VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belagavi – 590018

A Project Work

on

"AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER"

Submitted in partial fulfilment of the requirement for the award of the degree

BACHELOR OF ENGINEERING

in

ELECTRONICS & COMMUNICATION ENGINEERING

by

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2025 – 2026

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CERTIFICATE

*This is to certify that the **Project*** entitled **"AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER"** *has been successfully carried out by **Varsha K G** bearing **USN 1ST22EC082, Vedha D** bearing **USN 1ST22EC084, Vishalakshi N** bearing **USN 1ST22EC089, Arthi S** bearing **USN 1ST23EC400,** in partial fulfilment of the requirement for the award of the degree **BACHELOR OF ENGINEERING** in **ELECTRONICS & COMMUNICATION ENGINEERING** by **VISVESVARAYA TECHNOLOGICAL UNIVERSITY** during the academic year 2025-2026*

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DECLARATION

We, the students of 7th semester ECE, doing the Final Year Project, hereby declare that,

1. The hardware/software used in this project is not purchased from any external organization.
2. The hardware/software is not taken from any other previous final-year engineering projects.
3. Our project work adheres to **VTU norms**, and we have followed all rules and regulations.

In the event of violating any of the above conditions, we accept any action taken by the Department/College/VTU in this regard.

The Title of the Project is **"AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER "**.

The Project work is guided by **Asst**. **Prof. George Armstrong**.

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ABSTRACT

Fire-related emergencies are among the most hazardous and unpredictable situations faced in industrial, domestic, and natural environments. The increasing complexity of infrastructure, urban growth, and industrial activity has significantly amplified the frequency and severity of fire incidents. Traditional firefighting techniques heavily depend on the involvement of trained personnel who must physically operate in dangerous zones filled with extreme temperatures, dense smoke, and limited visibility. These factors not only delay response actions but also expose human firefighters to severe risks, often making timely intervention difficult and sometimes impossible. With the rapid advancement of robotics, intelligent sensing, and automation technologies, there is an increasing need to integrate these solutions into modern emergency response systems to enhance safety, efficiency, and operational reliability.

The proposed system, AetherResQ, is an AI-driven autonomous firefighting and rescue drone developed to support emergency response operations by providing real-time fire detection, surveillance, and targeted suppression. The drone integrates a Pixhawk flight controller for stable autonomous navigation, Arduino-based flame and PIR sensor modules for intelligent hazard identification, and MAVLink-based telemetry for continuous communication with the Ground Control Station. Upon detecting a fire event, the system activates its onboard extinguishing mechanism and performs suppression while maintaining flight stability. In addition, the drone is equipped to detect human presence in low-visibility environments and provide visual situational updates through live video feed, thereby assisting rescue teams in making faster and more informed decisions. The autonomous flight capabilities and real-time monitoring functions ensure that the drone can operate effectively in areas where human access is restricted or unsafe.

The development of AetherResQ demonstrates the potential of integrating artificial intelligence, unmanned aerial vehicles, and automated control systems in firefighting applications. The system significantly reduces the risk to human firefighters, improves response time, and enhances situational awareness in emergency conditions. With further refinement and scaling, the technology can contribute to modernizing firefighting operations across residential, industrial, and forest environments. The project highlights the importance of automated aerial systems as an emerging solution for future disaster management infrastructures, opening the pathway for smarter, safer, and more effective emergency response strategies.

ACKNOWLEDGEMENT

The successful completion of any task would be incomplete without the mention of the people who made it possible. Their constant guidance and encouragement crowned our efforts with success. We take this opportunity to express our deepest gratitude and appreciation to all those who helped us directly or indirectly towards the successful completion of our project work.

We would like to profoundly thank the **Management of Sambhram Institute of Technology** for providing such a healthy environment for the successful completion of our project work.

I would like to express my heartfelt thanks to **Dr. H. G. Chandrakanth**, Principal, Sambhram Institute of Technology, for his encouragement for the successful completion of the Project Work.

I would like to express my profound gratitude to **Dr**. **M. N. Eshwarappa**, HOD, Department of Electronics and Communication, Sambhram Institute of Technology, for his constant support and encouragement.

We would like to express our deepest and sincere gratitude to our Project Guide **Asst**. **Prof. George Armstrong**, Assistant Professor, Department of Electronics and Communication, for his constant support and guidance, which inspired us to explore various aspects in detail and led to the successful completion of this Project and Report

We would like to express our deepest and Sincere gratitude to our Project Coordinator **Asst. Prof. Khamer Unnisa H,** Assistant Professor, Department of Electronics and Communication for her constant support and guidance which inspired us to explore the avenues in detail and outcome of this excellent work

Lastly, we extend our heartfelt gratitude to our parents and friends, who have been a source of inspiration and instrumental in the successful completion of our project work.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

Fire disasters remain one of the most unpredictable and life-threatening emergencies across industrial areas, residential buildings, forests, and high-density urban zones. These incidents demand rapid response, accurate situational awareness, and safe operational methods. However, traditional firefighting techniques rely heavily on manual intervention, exposing firefighters to hazardous environments characterized by extreme temperatures, thick smoke, toxic gases, and collapsing structures. Such conditions significantly increase the risk to human life and often limit the efficiency, precision, and speed of rescue operations. With the continuous rise in fire accidents and the growing need for safer technological alternatives, modern engineering has shifted toward intelligent systems capable of supporting human responders while minimizing risk.

The rapid advancement of artificial intelligence (AI), robotics, sensor technology, unmanned aerial vehicles (UAVs), and autonomous navigation systems has opened new possibilities in emergency response applications. AI-enabled drones are capable of performing high-risk tasks that would otherwise endanger human lives. These drones can navigate through dangerous zones, detect fire sources, identify trapped individuals, map affected areas, and provide real-time aerial surveillance. Autonomous drones equipped with fire suppression mechanisms have the potential to reduce response time, enhance operational accuracy, and act effectively in environments where ground-based teams struggle to reach.

The proposed project, AetherResQ, aims to bridge the gap between conventional firefighting systems and intelligent autonomous technology. AetherResQ is an AI-driven firefighting and rescue drone designed to autonomously detect fire, locate human presence, and initiate fire extinguishing actions using an onboard suppression mechanism. The system incorporates a Pixhawk flight controller for stable and reliable UAV operation, integrated with Arduino-based sensing modules that process information from flame and PIR sensors. The drone uses MAVLink telemetry and Mission Planner or QGroundControl software for real-time data visualization, mission planning, and autonomous flight execution. Equipped with onboard cameras and sensors, the drone offers continuous monitoring of dangerous environments, allowing rescue teams to make informed decisions based on live data.

The drone is capable of autonomously navigating to the affected zone, maintaining stability during flight, and activating the fire extinguishing unit when the sensors detect critical fire intensity. Additionally, the system can identify human motion using PIR sensors and assist in rescue activities through a lightweight rescue harness capable of delivering essential supplies or guiding responders toward trapped victims. By integrating smart detection, autonomous decision-making, and aerial maneuverability, AetherResQ significantly reduces human exposure to hazardous environments and enhances the overall efficiency of emergency response operations.

This project addresses the critical limitations of existing systems, which often lack automation, advanced sensing capabilities, and autonomous suppression mechanisms. Conventional drones used in firefighting are mainly limited to surveillance and require continuous manual control, thereby restricting their usefulness in high-risk scenarios. The AetherResQ system overcomes these limitations by enabling autonomous behavior, rapid hazard identification, and smart action triggering through integrated sensors and control logic.

The proposed work further highlights the importance of combining AI, robotics, and UAV technology for developing an intelligent firefighting platform capable of responding quickly and accurately to real-world emergencies. Through automated fire detection, real-time monitoring, autonomous navigation, and onboard extinguishing capabilities, the system aims to provide a reliable and efficient alternative to manual firefighting techniques. The project ultimately contributes to the development of advanced drone-based emergency solutions, ensuring safety, precision, and effectiveness during disaster management operations.

1.1 ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) plays a pivotal role in modern autonomous systems, particularly in applications where rapid interpretation of environmental data and adaptive decision-making are essential. In firefighting scenarios, AI enables machines to behave intelligently, analyze incoming sensory information, and respond dynamically to rapidly changing hazards. Unlike conventional automated systems that rely purely on predefined rules, AI-driven platforms can learn patterns, identify abnormalities, and make operational decisions based on real-time conditions. Machine learning, computer vision, and pattern recognition techniques allow drones to detect fire intensity, discriminate between thermal variations, and identify human presence even in environments with dense smoke or reduced visibility. AI also improves fault tolerance by enabling predictive adjustments to flight stability and hazard response based on sensor fusion. With the integration of machine learning algorithms, the drone can optimize its detection accuracy over time, minimizing false triggers and improving mission reliability. Furthermore, AI-driven navigation assists the drone in autonomously determining the safest and most efficient route to approach the affected area while simultaneously avoiding obstacles. These capabilities allow the system to function effectively without continuous human intervention, making AI a crucial enabling technology for autonomous firefighting operations. As AI models evolve with increased data and computational capabilities, such systems will further enhance their autonomous decision-making, predictive fire spread analysis, and multi-agent collaboration, making them highly relevant for future large-scale disaster management frameworks.

