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UNMANNED AERIAL VEHICLE FOR SECURITY AND SURVEILLANCE IN THE NORTH- RIFT REGION OF KENYA

COMMUNICATION AND GROUND CONTROL SYSTEM

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This project report is submitted in partial fulfilment for the award of Bachelor of Engineering in Electrical and Electronics Engineering.

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Declaration

I declare that this project is my original work and has not been presented in any other university for award of a degree or otherwise.

Signature: Date:

Student

This project report has been submitted for examination with our approval.

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Course Project Coordinator

Acknowledgement

It is with deep gratitude that I would like to thank the almighty God for walking with m through this journey and granting me the knowledge to and technical expertise to produce a solution to the problem. Special thanks to my lecturers whose in-depth coaching and lectures has allowed me to build on my engineering creativity and innovation. Special gratitude to Mr. Justine Kipchumba and Dr Mary Ahuna for extending their faith in me to carry out this project.

Dedication

I would like to dedicate this project to my family whose support has led to the conceptualization of this project.

Table of Contents

List of Tables

List of Figures

Acronyms

ADC – Analogue to Digital Convertor

CPU – Central Processing Unit

CS – Chip Select

DAC – Digital to Analogue Convertor

EEPROM – Electrically Erasable Programmable Read-Only Memory

GND – Ground

I2C – Inter-Integrated Circuit

I2S – Inter-IC Sound

MISO – Master Input Slave Output

MOSI – Master Output Slave Input

OTP - One-Time Password

PCB – Printed Circuit Board

PWM – Pulse Width Modulation

RAM – Random Access Memory

ROM – Read-Only Memory

Rx – Receiver

SPI – Serial Peripheral Interface

SRAM – Static Random Access Memory

Tx –Transmitter

UART – Universal Asynchronous Receiver Transmitter

UAV – Unmanned Aerial Vehicle

Vin – Voltage Input

Abstract

In recent times, insecurity in the North-Rift region of Kenya has been on a steep rise. Crimes such as cattle rustling, communal violence, destruction of property and loss of lives have become a common occurrence in those areas. Traditional methods of crime mitigation, insecurity management and policing have proved ineffective due to numerous factors such as the rugged terrain and remoteness of the area. The perpetrators of this crimes have more in-depth understanding of the immediate environment than the police which they use to their advantage. The terrain renders ground patrol means such as vehicles and patrol on foot ineffective. Air-borne means such helicopters also tend to be expensive. This project proposes use of an Unmanned Aerial Vehicle (UAV) as a tool for security and surveillance in the region. The project will involve the design and development of a UAV capable of long-distance flight to perform surveillance and reconnaissance missions with a camera payload mounted on it. The UAV will include a variety of subsystems that will ensure satisfactory performance of the drone during these missions. Two such subsystems are the communication subsystem and the ground station subsystem. The communication subsystem allows for remote control of the drone while allowing reception of data from the drone such as a live video feed and critical sensor readings that aid in flight control. The ground station provides a platform to input control signals to manoeuvre the drone remotely and to receive, display and store critical readings to aid in the control of the drone as well as the video feed. It provides the drone with a long range to effectively carry out surveillance and security missions without limitations. Results obtained include a flight range of over 1.3Km and data transmission rates at this range were at around 300Kbps with minimal noise and bit error rate. Instantaneous data transfer was achieved and thus allowed for real-time control of the drone.

CHAPTER ONE

Introduction

1.1 Background Information

Security is an especially essential element in the society. Economic activities, infrastructure development and the social well-being of the community are all tied to security. Insecurity puts all the above in jeopardy and may nullify already existing benefits of a secure community.

There have been reports of houses belonging to two families had been torched, one person shot dead with another sustaining injury all occurring at sundown. The attackers, who were armed to the teeth with guns, made away with a herd of cattle. Such scenarios paint a picture of the desolate world of chaos that the central rift region has been thrown into (Koech & Kiplagat, 2022). Loss of life and property being a daily occurrence and a looming humanitarian crisis looming especially with a more recent attack in Kapsokum village as started by the Kenya Red Cross (Lutta, 2022).

Law enforcement agencies have also suffered at the hands of attackers. News reported 23 people including a senior police officer had been killed in a surprise attack in the areas of Kapkechir, Baringo South and Korkoron hills (Koech, 2022). Another attack claimed the lives of 40 police officers after a pursuit mission of cattle rustlers in Kerio Valley led them into an ambush. The bandits who carried out the attacks were seen to be highly trained and armed, and this had raised eyebrows in who could be involved (Ndanyi, 2022). Steps have been taken such as communal disarmament, deployment of security personnel and conflict resolution programs but the cycle is never ending, and community members have had to pick up arms and defend themselves (Kipsang, 2020).

To fight the cases of insecurity in the north rift region, a mechanism should be in place to do routine surveillance in the hotbeds of attacks in a manner that is not only efficient but also preserves human life. A mechanism that would provide the law enforcement agencies with a tactical advantage would be a big step in the fight against cattle rustling and inter-community clashes.

UAVs have been around for a while now and they are often used for recreational sports such as racing and acrobatic displays and in videography and photography. They are easy to control and fly and their technology has matured in the past few years. Already existing UAVs are not well designed to fit into a capacity of security and surveillance due to being loud, have short flight times, small communication ranges and low data rates, cannot forward GPS coordinates and have limited cameras with low resolution and no night vision enabled. A well-designed UAV would be a good means of keeping security in the region (Gilli, 2013).

An effective ground control station and an effective communication system are critical in assessing the performance of the drone in its various applications without which the drone becomes hazardous to people and property (Dougherty, 2015). With an effective ground and communication system, the drone is not limited by the rugged terrain which may expose problems to sub-standard designs due to scattering, diffraction, and reflection. The communication also provides a means to forward live surveillance videos to the ground station. It provides a good tactical advantage as it has an aerial view of the surrounding and can easily pick out bandits hiding in wait for an ambush using a camera and relaying live feeds. This will provide the law enforcement agencies with the necessary intelligence to figure out how to arrest the perpetrators carefully It also moves at fast speeds and longer distances and can thus track and catch up with bandits.

1.2 Problem Statement

Kenya's north rift region has been faced with devastating clashes and criminal activities. This rise is especially attributed to cattle rusting and expansionism in search of pastures in a region plagued by drought (Limo, 2017). It has resulted to displacement of families and death of not only people but also police officers. The perpetrators of the treacherous acts are heavily armed individuals who attack in the wee hours of the morning or late at night and the security agencies are always found unaware and unprepared. With a drone as a great solution to the insecurity crisis, the region is extremely remote, and the communication infrastructure is wanting since cell phone coverage and the internet is limited. Already existing drones make use of limiting network technologies that would not fit into the requirements of a mission ready drone. The drones are controlled from unsecured channels that may be a security risk revealing secrets to the enemy about the mission. The ground station that remotely controls the drone does not provide an interface to assist the pilot during flight time and thus the drone control becomes a cumbersome unassisted task. A great control mechanism for the drone is necessary to allow for long range control of the drone that is not only efficient but with high data rates, inexpensive and with low power consumption. There is need to provide a means of maintaining communication with the drone to enable carrying out of smooth tracking and recovery operations by law enforcement that is not only effective but fast and inexpensive but also safe to ensure no lives are lost. A means to detect an attack before it happens and communicate this via a secure channel is a tactical necessity that would ensure effective policing in the region.

1.3 Proposed Solution

The project proposes the design and development of a UAVs ground control and communication system that will provide a clear advantage to security agents in the north rift region in the war against insecurity. Unlike already existing UAVs ground control and communication systems, the project proposes a design with longer flight ranges, higher data rates, low noise, and secure data transfer. The drone will have the ability to forward GPS coordinates and a Night vision capable camera. The camera will enable the spotting of criminals and cattle rustlers making their way to attack or driving off with cattle. It will have a critical role in reconnaissance when security agents are in a tracking and recovery mission in pursuit of criminals who have made away with cattle. A live video feed will be provided allowing security personnel to assess the situation and figure out a way to detain the attackers. The system will help preserve human life, property and peace in the region and thus improving quality of life.

1.4 Objectives

In this project, I will be working in a team of four to realise an effective and fully functional drone. The following are the objectives of the project as well as the specific objectives that I will be tackling.

1.4.1 Main Objective

To design, develop and test systems for a drone as a security solution with the capacity to achieve flight and perform surveillance and reconnaissance security missions.

1.4.2 Specific Objectives

i. To design and implement an effective, secure, and stable communication system that will enable transfer of flight data and logs from the UAV as well as provide a control channel to fly the UAV over long distances.

ii.	To design and implement a ground control system that will generate control signals to fly the UAV.
iii.	To design and implement an interface to display operation status and assist in drone piloting.
iv.	To design and implement a good power supply system to provide the right amount of power for the ground station system.
v.	To design a printed circuit for the ground and UAV system implementation.
vi.	To design a storage mechanism to store flight data and logs.

1.5 Block Diagram

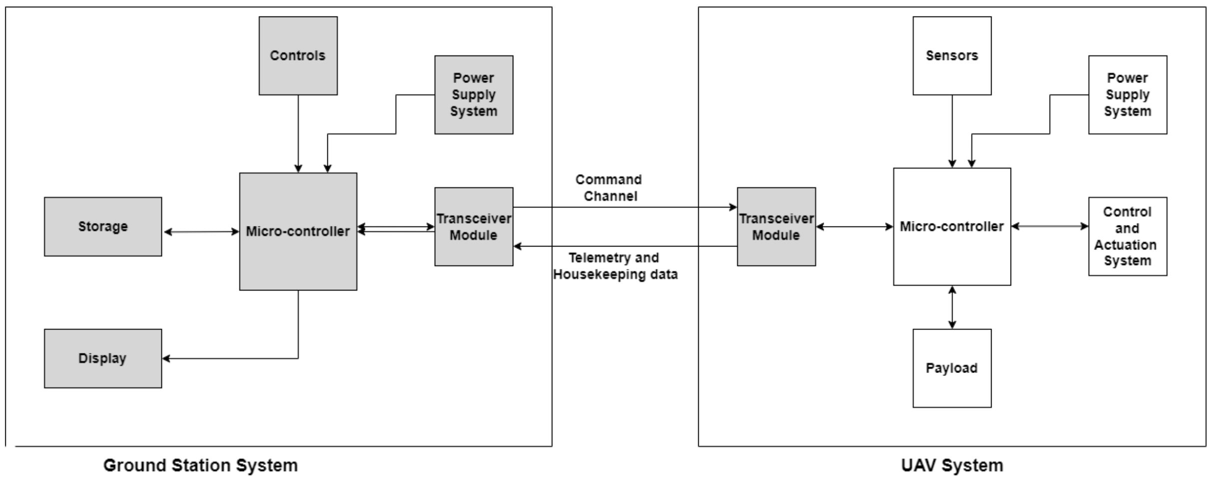


Figure 1: UAV and Ground Station System Block Diagram

The project will involve two distinct parts: the ground station and the unmanned aerial vehicle as shown above Figure 1.

1.1.1 Unmanned Aerial Vehicle

This is the flight capable section of our project. It is made up of various subsystems that enable to achieve flight.

1.1.1.1 Transceiver module

This module will allow full duplex transmission between the UAV and the ground station. Control signals and housekeeping data will be forwarded over this module.

1.1.1.2 Microcontroller

This will act as the brain of the UAV; it will provide control signals based on both sensor and control input to provide the necessary actuation of the UAV.

1.1.2 Ground Station

This is the grounded and stationery section of the system. It allows for the remote control of the UAV and reception of housekeeping data containing status of the UAV.

1.1.2.1 Controls

This system includes input devices that send out control signals that correspond to the actual motion or operation the pilot expects from a drone.

1.1.2.2 Transceiver Module

This a full-duplex communication device that allows control signals and data to be shared between the UAV and the ground station.

1.1.2.3 Storage

Stores flight logs, flight path coordinates, housekeeping data as well as the received video from the drone.

1.1.2.4 Display

This provides an interface to present flight data and operations visually to the pilot.

1.1.2.5 Power Supply

Provides the required amount of power for each system in the right voltage and current. Voltage and current sensors will be utilized to ensure the requirements are meant.

1.6 Project Specifications

System	**Parameters and Values**
Power	Input voltage: 5V Operating current: 2A Battery Rating 7.4V, 5000mAh
Computing	32-bit Dual-Core Tensilica Xtensa LX6 microprocessor Clock speed: 240MHz Performance: 600 DMIPS ROM: 448KB SRAM: 520KB Flash memory: 4MB Interfaces: ADCs, DACs, I2C, UART, I2S, PWM
Transmission	Range: 10km Tx voltage: 1.8 – 3.7V Tx Current: 93mA Rx voltage:1.8 – 3.7V Rx current: 12.15mA Frequency: 433MHz Channels: 100 Data rates: 300kbps Rx Sensitivity: -148dBm Max Tx Power: +20dBm Antenna:
Dimensions	PCB: Body:
Storage	SD card: 8GB
Interface	SPI: x3 Serial: x1
Control	Joystick: x2
Sensors	Voltage sensor: 25V max Current sensor: 30A max

CHAPTER TWO

Literature Review

2.1 Introduction

UAVs, especially drones, have been in the limelight for a few decades now with a wide array of uses which include photography, videography, land survey, entertainment, sport, and pest control. They have utilised existing technologies to be able to achieve flight and carry out the various applications they have been designed for. They are effective and their application can be extended to internal policing within the country's borders, but a redesign is needed to make it an effective inclusion to the security agency toolkit.

Existing communication solutions utilised in drone technology include Wi-Fi, Bluetooth, and radio waves. Wi-Fi is a wireless technology that is popular for providing wireless connectivity between devices in a small locale and the internet. Running on the ISM bands at 2.4GHz and 5GHz. It provides a high data rate connection to allow for massive data sizes to be transferred from one point to another. It however has the drawback of limited range and may require additional access points and infrastructure to extend the range making it expensive. Bluetooth can be utilised for limited distance control within 10 metres and thus not useful for long range control. Radio waves on the hand provide a robust and adaptable control signal transmission. Proper design and frequency selection will allow for long range control without any issues.

This chapter entails a discussion of the existing solution for the purpose of the implementation of an effective ground station and communication system for the control of the drone for security missions.

2.2 Existing Solutions

Since drones have been in existence for decades now, numerous control mechanisms and solutions have been integrated into it to allow for control and communication. Below is a description of those solutions.

2.2.1 Drone Ground Control Station with Enhanced Safety Features

Haque et al. (2017) proposed the design of a custom-made microcontroller-based ground station that is easily customizable by the user for whatever feature needed by a drone. The design approach involved a software unit be installed on a host computer, a telemetry module and control input devices all bridged together by the microcontroller. The microcontroller of choice was the ATMEGA2560 embedded on an Arduino Mega board. The software unit provided a means to visualize the flight data on the laptop that would assist the pilot gain understanding of the flight status and control parameters and not rely solely on a visual of the drone flight response. The control algorithm is flashed into the on-board microcontroller and not the software to ensure that in case of computer or software failure, the drone is still under control and not at risk of crashing. The microcontroller was programmed and interfaced in such a way as to allow expansion and future addition of sensors to monitor the ground control station and local weather conditions. Such data includes system voltage, temperature, fire alarm and power backup. The control input system was made up of hand-made components from variable resistors and toggle switches to provide control input for throttle, yaw, pitch, and camera rotation control. Signals from joysticks were converted from analogue signal to Pulse-Position Modulation (PPM) signal that is transferred to a radio transmitter, with the possibility of an externally mounted, over a wired interface and sent over to a drone. The receiver module made use of the MAVLink communication protocol to secure the signal.

Weaknesses

This ground-station had several drawbacks. One such drawback is that the ground station is fixed and not easily portable. The ground station involved two distinct parts physically connected by an interface; a computer and the actual controller. This would mean that the drone would be a cumbersome tool to setup before a mission. Another drawback was the use of an Arduino Mega board as part of the ground control station. This board is massive and consumes a huge amount of controller real estate that could have better been utilised in ergonomics or added features. The board also has limited processing capabilities and memory and thus affects its performance. The design did not implement a real-time operating system and instead utilised a linear instruction execution instead of a parallel and priority-based execution. This would have hindered the control and manoeuvrability of the drone during flight.

2.2.2 Design and Implementation of Drone in Healthcare Applications

Khandagale et al. (2020) propose the design of a communication system for their drone for healthcare operation using a combination of Wi-Fi and a mobile network providing internet connectivity. The ground station is made up of a smartphone running the Blynk app with virtual buttons and joystick that simulate a physical controller. The drone control process starts with the pilot pressing on the Blynk App interface to input the desired control signals.

The data is forwarded onto an IoT server awaiting fetching from the drone. The drone on the other hand contains an on-board portable hotspot device that is connected to a mobile internet network. It is through the hotspot created via this device that the drone gains access to the server using an Esp8266 as a receiver and reads the control parameter values. The Esp8266 also acts the microcontroller and sends out the necessary control signals to control the flight dynamics. The system makes use of a One Time Password (OTP) sent to the user's email address for verification and maintain a secure connection.

Weaknesses

The design proposed had a few critical drawbacks that would limit the use of the ground and communication system in an active surveillance and security mission. Firstly, the design made use of a mobile phone as a controller. Unlike a normal controller, mobile phones limit a pilot's dexterity. A mobile phones screen may be slippery either due to sweaty or oily hands resulting in the wrong control input. Phones also tend to have numerous tasks running in the background that may take away the processing power from the actual control and instead hang or operate other tasks considered of higher priority. The design also makes use of Wi-Fi and a mobile network as a communication and control media. This is a choice that is not practical in the case of North-rift as the region is quite remote and cellular networks tend to be weak or lacking. Wi-Fi is also a very unsecure means of communication especially for a critical application such as security. Numerous attacks such as the denial-of-service attack, man-in-the-middle attack and GPS-spoofing can be performed on the drone and a malicious actor may gain unauthorised access to the drone and use it for malicious activities (Hassija et al., 2021). The design and implementation also introduce higher latency compared with other forms of communication especially since data is conveyed and stored on a server before it is accessed by the drone.

2.3 Components

2.3.1 Microcontroller

A microcontroller is an IC integrated with various devices to perform a specific application. Microcontrollers contain one or more Central Processing Units (CPU), memory units and input/outputs peripherals all integrated in one chip. Instructions can be flashed into the microcontroller's memory and the CPU would fetch and execute all the instructions and performs arithmetic and logic operations to perform a particular task. Memory, CPU, and input/output peripherals are some important considerations in making choice of microcontrollers as this is what determines the suitability of a given microcontroller to a particular application. There exist several alternative microcontroller products in the market currently that have a variety or specifications that may be suitable for a given application. Popular microcontrollers are marketed as a chip on breakout boards. Such boards include the Arduino Uno running the ATmega328p chip, Arduino Mega running the ATmega2560 chip, ESP32 running the Tensilica Xtensa LX6 chip. By far, the ESP32 has the best features when it comes to memory, processing power and peripheral interfaces (Dogan Ibrahim, 2019). The board comparisons are as indicated in the table below.

