Malfunction of the clock results in unexpected data transmission even sometimes data loss. So, the clock synchronisation becomes very important when using serial communication.

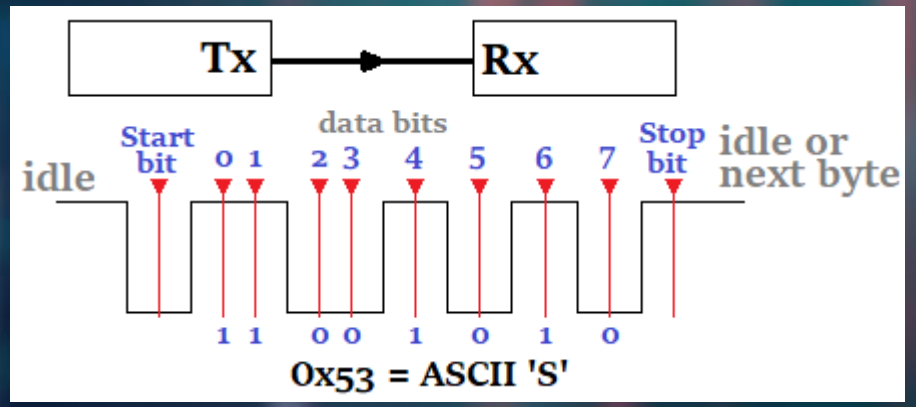
Synchronous Serial Interface

It is a point-to-point connection from a master to slave. In receiver side, the data is being extract using the clock provided by the transmitter and converts the serial data back to the parallel form. The well-known examples are I2C and SPI.



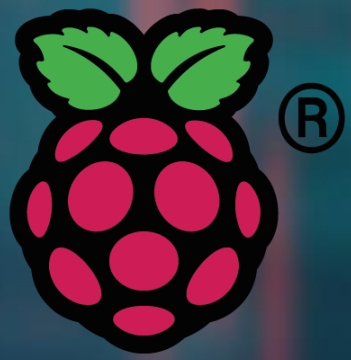
Asynchronous Serial Interface

On the transmitter side, there is a shifting of parallel data onto the serial line using its own clock. Also it adds the start, stop and parity check bits. On the receiver side, the receiver extracts the data using its own clock and convert the serial data back to the parallel form after stripping off the start, stop, and parity bits. The well-known examples are RS-232, RS-422 and RS-485.



Raspberry Pi Communication protocol

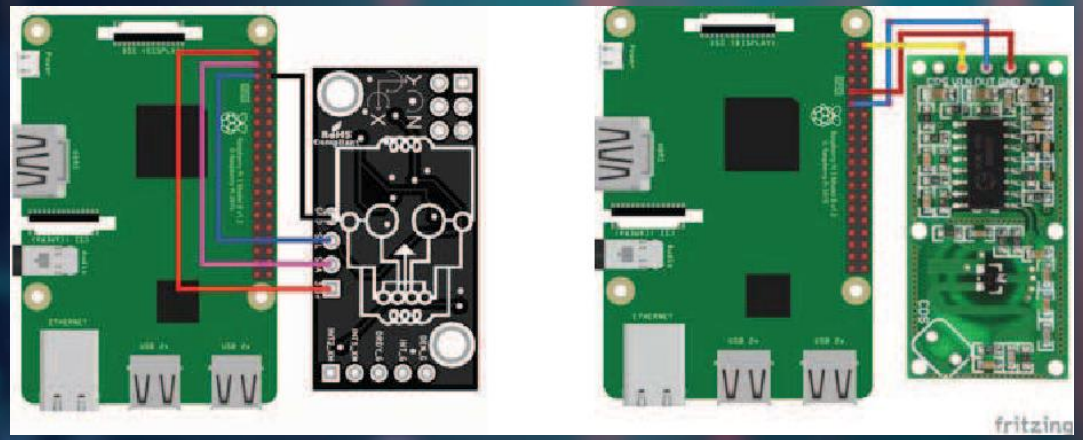
Raspberry Pi can communicate serial data with other devices using some of the common serial communication protocols, such as UART, I2C, SPI, and USB. There are two UART ports/interfaces, two I2C ports (one for HATS and other for external devices), two SPI ports, and four USB ports on RPi 3B/4B.



UART protocol

Basically it’ s an asynchronous multi-master protocol based on the Serial communication, which will allow you to communicate between the 2 boards.

Multi-master means that all connected devices will be free to send data when they want. This is one of the main difference with master-slaves protocols, where only the master device can initiate a communication.