Fig 1.1: Overview Of AI

1.2 AUTOMATION

Automation plays a crucial role in enhancing the efficiency and safety of firefighting missions, especially in environments that are too dangerous for human entry. Through automation, the drone is capable of performing tasks such as takeoff, navigation, hazard detection, and fire extinguishing without requiring constant manual control. This reduces the burden on operators and enables the system to act quickly during emergencies. Automated algorithms within the Pixhawk flight controller allow the vehicle to maintain stability, adjust altitude, and follow predefined mission routes with high precision. In addition, automated decision-making ensures that sensor-based triggers activate the firefighting mechanisms at the right moment, preventing the situation from escalating further. The presence of automated return-to-launch, mission planning, and telemetry monitoring further enhances the drone’s reliability and allows it to function seamlessly even in complex disaster scenarios. By minimizing human involvement in hazardous zones, automation ensures safer, faster, and more consistent emergency response.

1.3 ROBOTICS

Robotics and unmanned aerial vehicle (UAV) technology together form the backbone of modern aerial firefighting systems. UAVs provide exceptional maneuverability, rapid deployment capability, and access to locations that are inaccessible or unsafe for human firefighters. The integration of robotics with UAV platforms such as AetherResQ enables the drone to execute precise and stable flight operations under challenging environmental conditions. With components like brushless motors, ESCs, GPS modules, and IMU sensors, the drone achieves optimal performance, stability, and control. The Pixhawk flight controller ensures smooth flight dynamics, while its compatibility with MAVLink communication allows real-time transmission of flight data and sensor outputs. Robotics enhances the ability of the drone to interact with its surroundings, operate extinguishing devices, and support rescue mechanisms. This combination of robotics and UAV technology enables efficient fire suppression, improved surveillance, and enhanced situational awareness, making it a valuable tool in emergency management.

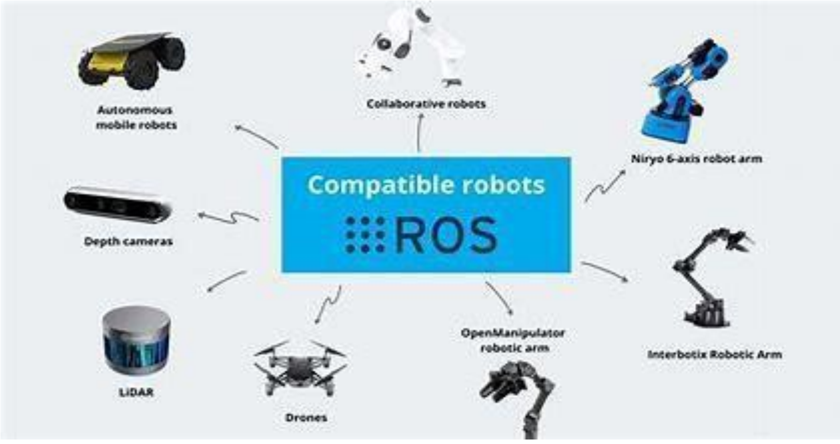

Fig 1.2: Overview of Robotics

1.4 PROBLEM STATEMENT

- **High Risk to Human Firefighters**: Firefighters are required to enter hazardous environments with extreme temperatures, toxic smoke, limited visibility, and structural instability, posing serious danger to life.
- **Delayed Response Time**: Locating the exact fire source or trapped victims often takes time, which reduces the effectiveness of rescue and suppression efforts during the critical early stages of a fire.
- **Limited Accessibility**: Many fire emergency zones, such as high-rise structures, collapsed buildings, industrial spaces, and dense forest areas, are difficult or impossible for manual teams to access safely.
- **Lack of Real-Time Situational Awareness**: Traditional methods rely on manual scouting and visual assessment, resulting in limited real-time information for emergency decision-making.
- **Dependence on Manual Control Systems**: Current firefighting drones used primarily for surveillance require skilled operators and do not support autonomous hazard detection or response actions.
- **Absence of Integrated Fire Suppression and Rescue Features**: Existing systems generally provide only monitoring capabilities and lack self-triggering extinguishing mechanisms or victim-detection features.

1.5 EXISTING SYSTEM

Current firefighting systems primarily depend on manual operations carried out by trained personnel using conventional fire extinguishing equipment and limited aerial support. While some drones are used for surveillance or visual inspection, they lack the ability to autonomously detect fire or execute extinguishing actions. Existing drone platforms are mostly remote-controlled and depend solely on the operator’s skills for navigation and monitoring. They do not integrate advanced sensing modules such as flame and PIR sensors, nor do they incorporate intelligent decision-making mechanisms required for autonomous functioning. Furthermore, most existing systems do not offer onboard firefighting capabilities or rescue assistance modules, limiting their effectiveness in critical situations. The absence of automation and sensor fusion results in slow detection, delayed response, and reduced operational safety. These limitations emphasize the need for a more advanced and intelligent system such as AetherResQ, which combines detection, suppression, surveillance, and rescue functionalities in a single autonomous platform.

1.6 PROPOSED SYSTEM

The proposed system introduces an autonomous firefighting and rescue drone equipped with intelligent detection, navigation, and response capabilities. The system is designed to overcome the limitations of traditional firefighting methods and existing drone-based solutions. The key features of the proposed system are as follows:

- AI-Enabled Fire Detection: The system utilizes flame sensors to detect real-time fire presence and intensity, enabling accurate identification of hazardous zones.

- Human Detection Capability: A PIR sensor is incorporated to detect human motion, assisting in locating trapped victims in low-visibility environments such as smoke-filled or structurally damaged areas.

- Autonomous Navigation: A Pixhawk flight controller is used to achieve stable autonomous flight with predefined mission paths, waypoint navigation, and automatic terrain handling.

- Onboard Extinguishing Mechanism: The drone includes a compact fire extinguisher unit that can be activated either automatically based on sensor feedback or manually from the Ground Control Station.

- Real-Time Surveillance and Telemetry: Live camera streaming and telemetry data transmission enable continuous monitoring of the affected area through GCS platforms such as Mission Planner or QGround Control.

- Sensor Fusion and Decision Control: Arduino-based processing integrates multiple sensor readings and triggers appropriate actions based on environmental conditions and hazard levels.

- Return-to-Launch (RTL) Safety Feature: The system is capable of automatically returning to its launch point when the mission is complete, battery is low, or communication is lost.

- Rescue Assistance Support: A lightweight emergency delivery or rescue mechanism assists in providing basic supplies or indicating victim locations for rescuers.

1.7 ORGANIZATION OF THE REPORT

The report is organized into seven chapters as outlined below:

CHAPTER 1 – INTRODUCTION:

This chapter presents an overview of the project, including the problem definition, motivation, existing system limitations, proposed system approach, scope of the work, and overall need for the project.

CHAPTER 2 – LITERATURE SURVEY:

This chapter provides a detailed study of existing research, past works, related technologies, and the analysis of methods used in similar systems. It highlights the research gap and justification for the proposed work.

CHAPTER 3 – METHODOLOGY:

This chapter explains the system design, workflow, and methodology adopted during the development phase. It describes how the proposed solution operates from detection to response.

CHAPTER 4 – HARDWARE AND SOFTWARE DESCRIPTION:

This chapter discusses the components used in the system, including sensors, controllers, communication modules, interfacing devices, and software tools required for implementation.

CHAPTER 5 – RESULTS AND DISCUSSION:

This chapter presents the implemented outcomes, testing observations, performance evaluation, and system verification based on real-time or simulated results.

CHAPTER 6 – ADVANTAGES, LIMITATIONS, AND APPLICATIONS:

This chapter outlines the benefits and constraints of the proposed system and describes the areas where such a system can be practically deployed.

CHAPTER 7 – CONCLUSION AND FUTURE SCOPE:

This chapter concludes the project work and summarizes the key contributions. It also discusses possible improvements and enhancements that can be implemented in future versions.

CHAPTER 2

LITERATURE SURVEY

[1] Hasan et al. present an IoT-centric architecture for fire monitoring and preliminary response. The study's motivation is the need for early detection and remote situational awareness in hazardous firefighting scenarios. Methodologically, the authors integrate temperature sensors, gas/heat detectors, and wireless IoT modules on a lightweight UAV platform. The system streams sensor telemetry and basic imagery to a cloud/GCS application, enabling remote alerts and operator-guided interventions. A major strength of their approach is low-cost, wide-area coverage for early detection and continuous monitoring; experiments show reliable detection of thermal anomalies and stable telemetry under moderate operational ranges. The paper also outlines the communication stack and some data-aggregation approaches that reduce false alarms through simple thresholding and temporal filtering. Limitations include minimal onboard autonomy, no onboard suppression mechanism, and limited onboard compute for advanced vision-based victim detection. The platform is oriented toward sensing and alerting rather than autonomous extinguishment or rescue. For AetherResQ, Hasan et al. provide an important baseline: AetherResQ builds on their IoT telemetry and remote-monitoring concepts but extends the system by adding true autonomy (Pixhawk-based mission execution), MAVLink mission automation, fused flame+PIR detection, a physical 3 kg extinguishing payload, and an integrated rescue harness. In short, Hasan et al. supply the remote-sensing backbone that AetherResQ upgrades with active response and rescue capability.

