A SUMMER INTERNSHIP REPORT ON

DRONE PAD SYSTEM WITH INTEGRATED WIRELESS CHARGING FOR AUTONOMOUS DRONE OPERATIONS: BMS Support Module Design for Smart Battery Switching in Drone Systems

Under the mentorship of

Dr. Ashwani Sharma

Associate Professor

Department of Electrical Engineering,

Indian Institute of Technology, Ropar

Submitted by

Adityaraj Panchal(0801EC231013)

Department of Electronics and Telecommunication Engineering,

SHRI GOVINDRAM SEKSARIA INSTITUTE OF TECHNOLOGY & SCIENCE, INDORE

JUNE-JULY 2025

Abstract

This project focuses on developing an autonomous drone surveillance system equipped with wireless charging capability. The drone performs routine surveillance missions and, upon reaching a low battery threshold, autonomously navigates to a nearby transmitter pad using a homing signal. These charging pads, which may be mounted on stationary or mobile platforms, wirelessly recharge the drone before it resumes its mission.

My contribution to this project focused on the development of a smart battery management support module aimed at enabling intelligent switching in drone battery systems. I began by studying the fundamental requirements of battery management systems (BMS) and analyzing the limitations of existing commercial modules. I observed that none provided the flexibility to digitally switch between modes based on battery configuration or application needs. To bridge this gap, I designed a custom BMS support module using the ESP32 microcontroller. This module interfaces with a mobile application to receive real-time commands and data, allowing it to dynamically control the BMS operation. It effectively transforms a standard BMS into a digitally switchable system, suitable for modern drone applications. The design was validated through both simulation and prototype implementation, ensuring compatibility, safety, and responsiveness in a multi-cell battery environment.

Introduction

As drones continue to revolutionize industries such as surveillance, logistics, agriculture, and disaster response, their ability to operate autonomously has become increasingly vital. However, one of the biggest limitations in current autonomous drone systems is the short battery life of Li-Po batteries. In most cases, when a drone's battery is depleted, it must be manually replaced or recharged—an approach that disrupts operations, increases human dependency, and limits scalability.

To overcome these challenges, the project aimed to develop a fully autonomous drone power management ecosystem, combining wireless charging with intelligent battery configuration switching. The system allows the drone to perform its task and, upon reaching a low battery condition, autonomously navigate to a wireless charging station (DronePad). This pad initiates inductive charging, and the charging process is managed entirely without human intervention.

While wireless charging solves the problem of energy replenishment, it is equally important to ensure that the battery configuration matches the drone's operational mode—whether high endurance, high power, or safety-critical situations. Most conventional Battery Management Systems (BMS) are fixed-mode and not designed for dynamic reconfiguration based on real-time mission demands.

To address this limitation, our system introduces a smart battery switching module, which acts as a digital interface between the Raspberry Pi onboard the drone and the battery's BMS. Upon receiving data from the DronePad, the Raspberry Pi sends configuration commands to this switching module, which reconfigures the battery (e.g., 3S, 4S, or 6S) accordingly. After switching, the existing BMS continues managing charge, discharge, and safety protections based on the selected configuration.

This integration of wireless charging, intelligent switching, and autonomous control creates a closed-loop, fully self-sufficient drone charging system, enabling longer missions, reduced human effort, and safer power management in real-world drone operations.

System Overview

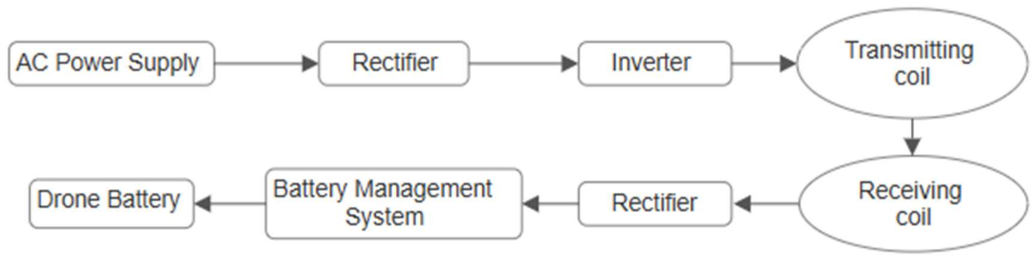


Figure 1:- Block Diagram of whole Project

Background and Motivation

- Unmanned aerial vehicles (UAVs) are increasingly deployed in surveillance, environmental monitoring, logistics, and military applications. Despite their growing utility, their limited onboard energy capacity severely constrains operational duration. Manual intervention for battery replacement or recharging not only interrupts missions but also increases logistical complexity and labor cost.