UART protocol

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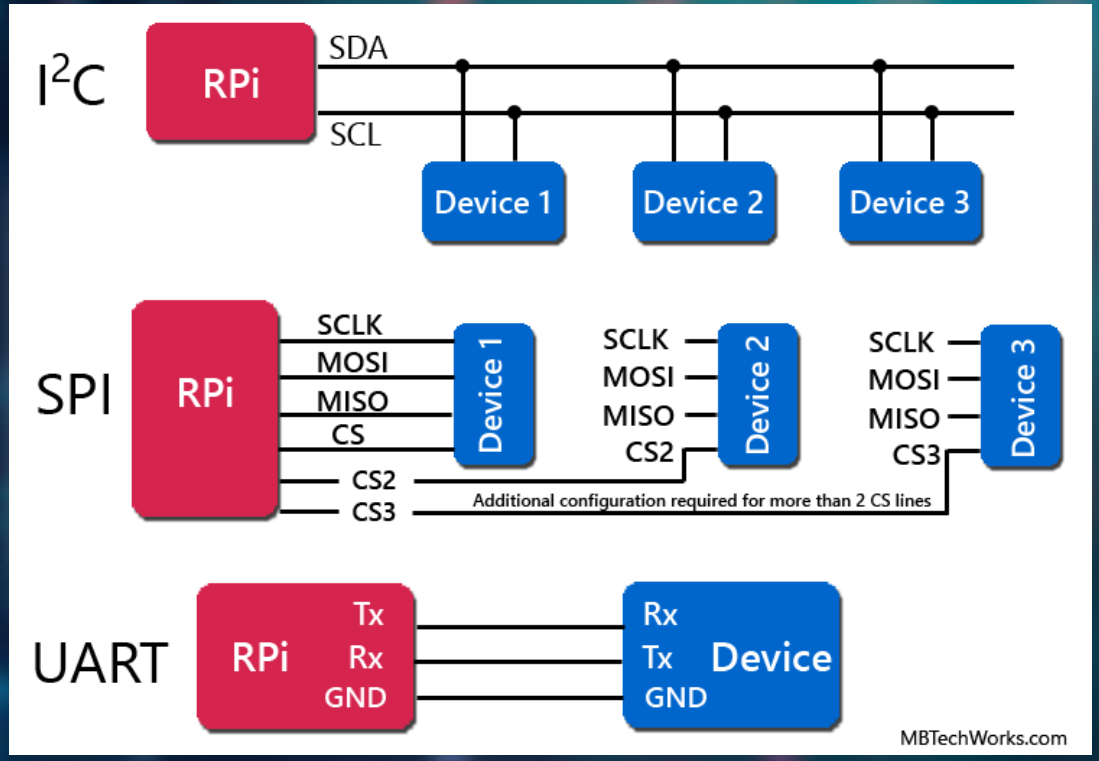