[2] Designing a quadcopter for fire and temperature detection with an infrared camera and PIR sensor. camera (or thermal module), PIR motion detector, a microcontroller for sensor fusion, and a lightweight flight platform. Algorithms are mostly threshold and rule-based: thermal hotspots above tuned temperature thresholds are flagged as possible fire sources, and PIR triggers are cross-checked to differentiate moving human signatures from static heat sources. The study reports improved detection accuracy by combining thermal imaging's spatial temperature profile with PIR's motion sensitivity—particularly useful in cluttered indoor environments where false positives are common. Experimental results demonstrate good short-range detection and reduced false alarm rates relative to single-sensor setups. Limitations include dependence on sensor calibration, limited range

of cheaper IR modules, and absence of an active suppression mechanism or heavy payload capability. For AetherResQ, this paper is directly relevant: it validates the sensor fusion approach (IR + PIR) that AetherResQ uses conceptually. However, AetherResQ expands beyond this study by integrating Pixhawk for autonomous navigation, MAVLink telemetry, heavier payload management (3 kg extinguisher), and a rescue harness subsystem—turning detection capability into anactionable firefighting and rescue pipeline.

[3] Autonomous fire fighting drone for fire detection and suppression, describe a prototype autonomous UAV platform that couples detection with suppression. Their work is motivated by the need to respond to fires faster than human crews can arrive, especially in constrained or hazardous areas. Architecturally, the system integrates thermal and optical sensors for fire localization, onboard flight autonomy for waypoint navigation and target hovering, and a suppression actuator—often a dedicated pump and nozzle or a payload-release mechanism. Control algorithms include mission planning, vision/thermal-based target locking, and closed-loop position control for accurate spraying or payload deployment. Experimental demonstrations show the drone can autonomously approach simulated hotspots and deploy a suppression agent with measurable reduction in flame intensity or spread. Key contributions include the integration workflow between sensing, target acquisition, and actuation, and practical considerations for nozzle control, droplet dispersal, and hover stability during actuation. The principal limitations noted are payload capacity versus flight endurance trade-offs, limited suppression agent volume per sortie, and environmental challenges (wind, heavy smoke) that degrade both vision and aerodynamic stability. AetherResQ complements and extends this work: while Alahakoon et al. focus on autonomous suppression, AetherResQ targets an integrated dual-use role—suppression plus human/animal rescue—by adding a robust rescue harness, Pixhawk-guided autonomous rescue missions, MAVLink telemetry for GCS coordination, and a balanced payload plan (1–3 kg extinguisher with rescue hardware) to maintain autonomy and endurance.

[4] Intelligent real-time fire detection system using thermal infrared camera on UAVs, investigates real-time fire detection using thermal infrared sensors mounted on UAVs and couples detection with intelligent onboard processing. The authors emphasize algorithmic techniques for differentiating real flames from heat sources and reflections, leveraging thermal temporal patterns, motion consistency, and spatial morphology analysis. They employ onboard thermal imaging combined with light-weight computer vision processing—

often simplified convolutional filters or handcrafted feature detectors—to achieve near real-time classification. Their evaluation comprises detection under varying conditions (day/night, wind, smoke) and compares detection accuracy with RGB-only systems. Results confirm thermal cameras' superiority in smoke-filled or low-visibility environments, with lower false positives and robust hotspot localization. Implementation challenges include thermal camera resolution limits, onboard compute constraints, and energy cost for continuous thermal processing. For AetherResQ, this paper's findings are foundational: AetherResQ adopts thermal-based detection where necessary but augments it with flame sensor redundancy and PIR detection to further reduce false negatives/positives. Additionally, AetherResQ integrates Pixhawk mission logic and MAVLink telemetry to act autonomously on thermal detections—triggering approach, extinctions, or rescue sequences—addressing the deployment and action gap in purely detection-focused work.

[5] PIXHAWK: A system for autonomous flight using onboard computer vision present Pixhawk, an influential open-source flight controller architecture combining reliable IMU-based stabilization with the capacity for autonomous mission execution and onboard computer vision integration. The paper lays out the hardware design, real-time control loops, sensor integration methods (GPS, IMU, barometer), and software stacks that enable waypoint navigation, failsafe behaviors, and plug-and-play extensibility for custom sensors and actuators. Their experiments demonstrate stable autonomous flight and vision-based tasks like visual odometry and object following. A major contribution is the modular software/hardware interface that allows researchers to rapidly integrate application-specific algorithms (e.g., CV for search tasks) without redoing low-level control. Limitations relevant to emergency-response applications include the need for additional high-level decision logic and payload interfaces for heavy actuators. For AetherResQ, the Pixhawk foundation is critical: AetherResQ uses Pixhawk for low-level flight control and mission management, while layering specialized modules (Arduino-based sensor logic, fire-extinguisher actuation, rescue-harness deployment) and MAVLink-based GCS interaction. The Meier et al. work thus supplies the stable autopilot core that AetherResQ leverages and extends for firefighting-rescue missions.

[6] Micro Air Vehicle Link (MAVLink) in a nutshell: A survey," IEEE Access, vol. 7, pp. deliver a systematic survey of MAVLink, the lightweight, efficient communication protocol widely adopted for UAV telemetry, control, and mission scripting. The survey analyzes MAVLink message formats, version differences, security considerations, and common deployment patterns between flight controllers (e.g., Pixhawk) and ground control stations (e.g., QGroundControl, Mission Planner). The authors highlight MAVLink's strengths—

compact messages, extensibility, and broad ecosystem support—and also discuss pitfalls like telemetry bandwidth limits, message ordering under unreliable links, and the lack of built-in strong security by default. The paper includes practical guidance for mission developers: message choice trade-offs for telemetry richness versus bandwidth, heartbeat/keepalive patterns, and interfacing custom payload controllers via companion computers or auxiliary serial links. For AetherResQ, MAVLink is integral: the project uses MAVLink for live telemetry of flame/PIR events, autonomous mission uploads, remote override, and rescue-command issuance. Koubâa et al.'s survey informs design choices—message selection for prioritized sensor alerts, fallback behaviors under link loss, and companion-computer interfaces to combine Arduino sensor logic with Pixhawk mission control—ensuring robust ground-station integration for mission-critical firefighting and rescue operations.

[7] Design of a multi-sensor fusion system for forest fire detection using visible and IR imagery, present a multi-sensor fusion architecture tailored to forestry applications, combining visible-spectrum and infrared imagery to enhance fire detection accuracy across varying environmental contexts. Their method uses complementary sensors: visible imagery provides spatial and textural cues, while IR supplies robust heat signatures under smoke or low-light. Fusion is performed at the feature-level using complementary descriptors and at decision-level by weighted voting or Bayesian fusion to combine classifier confidences. The paper demonstrates improved detection rates in early-stage fires and reduced false alarms compared to single-modality systems; it also discusses sensor alignment/calibration and computational cost trade-offs. Limitations include heavier payload and processing requirements, and the need for precise calibration for heterogeneous sensors. For AetherResQ, the core idea of multi-sensor fusion is adopted but adapted: rather than heavy multi-camera rigs, AetherResQ fuses simpler yet highly complementary sensors—flame sensors, PIR, thermal/IR where available, and RGB video—then combines sensor outputs through a rule-based and AI-assisted decision layer. The goal is to preserve detection reliability while keeping weight and power budget compatible with rescue and extinguisher payloads.

[8] An efficient approach with dynamic multiswarm UAVs for forest firefighting present a mechanically innovative UAV capable of deploying fire-extinguishing balls—spherical containers that burst on impact to release suppressant. Their work focuses on mechanical design (thrower mechanism), release timing, and precision targeting from altitude. The platform leverages relatively small drones for targeted suppression of localized fires (e.g., small urban fires or electrical fires). Experimental evaluation shows reliable release mechanics and effective suppression for small flames. Advantages include a light-weight suppression mechanism and simplicity of deployment. Drawbacks include limited

applicability to large-scale fires, requirement of accurate targeting, and possible collateral risk from dropping objects in populated areas. For AetherResQ, the ball-deployer concept suggests alternative suppression modalities; however, AetherResQ prioritizes a controllable onboard extinguisher nozzle and precision spray to actively fight fires while maintaining capability to perform rescues. The ball-thrower literature is still valuable as a low-cost suppression idea and for scenarios where dropping payloads is preferable to spraying (e.g., inaccessible vertical shafts).