Features	**Arduino Uno**	**Arduino Mega**	**ESP32**
CPU	Atmega328P	Atmega2560	Xtensa dual core
Word size	8-bit	8-bit	32-bit
Clock Frequency	16MHz crystal oscillator	16MHz crystal oscillator	240MHz
RAM	2KB (SRAM)	8KB (SRAM)	512KB (SRAM)
ROM	1KB (EEPROM)	4KB (EEPROM)	448KB
FLASH	32KB	256KB	
GPIOs	14x Digital I/O Pins 6x Analog Pins 6x PWM	54x Digital I/O Pins 16x Analog Pins 15x PWM	36x Programmable
ADCs	10-bit	10-bit	12-bit
DACs	N/A	N/A	2x 8-bit
SPI	1x	5x	4x
I2C	1x	1x	2x
UART	1x	4x	3x
Wireless connectivity	N/A	N/A	Wi-Fi: 802.11 b/g/n at 2.4GHz Bluetooth: v4.2
Weight	25g	37g	9.3g
Operating Voltage (I/O Voltage)	5V	5V	3.3V (5V tolerant I/O pins)
Operating Current (max)	200mA	1A	600mA

Nominal Input Voltage	5V via USB 7-12V via Jack pin	5V via USB 7-12V via Jack pin	5V via USB 3.3V via Vin

Figure 2: Arduino Uno Board

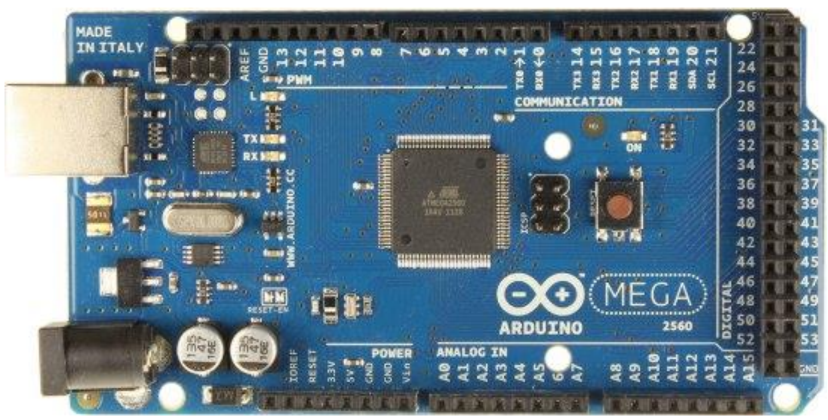


Figure 3: Arduino Mega

Figure 4: ESP32 Microcontroller

2.3.1.1 ESP32

From the features described in the table, the ESP32 is a superior microcontroller compared to the other two boards mentioned. The Esp32 has Bluetooth, Wi-Fi, and Radio connectivity within a single chip. It is superior in not only processing power but also in memory, I/O peripherals and has the capability of true multitasking by utilising both cores. The two cores in the ESP32 will allow for far greater control especially with the utilising of FreeRTOS as a real-time operating system for the drone (Kangunde et al., 2021). Tasks to be carried out will be scheduled and prioritisation of the critical tasks can be done. This microcontroller will thus meet the high computing processes demands as well as number of interfaces required to control a drone remotely.

2.3.1.1.1 ESP32 Power Modes

The ESP32 has five power modes that allow it to make use of the least possible power for a given project. Lower power consumption is especially important for systems that make use of batteries to increase battery life. The five power modes include: Active mode, Modem sleep mode, light sleep mode, Deep sleep mode and Hibernation mode.

Active mode

This is the normal operating mode of the chip where all features remain active. All processes remain always running and current consumption may reach 240mA and huge spikes up to

790mA may be observed when Wi-Fi and Bluetooth are used together. This is the most inefficient mode and dissipates the most current.

Modem Sleep Mode

This mode keeps every other process active except for the Bluetooth, radio, and Wi-Fi connectivity. The processor runs normally, and the clock has the capacity to be configured. Current consumption by the chip is at most 20mA at 240MHz operating frequency. The wireless connectivity processes turned on at predefined intervals where the microcontroller switches between Active and modem sleep mode under the Delivery Traffic Indication Message (DITM) control. This is the most preferred operation mode.

Light Sleep Mode

This mode has some similarity to modem sleep except that clocking has been fixed to a lower maximum which in turn reduces dynamic power consumption. This is achieved by turning off clock pulses which in turn pause the CPU. Active RTC and ULP-co-processor help keep the microprocessor running. Current consumption is around 0.8mA. this mode is limiting especially for a real-time operation application.

Deep Sleep Mode

In this mode, most of the RAM and all digital peripherals are powered off. The ULP co-processor, RTC controller, RTC peripherals and RTC fast and slow memory remain active. Current consumption is around 0.15mA and may be as low as 10 microamperes.

Hibernation Mode

In this mode, the ESP32 is inactive and negligible power is consumed. No process is active during this mode.

2.3.2 Control Input Devices

Input devices are modules that allow for the transfer of data (Haque et al., 2017) and control signals from a system user to the actual system process. These devices include keyboards, mice, joysticks, and buttons. A keen understanding of how a drone works will provide merit to make a choice on the best control input device to use.

2.3.2.1 Drone Motion Control

For the drone to be successfully flown and manipulated, there is need to manipulate the common drone movements in three-dimensional space along the three axes, which are yaw, pitch, and roll. Yaw is the rotation of the drone around the vertical axis. This rotation is characterised by the drone changing the direction its front or tail is pointing to, that is towards the right or left or side to side. It changes the direction the drone is pointing and is thus important in determining the direction the drone will fly to. Roll on the other hand is the rotation of the drone about the front-to-back axis. This movement is characterised by the drone rotating along the x-axis. This makes the drone move towards one side or the other. Lastly, pitch is the rotation along the side-to-side axis. It makes the drone tilt its front or back up or down. It is important in causing the drone to move forwards or backwards (Flynt, 2020). All these movements have varying effects depending on the amount of rotation described by the pilot. Another essential element of drone motion is the throttle. The throttle is the amount of thrust that the rotors produce. A higher throttle results in more thrusts and thus the higher the drone can reach. To achieve these movements with our drones, signals must be forwarded to the drone setting the values of these movements and rotations. Mechanisms to lock the drone into various flying modes may also be added. Keyboards despite having numerous keys and buttons, would be a cumbersome means of control for a drawn. Response and control signal time would be too long to allow effective and safe control. Mice would also be limiting as they require being placed on a flat surface for it to functioning which may be limiting in scenarios where the pilot is out on the field in an active mission. As such, effective control inputs that may be used on the ground station controller may include joystick modules and toggle buttons and switches.

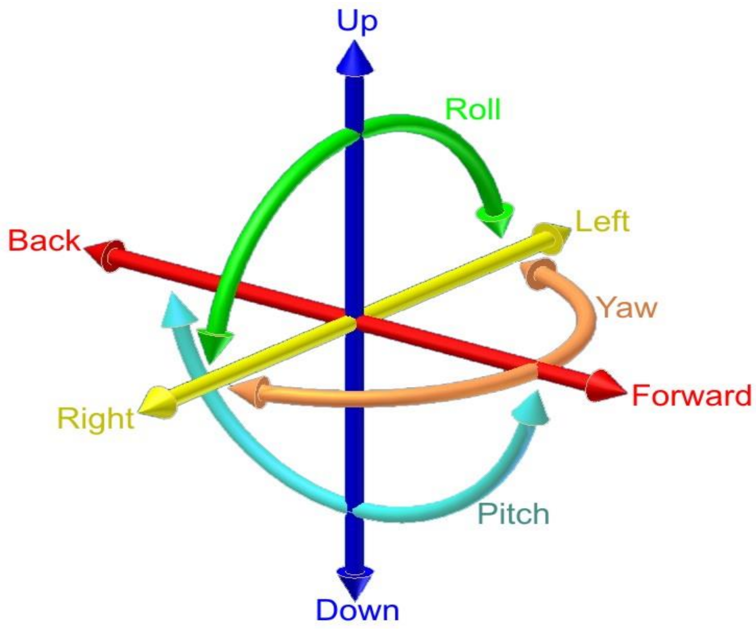


Figure 5: Pitch, Roll and Yaw

2.3.2.1 Joystick Module

This is an input device that is often used for the control of movement with high precision by controlling a lever. It is often used in gaming and robotic applications to achieve 2-axis control. It also contains a switch that activates when pushed down.

Figure 6: Joystick Module

How it works

The joystick is a self-centering spring-loaded device made up two independent 10K potentiometers. The basic idea of the joystick is that the lever's position on the x and y axis is translated into electronic signals by utilising a gimbal mechanism. The lever is connected to two shafts each representing one of the axes. Taking the x-axis, the lever is connected to a wiper which is in contact with a resistive track. Tilting the lever sideways sweeps the wiper and varies the resistance over which a voltage is passed through. Tilting the lever forwards varies the resistance. This produces an analogue output from 0V to the operating voltage of our module in our case 5V which can be set to describe the motions in the ADCs resolution. At rest, the joysticks give an output of 2.5V at each channel (In-Depth: How 2-Axis Joystick Works? Interface with Arduino & Processing, 2018). Each Joystick produces two analogue signals through pins VRx for x-axis and VRy for y-axis and therefore to set the values for yaw, roll, pitch, and throttle would require two such modules. These values can then be used as is to control the drone along those movements. The module has a voltage requirement of 5V and a maximum current of less than 10mA.

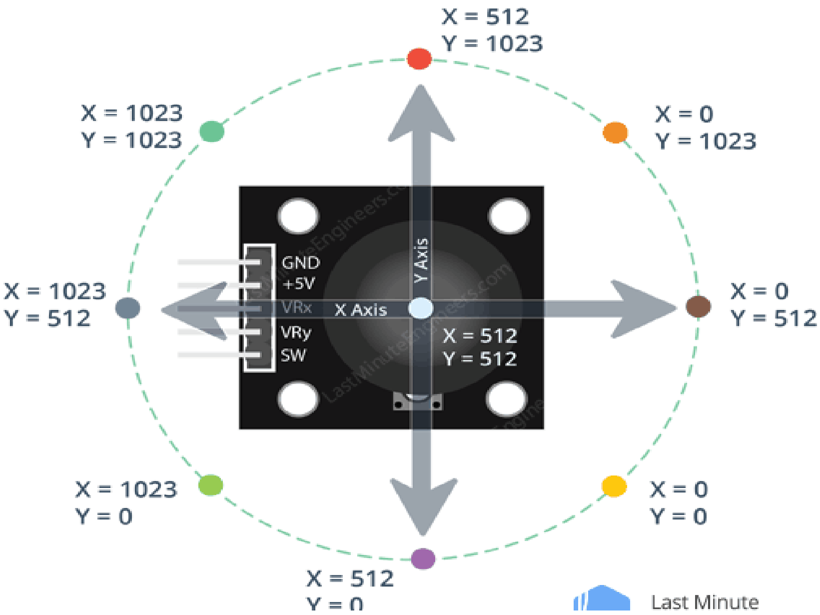


Figure 7: Joystick output per channel

2.3.2.2 Buttons and switches

These are basics components in electronics. Switches are devices with an "on" and "off" position and thus are binary devices. Buttons on the other hand are also binary devices however unlike switches have a momentary "on" position and then reverts back to its "off" position. They allow a user to select between an open circuit and a short-circuit that is effectively used in control. They are the simplest input devices. Both are actuated by human hands typically and are useful in sending signals from one system or device to another. Buttons and switches can be used for a variety of applications such as turning on devices by allowing power through, turning on and off alarms and so many more (SparkFun, n.d.). Several types of buttons and switches exists. Examples include momentary pushbuttons, dual push button switches, limit switches, proximity switches and so many more. Our system will make use of additional buttons and switches to control various aspects of the controller. A toggle switch will be used to turn on or off the controller. A slider switch will be used to set flight modes of the drone such as beginner mode, sport mode, active track mode etc. A menu pushbutton will also be set to allow for the navigation of a list of controller interfaces to check and configure various flight simulators.

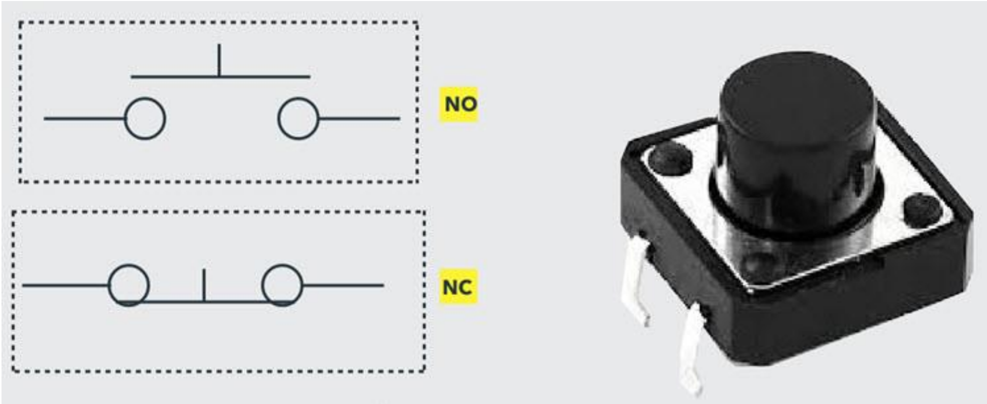


Figure 8: Button and circuit diagram

2.3.3 Transceiver Module

Data transfer is an integral part of any control mechanism over a given range of distance. Data can be transferred to its destination either by wireline methods which is advantageous over short distances or via wireless means that have the advantage of lowering costs if wireline methods were to be used. Wireless communication requires a transmitter and receiver pair where a transmitter converts data into signals that are converted into electromagnetic waves and transmitted over space. These waves are captured by the receiver antenna and converted into electrical signals that the receiver detects and extracts the message and extracts data despite presence of noise in the signal. This describes the simplex mode of communication.

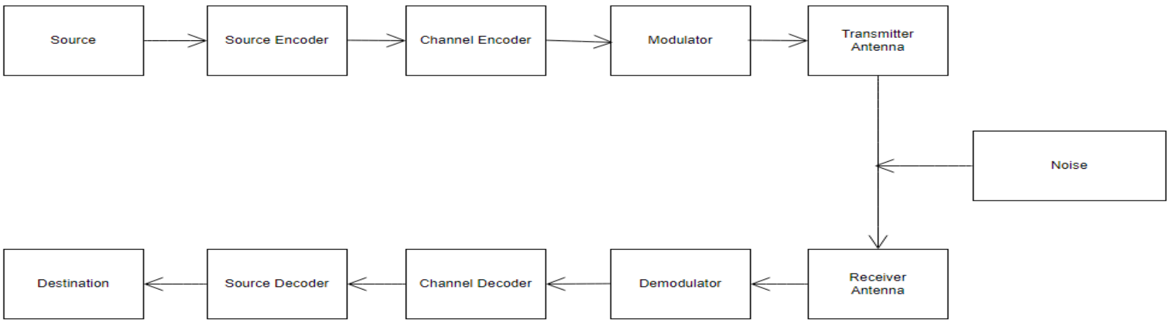


Figure 9: Digital communication

However other modes can be achieved such as half-duplex and full duplex communication modes. Half-duplex mode communication refers to the capability of communication devices being capable of communicating bi-directionally but only one device communicates at a time. The full duplex is the most preferred choice as it involves communication devices that can communicate simultaneously and bi-directionally over. They achieve this through a variety of ways such as Frequency Division Multiplexing (FDM). This technique involves the division of available bandwidth into smaller sections of non-overlapping channels, and each used to carry separate signals. A transceiver module could effectively receive signals over one channel and transmit over the other. Another technique would be Time Division Multiplexing (TDM); however, these is complicated and requires highly defined synchronization. Various transceiver modules are available that can allow data transfer using various modulation and encoding techniques. Often communication transmission occurs on the narrowband spectrum. This however has its disadvantages.

Disadvantages of narrowband spectrum

1. Slower data rates.
2. Prone to intentional or unintentional interference which may result in signal jamming.
3. Can be easily detected since it has a high spectral density.

Due to these disadvantages, a better modulation technique is needed. Spread spectrum modulation on the other hand is a collective class of signalling techniques employed before transmitting a signal to provide secure communication. The signal strength is distributed over a wide range of frequencies that are wider than the minimum required to transfer data. The power density is low since band occupy a wide range of frequencies and the energy is widely spread. This modulation technique has numerous advantages.

Advantages of Spread Spectrum

1. It is highly resistant to interference or jamming.
2. It allows for multiple users can share bandwidth without interfering with each other.
3. It is difficult to jam and detect these signals and this makes them appropriate for use in military and security operations.

For use in our security operation, the spread spectrum modulation technique would be the best choice as a control and data transfer mechanism.

2.3.3.1 SX1278 Transceiver Module

The SX1278 transceiver module is a Lora-based communication module that makes use of proprietary spread spectrum by SemTech. It is a single chip transceiver module that carries out the digital communication process. It has the strong ability of anti-jamming and interference resistance. It provides a far much superior modulation scheme than the traditional spread spectrum design such as longer distances, lower interference, and low power consumption (SemTech, n.d.).

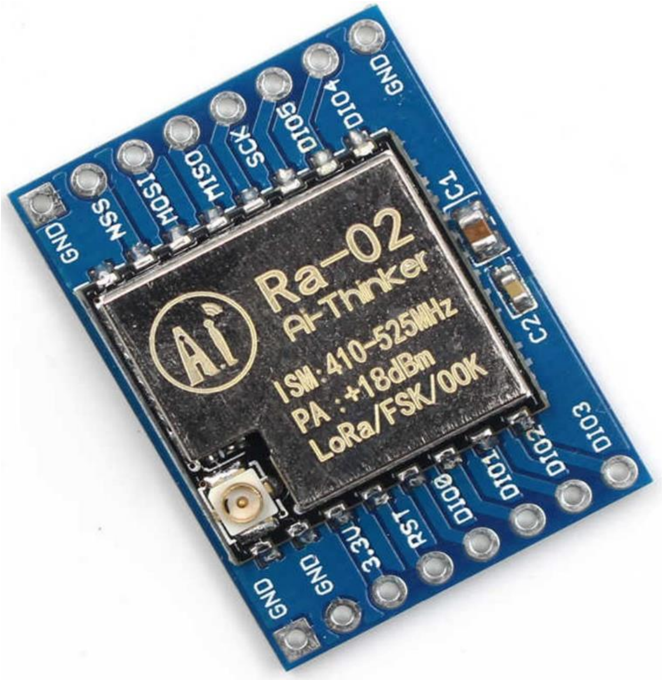


Figure 10: LORA R-02 Module

The Modules features include:

- Lora Spread Spectrum modulation
- +20dBm constant power output gain at 100mW.
- High receiver sensitivity of -148dBm
- Provides a half-duplex communication SPI interface.
- Programmable bit rates of up to 300kbps.
- Supports multiple modulation modes such as FSK, GFSK, MSK, GMSK, Lora and OOK modulation modes.
- Has a small footprint.
- Comes in modules within the various ISM frequency support within the various regions.
- Long range communication beyond 10km.
- 5V and 20mA power requirements.

The advantages put sx1278 as an obvious choice as a tool to allow data transfer to and from our ground station to our drone.

Pin interfaces

Pin	Name	Description
1	GND	Ground (0 V)
2	D101	Digital I/O
3	D102	Digital I/O
4	D103	Digital I/O
5	VCC	Power (3.6 V Maximum)
6	MISO	SPI Data Output
7	MOSI	SPI Data Input
8	SLCK	SPI Clock
9	NSS	SPI Chip Select
10	D100	Digital I/O
11	RESET	Reset
12	GND	Ground (0 V)

Table 1: Pin Configuration of the SX1278 Transceiver Module

2.3.4 128x64 LCD

A Liquid Crystal Display (LCD) is a flat panel display that contains liquid crystals that have light-modulating characteristics to produce visual feedback. These crystals become visible when electricity is passed through them (Lueder, 2010). They are used in laptops, mobile phones, TVs, and other consumer electronics. LCDs made of small blocks called pixels each with a separate red, blue, or green light that can be independently turned on or off quickly to make moving picture. Some older generation LCDs however have pixels coloured with only one colour, usually black. These are usually either turned on or off. There is a variety of a LCDs currently present in the market but one useful LCD for our project is the 128x64 graphic LCD with LED backlight. It is driven by an ST7920 LCD controller. It can display both characters, bitmap images and graphics. It has a good surface area of display that is large enough to give out enough visual feedback to the pilot on flight status. It has a power requirement of 5V and 18mA. It has 20 interface pins and has 64 rows and 128 columns of pixels (EFY Enterprises Pvt Ltd, 2015).