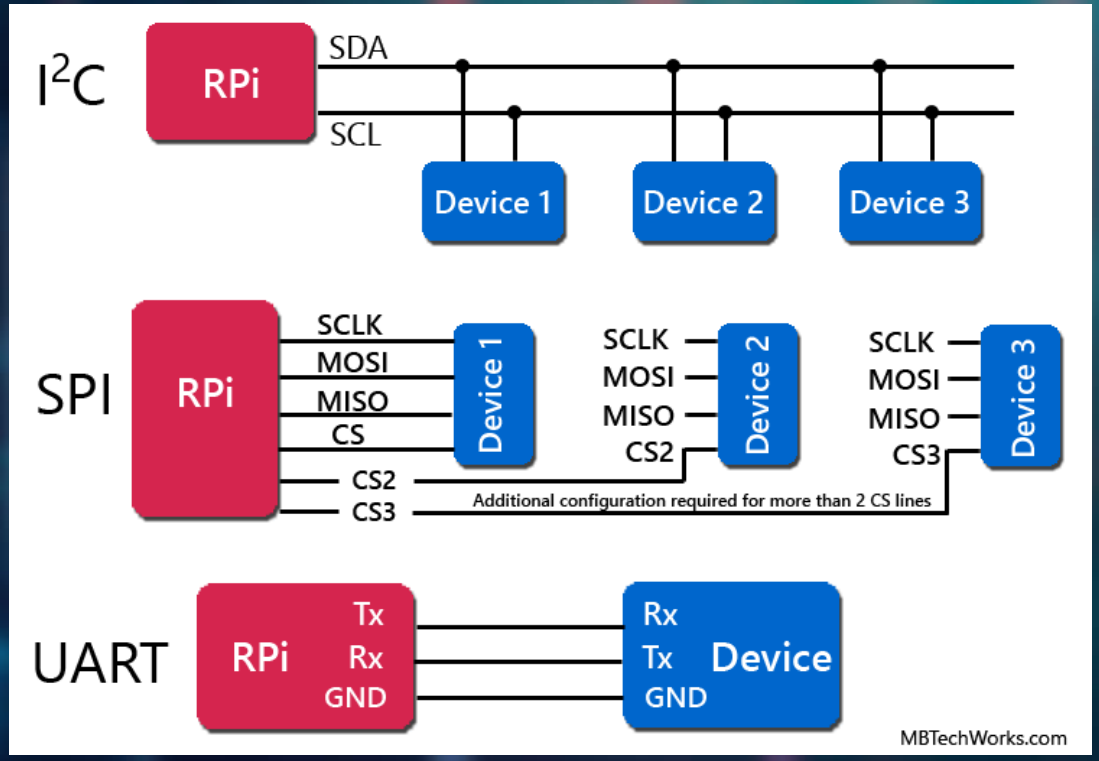
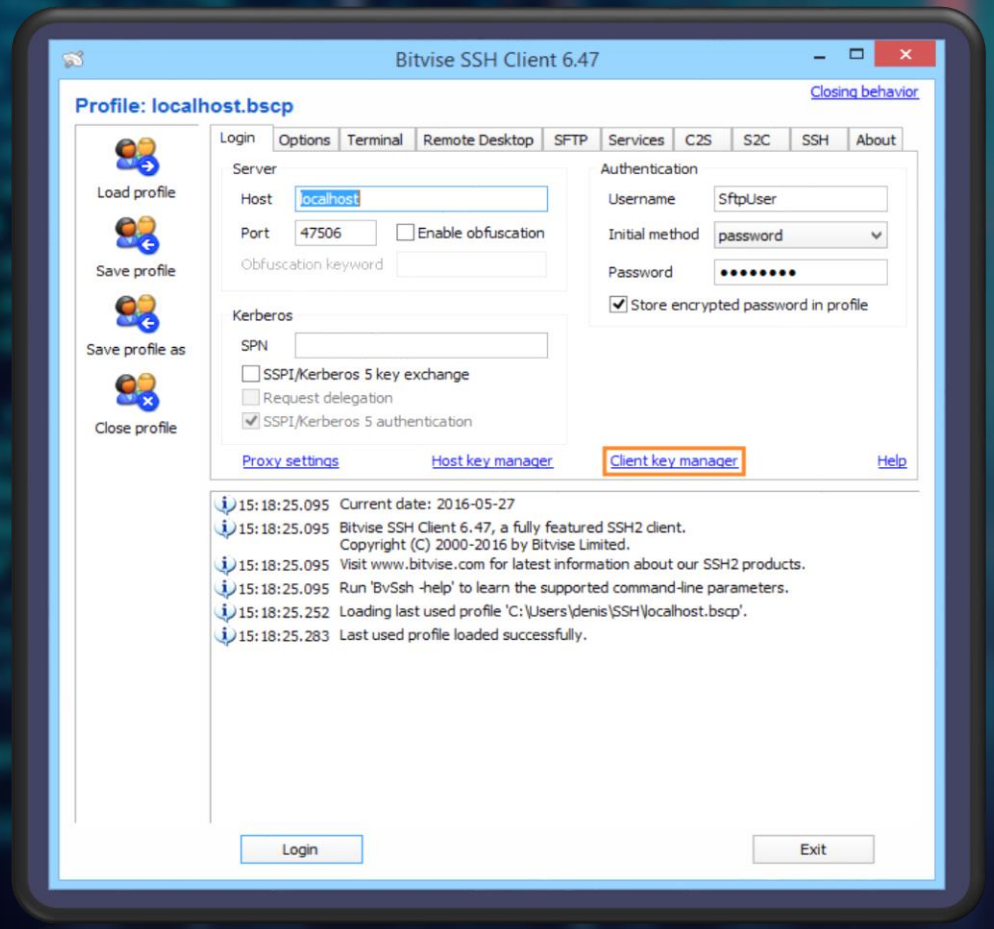