- This project aims to overcome those limitations by enabling fully autonomous drone operation through wireless charging. The drone monitors its battery state and, upon reaching a critical threshold, autonomously locates and docks with a wireless charging pad. Once recharged, it resumes its mission without any human involvement. This architecture supports seamless, continuous drone operation across diverse environments, including remote or high-risk zones.

High-Level System Description

- The system integrates multiple subsystems working in coordination:

• Autonomous Drone Subsystem

- Executes surveillance or mission paths independently, continuously monitors its battery level, and determines when to initiate charging. It is equipped with a receiver coil and rectification hardware for inductive wireless power reception.

• Localization and Navigation Subsystem

- The drone locates the charging pad using a homing signal (e.g., RF beacon) emitted by the pad. Localization logic enables precise landing and alignment with the transmitter coil to ensure optimal power coupling.

• Wireless Power Transfer (WPT) Subsystem

Enables inductive charging through a high-frequency magnetic link between transmitter and receiver coils. Power is only transferred when proper coil alignment is detected.

• Smart Battery Switching Module Subsystem (subject of this report)

- Converts a conventional fixed-mode Battery Management System (BMS) into a digitally reconfigurable one. The Raspberry Pi onboard the drone receives input from the DronePad and sends battery configuration commands to the ESP32-based switching module.
- This module interprets the command and activates switching logic to set the battery in the desired S-configuration (e.g., 3S, 4S, or 6S). Once the reconfiguration is completed, the standard BMS takes over and manages protection, charging, and discharging autonomously based on the selected setup.
- This subsystem allows drones to adapt battery usage in real-time according to operational demands, improving efficiency, flexibility, and safety in autonomous drone operations**.**

1. Selection of BMS: Why NXP RDDRONE-BMS772?

The **RDDRONE-BMS772** by NXP Semiconductors is a high-performance, flexible, and industry-grade Battery Management System (BMS) specifically designed for drone and robotic applications. It supports **3S to 6S** lithium-ion and lithium-polymer battery packs and integrates extensive safety, communication, and control features, making it an ideal choice for autonomous UAV systems.

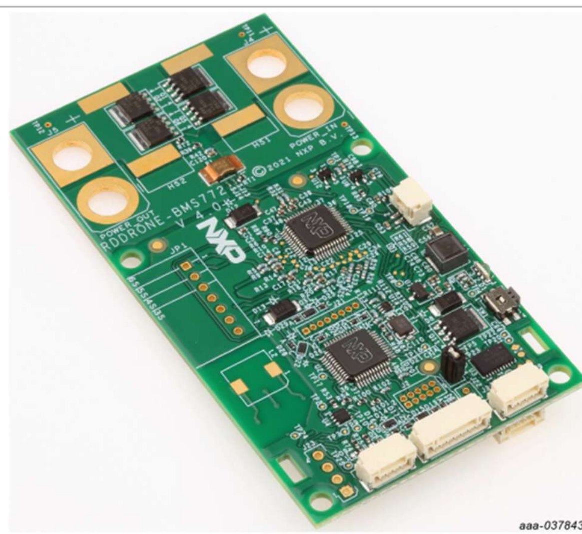


Figure 1. RDDRONE-BMS772 board

Key Features of RDDRONE-BMS772:

- Supports **battery stacks from 3S to 6S** with operating voltage from **6.0 V to 26 V**.

- High-accuracy **cell and stack voltage measurement** with ±5 mV precision.
- Supports **charging/discharging currents up to 200 A peak** (with full MOSFET bank and heatsink).
- Built-in **active cell balancing** to maintain uniform cell voltages.
- Multiple power-saving modes: **deep sleep and automatic sleep** with ultra-low leakage current.
- Integrated **authentication**, safety diagnostics, and cell monitoring.
- Communication via **CAN, I2C, and NFC**, compatible with PX4 DroneCode and HoverGames platforms.
- Debugging via **SWD, JTAG**, and DCD-LZ interfaces.