[9] Design and implementation of fire extinguishing ball thrower quadcopter present a mechanically innovative UAV capable of deploying fire-extinguishing balls—spherical containers that burst on impact to release suppressant. Their work focuses on mechanical design (thrower mechanism), release timing, and precision targeting from altitude. The platform leverages relatively small drones for targeted suppression of localized fires (e.g., small urban fires or electrical fires). Experimental evaluation shows reliable release mechanics and effective suppression for small flames. Advantages include a light-weight suppression mechanism and simplicity of deployment. Drawbacks include limited applicability to large-scale fires, requirement of accurate targeting, and possible collateral risk from dropping objects in populated areas. For AetherResQ, the ball-deployer concept suggests alternative suppression modalities; however, AetherResQ prioritizes a controllable onboard extinguisher nozzle and precision spray to actively fight fires while maintaining capability to perform rescues. The ball-thrower literature is still valuable as a low-cost suppression idea and for scenarios where dropping payloads is preferable to spraying (e.g., inaccessible vertical shafts).

[10] Mechanical design and analysis of payload drop system for fire-extinguishing balls analyze the mechanical and structural design considerations for UAV payload-drop mechanisms intended for extinguishing agents—similar to ball-drop systems. Their work models stresses, release dynamics, and aerodynamic effects during deployment to ensure safety and accuracy. The study uses finite-element analysis for payload carriers, tests for release reliability under vibrations and acceleration, and evaluates trajectory prediction models to improve targeting. Key findings emphasize the need for robust locking/release actuators, proper center-of-mass considerations to avoid mid-flight instability, and reliable release timing under variable environmental conditions. Limitations include the inherent one-shot nature of drop systems and constraints on the amount of extinguishing agent deliverable per mission. For AetherResQ, such mechanical-design insights are useful in designing any payload-release subsystem (e.g., rescue harness release mechanisms or emergency payload drops). However, AetherResQ’s emphasis is on an actively controlled extinguisher and a

reusable rescue harness rather than one-time drop payloads, so the paper's mechanical robustness lessons can be adapted to improve the safety and reliability of AetherResQ's deployment/release hardware.

[11] IoT-enabled smart fire suppression drone for enhanced efficiency, describe a system where drones are integrated into broader IoT ecosystems for coordinated fire suppression at scale. The platform focuses on persistent telemetry, cloud-based analytics, and orchestration—drones communicate status and sensor feeds to central servers that optimize sortie scheduling, resource allocation, and multi-drone tasking. The authors show improvements in response times through predictive analytics and networked coordination. They also discuss practical deployment issues: bandwidth constraints for high-resolution video, latency-sensitive control loops, and security concerns for command-and-control links. The main limitation is operational reliance on infrastructure—reduced performance in network-degraded or denied settings. For AetherResQ, Yao et al. reinforce the benefits of connecting drones into IoT frameworks; AetherResQ leverages similar telemetry concepts but keeps autonomy local (Pixhawk + onboard decision logic) so it can operate under intermittent connectivity—while still supporting cloud/GCS functions when a link is available. AetherResQ thus balances IoT-coordination benefits with mission-critical offline autonomy.

[12] IoT-based autonomous search and rescue drone for precision firefighting resent an IoT-backed UAV designed for autonomous search-and-rescue with firefighting adjuncts. The paper integrates victim tracking algorithms, autonomous navigation in GPS-challenged environments, and sensor suites for environmental assessment. Their contributions include a hierarchical autonomy model (mission planning at GCS, local reactive behaviors onboard), predictive victim-location models using thermal and motion cues, and tested rescue-gadget prototypes for light payload delivery (e.g., emergency kits). Performance evaluations highlight robust victim detection and successful autonomous sorties in controlled tests. Key limitations are the modest payload lifting capability and the challenge of coupling rescue hardware with suppression hardware in a weight-constrained package. For AetherResQ, Al-Zubaidi et al. provide a close resonance: both projects target search-rescue integration with firefighting. AetherResQ differentiates itself by committing to a heavier active-extinguishing payload (3 kg class) and an actual lifting-capable rescue harness, plus explicit Pixhawk–Arduino integration for smooth actuation and mission control—making AetherResQ a platform designed for both suppression and extraction where Al-Zubaidi focuses more on detection and lightweight aid delivery.

CHAPTER 3

METHODOLOGY

3.1 BLOCK DIAGRAM

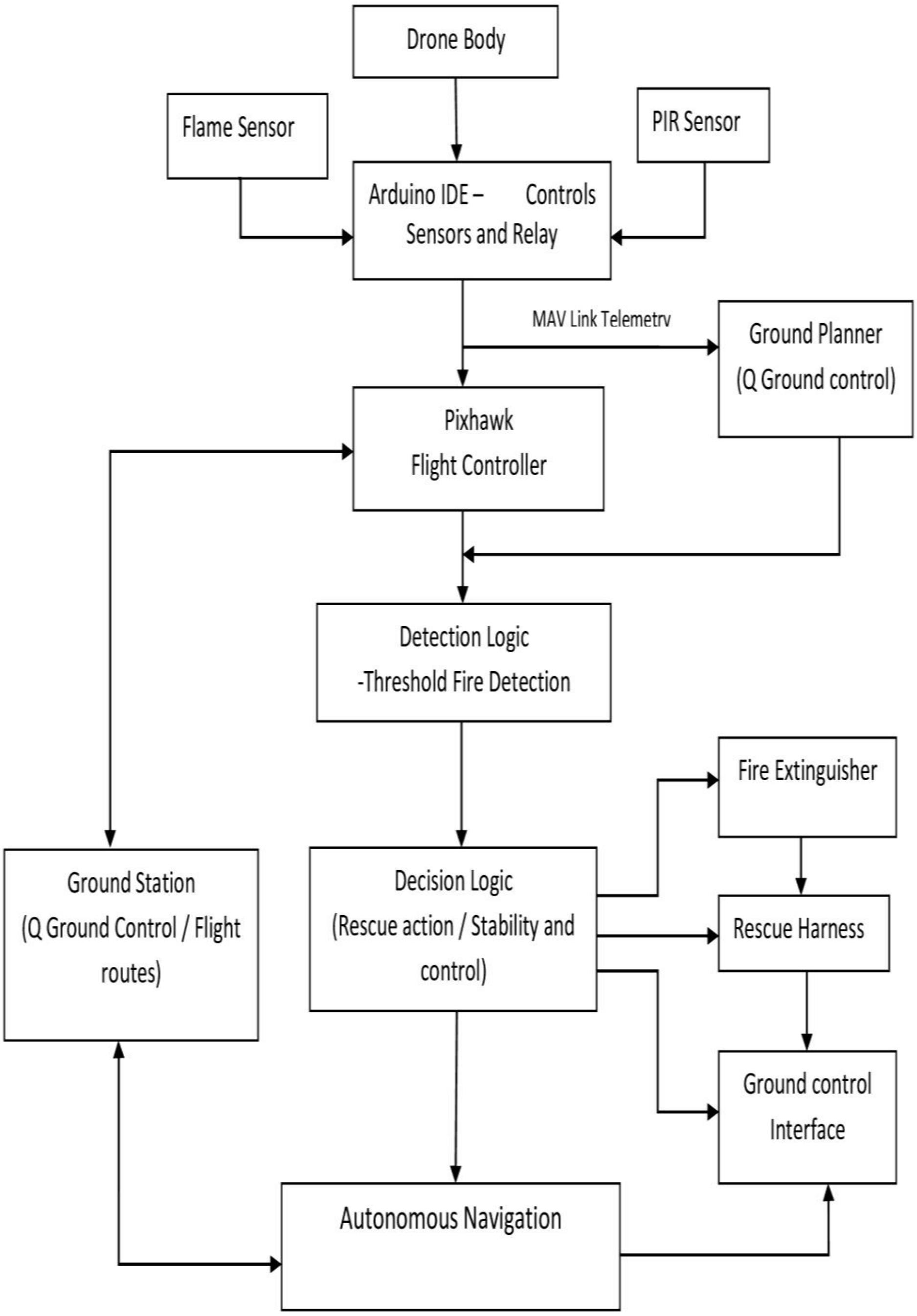

Fig 3.1: Block Diagram for the model

The block diagram illustrates the complete functional flow of the AI-driven firefighting and rescue drone. The Flame Sensor and PIR Sensor continuously monitor fire and human presence. Their outputs are processed by the Arduino, which controls the sensors and relay mechanism and sends real-time data to the Pixhawk Flight Controller via MAVLink telemetry.

The Pixhawk, supported by the Ground Planner (QGroundControl), handles flight stabilization, altitude control, and autonomous navigation. The sensor values are analyzed in the Detection Logic, where fire intensity is compared with a defined threshold. When fire is detected, the Decision Logic triggers the Fire Extinguisher and, if a human is detected, activates the Rescue Harness through the ground-control interface.

The Autonomous Navigation module guides the drone safely to the target location and executes firefighting or rescue actions. The Ground Station continuously monitors flight routes, mission status, and provides manual override when required. Thus, all modules work together to achieve autonomous fire detection, extinguishing, and rescue support.