I2C and SPI

I2C and SPI used when we need master-slaves configurations: for example when we have one board and multiple sensors or actuators.



Teensy Configuration



Robot base configuration

```
//uncomment the base you're building
#define LINO_BASE DIFFERENTIAL_DRIVE
// #define LINO_BASE SKID_STEER
// #define LINO_BASE ACKERMANN
// #define LINO_BASE ACKERMANN1
// #define LINO_BASE MECANUM
```

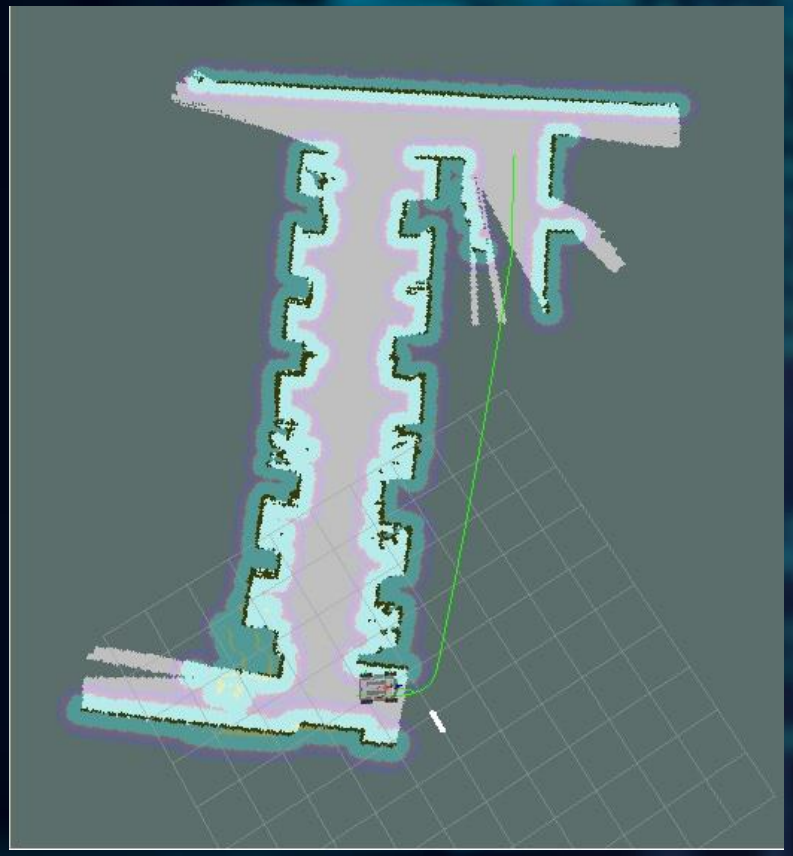
```
//uncomment the IMU you're using
#define USE_GY85_IMU
// #define USE_MP6050_IMU
// #define USE_MPU9150_IMU
// #define USE_MPU9250_IMU
```

```
//uncomment the motor driver you're using
#define USE_L298_DRIVER
// #define USE_BTS7960_DRIVER
// #define USE_ESC
```

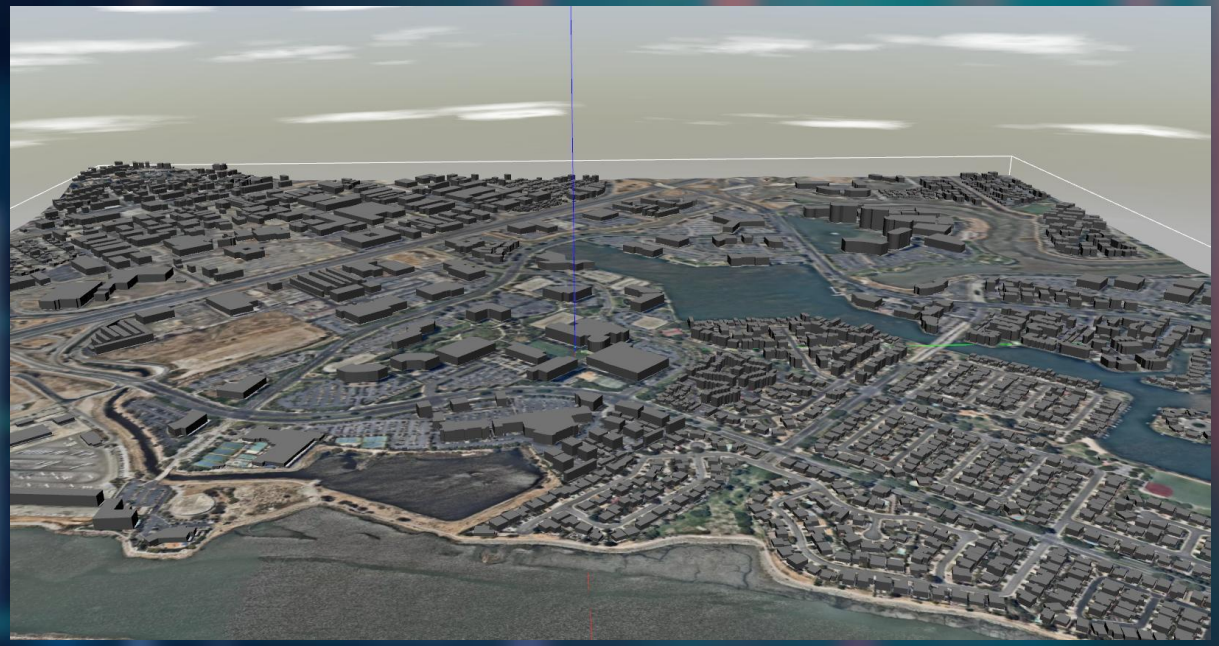
```
//define your robot' specs here
#define MAX_RPM 330               // motor's maximum RPM
#define COUNTS_PER_REV 1550       // wheel encoder's no of ticks per rev
#define WHEEL_DIAMETER 0.10       // wheel's diameter in meters
#define PWM_BITS 8                // PWM Resolution of the microcontroller
#define LR_WHEELS_DISTANCE 0.235  // distance between left and right wheels
#define FR_WHEELS_DISTANCE 0.30   // distance between front and rear wheels
#define MAX_STEERING_ANGLE 0.415  // max steering angle. This only applies to Ackermann steering
```