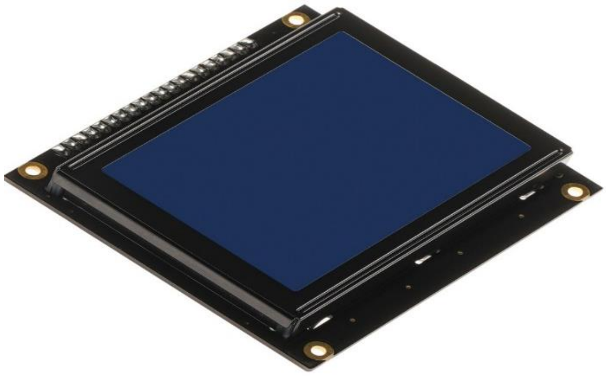


Figure 11:128x64 LCD

2.3.5 Micro SD Card Module

When working with data especially during transmission, data storage may need to be implemented. These allows for saving files and data for later use and processing. This is incredibly important especially in the case of drone flight status and operation. These data will serve as a blueprint for better flight plans and system maintenance as well as provide a reference point. To implement data storage in the ground station controller, a micro-SD card module will come in handy. It provides a means for data logging and storing files into a micro-SD card that would otherwise quickly fill up the microcontroller's memory (Arduino, n.d.). Files that could be stored may include received data from the drone especially sensors and payloads, useful files that will be used during flight control such as graphics and bitmap images and so many more. The module has a power consumption of 5V and 200mA maximum current.

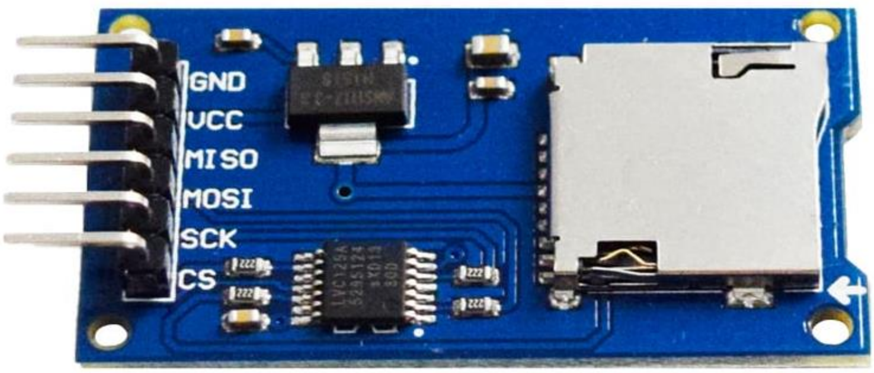


Figure 12: Micro-SD Card Module

2.3.6 Sensors

These are devices that detect changes in the physical environment and output a signal that is directly proportional to that change. They allow systems to be able to interact with the physical environment as well as execute instructions based on these changes. The physical quantities that can be measured by sensors include temperature, humidity, pressure, position, force, vibrations and so on. There are a few categories of sensors such as contact, non-contact, rotary and linear sensor categories. Our controller will require sensors to ensure smooth and continuous operation. The main sensors to be utilised include voltage and current sensors.

2.3.6.1 Voltage Sensor

Voltage sensors are devices that allow monitoring of the voltage levels of an electrical source such as battery, mains and solar. They can detect magnetic fields, electromagnetic fields, and measure contact voltage. There exist three main types of voltage sensors include: AC sensors, DC sensors and specialized sensors. AC sensors measure AC voltage while DC sensors measure DC voltage. Specialized sensors are those voltage sensors that measure voltage in systems with specific requirements or parameters. Voltage sensors may be applied for reasons such as power demand monitoring, power failure monitoring, load sensing, safety switching and so many more. Voltage sensors works on the principle where the device takes in an input of the voltage itself and provides an analogue voltage signal as an output that can be interpreted into numerical figures. There are two main types of voltage sensors available: capacitive type and resistive type voltage sensors.

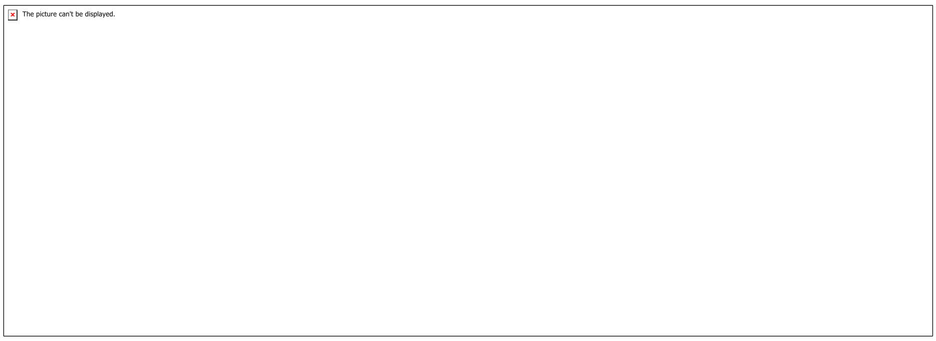


Figure 13 Capacitive and Resistive Voltage sensors

The basic operating principle of the voltage sensor is voltage division using either capacitors or resistors. A voltage is fed into the divide circuit and R1 will represent the reference resistor. Voltage developed across the reference resistor of sensor is buffered and the given to the amplifier. The sensor’s output voltage can be expressed as:

$$V_{out} = \frac{R2}{R1 + R2} * \ V_{ref}$$

An amplifier can be used to amplify the voltage to get the readings for better performance.

A variety of voltage sensor modules exist, and the choice is often made in consideration to application and cost. One such module that works well for low voltage applications with high accuracy and affordable rates is the B25 Voltage sensor module. It has the capacity to measure voltage levels of up to 25V (Carr, 1997, pp. 40–180). The module operates on 5V and a low current of less than 1mA.

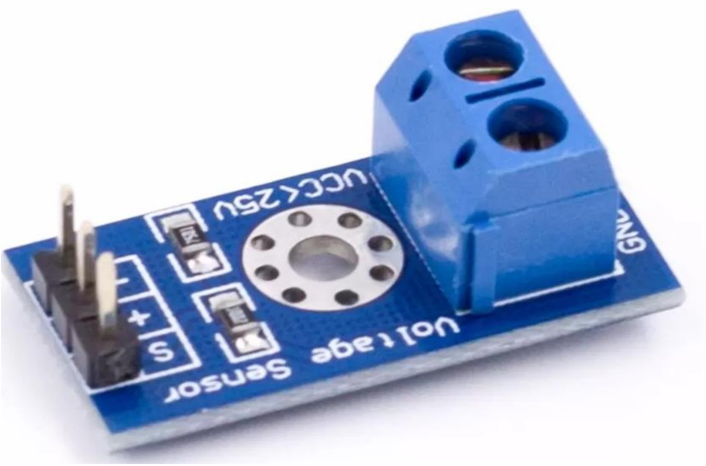


Figure 14: Voltage sensor

Pin configuration

Pinout	Description
VCC	Positive terminal of the External voltage source (0-25V)
GND	Negative terminal of the External voltage source
S	Analog pin connected to Analog pin of the microcontroller
+	Not Connected
-	Ground Pin connected to GND of microcontroller

2.3.6.2 Current Sensor

This is a device that detects and converts current to an easily measurable output voltage proportional to the magnitude of the current through the path under measurement. Various sensors exist with each having a current range. Current sensors are based on the open or closed loop hall effect concept. The closed-loop hall effect sensor works by the virtual that a coil is driven to produce a magnetic field opposing the field of the current under test. A null-detecting device, hall sensor, is used and an output voltage signal proportional to driving current is produced. This output can then be measured. An open-loop hall effect sensor works by creation of a magnetic flux ty primary current and which is concentrated in a magnetic circuit and measured using a hall device which produces an exact instantaneous representation of the primary current. An excellent choice for a current sensor and one I will integrate is the ACS712 module. Its specifications include 4.5V to 5.5V DC supply voltage, current of 1mA and current measuring range of 20A with a sensitivity of 100mV/A (Carr, 1997, pp. 40–180).

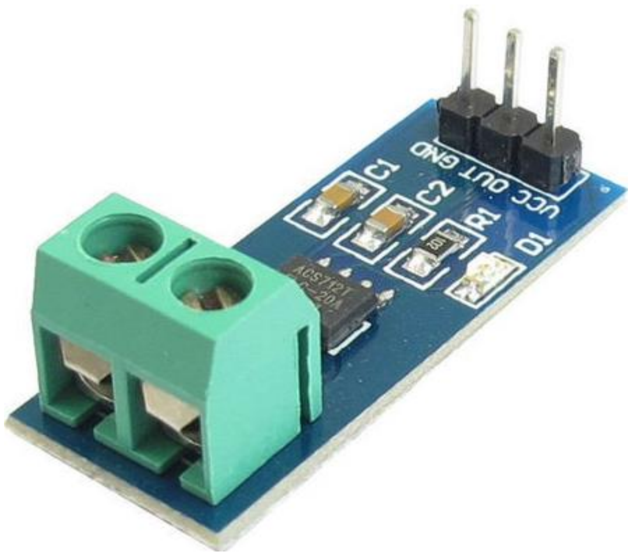


Figure 15: Current Sensor

Pin configuration

Pin Number	Pin Name	Description
1	Vcc	Input voltage is +5V for typical applications
2	Output	Outputs Analog voltage proportional to current
3	Ground	Connected to ground of circuit

T1	Wire In	The wire through current must be measured is connected here
T2	Wire Out	The wire letting current flow to load.

2.3.7 Battery

Every electrical device needs a source of power. Various sources of power may be used and may include solar power, mains electricity, biofuel, batteries, or fossil fuels. The choice of power is made with considerations of the device applications, load, and duration of operation in mind. Batteries provide a means to store electrical power and supply it when demand arises. It provides the device with the flexibility and mobility during operation and tends to minimize the size of the device design and fabrication. The choice of battery will take into consideration the voltage and current consumption of the device or load. A power budget must be calculated, and suitable batteries acquired. Arrangement of the batteries in series or parallel may be considered to allow for the achievement of the total voltage or current to meet demands. There are numerous battery types present and they may be categorised as either primary or secondary cells. The following are the characteristics of these categories.

Primary	**Secondary**
Chemical to Electrical energy conversion	Chemical-Electrical-Chemical conversion
Not rechargeable	Rechargeable
Discarded after sole use	More than 300 charge cycles
No free or liquid electrolyte	May contain free or liquid electrolyte
Low initial cost	Higher initial cost
Portable	Traditional cells are not portable. However advanced Lithium battery technology has allowed for portability.
Ideal for low load or discharge rate use	Ideal for high discharge rate performance at heavy loads.
Lower energy density	Higher energy density

From the characteristics, primary cells limiting despite being a cheaper option. Secondary cells are highly recommended due to their ability to be recharged, high discharge rates as well as high energy density. Secondary cells include Lithium-ion batteries and Nickel-metal hydride battery among notable mentions.

2.3.7.1 Lithium-Ion Batteries

Lithium-ion batteries have become popular, and a variety of such batteries have been produced due to their advantageous characteristics. The varieties include Lithium Cobalt Oxide ($LiCoO_2$), Lithium Manganese Oxide ($LiMn_2O_4$), Lithium Nickel Cobalt Aluminium oxide ($LiNiMnCoO_2$), Lithium Iron Phosphate ($LiFePo_4$) and so many more. The batteries vary in performance and $LiNiMnCoO_2$ batteries have the highest energy density above 240 to 693Wh/Kg followed closely by $LiCoO_2$ and then $LiFePO_4$. $LiFePO_4$ cells have higher charging cycles than any other batteries with at least 3000 cycles and at most 10000 cycles and has lower storage discharge rates. These batteries have nominal voltage of between 3.6 V and 3.85V with a fully charged voltage of 4.2V. Charge and discharge density is around 80 to 90%. Their capacities are often rated for between 2600mAh and 5000mAh (Dahlin & Strøm, 2010, pp. 1–435).

Advantages

High specific energy and high load capabilities with power cells

Have long cycle and extended shelf-life thus are maintenance free

Have high capacity, low internal resistance, and good columbic efficiency.

Have a simple charge algorithm and short charge times.

Have low self-discharge compared to other battery times compared to Nickel Metal hydride batteries.

One practical battery to use is the 18650 Lithium-ion batteries. These $LiFeO_4$ batteries that comes in a dimensional size of 18mm by 65mm and are widely used for a variety of applications that require high current output and maximum drain. They have found use in laptops, flashlights, electric vehicle battery packs and so on. Thus are a viable solution for our project.

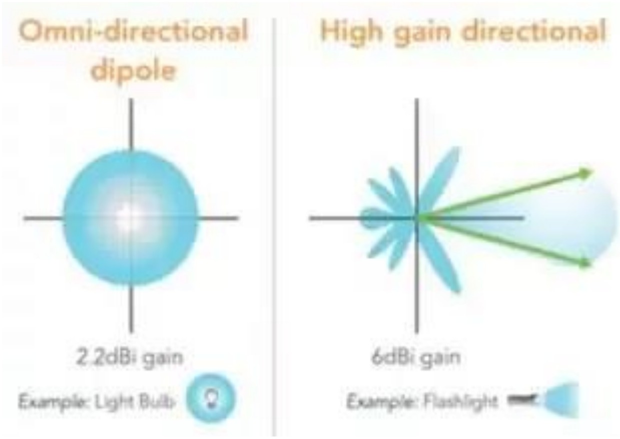
Figure 16: 18650 Lithium-Ion battery

2.3.8 Antenna

These are transducers that convert electrical energy to electromagnetic waves that are radiated and vice versa. They play a key role in wireless communication and exceptional care needs to be taken and parameter consideration during their design to ensure optimal performance. These parameters include gain, directivity, efficiency, band width, impedance, and radiation pattern.

2.3.8.1 Types of Antennas

Numerous antenna types exist, and they are deployable depending on the application requirements. They are ideally subdivided into two groups: directional and omnidirectional antennas. Directional antennas are antennas whose radiation pattern is focused to a specific direction. They have the benefit of having better distance of coverage, high energy efficiency, higher gain, and minimal interference. Limitations of directional antennas include limited area of coverage, narrow beamwidths and antenna deafness to signals received outside the main lobe direction. Applications of directional antennas include TV and radio reception. Omnidirectional antennas on the other hand are antennas that radiate energy equally in all directions. They provide the advantage of having a wide coverage area, easy installation, reception in all directions. Their limitations include lower gain, limited range, and lower energy efficiency. One key application of omnidirectional antennas is broadcasting.



Types of Antennas	Examples	Applications
Wire Antennas	Dipole, Monopole, Helix, and Loop antennas	Personal applications, buildings, ships, automobiles, space crafts, broadcasting
Aperture Antennas	Waveguide and Horn Antennas	Flush-mounted applications, aircraft, spacecraft.
Reflector Antennas	Parabolic and corner reflectors	Microwave communication, satellite tracking, radio astronomy.
Lens Antennas	Convex-plane, concave-plane, convex-convex, concave-concave lenses	High frequency application
Micro-strip Antennas	Circular-shaped, rectangular shaped metallic patch above the ground plane	Planes, spacecraft, satellites, missiles, cars, mobile phones
Array Antennas	Yagi-Uda, micro-strip patch array, aperture array, slotted wave guide array	High gain applications. Applications requiring controlled radiation pattern.

Antenna Design

For remote control purpose that require an omnidirectional antenna, a monopole or dipole antenna may be used. Choice of either depends on the system requirements and available space for antenna placement. The design of an antenna depends on the wavelength of the given frequency and the choice of type of antenna to be used.

Monopole Antenna Design

To design a monopole antenna, first the wavelength, λ is acquired using the following formula:

$$\lambda = \frac{C}{f}$$

Where C is the speed of light and

f is the operating frequency

Once λ is calculated, the monopole antenna length, L becomes a quarter of that wavelength hence the monopole antenna is also known as a Quarterwave antenna.

$$L = \frac{\lambda}{4}$$

The above calculation can be summarised as follows:

$$L = \frac{C}{4f}$$

Dipole Antenna Design

A dipole antenna on is also known as a half wave antenna. It is of half the wavelength of the given frequency. The design length is calculated as:

$$\lambda = \frac{C}{f}$$

$$L = \frac{\lambda}{2}$$

$$L = \frac{c}{2f}$$

Conclusion

The above is a detailed discussion on the existing systems that can be utilised to achieve an effective long range drone control system along with the justification for the selection of the components for this project based on the pros and cons and the relevance of this study.

CHAPTER 3

Project Design and the Complete Circuit Diagram

3.1 Introduction

This chapter takes a step by step investigate the design of the drone control system with a detailed discussion on design approach, hardware interfacing and programming of the system to ensure prompt control of the drone as well as reception of relevant flight data for both pilot use and storage for future flight analysis. The circuit designs are made in Kicad an open-source electronics schematic and printed circuit board design tool with Proteus as a simulation tool. Kicad will allow us to define part placement on the PCB while Proteus allows us to simulate and predict behaviour and circuit operation in a real-world circuit for electronic and mechanical parts of the design.

3.2 Circuit Block Diagram

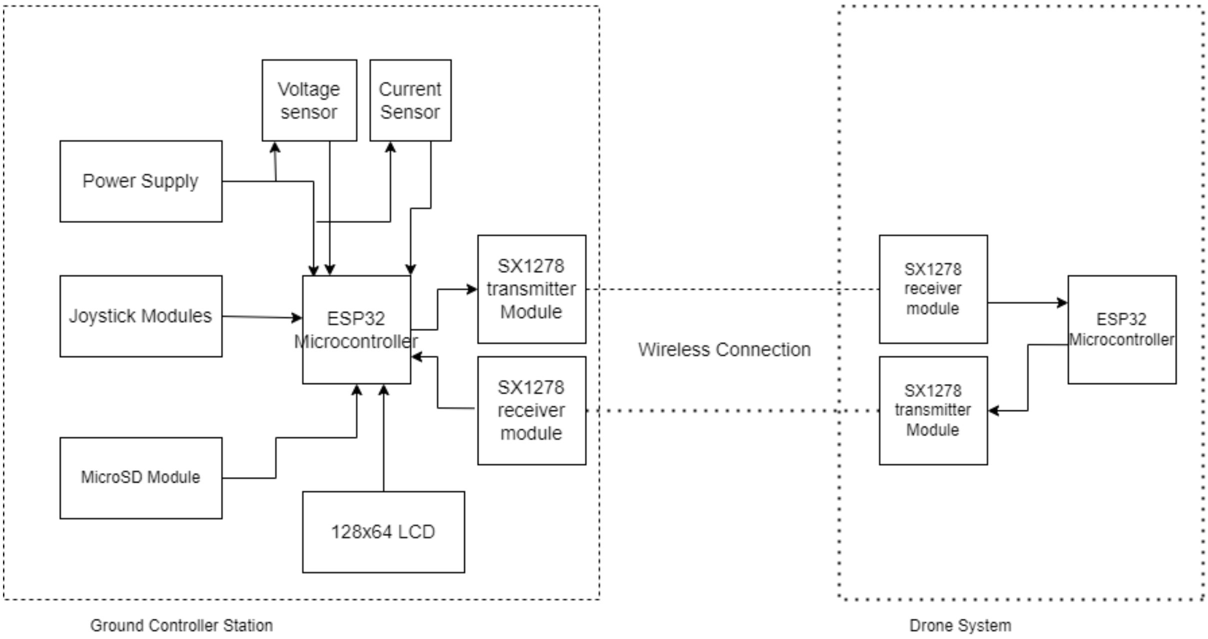


Figure 17: System Circuit Block Diagram

3.3 Project Design

The project design phase will ensure that various circuits will be designed and interfaced with each other to produce an effective and efficient system. Considerations will be made to ensure a system with low interference, low latency, and high performance.