3.2 WORKING FLOWCHART

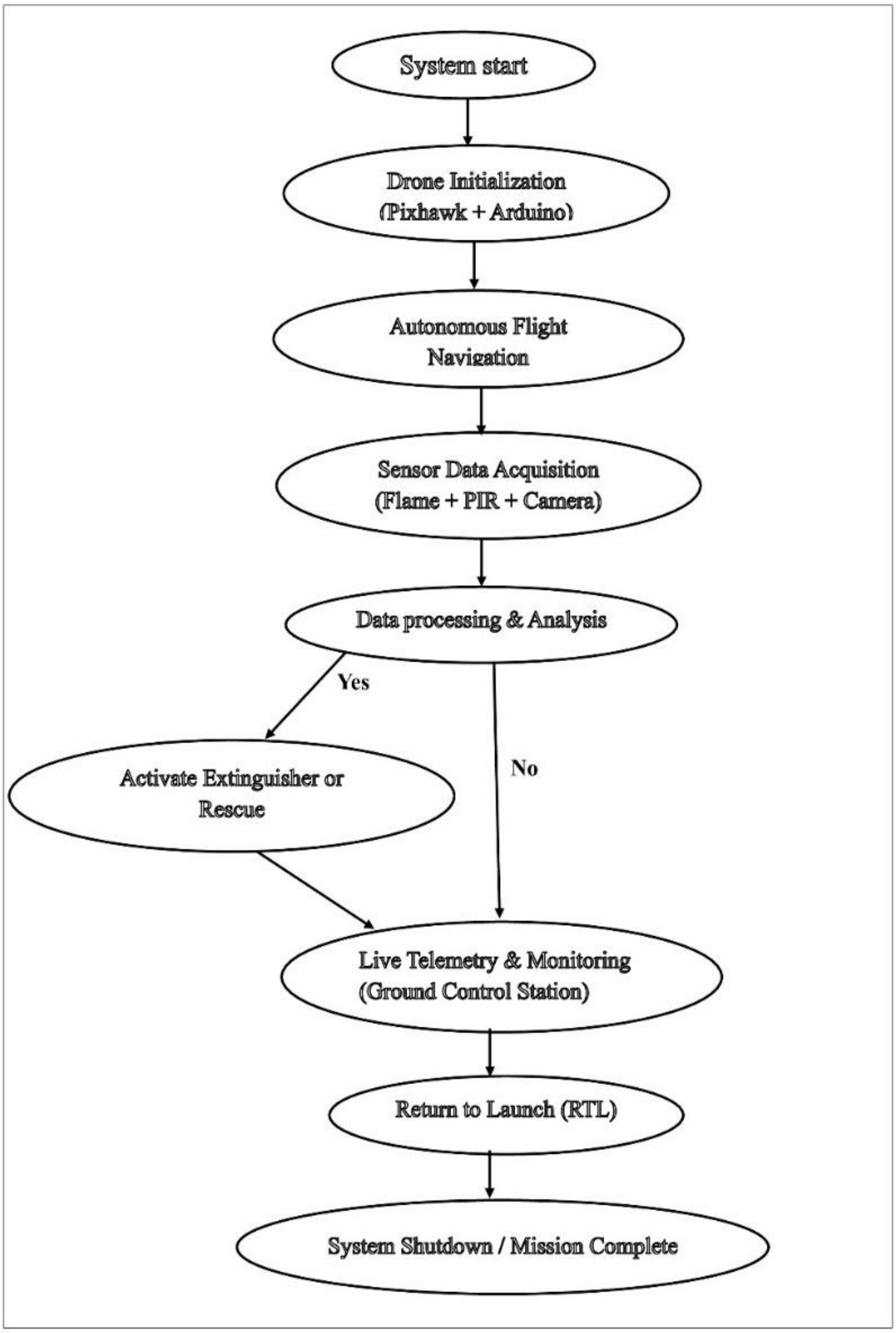

Fig 3.2: Flowchart for the working of model

1. **System Start**
   - The drone system powers ON and performs basic startup checks to ensure all components are ready.
2. **Drone Initialization (Pixhawk + Arduino)**
   - The Pixhawk flight controller and Arduino-based sensor interface are initialized. All communication links, motor ESCs, and sensor modules are configured.

3. **Autonomous Flight Navigation**
   - After initialization, the drone switches to autonomous mode. It follows predefined GPS waypoints or a programmed flight mission without manual control.
4. **Sensor Data Acquisition (Flame + PIR + Camera)**

   During flight, the drone continuously collects real-time data from:
   - Flame sensor for fire detection
   - PIR sensor for human/animal movement detection
   - Camera for visual monitoring and computer vision processing
5. **Data Processing & Analysis**
   - The onboard controller analyzes sensor outputs and live video to determine if fire or humans/objects are detected.
6. **Decision Making**

   If abnormal condition is detected (Yes):
   - The drone activates the fire extinguisher or rescue mechanism depending on the situation.

   If no risk is detected (No):
   - The drone continues normal surveillance.
7. **Live Telemetry & Monitoring (Ground Control Station)**
   - All sensor readings, video feed, and drone parameters are transmitted to the Ground Control Station (GCS) for monitoring and mission supervision.
8. **Return to Launch (RTL)**
   - After completing the mission or on low battery, the drone automatically returns to its home position using GPS-based RTL mode.
9. **System Shutdown / Mission Complete**
   - Once landed, the motors stop and the system safely shuts down, marking the end of the operation.

3.3 WORKING METHODOLOGY

The AetherResQ autonomous firefighting and rescue drone is designed to detect fire outbreaks, identify human presence in hazardous zones, and perform fire suppression while transmitting real-time environmental and visual data to responders. The system supports both autonomous operation through pre-configured GPS-based mission control and manual override through a Ground Control Station (GCS). The integration of onboard sensors such as flame sensors, PIR sensors, and a live camera feed allows intelligent monitoring, emergency response activation, and support for rescue missions in situations where human entry is risky

1. OPERATION MODES

A. Autonomous Operation

In this mode, the drone follows pre-programmed GPS waypoints configured using Mission Planner software. During flight, the onboard flame and PIR sensors continuously scan the environment. When fire is detected beyond the set threshold, the extinguishing mechanism is activated automatically. If human presence is detected, the drone sends an alert to the Ground Control Station along with live video feed. The onboard Pixhawk controller ensures efficient and stable autonomous navigation along with obstacle avoidance and Return-to-Launch (RTL) after mission completion or low-battery condition.

B. Manual/Remote Control Mode

In manual operation mode, the drone is controlled directly through the Ground Control Station or RC controller. This mode is used during testing, emergencies, or when autonomous execution is not suitable for the environment. The operator can manually maneuver the drone, activate the extinguishing system, adjust flight parameters, and monitor live telemetry and onboard video through the communication link.

2. SUBSYSTEMS AND WORKING MECHANISM

A. Flight and Navigation Control

Pixhawk serves as the primary flight controller responsible for stabilizing the drone and executing mission commands. GPS, barometer, and IMU sensors assist in maintaining altitude, balance, and waypoint navigation. The drone can move in upward, downward, left, right, forward, and backward directions as commanded either autonomously or manually.

B. Fire Detection and Suppression

A flame sensor continuously measures fire intensity. When fire is detected, the system evaluates its severity based on calibrated threshold values. If the fire level exceeds the threshold, the relay-controlled extinguishing system is activated to release suppressant material

C. Human Detection System

A Passive Infrared (PIR) sensor is used to detect heat signatures and motion. If the drone identifies human presence in a fire zone, the system sends an alert message to the Ground Control Station while marking the coordinates for rescue teams.

D. Live Video Transmission and Telemetry

A camera module streams real-time video to the GCS for situational awareness. Telemetry modules transmit flight data, including altitude, temperature, GPS position, and sensor values. This enables monitoring and remote decision-making during operation.

E. Communication and Control Feedback

Communication between the drone and GCS is achieved via MAVLink protocol, enabling bidirectional data exchange. The system supports both real-time control feedback and emergency override commands, ensuring operational safety and flexibility.

3. Adaptive Response Mechanism

The drone dynamically adjusts actions based on sensor feedback. If fire is detected, suppression begins automatically. If a human is detected near fire, suppression is temporarily delayed for safety and emergency alerting begins. In the event of low power, signal loss, or mission completion, the drone automatically triggers Return-to-Launch (RTL) .

CHAPTER 4

HARDWARE AND SOFTWARE DESCRIPTION

4.1 HARDWARE DESCRIPTION

4.1.1 PIXHAWK FLIGHT CONTROLLER

Fig 4.1: Pixhawk Flight Controller

Technical Specifications

- Processor: 32-bit ARM Cortex M4
- Sensors: Triple IMU, Accelerometer, Gyroscope, Magnetometer
- Barometer: MS5611 high-precision
- I/O Ports: I2C, SPI, UART, PWM outputs
- Communication: MAVLink
- Voltage Input: 4.8V–5.4V
- Autonomous Modes: Auto, RTL, Loiter, PosHold

Working Principle

- Pixhawk fuses IMU, GPS, barometer, and compass data to estimate the drone’s attitude.
- It applies PID algorithms to stabilize roll, pitch, yaw, and altitude.