Mapping and Navigation Algorithms

Indoor vs Outdoor Mapping

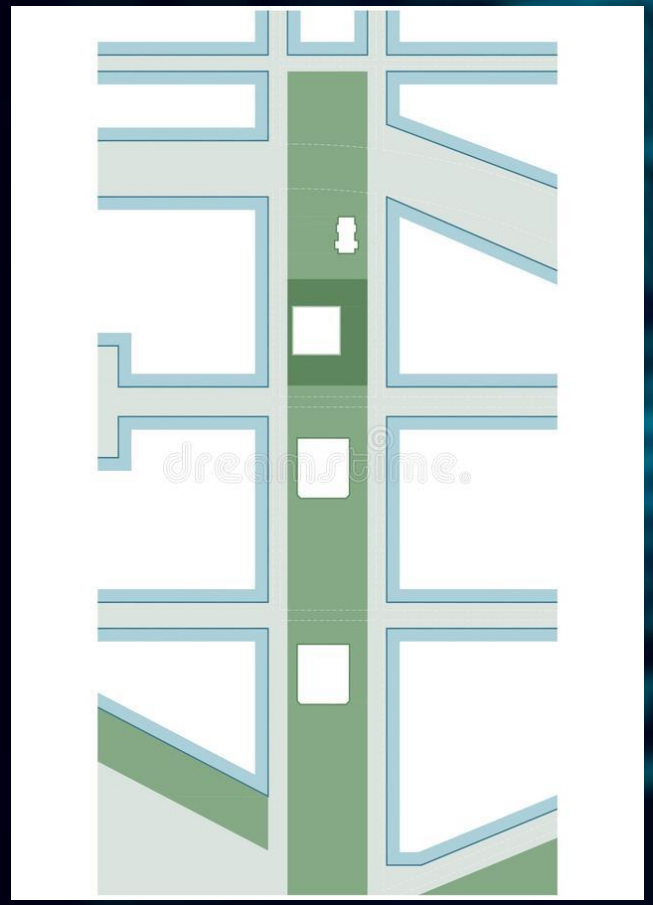


Indoor



Outdoor?