3.3.1 Power Supply

From a power budget analysis, a power supply with a voltage of 5V and a maximum current supply of 1.5A is needed for the ground station. The system is prone to high current peaks especially due to ESP32, micro-SD card and transceiver modules and 2A would suffice.

Table 2: Power Budget Analysis

Component	**Number**	**Voltage (V)**	**Max. Current (A)**
ESP32	1	5/3.3	0.6
128x64 LCD	1	5	0.018
Joystick module	2	5	0.001
Micro SD module	1	5	0.2
Voltage sensor	1	5	0.001
Current Sensor	1	5	0.010
SX1278 Transceivers	2	3.3	0.1
Total Power		5V	0.93

To allow for portability, 18650 batteries will be used. To achieve 5V supply, two 18650 lithium-ion batteries rated at 5000mAh will be used each at a nominal voltage of 3.7V and a fully charged voltage of 4.2V. This would result in a combined series voltage of between 7.2V and 8.4V.

Voltage Regulation

To meet the power requirements of the above tabulated components, 5V and 3.3V buses must be designed. This will involve a two-stage voltage regulation. It is important that each component receives its rated voltage otherwise there is risk of damaging the hardware components. At the input, a 1N4007 diode rated at 1000V and 1A operating current and support for 30A peak current will be required to provide protection against reverse polarity connection of the power supply. A voltage drops of 0.7V is experienced across the diode.

To step down the DC voltage from the batteries, linear regulators will be used instead of the more effective switched regulators to reduce interference. An LM7805 linear regulator will be used to regulate the voltage to a stable 5V supply. The IC however suffers from heavy heat loss and a heat sink may be required for heavy current consumptions.

Power dissipated as heat can be calculated as:

$$P = (V_{in} - V_{out}) * I_{in}$$

Where V_{in} is Unregulated Input Voltage

V_{out} is Regulated Output Voltage

I_{in} is Input current consumed

In our case, considering a maximum voltage of 8.4V and a maximum current of 1.5 A, power dissipated will be:

$$P = (8.4 - 0.7 - 5) * 1.5$$

$$= 4.05 \text{ Watts}$$

The power value is a worst-case scenario, and a more realistic value is around 2.7W at a current of 1A. This requires a heatsink to dissipate the heat generated.

To ensure a stable power supply two capacitors will be needed. A 0.33uF capacitor connected between the input and ground for impedance matching and a 0.1uF capacitor between the output and ground to provide for transient response. A stable output of 5V will be gotten at the output pin. A switch is then placed after the output. This switch will turn the controllers power supply on and off.

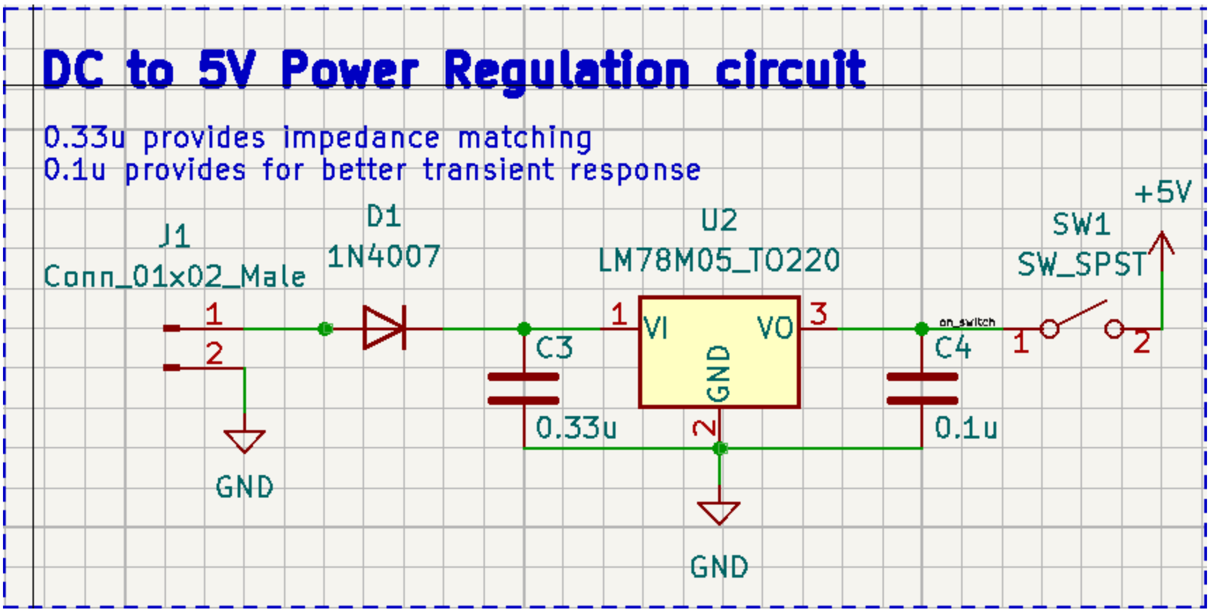


Figure 18: DC to 5V power regulation circuit

A power indicator led is added to provide an indication of the controller being powered.

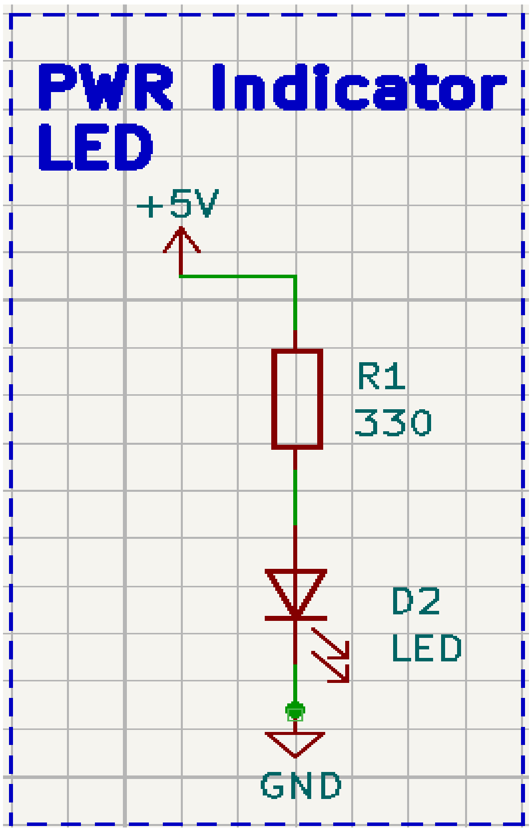


Figure 19: Indicator LED

For the 3.3V voltage bus, an AMS117 linear regulator will be used to provide a stable output. Two capacitors of 10uF are placed between input - ground and output - ground.

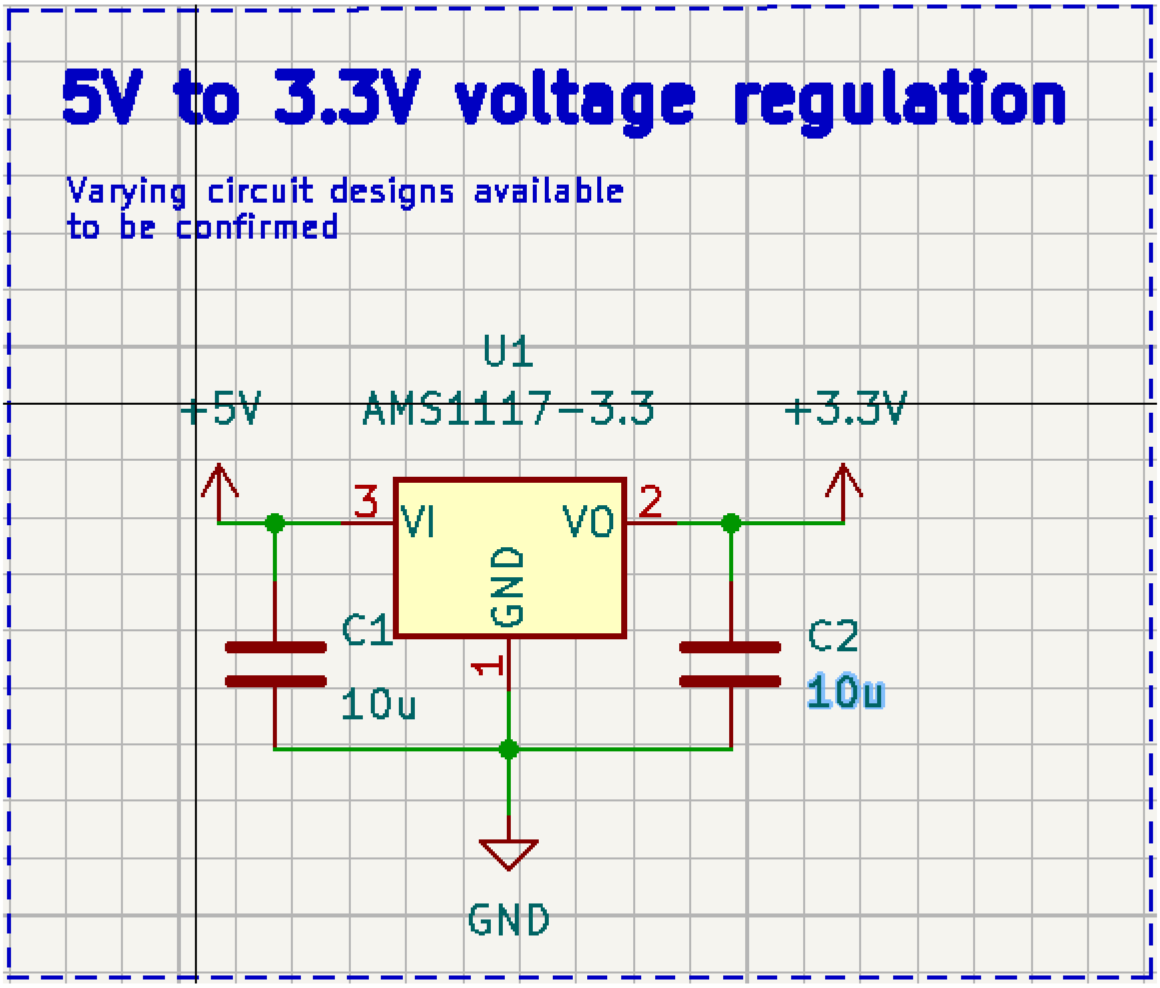


Figure 20: 5V to 3.3V voltage regulation

The 5V and 3.3V buses are ready to be fed into respective input interfaces at that voltage. The ESP32 may be supplied with unregulated 5V to 12V through the 5V pin or regulated 3.3V through the 3.3V pin. However, powering via the 3.3V is risky as this bypass the inbuilt regulator and a much higher voltage may destroy the board.

3.3.2 Interfacing ESP32 with 128x64 LCD

For an LCD with an ST7920 controller, the VCC and GND pins will be connected directly to the 5V and ground terminals. V0 pin will be connected to a 10K potentiometer's wiper with the input being connected to 3.3V and the GND pin connected to the ground. The RS, RW, E and RST pins are connected to GPIO pins 5, 23, 18 and 22, respectively. BLA and BLK will then be connected to VCC and ground, respectively. PSB pin will be connected to ground.

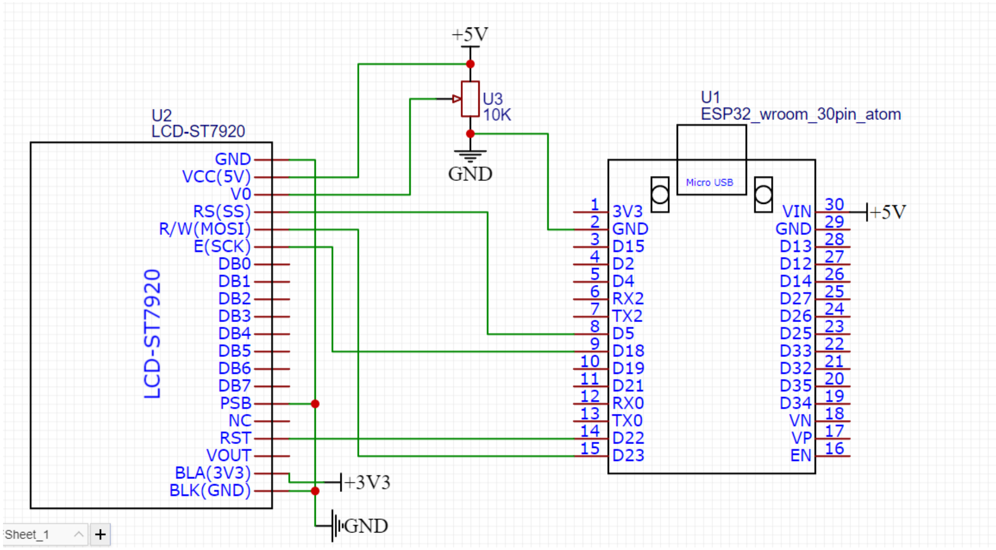


Figure 21: Interface between 128x64LCD and ESP32

3.3.3 Interfacing ESP32 with 2-axis Joystick modules

Two Joystick modules will be utilised. The left and right Joystick modules will be fed by the 5V power supply via the 5V and GND pins. Analogue pins VRx and VRy will be connected to GPIO pins 34 and 39 respectively for the left joystick and pins 33 and 32 for the right joystick. The SW pins will be connected to digital pins 36 for the left joystick and 35 for the right pin.

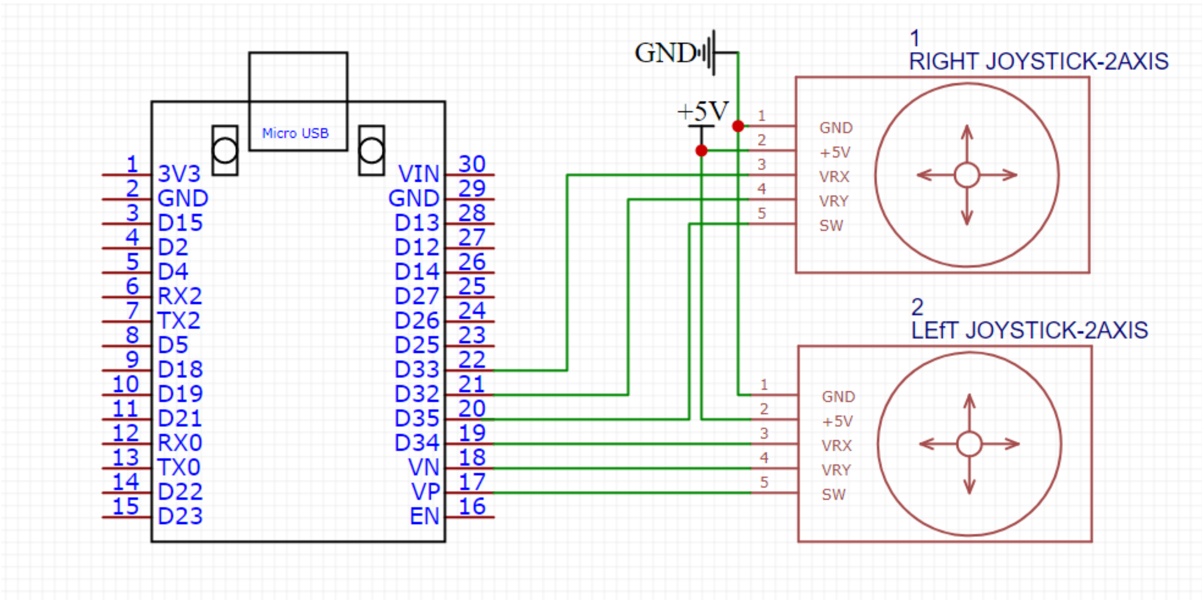


Figure 22: Interface between two joystick modules and ESP32

3.3.4 Interfacing ESP32 with Micro SD card module

With the micro-SD card module communicating via SPI protocol, the interfacing will be done using the corresponding SPI interfaces available on the ESP32. The module's power pins will be connected to the 3.3V bus and its GND pin connected to ground. The CS, MOSI, CLK and MISO pins will be connected to GPIO pins 5, 23, 18 and 19, respectively.

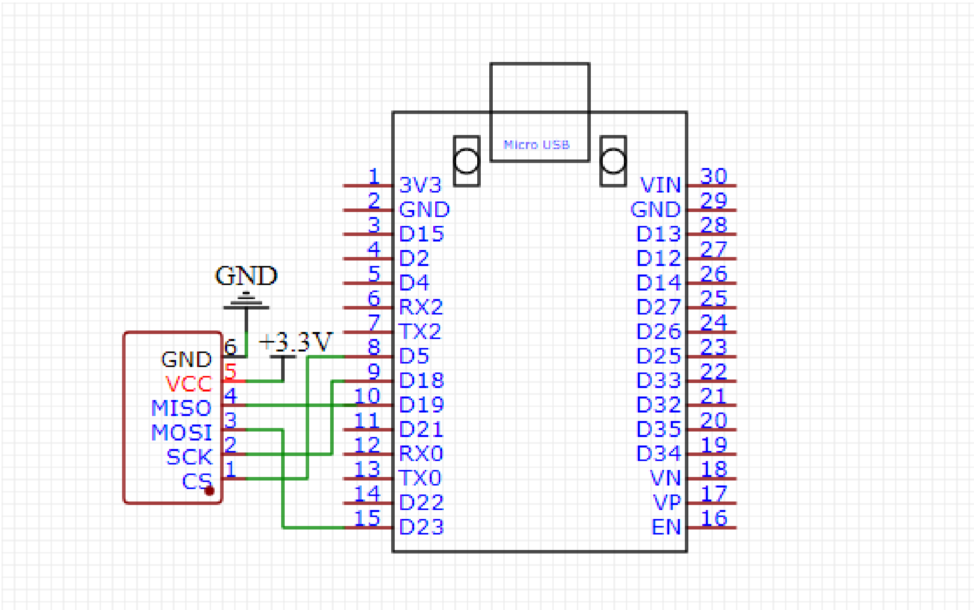


Figure 23: Interfacing an ESP32 and Micro SD card Module

3.3.5 Interfacing ESP32 with SX1278 Transceiver module

The transceiver module communicates over SPI protocol and thus will be connected to the corresponding ESP32 SPI interfaces. The transceiver is connected to the 3.3V bus and ground over its corresponding pins. The SCK, MISO, MOSI and NSS module pins are connected to GPIO pins 13, 12, 14 and 15. DIO0 is also connected to GPIO pin 27.