However, the BMS772 has a limitation: the desired configuration (3S to 6S) must be **hard-set using physical solder jumpers**. This manual setup prevents dynamic reconfiguration in systems where the number of active cells needs to adapt based on real-time mission requirements.

2. Motivation for Smart Switching Module

The goal of this project was to develop a **digital switching system** that allows real-time reconfiguration of the BMS input tap points, converting the BMS772 into a **digitally switchable system** without modifying its hardware or firmware.

This enables:

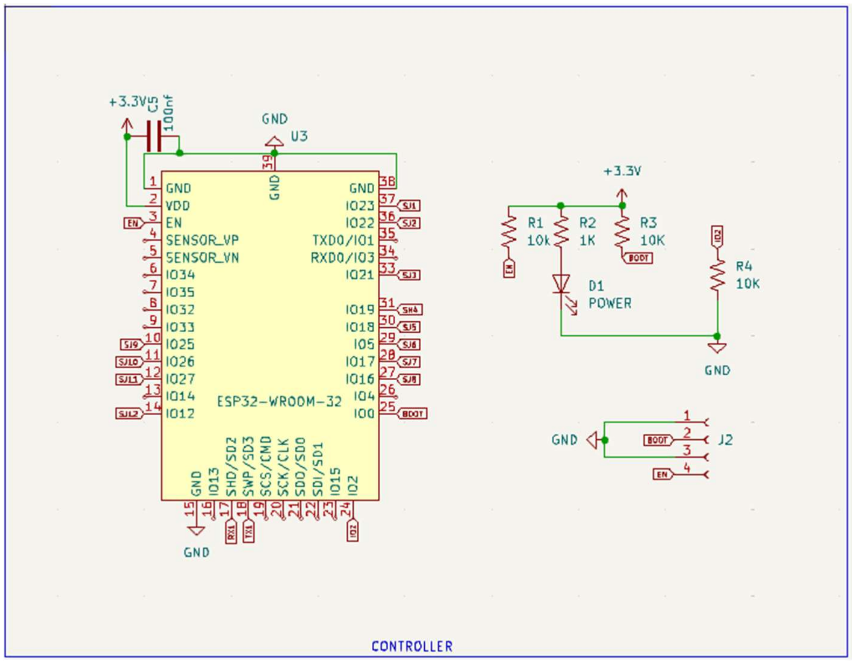
- Selection of 3S, 4S, 5S, or 6S modes via command from the drone's onboard Raspberry Pi.
- Seamless integration with autonomous wireless charging workflows.
- Intelligent energy optimization based on mission duration or available battery capacity.

3. Schematic Breakdown

To implement digital control over the BMS configuration, we selected the **ESP32-WROOM-32** microcontroller due to its robust processing capabilities and built-in UART, Wi-Fi, and GPIO peripherals. ESP32 supports seamless communication with the onboard **Raspberry Pi**, which serves as the drone’s mission controller. Its ability to handle multiple GPIO lines and serial communication made it an ideal choice for directly controlling switch ICs and receiving battery configuration commands.

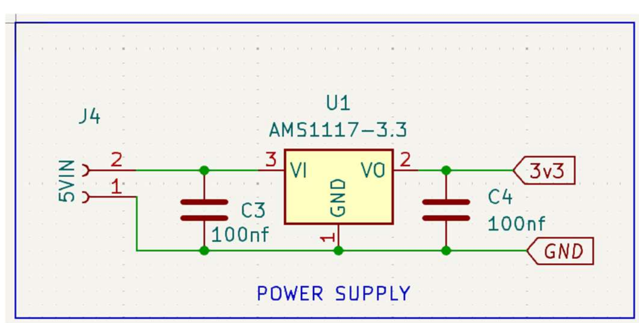
a. Microcontroller Section – ESP32-WROOM-32

The ESP32-WROOM-32 module acts as the brain of the switching system. It processes UART commands received from the drone's Raspberry Pi and activates the necessary switch combinations using its GPIO pins.



- Operates at 3.3V regulated voltage.
- Uses GPIOs to control 12 individual switches via the CD4066 ICs.
- UART TX/RX connected to both USB-to-serial circuit and an external header for communication with Raspberry Pi.
- Optional debug LEDs are connected to GPIOs for visual confirmation of selected mode.