Outdoor Mapping



- Very Challenging
- Needs to be very accurate
- Rare

-just very few companies worldwide

Outdoor Mapping

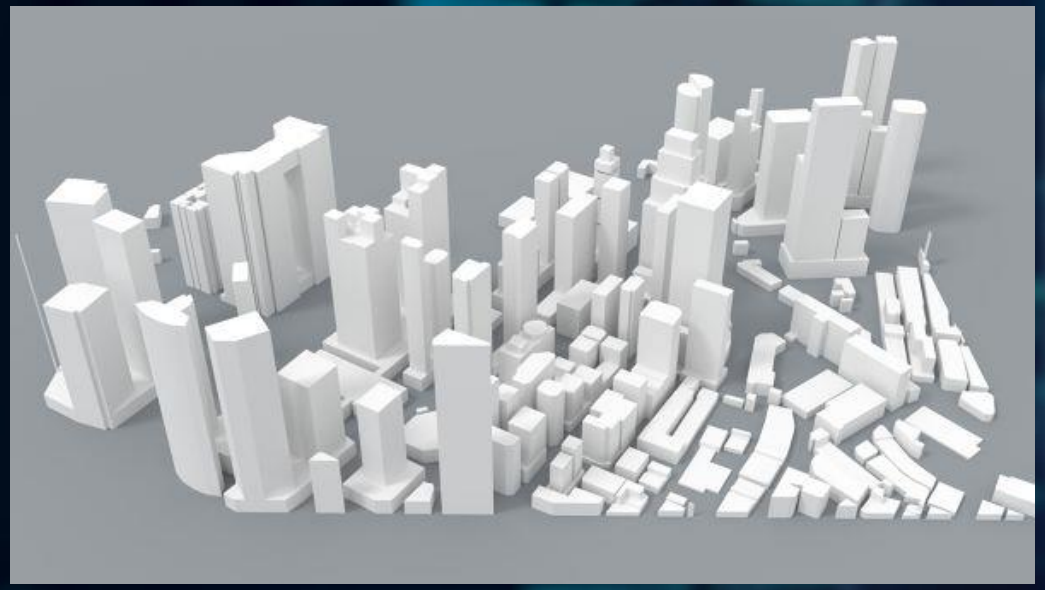
Lidar and Radar System

Video Frames