Working Process

- Reads IMU, compass, barometer & GPS data
- Generates PWM signals for motors via ESCs
- Executes autonomous missions through MAVLink
- Communicates telemetry to GCS

Power Management

- Powered by a 5V BEC
- Independent power rails for redundancy
- Current & voltage monitoring via Power Module

Advantages

- High accuracy and stability
- Supports advanced autonomous flight
- Reliable failsafe and safety features

Limitations

- Requires PID tuning
- Sensitive to vibration

4.1.2 GPS MODULE WITH BUILT -IN COMPASS

Fig 4.2: GPS Module with Built-in Compass

Technical Specifications

- Model: Ublox M8N
- Accuracy: ±2.5 meters
- Update Rate: 5–10 Hz
- Connectivity: I2C + UART
- Voltage: 3.3V–5V

Working Principle

- Uses satellite signals to determine global position and compass to provide drone heading.

Working Process

- Locks GPS satellites
- Sends coordinates to Pixhawk
- Provides heading information
- Power Management

Advantages

- Accurate navigation
- Stable heading control

Limitations

- Affected by metallic interference

4.1.3 RADIO RECEIVER (FLYSKY / FRSKY)

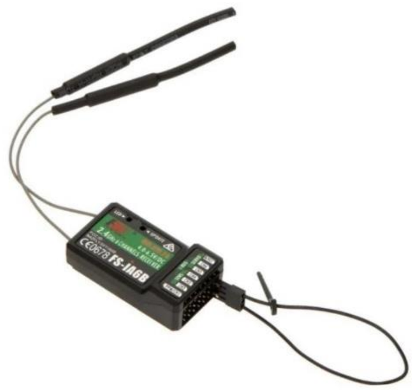

Fig 4.3: Radio Receiver (Fly Sky / Frisky)

Technical Specifications

- Channels: 6–8
- Frequency: 2.4 GHz
- Voltage: 4–6V
- Range: 500 m–1 km

Working Principle

- Receives control signals from the RC transmitter and forwards them to Pixhawk.

Working Process

- PPM/SBUS signal decoding
- Manual override of flight modes

Advantages

- Reliable control
- Emergency manual operation

Limitations

- Limited range
- Interference possible

4.1.4 SAFETY SWITCH / ARM BUTTON

Fig 4.4: Safety Switch / Arm Button

Technical Specification

- Operating Voltage: 5V DC
- Interface: Digital Trigger Input to Pixhawk
- Status Indicator: Dual-color LED (Flashing – Disarmed, Solid – Armed)
- Connector Type: 2/3-pin JST
- Function: Manual motor arming / disarming

Working Principle

The Safety Switch / Arm Button acts as a hardware-level safety interlock.

Pixhawk will not send PWM signals to motors unless:

- GPS is locked (in GPS-required modes)
- The Arm Button is pressed for 2–3 seconds

Working Process

- The pilot powers ON the drone.
- Pixhawk performs IMU, GPS, and sensor checks.
- When checks pass, the LED on the safety switch begins blinking.
- The operator presses and holds the switch for 2–3 seconds.
- LED turns solid → motors are armed and ready for takeoff.
- To disarm, the switch is pressed again (or disarmed via RC).

Power Management

- Draws very minimal current (~10–20 mA) from Pixhawk's 5V rail.
- LED indication provides low-power visual feedback.
- No influence on total battery consumption.

Advantages

- Prevents accidental motor start, ensuring ground safety
- Simple, reliable, and mandatory for all Pixhawk systems
- Provides clear visual and manual confirmation of arming state
- Works even when RC signal fails (extra safety layer)

Limitations

- Requires physical access to the button before flight
- Not usable remotely (must be pressed manually)
- LED may be difficult to see in bright outdoor sunlight

4.1.5 BUZZER MODULE

Fig 4.5: Buzzer Module

Technical Specifications

- Operating Voltage: 5V DC
- Current Consumption: 10–30 mA
- Sound Output: 85–95 dB
- Interface: Connects to BUZZ port on Pixhawk
- Indicators: Arming, GPS lock, error, failsafe, battery warnings

Working Principle

The buzzer provides audible feedback based on signals sent by Pixhawk firmware.

- Arming status
- GPS lock acquired
- Low battery
- Failsafe triggered
- Mode changes
- Pixhawk uses PWM-type pulse patterns to generate different beep sequences.

Working Process

- Pixhawk initializes → buzzer gives startup tone
- When GPS achieves 3D Fix → double beep
- When safety switch is armed → long beep
- During low battery → repeated warning beeps
- During failsafe → continuous rapid beeping
- During disarm → short beep sequence

Advantages

- Provides immediate audio alerts for critical events
- Helps identify problems quickly during pre-flight
- Useful during line-of-sight operation
- Low power consumption
- Increases operational safety and situational awareness

Limitations

- Not effective in noisy environments
- Limited range (audible up to 10–20 meters only)
- Cannot provide detailed information (only simple tones)
- May be difficult to hear when props are spinning

4.1.6 PIR SENSOR

Fig 4.6: PIR sensor

Technical Specifications

- Range: 6–10 meters
- Output: Digital HIGH/LOW
- Voltage: 5V

Working Principle

Detects human presence by sensing changes in infrared radiation.

Working Process

- PIR detects heat movement
- Sends HIGH signal to ESP32
- Drone activates rescue alert or response

Power Management

- Very energy-efficient (<1 mA)

Advantages

- Reliable human detection
- Low cost and low power

Limitations

- Cannot measure distance
- No identification capability

4.1.7 I2C PORTS(INTEGRATED CIRCUIT COMMUNICATION PORTS)

Fig 4.7: I2C Ports (Inter-Integrated Circuit Communication Ports)

Technical Specifications

- Communication Protocol: I2C (Two-Wire Serial Protocol)
- Number of Lines: SDA (data), SCL (clock)
- Voltage Level: 3.3V (Pixhawk)
- Max Devices Supported: Up to 127 addresses
- Speed: 100 kHz (Standard Mode), 400 kHz (Fast Mode)
- Connected Devices: Compass, Airspeed Sensor, OLED Display, External Sensors

Working Principle

- I2C is a multi-master, multi-slave serial communication protocol used to connect multiple sensors to Pixhawk using only two wires:
- SDA → data line
- SCL → clock line
- Each sensor has a unique 7-bit address, allowing Pixhawk to communicate with multiple modules simultaneously.

Working Process

- Pixhawk initiates communication by sending a start condition.
- It sends a 7-bit address to select a specific sensor (e.g., compass).
- Sensor acknowledges the request.
- Data is transferred between Pixhawk and the device.
- Communication ends with a stop condition.
- Process repeats for next sensor (air speed, OLED, etc.)
- This enables multiple sensors to work simultaneously without additional wiring.

Power Management

- All I2C sensors are powered through Pixhawk’s 3.3V or 5V supply
- Very low current consumption (2–20 mA per sensor)
- Supports low-power sleep states in connected sensors

Advantages

- Supports multiple sensors with only two wires
- Ideal for small drones (reduced wiring weight)
- Power-efficient communication
- High reliability and noise tolerance
- Easy integration of additional modules

Limitations

- Limited wire length (noise increases > 50 cm)
- Slow compared to SPI protocol
- Risk of bus hang if a sensor becomes unresponsive

4.1.8 BRUSHLESS DC MOTORS

Fig 4.8: Brushless DC Motor (2212 – 950KV)

Technical Specifications

- KV Rating: 950 KV
- Operating Voltage: 2S–4S Li-Po (7.4V – 14.8V)
- Maximum Thrust: 850–1000 g per motor
- Maximum Power Output: 150–300 W
- Shaft Diameter: 3.17 mm
- Stator Configuration: 12N14P
- Weight: ≈50 g

Working Principle

- A Brushless DC (BLDC) motor operates on the principle of electromagnetic induction, where a rotating magnetic field interacts with the armature coils.
- Unlike brushed motors, the commutation is performed electronically, enabling higher RPM, efficiency, and reduced heat.

Working Process

- ESC supplies 3-phase AC to the BLDC motor.
- Rotor’s permanent magnets align with the rotating electromagnetic field.
- Propeller attached to the shaft rotates at high RPM.
- Rotation generates lift and thrust, enabling drone flight.

Power Management

- High efficiency (>85%) ensures lower current draw for the same thrust.
- Natural cooling through airflow during flight prevents overheating.