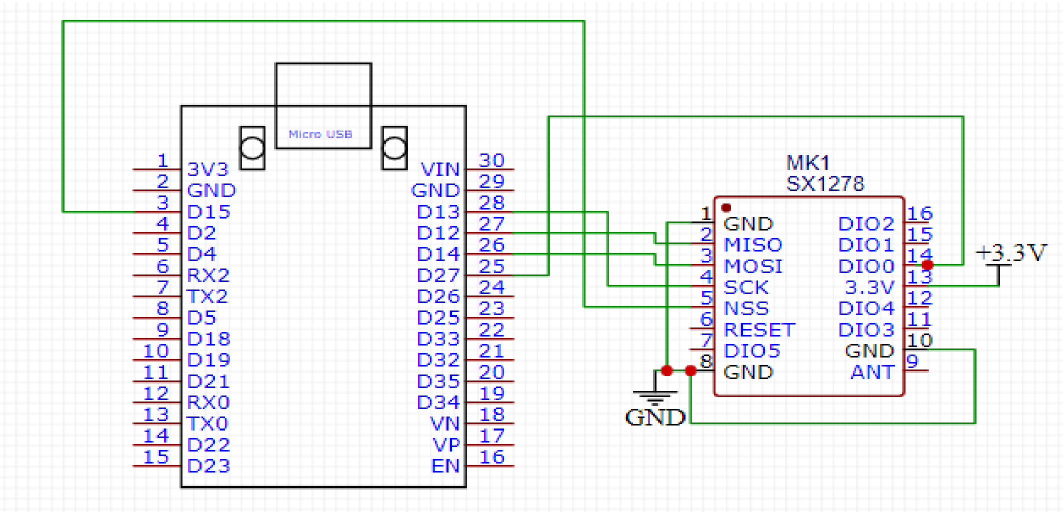
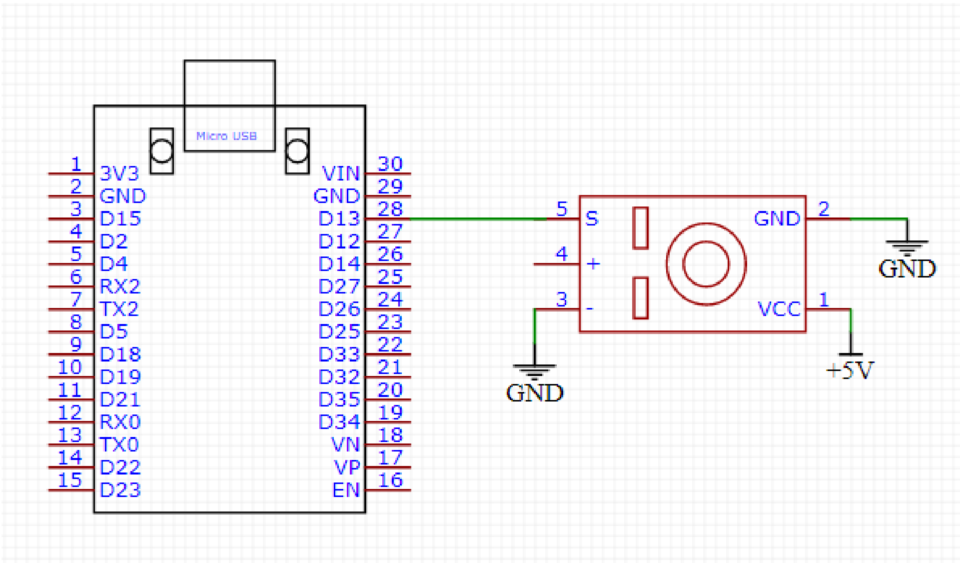


Figure 24: Interfacing SX1278 with ESP32

3.3.6 Interfacing ESP32 with Voltage Sensor

The voltage sensor's VCC interface is connected to the positive terminal of the voltage source to be measured which should be between the range of 0 -25V and not more. GND interface is connected to the negative terminal of the voltage source to be measured. The S interface is connected to an analogue pin, in this case GPIO pin 31. The + interface need not be connected while the – interface is connected to the microcontrollers ground.



3.3.4 Interfacing ESP32 with ACS712 Current Sensor

The current sensor's VCC interface is connected to the 5V bus and GND is connected to ground. OUT pin is connected to an analogue GPIO pin in this case 30. The load, which is our entire system, is supplied by a positive wire that passes through the T1+/ wire in phoenix connector and then out through T1-/ wire out phoenix connector.

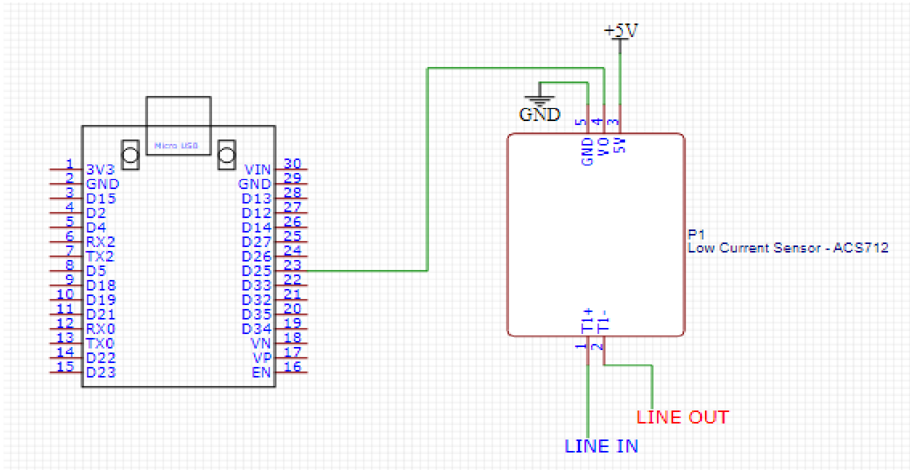


Figure 25: Interfacing ACS712 with ESP32

3.3.5 Antenna design

The communication transmitter and receivers will operate at 433.92Mhz. A monopole antenna is the best choice as it will allow for omnidirectional transmission. The antenna will be designed using the formula below which takes into consideration the speed of light as the radio wave speed and the operating frequency.

$$L = \frac{C}{4f}$$

$$L = \frac{3.0 \cdot 10^8}{4 \cdot 433.92 \cdot 10^6}$$

$$\mathrm{L} = 0.1728 \text{ metres}$$

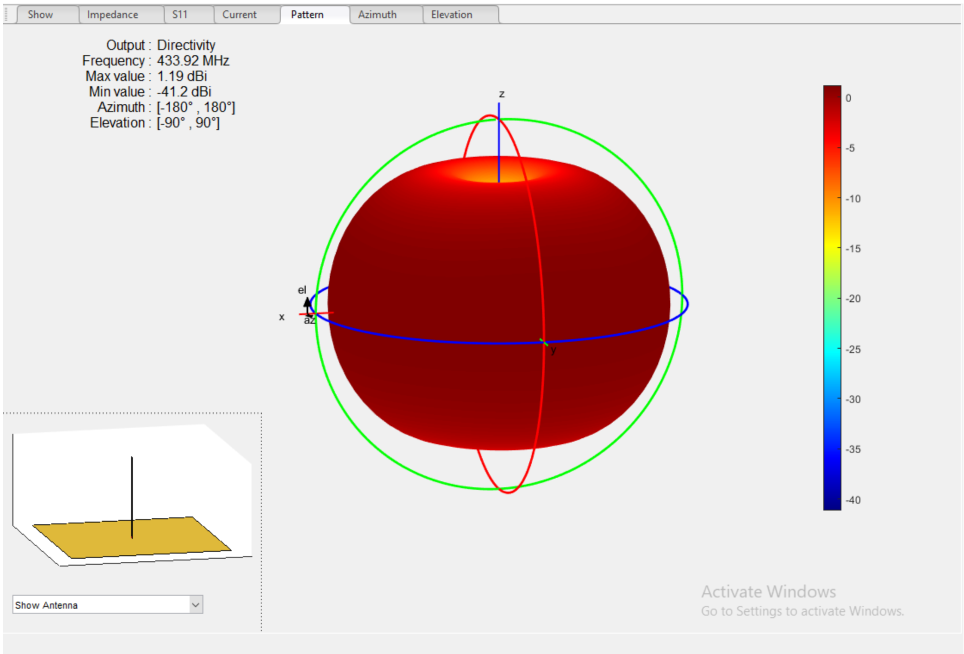
$$\mathrm{L} = 17.3 \text{ centimetres.}$$

The length of the antenna will be cut into the length above. An insulated copper wire is preferred, and it should be kept as straight as possible. An extra short length should be placed to allow for soldering on the module.

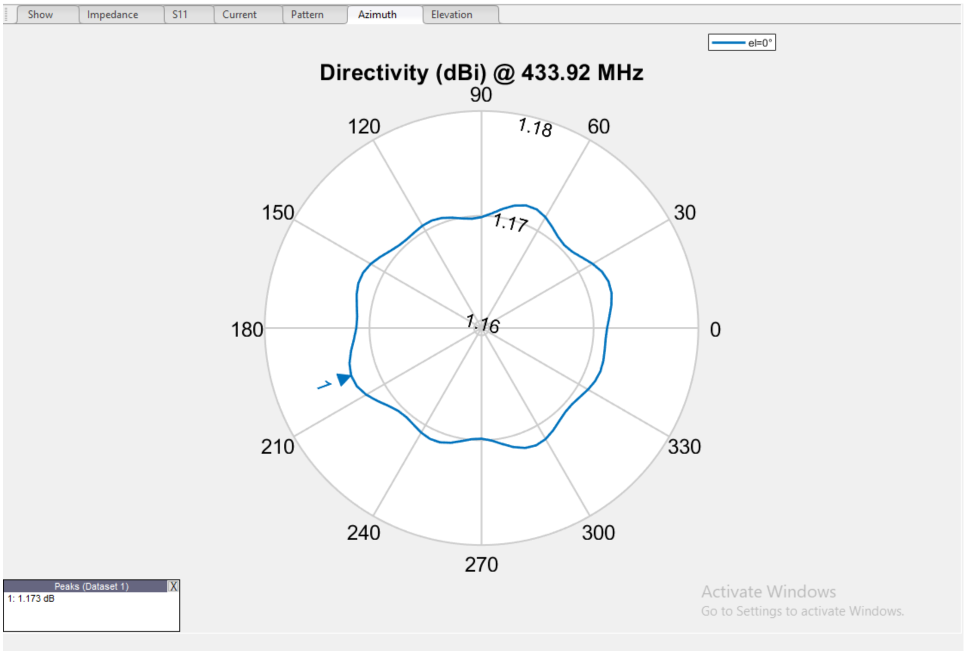
3.3.5.1 Antenna Design Simulation

The above antenna dimensions were fed into MATLAB and the antenna's operational parameters were simulated and the result of the radiation pattern is as shown below.

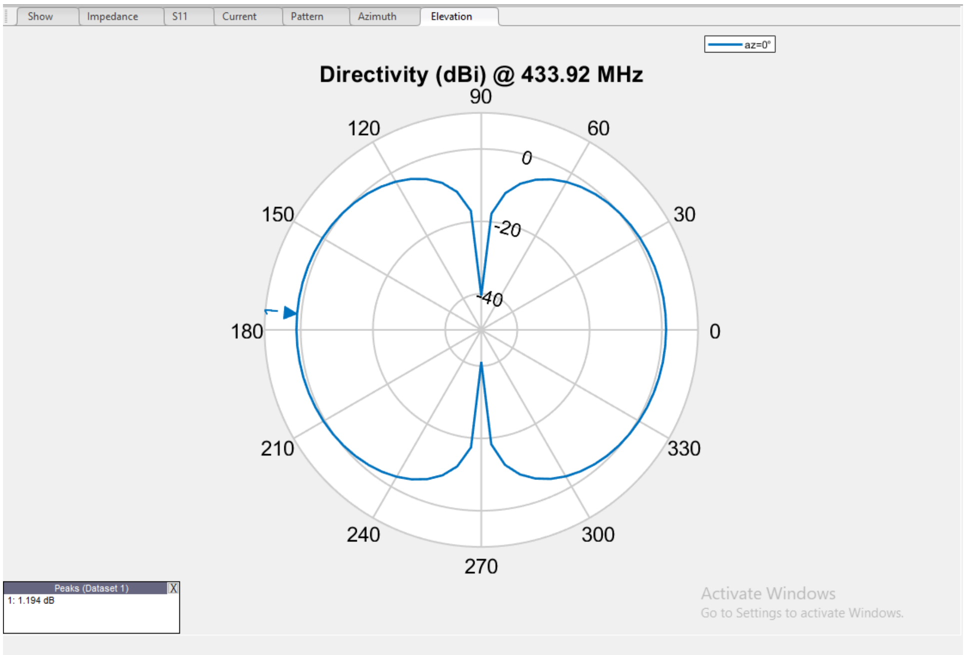
Radiation Pattern



Azimuth

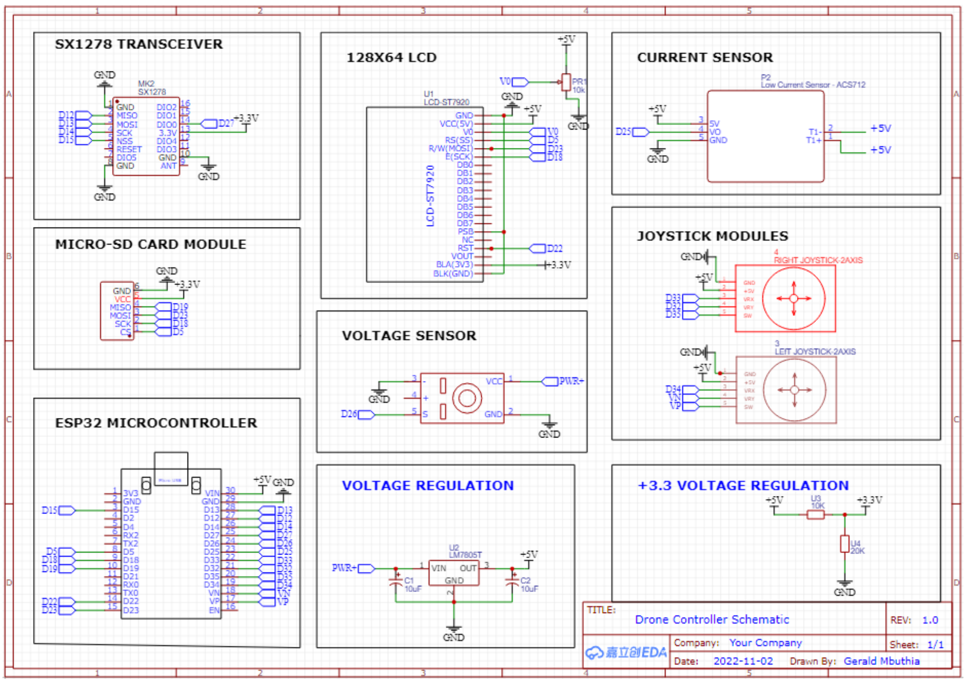


Elevation



The above radiation characteristics are desirable for the ground station's use as radio transmitter at 433Mhz. The radiation pattern provides a near isotropic radiation with minimal radio dead spots. With a gain of 1.19dBi, it provides a satisfactory radiation range.

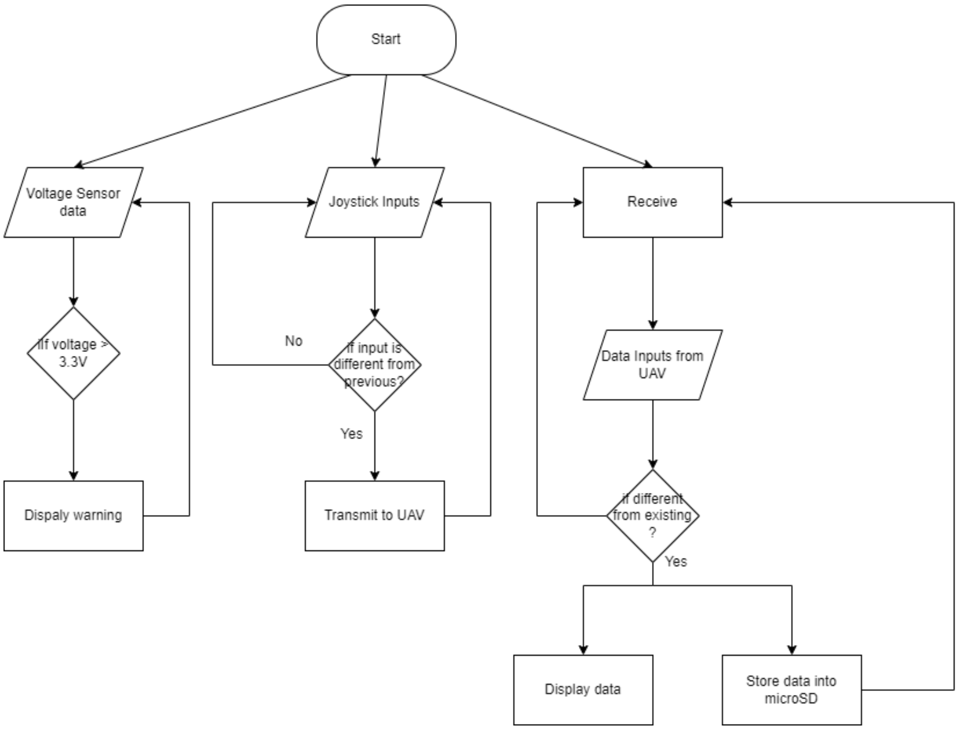
3.3.6 Full Circuit schematic



3.4 Software Development

The software is designed utilising a real-time operating system to ensure efficient utilisation of the resources within the microcontroller by utilising both cores and utilisation of multitasking.

3.4.1 System Flow Chart



3.4.2 Program Code

The program code was written in Arduino C following a modular convention where each particular piece of hardware or module had its own controlling function. This ensured that clean was written and that debugging was made easy. A series of libraries were included to take care of the low-level abstractions and assist in easy implementation of code. No time delays are included in the code to ensure fast response times,

Conclusion

In this chapter, the components chosen for the design, their interfacing and powering is shown in the block diagrams and schematics. The program flow chart and code are also developed.

CHAPTER 4

Testing, Results and Discussion

4.1 Introduction

This chapter aims at implementing the circuit diagrams designed in chapter three. Various components to be used are acquired and connected in line with the schematics and the circuit is built onto a breadboard for testing. Once the circuit is confirmed to be working as expected, it is then fabricated onto a strip board. The connection will be done in four stages and test points tested at every relevant stage. Values obtained are tabulated and compared with the expected results.

4.2 Implementation Process

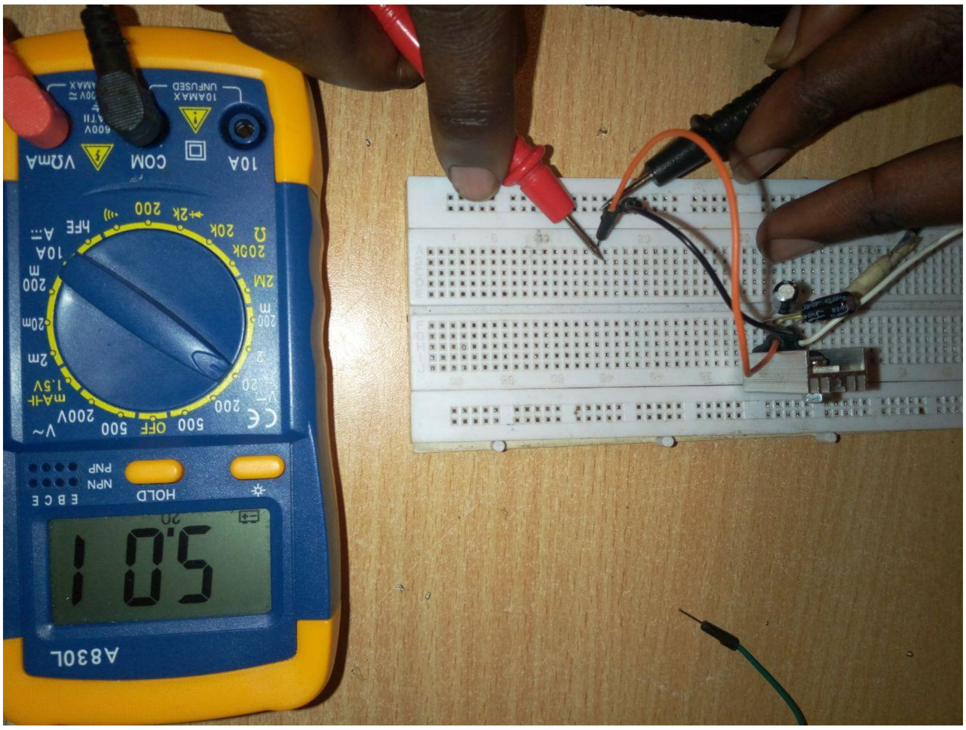
All the components that make up the system are acquired, and a test circuit constructed in several sections. The components include LCD, current and voltage sensors, joystick modules, regulator, 10k resistors, capacitors, and transceivers. The test circuit is made up of power supply, control, sensing, transmission, and display sections.