Depth Camera

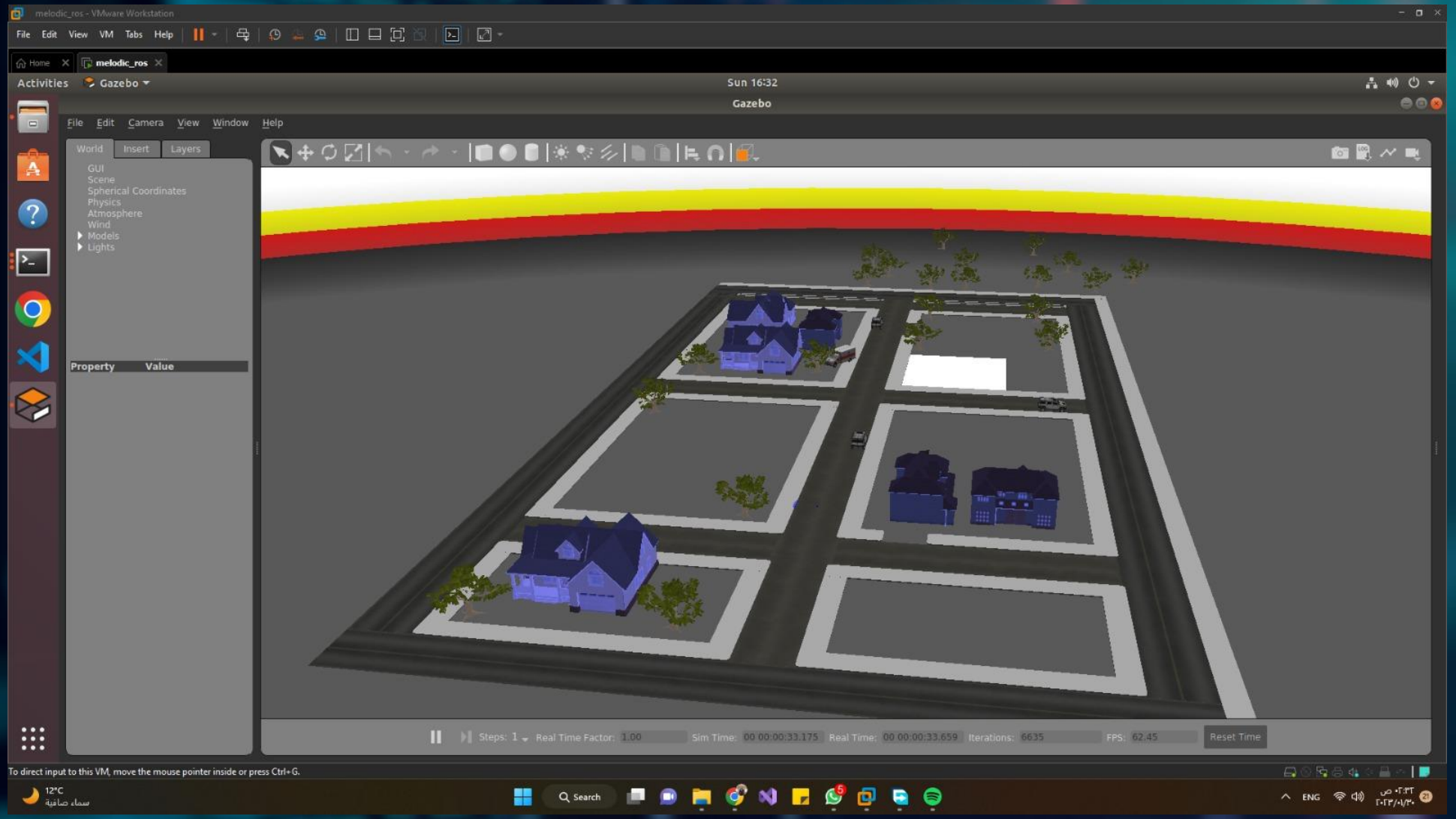
Outdoor Mapping

Our Solution

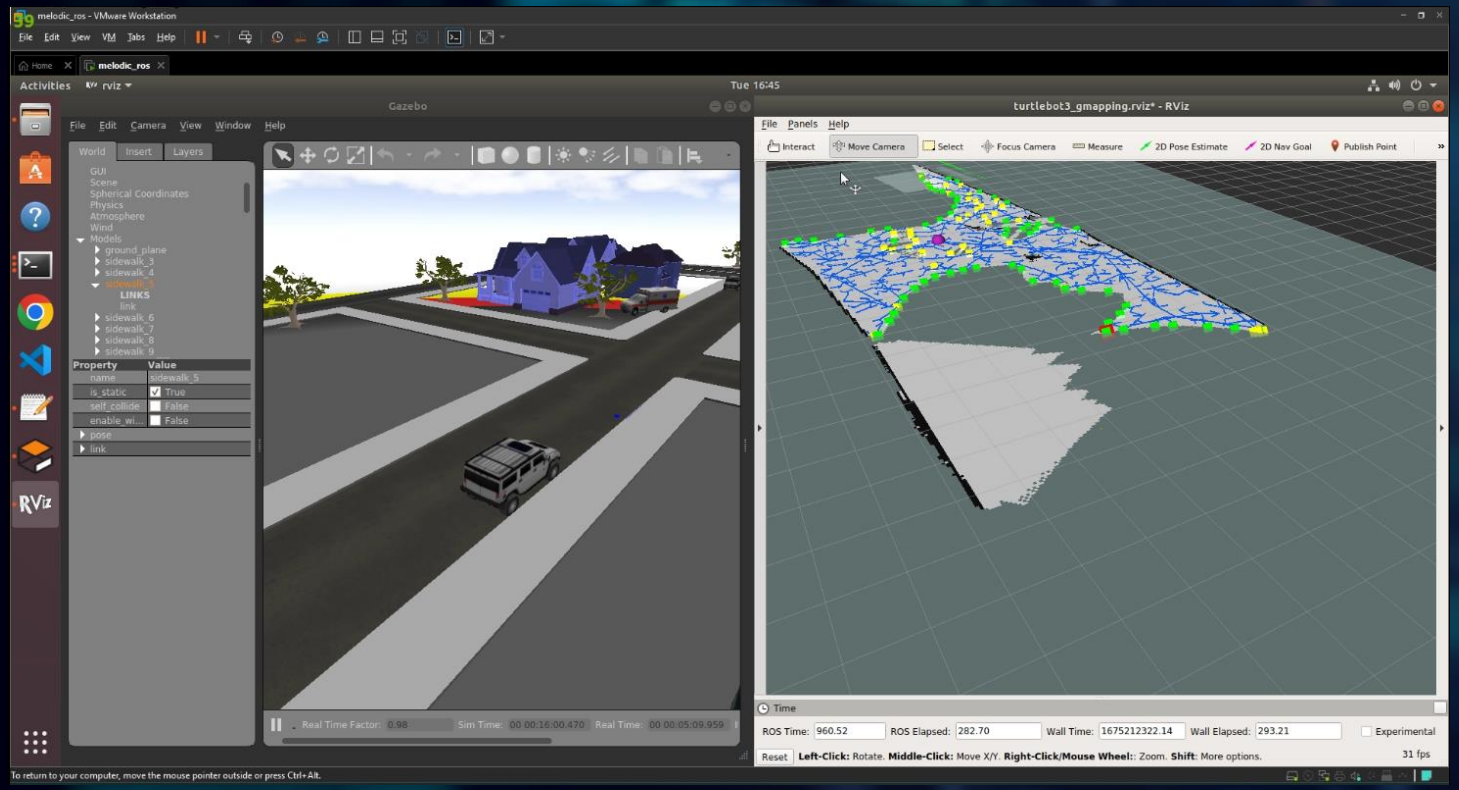


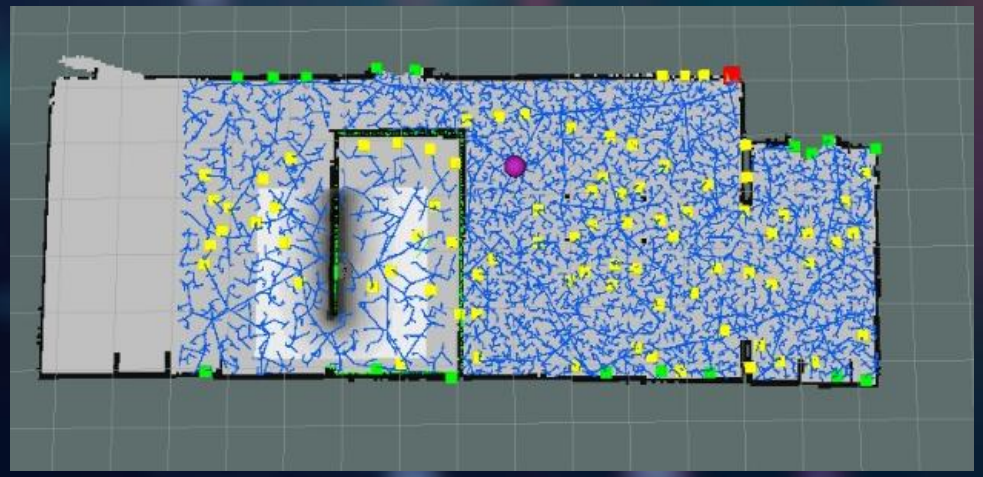
CAD Models + Navigational Systems Corrections