Advantages

- High thrust-to-weight ratio
- Low heating and long lifespan
- Smooth throttle response
- Excellent efficiency, ideal for drones

Limitations

- Cannot operate without ESC
- Requires proper calibration and balancing
- Sensitivity to dust and water

4.1.9 ELECTRONIC SPEED CONTROLLER (ESC) – 30A

Fig 4.9: Electronic Speed Controller (ESC) – 30A

Technical Specifications

- Continuous Current: 30A
- Peak Current: 40A for 10 seconds
- Supported Voltage: 2S–4S Li-Po
- Firmware: SimonK / BLHeli
- Output: 3-Phase PWM-controlled AC

Working Principle

- The ESC acts as an electronic commutator.
- It converts DC battery voltage into three-phase AC required to drive BLDC motors.
- The input throttle signal (from Pixhawk) modifies output frequency → controls motor speed.

Working Process

- Receives PWM/PPM/S.BUS throttle signal from Pixhawk.
- Converts DC to controlled 3-phase AC waveforms.
- Adjusts phase timing to control RPM.
- Supports braking and direction control (if configured).

Power Management

- Includes heat-sink for thermal dissipation.
- Uses BEC (if present) to supply power to flight controller.
- Overcurrent protection prevents motor burnout.

Advantages

- Very fast throttle response
- Stable motor output
- Higher efficiency with SimonK firmware

Limitations

- Must match motor KV and current requirements
- Can overheat in high-load conditions
- Sensitive to water damage

4.1.10 PROPELLERS

Fig 4.10: Propellers (10 × 4.5 inch)

Specifications

- Diameter: 10 inches
- Pitch: 4.5
- Material: ABS / Carbon Fiber
- Type: CW + CCW pair
- Mount Type: Hub-mount with nut

Working Principle

Propellers generate lift by displacing air downward.

Lift is proportional to:

- RPM
- Blade pitch
- Blade length
- Air density

Working Process

- Motor rotates propeller.
- The angled blades push air downward
- Newton’s Third Law → Drone moves upward.
- Differential speeds allow yaw, pitch, roll control.

Power Management

- Lower pitch increases efficiency.
- Balanced propellers reduce battery heating and vibration.

Advantages

- Lightweight and efficient
- Good stability for quadcopters
- Affordable and easy to replace

Limitations

- Fragile during crashes
- Must be well-balanced to avoid vibrations

4.1.11 DRONE FRAMES

Fig 4.11: Drone Frame (F450 / S500)

Technical Specifications

- Material: Glass-fiber reinforced nylon
- Wheelbase: 450mm / 500mm
- Weight: 300–450 g
- Arm Material: ABS composite

Working Principle

- Provides structural support for motors, Pixhawk, battery, and payload while absorbing flight vibrations.

Working Process

- Distributes weight symmetrically
- Ensures proper motor alignment for stability
- Houses landing gear and payload mount

Power Management

- Improves battery efficiency by reducing frame weight
- Dampens vibrations to reduce IMU noise

Advantages

- Strong and durable
- Low vibration
- Easy to assemble and maintain

Limitations

- Limited payload capacity
- Fixed size—not foldable

4.1.12 LI-PO BATTERY

Fig 4.12: Bluetooth Module Li-Po Battery (2200–5200 mAh)

Technical Specifications

- Voltage: 11.1V (3S)
- Capacity: 2200–5200 mAh
- Discharge Rating: 25C–40C
- Cell Chemistry: Lithium-Polymer (Li-Po)

Working Principle

- Li-Po cells store electrical energy via lithium-ion charge displacement.
- High discharge rates provide large currents required by drone motors

Working Process

- Supplies DC power to ESCs.
- Pixhawk draws regulated 5V via Power Module.
- Battery voltage decreases during flight.
- Pixhawk triggers low-voltage failsafe if critically low.

Working Process

- Pixhawk draws regulated 5V via Power Module.
- Battery voltage decreases during flight.
- Pixhawk triggers low-voltage failsafe if critically low.

Power Management

- Must be balance-charged using iMAX B6.
- Recommended discharge cutoff: 3.3V per cell.
- Avoid over-charging or deep discharge.

Advantages

- High energy density
- Lightweight
- Supports high-current loads

Limitations

- Risk of fire if damaged
- Requires careful charging
- Shorter lifespan under heavy load

4.1.13 RELAY MODULE

Fig 4.13: Relay Module

A relay module is an electromechanical switch that allows a low-power microcontroller (Arduino, NodeMCU, Raspberry Pi) to control high-voltage devices such as water pumps, motors, lights, and appliances. It acts as an interface between the low-voltage logic circuits (3.3V/5V) and high-power electrical loads (12V/220V AC). Relay modules are used in home automation, smart agriculture robots, industrial control, and IoT applications.

Technical Specifications

- Operating Voltage**:** 5V or 12V DC
- Trigger Voltage**:** 3.3V – 5V (microcontroller-compatible)
- Max Load: 250V AC / 10A or 30V DC / 10A
- Channels: Available in 1, 2, 4, 8, or 16-channel configurations
- Relay Type: Electromagnetic or Solid-State
- Switching Time: Around 10ms

Working Principle

- Relay consists of an electromagnetic coil, COM, NO, and NC contacts
- Coil generates a magnetic field when energized
- Switches power path between COM → NO (ON) or COM → NC (OFF)
- Transistor controls relay from a microcontroller signal
- Diode provides flyback protection; optocoupler isolates control side

How It Works

- Microcontroller sends signal → coil energizes
- Magnetic field activates switch → connects COM to NO
- When signal stops → coil de-energizes → connects COM to NC
- Enables control of high-power devices with low-voltage logic

Relay Contacts

- COM (Common): Main input connection
- NO (Normally Open): Connected only when relay is ON
- NC (Normally Closed): Connected when relay is OFF

Advantages

- Enables low-power microcontrollers to switch high-voltage devices
- Offers electrical isolation for safe operation
- Suitable for controlling multiple devices (multi-channel)

Limitations

- Mechanical parts subject to wear over time
- Slower switching speed (~10ms)
- Cannot handle very high currents beyond 10A

4.1.14 FLAME SENSOR

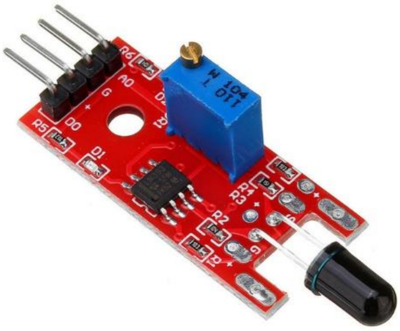

Fig 4.14: Flame sensor

Technical Specifications

- IR Detection Range: 760–1100 nm
- Detection Distance: 80–100 cm
- Outputs: Analog + Digital

Working Principle

- Detects IR radiation emitted from fire flames using a photodiode.

Working Process

- Converts IR intensity to electrical signal
- Sends analog/digital output to ESP32/Arduino

Power Management

- Very low power consumption (<20 mA)

Advantages

- Fast flame detection
- Simple interfacing

Limitations

- Cannot detect smoke
- False alarms under sunlight

4.1.15 PRESSURIZED FIRE EXTINGUISHER

Fig 4.15: Pressurized Fire Extinguisher

Technical Specifications

- Capacity: 500 ml
- Type: Foam / Liquid fire suppressant
- Discharge Pressure: 3–7 bar

Working Principle

- When the solenoid valve opens, internal pressure pushes foam/liquid through the nozzle, dispersing it onto the fire.

Working Process

- Arduino/ESP32 triggers relay.
- Relay powers solenoid valve.
- Valve opens → pressurized suppressant is released.

- Spray exits through the nozzle to extinguish fire.

Power Management

- Relies on mechanical pressure, not electrical power.
- Only the solenoid uses electrical energy.

Advantages

- Effective on Class A/B fires
- Lightweight for drones
- Quick discharge

Limitations

- Limited capacity
- Not suitable for large fires
- Must be refilled or replaced after use

4.1.16 GAS SENSOR

Fig 4.16: Gas Sensor

Technical Specifications

- Operating Voltage: 5V DC
- Heater Voltage: 5V (±0.2V)
- Power Consumption: < 900 mW

Detection Range:

- MQ5: LPG, Natural Gas
- MQ135: Air Quality, CO_2, NH_3
- Output Type: Analog voltage (0–5V)
- Preheat Time: 20–25 seconds
- Sensitivity: Adjustable using onboard potentiometer

Working Principle

- The gas sensor operates on the principle of change in resistance of a heated semiconductor (SnO_2) when exposed to combustible or toxic gases.
- When harmful gases enter the sensor chamber, the resistance of the sensor's conductive layer changes.
- This change is converted into a varying analog voltage, indicating gas concentration.

Working Process

- Heater coil warms the semiconductor material.
- Gases interact with the heated tin-oxide surface.
- Resistance value changes proportional to gas concentration.
- Sensor outputs a corresponding analog voltage.
- ESP32/Arduino reads this value and triggers alerts or safety actions.

Power Management

- Requires continuous heating, so power consumption is moderately high.
- Always connect through a regulated 5V supply.
- Avoid powering directly from weak microcontroller pins.
- Use separate power rail or buck converter to reduce noise.