4.2.1 Tools to be used

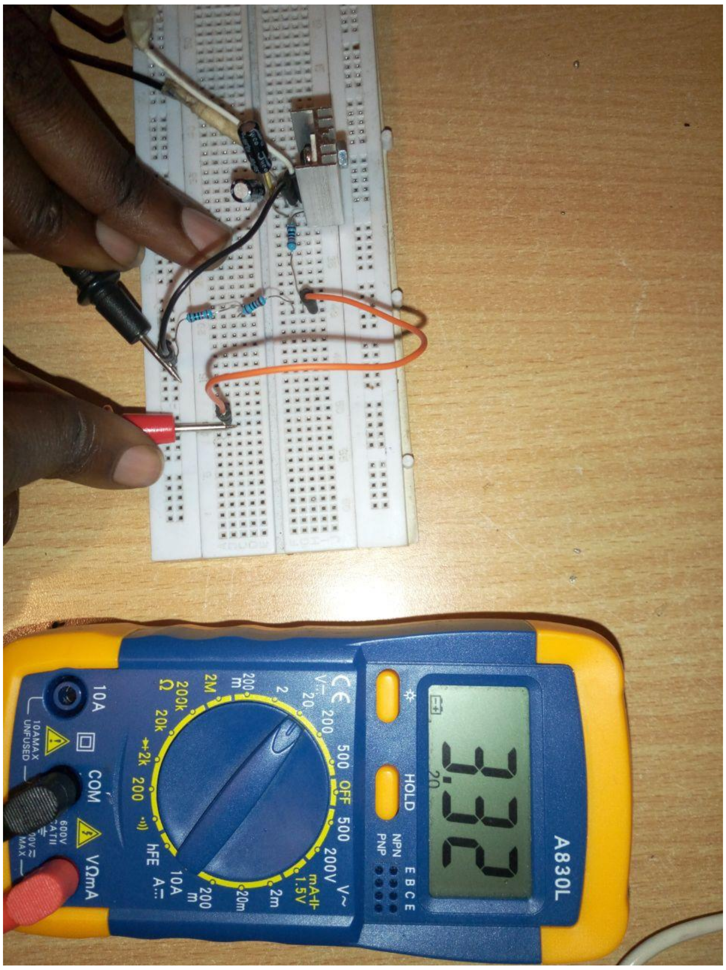
Tools to be used during construction and testing of the system include soldering gun and solder wire, multimeter, breadboard, side cutter and screw drivers. Soldering gun is used to melt the solder wire used to make connections between two conductive surfaces. The multimeter provides a means of measuring circuit properties such as voltage, current, resistance and capacitances. The side cutter is used to cut the jumper wires to required lengths and strip the ends of the jumper wires for ease of connection on the breadboard. The breadboard provides a base to mount the components for testing.

4.2.2 Power Supply

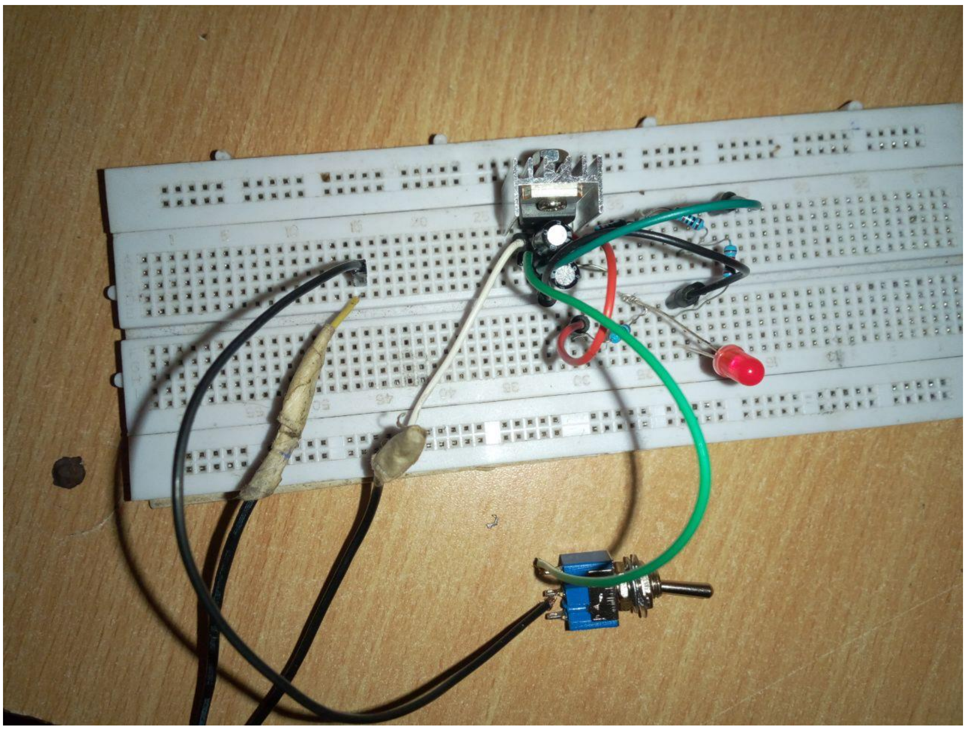
Power will be supplied from batteries with nominal voltages of at least 7V. This may allow the circuit to be driven by two Li-ion batteries at 7.2V total voltage or a single 9V battery. The voltage is stepped down to 5V using a n LM7805CV linear regulator. Due to high heat dissipation, a heat sink is provided with characteristics making it suitable enough to dissipate the generated heat. Capacitors are provided across the input and output interfaces of the regulator to stabilize the voltage and provide for transient current requirements by the system.



A voltage divider made up of three 10k resistors is added to the circuit to provide a 3.3V bus required to drive some of the components within the system.

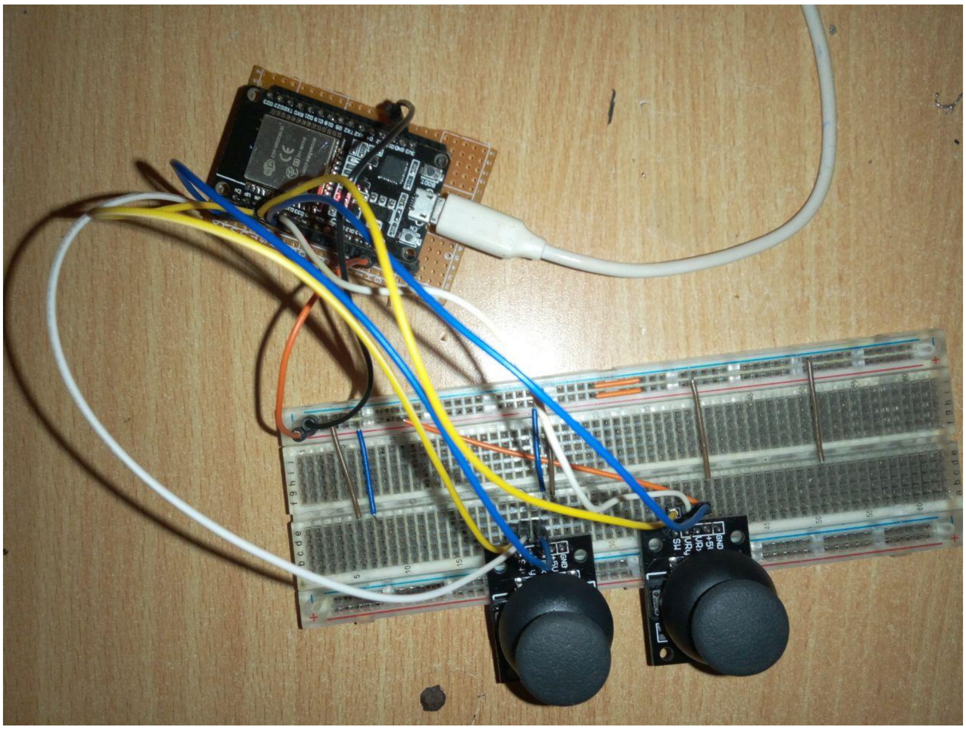


Additional components such as a toggle switch, indicator led, and diode are added to the system to complete it.



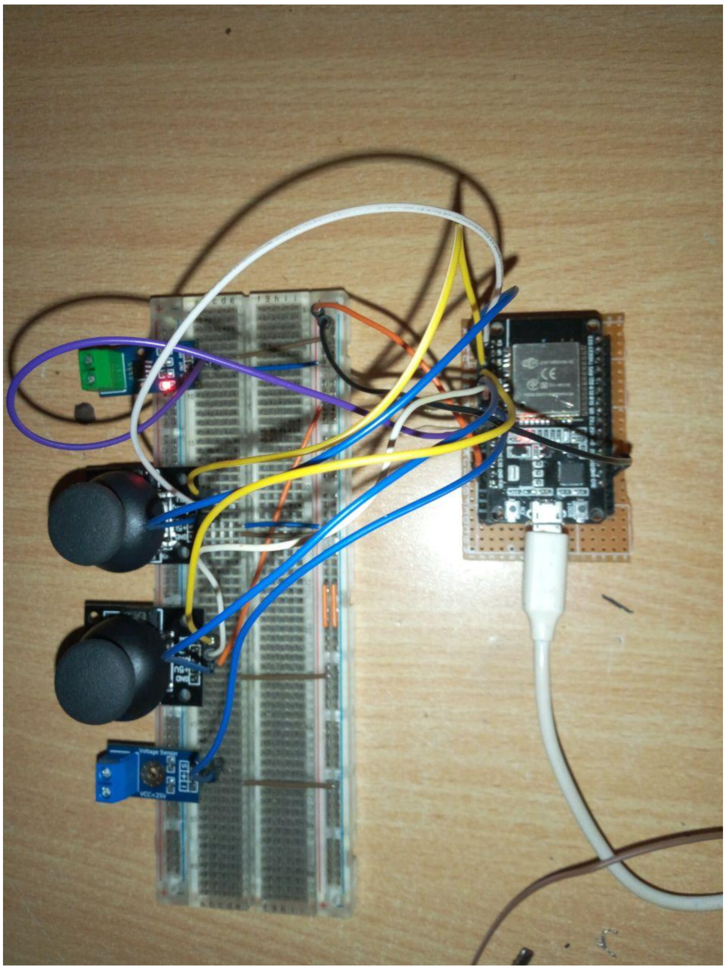
4.2.3 Control System Interfacing

The joystick modules are interfaced as shown below. The power pins are connected to 5v and GND respectively. For the left-hand and right-hand joysticks, Vx and Vy are connected to analogue pins 36, 39 and 35 and 34 respectively.



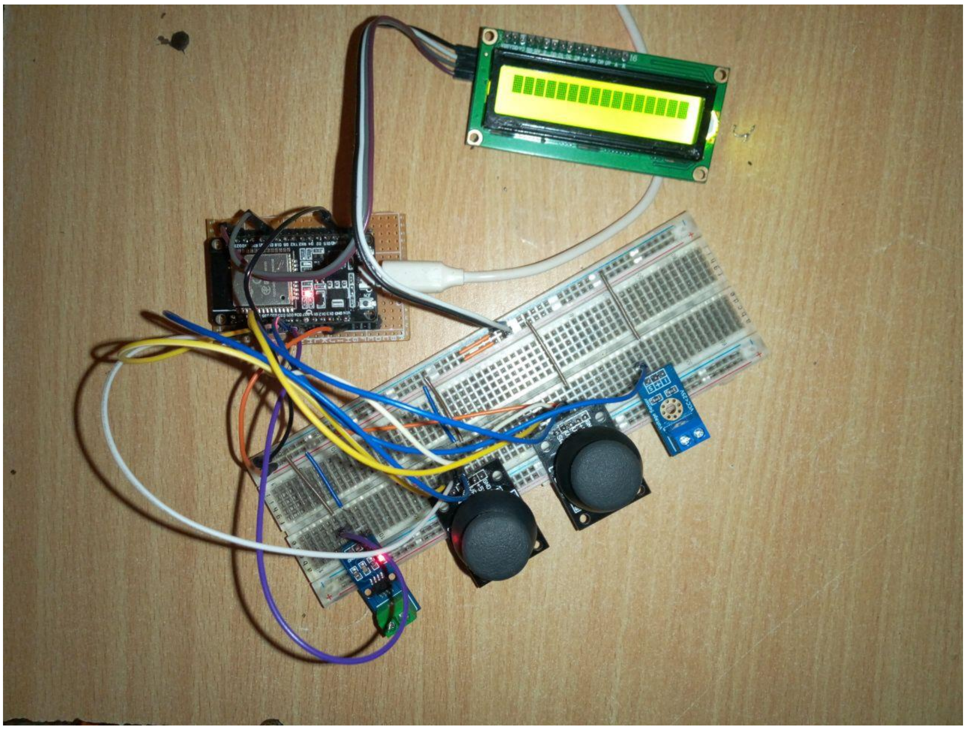
4.2.4 Sensing System Interfacing

This is comprised of the voltage sensor and the current sensor and were interfaced as shown below. The output of the voltage and current sensors are connected to pins 32 and 33 respectively.



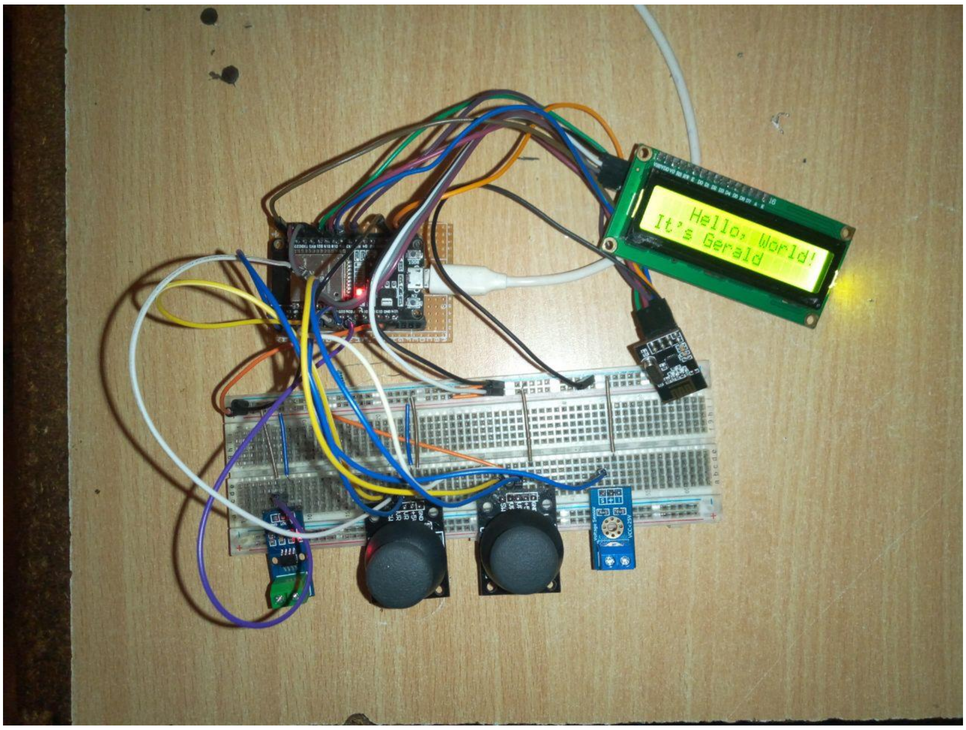
4.2.5 Display section interfacing

The display section includes an I2C LCD which will convey messages to the pilot via its screen and is interfaced as shown below. The LCD is connected to 5V and GND while its SCL and SDA pins are connected to pins 22 and 21 respectively.



4.2.6 Transceiver circuit interfacing

Due to the Sx1278 running out of stock, the FS100A transceiver was used for testing purposes. The FS100A in this case makes use of digital pins to receive signals to be transmitted and utilises amplitude-shift keying as a modulation protocol. The interfacing is as shown below. Where the system is powered by 5V and is GND and its data pin is connected to pin13.

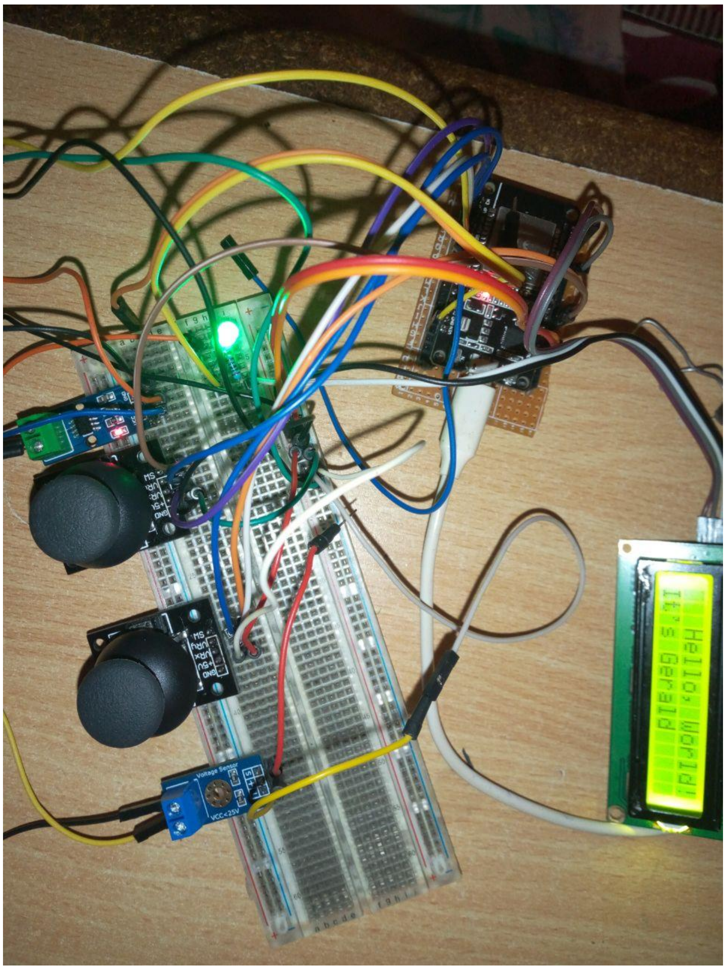


4.2.7 Antenna Design

An insulated copper length of 17.3 centimetres was cut with an extra 0.2 centimetres allowance for soldering. The tip to be soldered had the insulation removed and soldered on to the FS100A transmitter's antenna pad. A similar procedure was done on the receiver side.

4.2.6 The complete prototype on the breadboard

The complete prototype on the breadboard was assembled and the code run and tested. The system works primarily on analogue signals from the control and sensing systems. As well as the power supply from two lithium-ion batteries.



4.3 Unit Tests

The individual components were tested to ensure they worked as expected. This test involved the use of a multimeter and oscilloscope to measure the signal voltages from the various components within the sensor. The measurements were taken at full system load.

4.3.1 Battery Output

The battery containing two 18650 cells in series had their terminals tested for both voltage as well as current at full load. The results are tabulated and compared below.