Outdoor Mapping

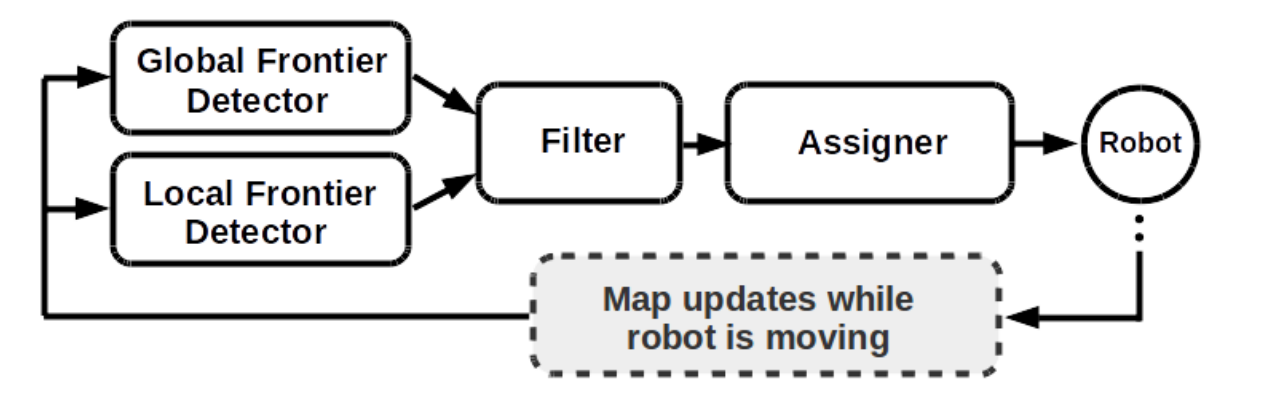


Outdoor Mapping





Exploration Algorithm (RRT)




Business

The Last mile problem

our Solution

it’s not just a simple delivery robot it’s a concept capable of changing the whole delivery system

Market

Size

Market growth will ACCELERATE at a CAGR of

19.85%

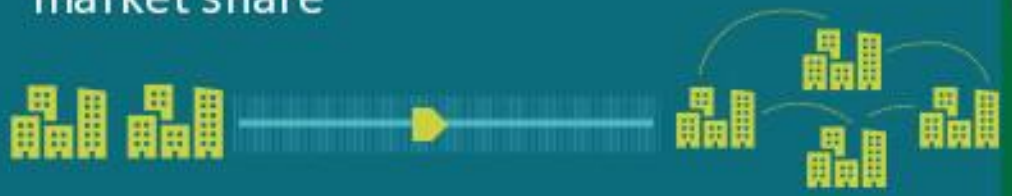
INCREMENTAL GROWTH

$ 24.78 bn

The year-over-year growth rate for 2022 is estimated at

19.34%

The market is **FRAGMENTED** with several players occupying the market share



41% of the growth will originate from **NORTH AMERICA**

One of the **KEY DRIVERS** for this market will be **GROWTH IN E-COMMERCE INDUSTRY**

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GLOBAL AUTONOMOUS DELIVERY ROBOTS MARKET 2022-2026

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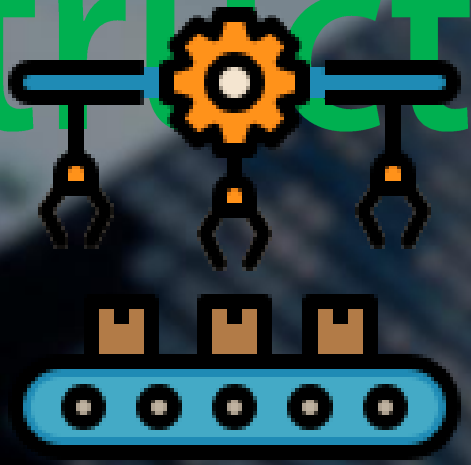
Spares &
Maintenance

Channels

Company Website

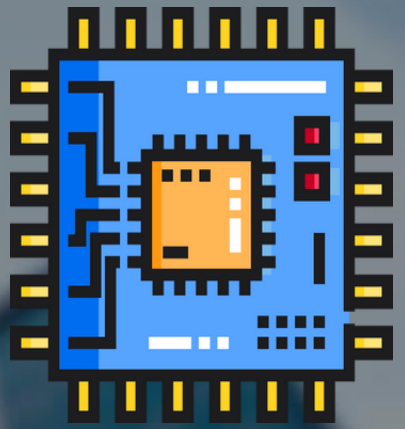
Company headquarters

Cost structure



manufacturing

Marketing



Components Fees

Salaries

Competitions & Achievements

EGYPT

NTRA

The International Science And Engineering Innovations Competition ISEIC ,2023

Air Defence collage

ISEIC - 2023

Egypt IoT & AI CHALLENGE

Challenges faced

Thank you