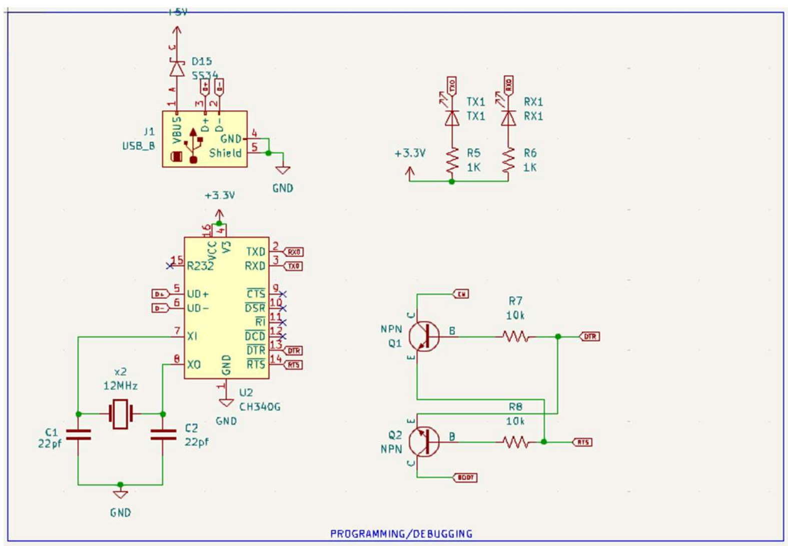
b. Power Supply Section



The module is powered by the drone's Li-Po battery (typically 12V to 24V), stepped down using linear regulators:

- **AMS1117-3.3**: Converts 5V to 3.3V for logic-level operation.
- Capacitors placed at input/output for voltage stability.
- Proper grounding and filtering ensure minimal electrical noise.

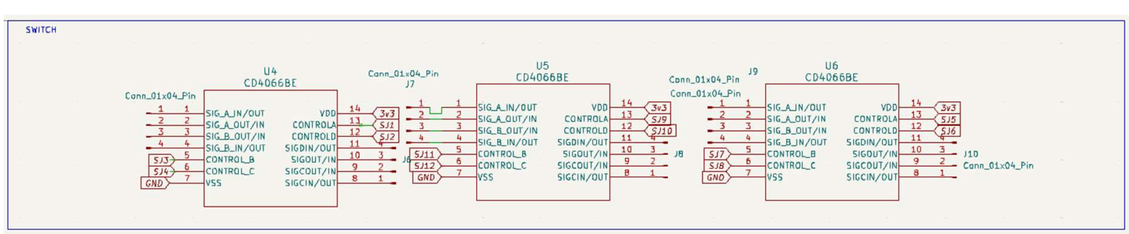
c. USB to UART Programming Circuit – CH340G



To support easy programming and debugging:

- **CH340G** handles USB-to-serial conversion.
- Connected to ESP32's UART0 pins.
- **12 MHz crystal oscillator** used for USB timing.
- Programming mode controlled using NPN transistors connected to EN and IO pins.
- USB-B connector allows easy access for firmware upload.

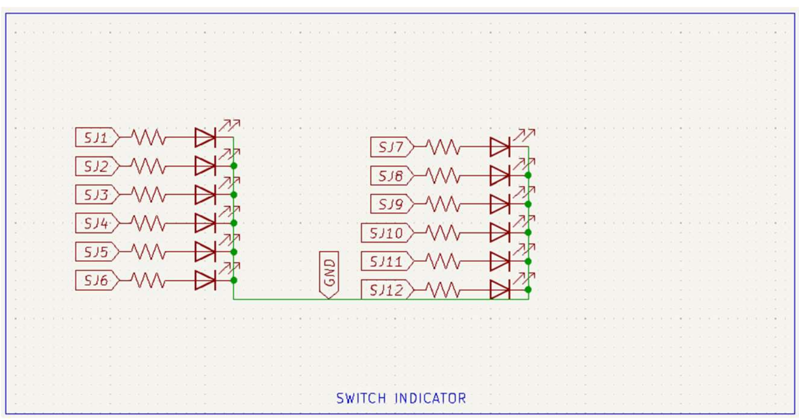
d. Switching Logic – CD4066BE Analog Switch ICs

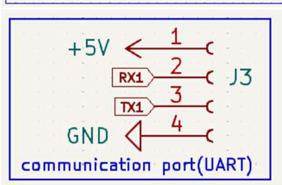


The switching matrix is the core of this design. It replaces the BMS772's fixed jumpers with software-controlled switches.