No. of cells	**Quantity**	**Expected Value**	**Actual Value**	**Remarks**
Single	Voltage	3.7V	4.3V	Within expected limits. This indicates cell is fully charged.
	Current	-	-	Did not power system.
Both	Voltage	7.2V	8.5V	Within expected limits.
	Current	500mA	600mA	Within expected limits

4.3.2 LM7805 Regulator

The regulator takes in the power from the batteries and the output voltage and current are tabulated and compared as shown below

Quantity	**Expected Value**	**Actual Value**	**Remarks**
Voltage	5V	4.92V	Within expected limits
Current	600mA	550mA	Within expected values

4.3.3 ESP32 Microcontroller

The input voltage and current of the microcontroller are measured and the results are tabulated and compared as shown.

Quantity	**Expected Value**	**Actual Value**	**Remarks**
Voltage	5V	4.92V	Within expected limits
Current	500mA	300mA	Within expected values

4.3.4 SD Card Module

The input voltage and current consumption of the SD card module are measured and results tabulated and compared as shown in the table.

Quantity	**Expected Value**	**Actual Value**	**Remarks**
Voltage	5V	4.92V	Within expected limits
Current	40mA	10mA	Within expected values

4.3.5 Joystick Modules

The joystick modules had both their input and output voltage and current measured and tabulated. The values of the output were taken when the module is producing the maximum values of the analogue signal.

Quantity	**Expected Input Value**	**Actual Input Value**	**Expected Output Value (max)**	**Actual Output Value (max)**	**Remarks**
Voltage(avg)	5V	4.92V	5V	4.92V	Within expected limits
Current (avg)	14mA	9mA	7mA	1mA	Within expected values

4.3.5 FS100A Transmitter Module

The voltage and current consumption of the FS100A transmitter is measured and results tabulated during operation.

Quantity	Expected Value	Actual Value	Remarks
Voltage	5V	4.92V	Within expected limits
Current	5mA	4mA	Within expected values

4.3.6 Voltage Sensor

The voltage and current consumption by the voltage sensor is measured and results tabulated and compared.

Quantity	Expected Value	Actual Value	Remarks
Voltage	5V	4.92V	Within expected limits
Current	1mA	<1mA	Within expected values

4.3.7 Current Sensor

The voltage and current consumption of the current sensor is measured and the results tabulated and compared as shown below.

Quantity	Expected Value	Actual Value	Remarks
Voltage	5V	4.92V	Within expected limits
Current	10mA	10mA	Within expected values

4.3.8 LCD

The voltage and current consumption of the 16x2 LCD is measured and the results tabulated and compared as shown below.

Quantity	Expected Value	Actual Value	Remarks
Voltage	5V	4.92V	Within expected limits
Current	20mA	20mA	Within expected values

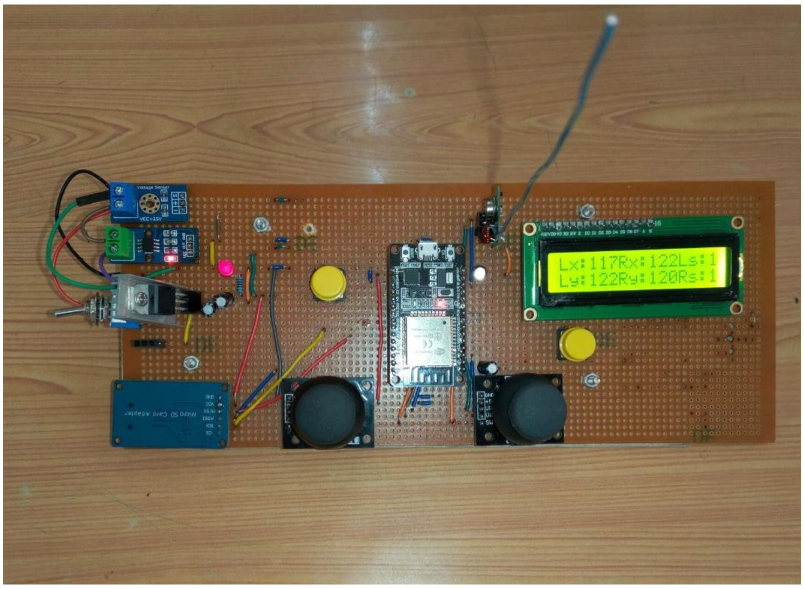
4.4 The Complete Fabricated System

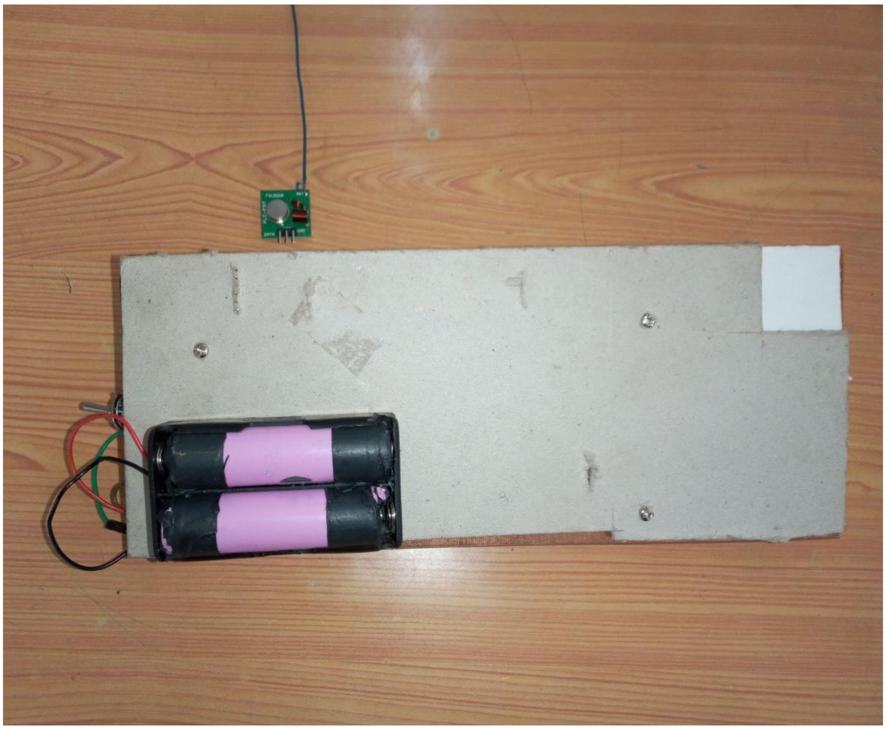
The system that was implemented on the breadboard is now transferred onto a PCB by soldering using a solder wire and soldering gun. Special care is taken to avoid short circuits and loose connections and a multimeter is used to ensure the integrity of the circuitry. Components were placed in a manner so as to minimize noise and interference and to minimize the footprint of the ground control system. Special components were added in to the design to improve system reliability. These are two buttons, an insulating stiff cardboard and screws. The insulating stiff cardboard enhanced the PCBs mechanical strength while insulating the conducting strips from shorts.

This project is a multidisciplinary project and the structural and casing design was beyond my scope of research and the Mechanical team were assigned this objective.

4.4.1 Ground Control Station

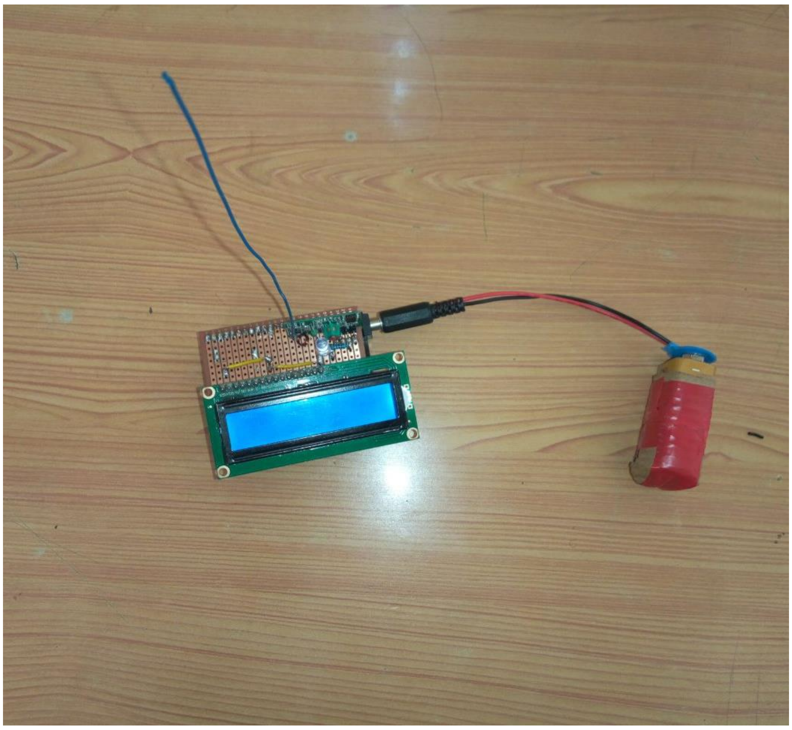
The ground control station realised on the PCB is as shown in the image captured below.

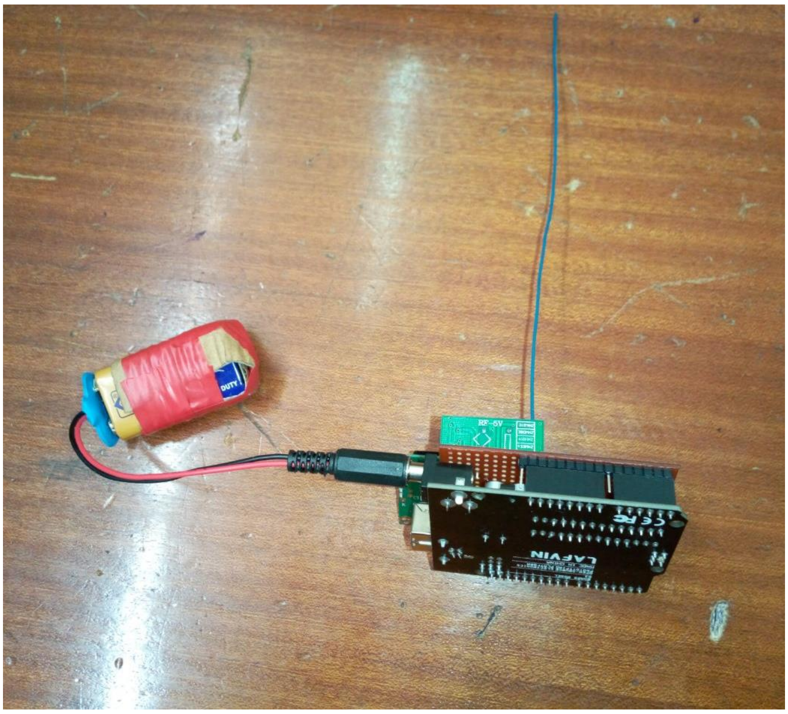




4.3.1.2 Receiver Unit

A receiver unit was necessary to simulate the receiver end-point of the system. And was realised as a PCB shield that would slide in directly onto the Arduino. The FS100A receiver is soldered on with an LED to indicate incoming data stream.





4.4 Testing and Results

The fabricated system underwent testing to ensure reliable and optimal operation. Tests carried out included hardware and System Tests.

4.4.1 Hardware Testing

The tests carried out in this section included:

- Short-circuit/ continuity test
- Voltage and Current test

4.4.1.1 Short Circuit Test

This test was carried out to ensure that the connections made were as designed and no short-circuits had occurred through the system. It was also made to ensure that the circuit was continuous where it was intended and open where it was expected. The system was found to be correctly connected and complete. This was done with no power supplied to the system.

4.4.1.2 Voltage and Current Test

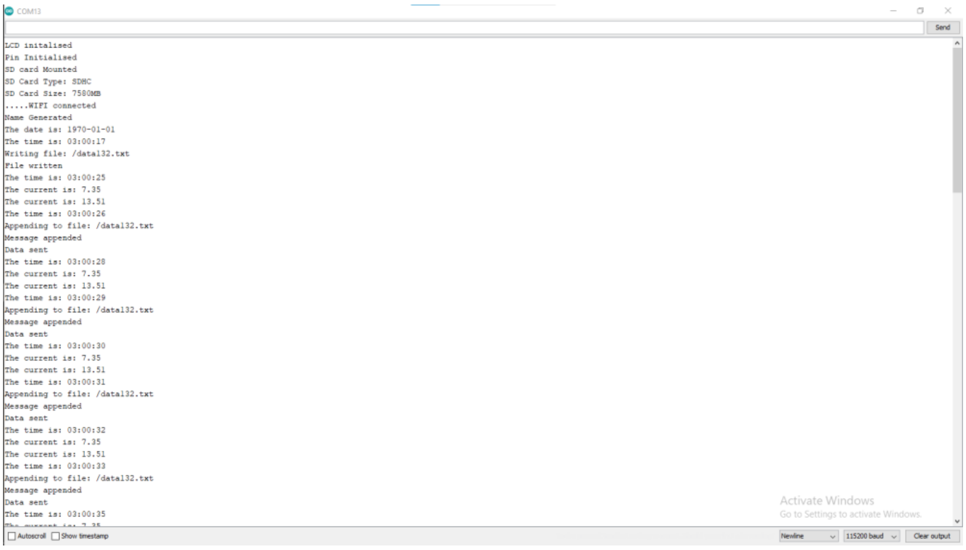
The voltage and current consumption were tested and compared to what was earlier measured and tabulated in section 4.3. The values were confirmed to be consistent.

4.4.2 System Testing

The software was flashed into the microcontroller via the Arduino IDE and the tests were conducted to ascertain that all the modules were operating in harmony to achieve the systems objectives.

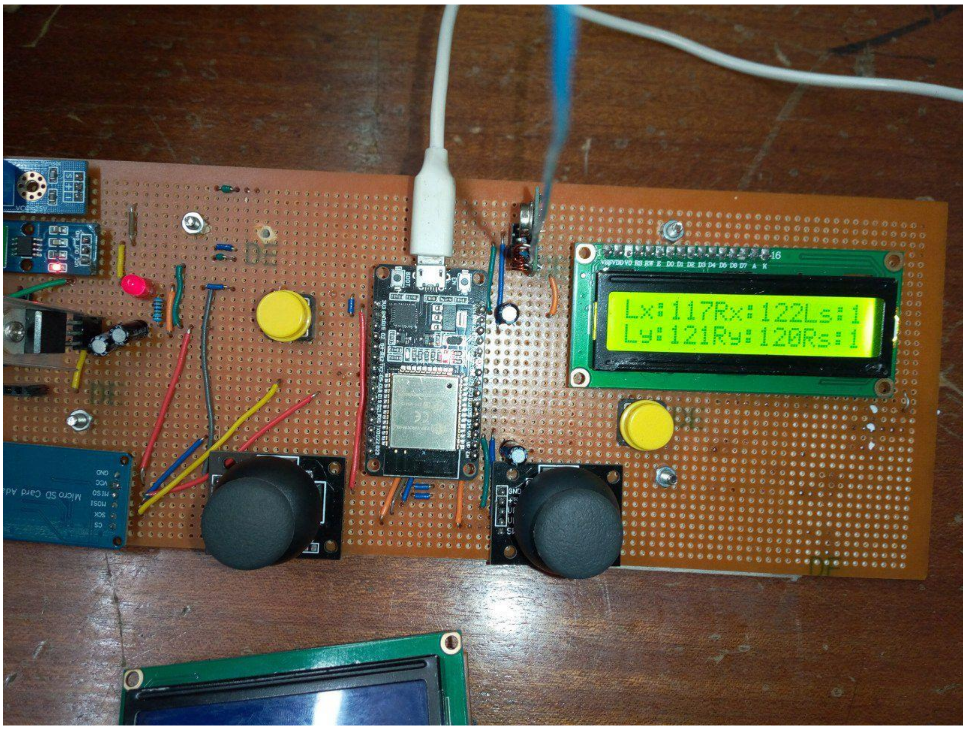
4.4.2.1 Serial Output Information

The software is run and the data printed to the serial from the code was printed in totality. The variables containing sensor data were as expected and were proved by the multimeter. The output was as shown in the image below.



4.4.2.2 LCD display during operation

During operation, the LCD displays the current values of the left and right controller Vx, Vy and Sw outputs as shown below.



4.4.2.3 Transmission Range

The system transmission range was measured both with an antenna and without an antenna and the results tabulated as shown below.

Quantity	Expected Distance	Actual Value
Without Antenna	50m	20m
With Antenna	150m	60m

4.5 Discussion

The system hardware components were interfaced appropriately to the power supply as required by their specifications. The various signal pins of the various modules in the system were connected directly to their assigned ESP32 pins. These signal pins included digital pins, analogue pins, SPI communication pins and I2C communication Pins. These pins were later referenced in the firmware and thus data and signals were forwarded at the command of the ESP32 depending on the particular task to be carried out. The software was written with a modular approach, with each module coinciding to the particular task to be accomplished. The various modules include:

- SD card Mounting
- Filename generation
- Time and Date acquisition
- Voltage and Current sensing
- File write and appending.
- Data transmission
- LCD display
- Control input reception

Each of these modules had a coinciding function in the firmware that executed that particular task. Optimizations were needed to ensure the software was fast and efficient without any lag in the system. The design and development were satisfactory for a first version of the prototype and further design may be utilised to refine and improve on the current design.

Conclusion

In this chapter, the steps taken in the development and fabrication of the circuit are indicated and images displayed of the procedures taken. The fabrication of the system on the strip board is also indicated. Tests were carried out to prove the reliability and effectiveness of the system. Software was written that enabled the hardware to carry out their respective functions.

Chapter 5

Conclusion and Recommendation

5.1 Introduction

This chapter discusses the conclusions that arise from the design and construction of the automatic gas leakage and fire detection system with real time mitigation, the extent to which the study objectives are met is also stated. Lastly, this chapter gives a summary of achievements, applications of the system in different areas and recommendations that can be used to better the project in future studies.

5.2 Statement of Initial Objectives.

The initial objectives of the UAV Communication and Control System were to:

i. To design and implement an effective, secure, and stable communication system that will enable transfer of flight data and logs from the UAV as well as provide a control channel to fly the UAV over long distances.
ii. To design and implement a ground control system that will generate control signals to fly the UAV.
iii. To design and implement an interface to display operation status and assist in drone piloting.
iv. To design and implement a good power supply system to provide the right amount of power for the ground station system.
v. To design a printed circuit for the ground and UAV system implementation.
vi. To design a storage mechanism to store flight data and logs.

5.3 Summary of Achievements

The designed communication system was effective and stable enough to forward flight data and logs over a distance. Encoding techniques were utilised to secure communication. The ground communication system was able to forward control signals to the UAV and allow it to pitch, yaw, and roll. An LCD system was implemented, and which displayed operation status and provided drone piloting assistance. The power supply provided a well-regulated 5V and

3.3V output that was void of noise and fluctuations thus safely powering the system without the risk of shorting or reverse polarity. Voltage and current sensors were utilised to ensure that a good record of power consumption was recorded. A storage mechanism was utilised to store flight data and logs that would be essential for later analysis and provide knowledge on future development.

5.4 Benefits of the Study

The study has provided a base from which further development can be built upon. The system provides fast and uninterrupted processing due to its use of a real-time operating system on its 240MHz dual-core processor allowing for instantaneous UAV control. The system as is meets the minimum requirement of a flight controller by providing a secure, reliable, and effective means of communication between the UAV and pilot. The communication system is independent of third-party network infrastructure making it easy to use in a wide range of environments and especially remote areas. It has illustrated the importance of better data handling techniques that are essential to the future development of the UAV to completely solve the issue of insecurity in the Central-rift region of Kenya. A secondary benefit is allowing me to put into practise the knowledge acquired during my five-year duration in school.