- 3x **CD4066BE** ICs used, each containing 4 bilateral SPST analog switches.
- Signal lines are routed through these switches to the tap pins of the BMS.
- ESP32 controls the ON/OFF state of each switch via GPIO.
- Combinations of switch activations define different configurations (3S, 4S, 5S, or 6S).

e. Indicators and Connectors





- LEDs connected to selected GPIOs for configuration indication.
- BMS tap connections provided via 2.54 mm headers.
- Separate UART header for Pi integration.
- Mounting holes included for drone chassis attachment.

4. PCB Design and Layout in KiCad

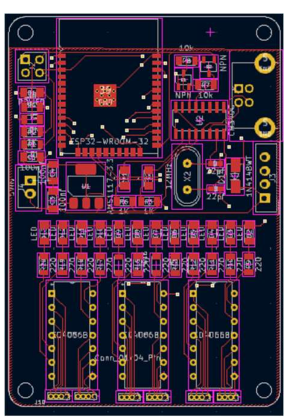
The complete schematic was captured and converted into a 2-layer PCB using **KiCad**. Emphasis was placed on clean signal routing, minimal noise, proper power decoupling, and compact board layout suitable for drone integration.

Key Design Highlights:

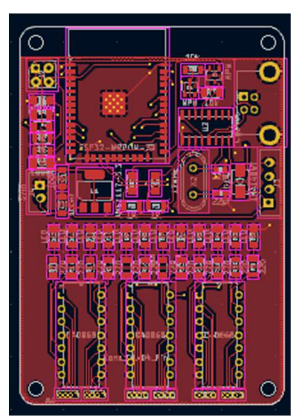
- **Form Factor**: Compact rectangular board with mounting holes for drone enclosure integration.
- **Microcontroller Zone**: The ESP32-WROOM-32 is centrally placed with minimal trace lengths to switching and UART sections.
- **Switching Section**: All three CD4066BE ICs are aligned side by side in the lower half of the board for balanced signal routing and ease of debugging.
- **Power Section**: AMS1117 regulators and associated capacitors are positioned near the power input to reduce voltage drop and ripple.
- **USB Programming Interface**: A USB-B port connects directly to the CH340G and crystal oscillator block, placed along the top edge for easy access.
- **Indicator LEDs**: Positioned above the switching ICs for direct mapping to the active switch channels.
- **Connectors**: All UART, power, and BMS tap headers are aligned along the board edges for modular wiring and stackability.

Top Layer Design:

- Hosts all **active components** such as ESP32, CD4066 ICs, AMS1117 regulators, and CH340G USB interface.
- **Signal traces** are routed with minimal crossover to ensure noise-free switching logic.
- Fine-pitch **GPIO routing** from ESP32 to switch control pins, with clearly marked silkscreen.
- All components are placed to optimize trace lengths and minimize interference from power sections.
- **Decoupling capacitors** placed close to IC power pins to suppress voltage ripple.
- e



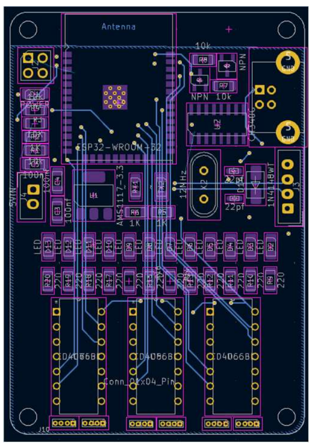
Front layer routing

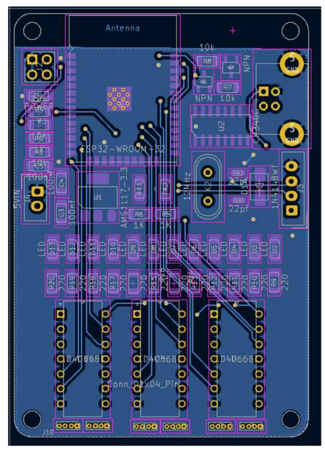


Front layer copper zone

Bottom Layer Design (Ground Plane & Power Routing):

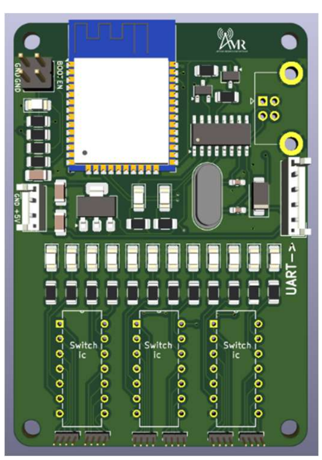
- A **continuous ground fill zone** is implemented to reduce EMI and maintain signal return paths.
- Power tracks from regulators are routed along the shortest possible path to their loads.
- **Via stitching** used between top and bottom layers for thermal and electrical integrity.
- GND zones under analog switches shield sensitive traces and provide low-impedance return paths.



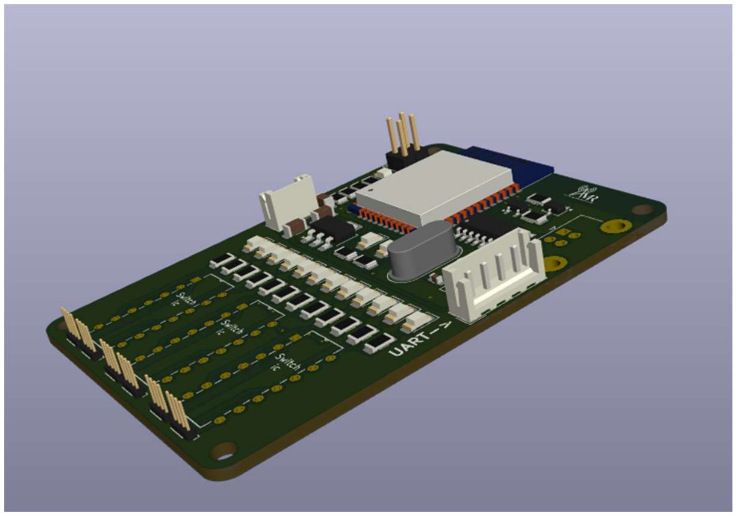


3D Model and Physical View:

- The **3D render** confirms proper alignment of the USB port, headers, and mounting holes.
- Connector orientation is verified for direct plug-in to the drone's battery tap lines and Pi UART pins.
- All tall components (USB port, ESP32 module) fit within enclosure height limits.



- Silkscreen elements such as **AMR Lab logo, IIT Ropar branding, and GPIO labels** are cleanly laid out



3D view

5. Assembly and Testing

Once the PCB was fabricated, the module was assembled using standard through-hole and SMD soldering techniques. Proper electrostatic precautions were taken during component handling to protect the ESP32 and CD4066 ICs.

Assembly Steps:

- All SMD components including AMS1117 regulators, capacitors, and CH340G IC were soldered first.
- The ESP32 module and CD4066 ICs were placed and soldered with fine-point tip for accuracy.
- Headers for BMS taps, UART, and USB were installed and aligned for external interfacing.
- Visual inspection and multimeter continuity tests were conducted post-soldering.

Firmware Upload:

- The ESP32 firmware was written in the Arduino IDE using HardwareSerial and GPIO control libraries.

- The USB-B port and onboard CH340G circuit allowed easy programming from a laptop.
- Boot mode was triggered using onboard EN and IO0 transistor toggling logic.

Functional Testing:

- The Raspberry Pi was connected via UART and sent 3s/4s/5s/6s commands.
- GPIO outputs were monitored via oscilloscope and LEDs to confirm accurate switching.
- The CD4066 switches routed the battery tap lines correctly to emulate the required BMS configurations.
- Voltage at BMS headers was verified to ensure proper routing and no short circuits.

Test Scenarios:

- 3S to 6S configurations were cycled repeatedly with successful switching.
- Load testing with dummy cells was done to simulate real balancing conditions.
- Fail-safes were validated by sending invalid or missing commands.

The successful assembly and testing of this module confirms the viability of a fully digital, real-time switchable BMS configuration system for drones using the NXP RDDRONE-BMS772 platform.