5.5 Application of the system

The communication and ground control system will provide a platform to receive control signals and transmit them to a UAV enabling control of the UAVs flight path. It will also allow for the reception of flight data and storage allowing it to provide feedback to the pilot which will assist in actual flight. The system can be utilised in any environment especially remote areas as it does not rely on third party networks to provide a communication channel making it highly adaptable.

5.6 Challenges Faced during Design and Implementation

Numerous challenges were faced during the development of this work as follows;

i. Insufficient funds were a major setback in the realisation of this project since the components utilised in the development of drones are expensive due to the high-quality requirements that are required to be met.
ii. Electronic component availability was a major issue due to this period being the time of the year when most students are working on their final year projects. Components

like the Lithium-ion batteries, sx1278 transceiver, SD-card modules were in limited supply and thus long wait times were experienced and alternative components were sort out.

iii. The short development time limited the implementation time with more time being required to fine tune and refine the hardware and software components to achieve a more efficient and powerful system.

5.7 Recommendations for Future Work

Even though the system has met its objectives, below are recommendations on how the system can be improved in future designs;

i. A full duplex communication module should be incorporated in future to handle both UAV control transmission and flight data and logs reception by the drone. This will lower the overall power consumption while minimising space occupied and the overall mass of the controller and the UAV.

ii. The system should be realised on an actual manufactured PCB with the modules being broken down into their discrete components and placed on the PCBs and smaller components used. This will reduce the overall mass of the system while ensuring better power efficiency, lower noise, and improved reliability.

iii. Additional control sensors added onto the controller such as gyroscopes to implement motion control to supplement the joystick control modules. This will provide better control options for the drone pilot.

iv. Implement a GPS transceivers onto the controller that can be tracked by the UAV. This will allow for the UAV to be able to find its way to the last location of the controller in case a connection is lost. This will also allow for the implementation of better flight planning.

5.8 Final Conclusion

The communication and ground system for the UAV has been found to provide an effective means of flying a UAV and has provided a basis from which further research and development can be carried out to realise an operational and tactical UAV to maintain security and allow for surveillance.

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Appendices

Appendix A: Ground Control Software

```
#include "FS.h"

#include "SD.h"

#include "SPI.h"

#include <Wire.h>

#include <WiFi.h>

#include <RH_ASK.h>

#include <WiFiUdp.h>

#include <NTPClient.h>

#include <LiquidCrystal_I2C.h>



#define vx 34//left controller

#define vy 35

#define sw 26

#define vx1 36//right controller

#define vy1 39

#define sw1 25

#define eeSize 1
```

```
#define rx 5

#define tx 13

#define voltPin 32



const char *ssid = "Faiba4G";

const char  *password = "Lexus570";



float ref_voltage = 5.0;

float adc_voltage = 0.0;

float in_voltage = 0.0;

float R1 = 30000.0;

float R2 = 7500.0;

float curr = 0.0;



int adc_value = 0;

int vxVal = 0;

int vyVal = 0;

int vx1Val = 0;

int vy1Val = 0;

int id = 0;
```

```
int eval;

long cardSize;

bool swVal;

bool sw1Val;

bool activate = false;

String dataToLog = "";

String pathTxt = "";

String card = "";


WiFiUDP ntpUDP;

NTPClient timeClient(ntpUDP, "pool.ntp.org", 3600, 60000);

RH_ASK rf_driver(2000, rx, tx, 0);

LiquidCrystal_I2C lcd(0x27, 16, 2);


String randomGen() {

  randomSeed(analogRead(27));

  eval = random(300);

  Serial.println("Name Generated");

  return String(eval);

}
```

```
void lcdPrint(String txt, int col, int row, bool clr, int delTime = 0, bool var = false) {
  if (clr) {
    lcd.clear();
  }
  lcd.setCursor(col, row);
  lcd.print("   ");
  lcd.setCursor(col, row);
  lcd.print(txt);
  delay(delTime);
}
void lcdBegin() {
  lcd.init();
  lcd.begin(16, 2);
  lcd.backlight();
  lcd.clear();
  lcdPrint("Drone Controller", 0, 0, true, 0);
  lcdPrint("Setting up...", 0, 1, false, 2000);
  lcdPrint("LCD ON", 0, 0, true, 2000);
  Serial.println("LCD initalised");
}
```

```
void pinInit() {

  pinMode(sw, INPUT_PULLUP);

  pinMode(sw1, INPUT_PULLUP);

  Serial.println("Pin Initialised");

}

void controls() {

  vxVal = map(analogRead(vx), 0, 4095, 0, 255);

  vyVal = map(analogRead(vy), 0, 4095, 0, 255);

  vx1Val = map(analogRead(vx1), 0, 4095, 0, 255);

  vy1Val = map(analogRead(vy1), 0, 4095, 0, 255);

  swVal = digitalRead(sw);

  sw1Val = digitalRead(sw1);

  lcdPrint(String(vxVal), 3, 0, false);

  lcdPrint(String(vyVal), 3, 1, false);

  lcdPrint(String(vx1Val), 9, 0, false);

  lcdPrint(String(vy1Val), 9, 1, false);

  lcdPrint(String(swVal), 15, 0, false);

  lcdPrint(String(sw1Val), 15, 1, false);

}

void sdCardMount() {
```

```
if (!SD.begin(5)) {
  Serial.println("Card Mount Failed");
  Serial.println("Restarting system");
  lcdPrint("Card Mount Fail", 0, 0, true, 2000);
  lcdPrint("Restarting ...", 0, 1, false, 1000);
  ESP.restart();
  activate = false;
}
Serial.println("SD card Mounted");
activate = true;
uint8_t cardType = SD.cardType();
if (cardType == CARD_NONE) {
  Serial.println("No SD card attached");
  lcdPrint("No SD card", 0, 0, true, 1000);
  return;
}
Serial.print("SD Card Type: ");
if (cardType == CARD_MMC) {
  card = "MMC";
  Serial.println("MMC");
```

```
  } else if (cardType == CARD_SD) {
    card = "SDSC";
    Serial.println("SDSC");
  } else if (cardType == CARD_SDHC) {
    card = "SDHC";
    Serial.println("SDHC");
  } else {
    card = "UNKNOWN";
    Serial.println("UNKNOWN");
  }
  lcdPrint("SD Type: " + card, 0, 0, true, 1000);
  cardSize = SD.cardSize() / (1024 * 1024);
  lcdPrint("SD size: " + String(cardSize) + String("MB"), 0, 1, false, 3000);
  Serial.printf("SD Card Size: %luMB\n", cardSize);
}
void writeFile(fs::FS &fs, const char * path, const char * message) {
  Serial.printf("Writing file: %s\n", path);
  lcdPrint("File Path:", 0, 0, true, 1000);
  lcdPrint(pathTxt, 0, 1, false, 3000);
  File file = fs.open(path, FILE_WRITE);
```

```
  if (! file) {
    Serial.println("Failed to open file for writing");
    return;
  }
  if (file.print(message)) {
    Serial.println("File written");
  } else {
    Serial.println("Write failed");
  }
  file.close();
}
void appendFile(fs::FS &fs, const char * path, const char * message) {
  Serial.printf("Appending to file: %s\n", path);
  File file = fs.open(path, FILE_APPEND);
  if (!file) {
    Serial.println("Failed to open file for appending");
    return;
  }
  if (file.print(message)) {
    Serial.println("Message appended");
```

```
  } else {
    Serial.println("Append failed");
  }
  file.close();
}
void dataLog() {
  long tm = millis();
  dataToLog = String(id++) + "\t" + String(getTime()) + "\t" + String(in_voltage) + "\t" +
        String(curr) + "\t" + String(vxVal) + "\t" + String(vyVal) + "\t" + String(vx1Val) +
        "\t" + String(vy1Val) + "\t" + String(swVal) + "\t" + String(sw1Val) + "\t\r\n";
  appendFile(SD, pathTxt.c_str(), dataToLog.c_str());
}
void sendData() {
  String toSend = String(vxVal) + "," + String(vyVal) + "," + String(vx1Val) + "," +
        String(vy1Val) + "," + String(swVal) + "," + String(sw1Val);
  const char *msg = toSend.c_str();
  rf_driver.send((uint8_t *)msg, strlen(msg));
  rf_driver.waitPacketSent();
}
void vSense() {
```

```
  adc_value = analogRead(32);

  adc_voltage  = (adc_value * ref_voltage) / 4096.0;

  in_voltage = (adc_voltage / (R2 / (R1 + R2))) * 0.6667;

  Serial.print("The voltage is: ");

  Serial.println(in_voltage);

}

void currSense() {

  unsigned int x = 0;

  float AcsValue = 0.0, Samples = 0.0, AvgAcs = 0.0, AcsValueF = 0.0;

  for (int x = 0; x < 5; x++) {

    AcsValue = analogRead(33);

    Samples = Samples + AcsValue;

    delay (3);

  }

  AvgAcs = Samples / 150.0; //Taking Average of Samples

  curr = (2.5 - (AvgAcs * (3.3 / 4096.0)) ) / 0.185;

  Serial.print("The current is: ");

  Serial.println(curr);

}

String getTime() {
```

```
  timeClient.update();

  String formattedTime = timeClient.getFormattedTime();

  Serial.print("The time is: ");

  Serial.println(formattedTime);

  return formattedTime;

}

String getDate() {

  timeClient.update();

  String formattedDate = timeClient.getFormattedDate();

  Serial.print("The date is: ");

  Serial.println(formattedDate.substring(0, formattedDate.indexOf("T")));

  return formattedDate.substring(0, formattedDate.indexOf("T"));

}

void setup()

{

  Serial.begin(115200);

  lcdBegin();

  pinInit();

  rf_driver.init();

  sdCardMount();
```

```
WIFI. Begin(ssid, password);

while (WiFi.status() != WL_CONNECTED) {

  delay(500);

  Serial.print(".");

}

Serial.println("WIFI connected");

lcdPrint("Wifi connected", 0, 0, true, 100);

lcdPrint(ssid, 0, 1, false, 1000);

timeClient.begin();

timeClient.setTimeOffset(10800);

lcdPrint("File Path", 0, 0, true, 100);

lcdPrint(pathTxt, 0, 1, false, 1000);

pathTxt = ("/" + String("data") + String(randomGen()) + String(".txt"));

String flightTxt = String("Controller On.\nInitialized tests and completed
        successfully.\nMission details..........\n")
            + "\tLCD Okay\n\tFilename >>>" + String(pathTxt) + "\n\tPins initialised
        Okay\n\tTransceiver Transmission Okay\n\tSD card Mounted Successfully. Type:"
            + String(card) + "; Size:+" + String(cardSize) + "MB;\n\tConnected to Wifi
        >>>" + String(ssid) + " on " + String(getDate()) + " at " + String(getTime())
            + " successfully\n\tGround Station System execution begins
        now\n\r\r\nId\tTime\t\tVoltage\tCurrent\tMemory\tLx\tLy\tRx\tRy\tLs\tRs\n"
```

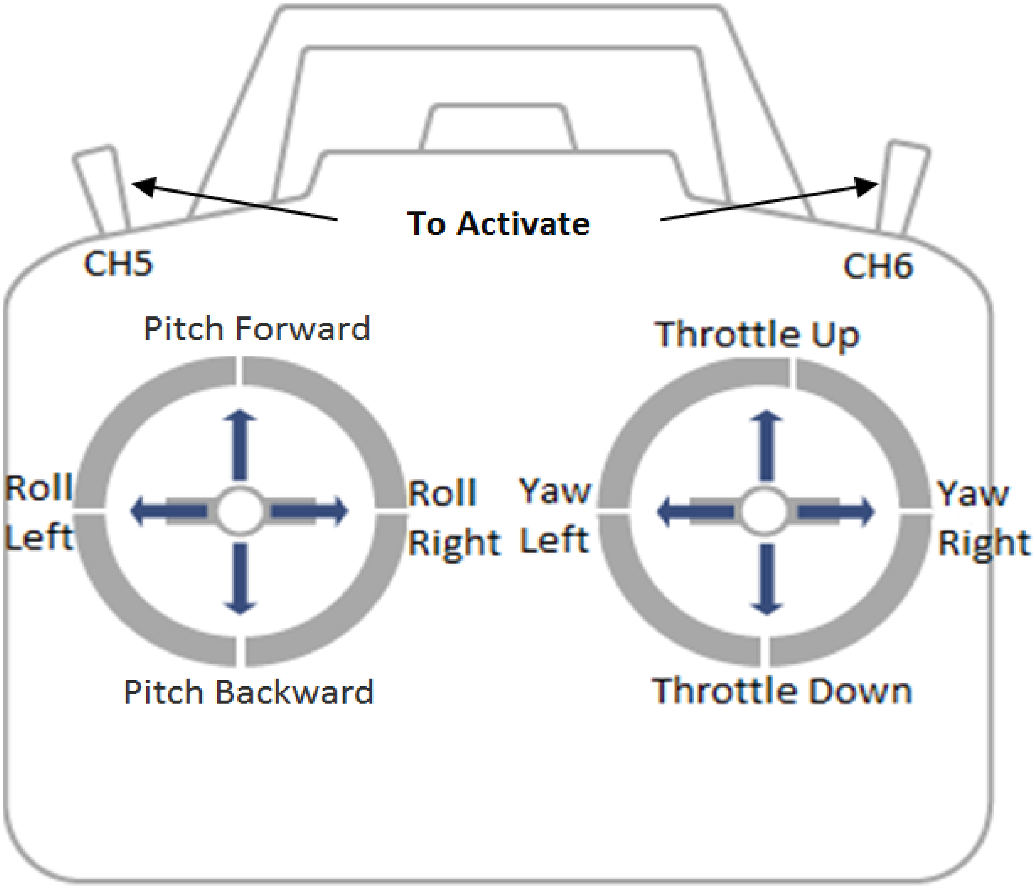
```
            +
        "..........................................................................................................................\n"
        ;
  delay(10);
  writeFile(SD, pathTxt.c_str(), flightTxt.c_str());
  lcdPrint("SD card write...", 0, 0, true, 100);
  lcdPrint("Successful", 0, 1, false, 2000);
  lcdPrint("Lx:", 0, 0, true);
  lcdPrint("Ly:", 0, 1, false);
  lcdPrint("Rx:", 6, 0, false);
  lcdPrint("Ry:", 6, 1, false);
  lcdPrint("Ls:", 12, 0, false);
  lcdPrint("Rs:", 12, 1, false);
  delay(1000);
}
void loop()
{
  getTime();
  vSense();
  currSense();
```

```
  controls();

  dataLog();

  sendData();

}
```

Appendix C: Flight Log Data

Appendix C: Controller Signal and Function Assignment Guide

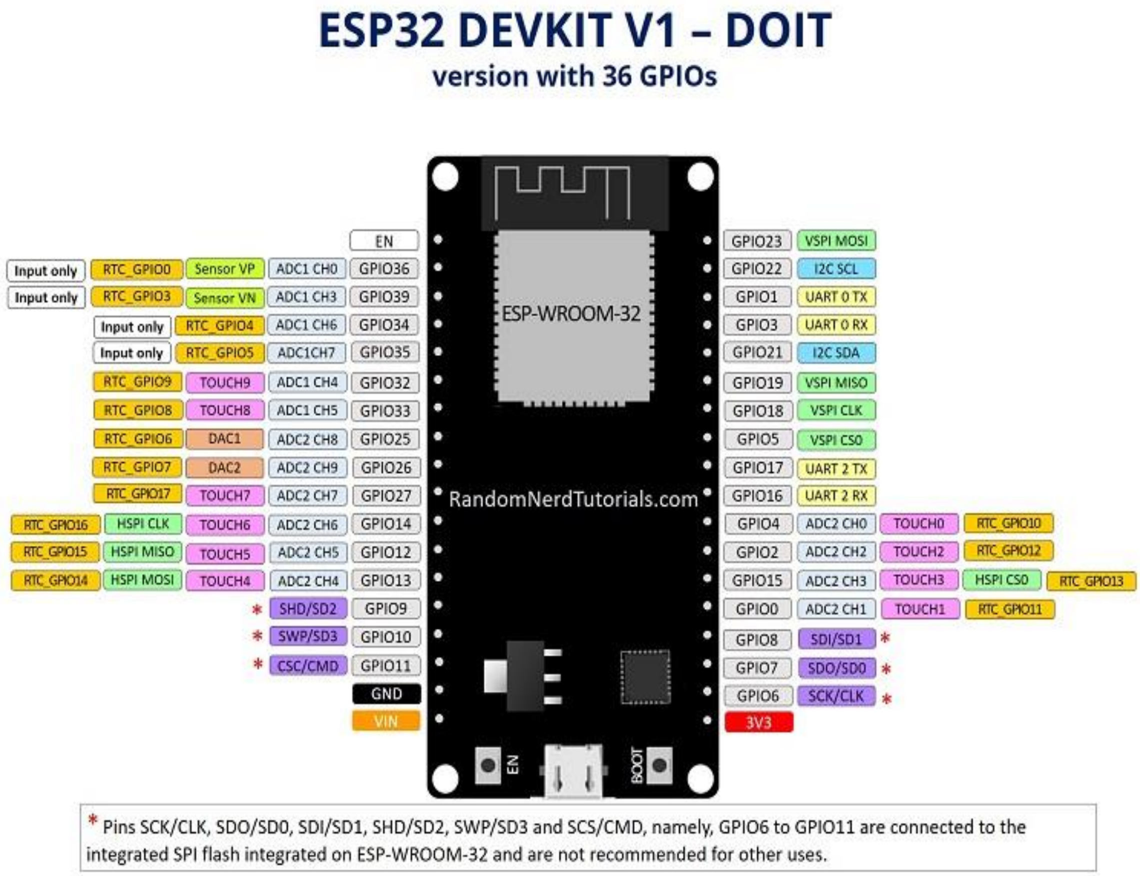
Control Signal Mapping on Controller



Control Signal and Function

Action	RC transmitter position	Copter behaviour	RC value
Pitch forward	left stick; up position	goes forward	pitch value increases
Pitch backward	left stick; down position	goes backward	pitch value decreases
Roll right	left stick; right position	goes right	roll value increases
Roll left	left stick; left position	goes left	roll value decreases
Yaw right	right stick; right position	heading turns to right	yaw value increases
Yaw left	right stick; left position	heading turns to left	yaw value deceases
Throttle up	right stick; up position	goes up	throttle value increases
Throttle down	right stick; down position	goes down	throttle value decreases

Appendix D: ESP32 Pin Configuration



Appendix E: SD Card Module Datasheet

eBay Search:

Micro SD Card Micro SDHC Mini TF Card Adapter Reader Module for Arduino

Description

- The module (MicroSD Card Adapter) is a Micro SD card reader module for reading and writing through the file system and the SPI interface driver, SCM system can be completed within a file MicroSD card
- Support Micro SD Card, Micro SDHC card (high speed card)
- Level conversion circuit board that can interface level is 5V or 3.3V
- Power supply is 4.5V ~ 5.5V, 3.3V voltage regulator circuit board
- Communications interface is a standard SPI interface
- 4 M2 screws positioning holes for easy installation
- Control Interface: A total of six pins (GND, VCC, MISO, MOSI, SCK, CS), GND to ground, VCC is the power supply, MISO, MOSI, SCK for SPI bus, CS is the chip select signal pin;
- 3.3V regulator circuit: LDO regulator output 3.3V for level conversion chip, Micro SD card supply;
- Level conversion circuit: Micro SD card to signal the direction of converts 3.3V, MicroSD card interface to control the direction of the MISO signal is also converted to 3.3V, general AVR microcontroller systems can read the signal;
- Micro SD card connector: self bomb deck, easy card insertion.
- Positioning holes: 4 M2 screws positioning holes with a diameter of 2.2mm, so the module is easy to install positioning, to achieve inter-module combination.