Advantages

- Detects a wide range of gases (LPG, CO, methane, smoke).
- Low cost and easy to interface.
- Simple analog output for microcontroller processing.
- Works well in fire-prone environments and early leakage detection.

Limitations

- Requires 20–30 seconds warm-up time.
- Sensitive to humidity and temperature variations.
- Cannot identify specific gas types without calibration curves.
- Consumes more power due to heater coil.
- Needs regular calibration for accurate readings.

4.1.17 SPRAY NOZZLE

Fig 4.17 Spray Nozzle

Technical Specifications

- Material: Brass/Steel
- Spray Type: Fine Mist / Jet
- Flow Rate: Depends on pressure & orifice

Working Principle

- The nozzle accelerates fluid and atomizes it into fine droplets, increasing contact area with the flame.

Working Process

- Pressurized suppressant enters nozzle.
- Nozzle geometry shapes flow.
- Converts liquid into mist or jet.
- Covers fire surface for maximum suppression.

Power Management

- No electrical power required
- Fully mechanical

Advantages

- Efficient spray coverage
- Lightweight

Limitations

- Can clog if particles present
- Spray pattern fixed (not adjustable)

4.1.18 POWER DISTRIBUTION BOARD

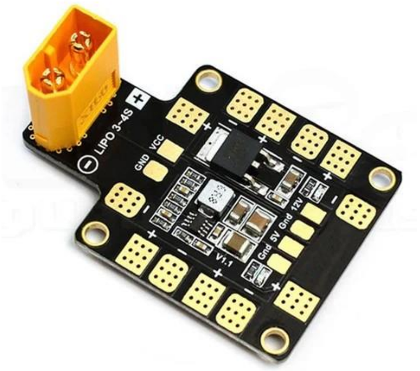

Fig 4.18 Power Distribution Board

Technical Specifications

- Input Voltage: 7–22V
- Outputs: XT60, ESC solder pads
- Embedded Sensors: Current & voltage sensing

Working Principle

- Distributes Li-Po battery power evenly to all ESCs and Pixhawk while monitoring current and voltage.

Working Process

- Battery connected via XT60.
- Power is distributed to all four ESCs.
- BEC provides 5V regulated power to Pixhawk.
- Telemetry sends battery health to Mission Planner.

Power Management

- Protects Pixhawk from voltage spikes
- Monitors battery consumption

Advantages

- Organized wiring
- Real-time battery telemetry

Limitations

- Can heat up under heavy load
- Requires soldering skills

4.1.19 ELECTRONIC SOLENOID VALVE

Fig 4.19 Electronic Solenoid Valve

Technical Specifications

- Voltage: 12V or 5V (depending on model)
- Current: 300–500 mA
- Material: Brass / Stainless Steel
- Type: Normally Closed (NC)

Working Principle

- A solenoid creates a magnetic field when energized, lifting a plunger and allowing fluid flow.

Working Process

- Magnetic field forms.
- Plunger lifts → valve opens.
- Extinguishing fluid flows out.
- Power removed → valve closes.

Power Management

- Requires DC power only when opening
- Keep usage short to avoid overheating

Advantages

- Fast response
- Reliable and easy to control
- Supports high pressure

Limitations

- Consumes high current
- Heats up with prolonged activation
- Sensitive to particles/dust

4.1.20 ARDUINO UNO BOARD

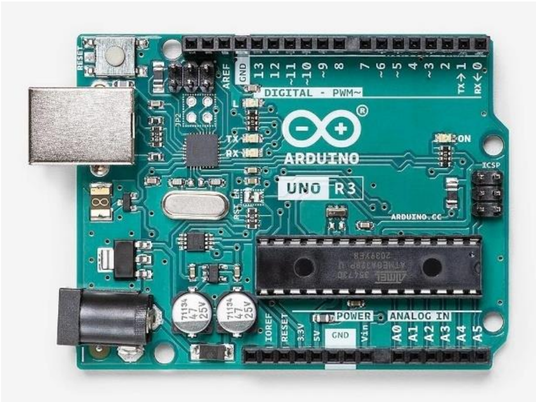

Fig 4.20 Arduino Uno Board

Technical Specifications

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7–12V
- Digital I/O Pins: 14 (6 PWM output)
- Analog Input Pins: 6
- Clock Speed: 16 MHz
- Flash Memory: 32 KB
- Communication: USB, UART, I2C, SPI

Working Principle

- Arduino operates as a microcontroller that takes input from sensors, processes it through programmed logic, and controls connected devices such as actuators and relays.

Working Process

- Power is supplied to the board.
- Program instructions stored in memory are executed.
- Input sensors send data to the microcontroller.
- Microcontroller processes the input based on logic.
- Output is sent to motors, relays, valve, or other modules.

Power Management

- Can be powered using USB, DC jack, or Vin pin.
- Regulated 5V and 3.3V pins available for powering external components.
- Requires low power for operation (suitable for battery-based systems).
- Stable voltage is required to avoid reset or malfunction.

Advantages

- Easy to program and debug
- Low-cost and highly reliable
- Supports multiple sensors and modules
- Open-source platform with large community support

Limitations

- Limited processing speed compared to advanced controllers (ESP32/Pi)
- Limited memory for complex programs
- Requires external motor drivers for high-power devices

4.2 SOFTWARE DESCRIPTION

4.2.1 ARDUINO IDE

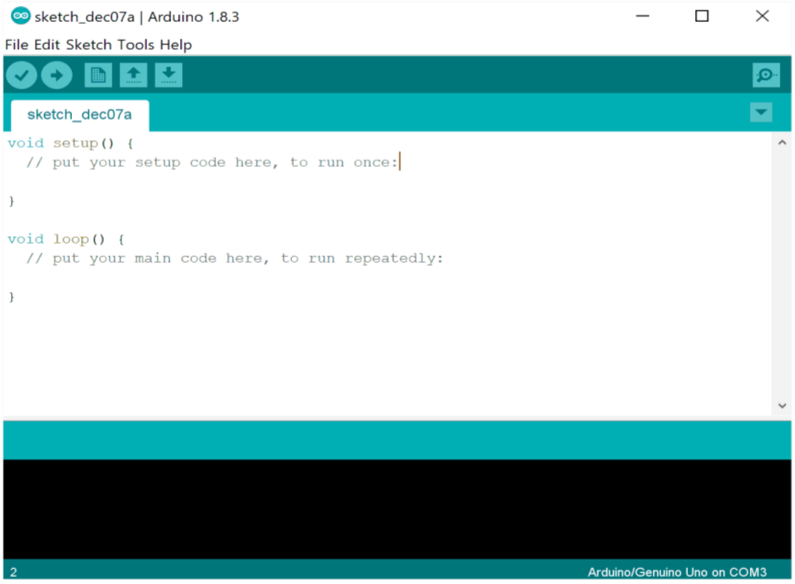

Fig 4.12: Arduino IDE Interface

The Arduino Integrated Development Environment (IDE) is an open-source software used to write, compile, and upload code to Arduino microcontrollers such as Arduino UNO, Mega, Nano, NodeMCU, and ESP8266. It supports C and C++ programming languages with built-in libraries that facilitate hardware interaction.

The IDE is compatible with Windows, macOS, and Linux, providing a simple and user-friendly interface for developing embedded systems and IoT projects.

Features of Arduino IDE

- Code Editor: Syntax highlighting, indentation, and error checking
- Compiler & Uploader: Converts and uploads code to microcontrollers
- Serial Monitor: Displays real-time data via serial communication
- Library Manager: Adds external libraries easily
- Board Manager: Supports multiple Arduino and ESP boards
- Sketch System: Each program is a .ino sketch file

Installation and Setup

- Download Arduino IDE from official site
- Install based on OS (Windows/macOS/Linux)
- Launch the IDE after installation

Connecting Arduino

- Use USB to connect Arduino/ESP to PC
- Open IDE → Select correct board and COM port

ESP8266/ESP32 Board Setup

- Add Board URLs in Preferences
- Use Board Manager to install ESP8266/ESP32 packages

Basic Arduino Sketch Structure

- void setup(): Runs once for initialization
- void loop(): Runs continuously after setup
- Used to define pin modes, logic, and functions

Key Components

- Sketch Area: Where code is written (.ino file)
- Toolbar: For verifying, uploading, opening, saving code
- Serial Monitor: For real-time data display and debugging

Uploading Code

- Write code → Verify for errors
- Select correct board and port
- Click Upload → "Done Uploading" confirms success

Installing Libraries

- Manual: Add .zip libraries via "Include Library" option
- Library Manager**:** Search and install from official repository

Troubleshooting Errors

- Compilation error**:** Code mistake → Debug syntax
- Upload error**:** Wrong board → Re-select correct board
- Board not detected**:** Use a proper USB data cable and reinstall drivers

Advantages:

- Beginner-friendly interface
- Extensive library and board support
- Open-source and community-backed

Limitations:

Lacks advanced debugging tools

Limited for large-scale software projects

No built-in version control or code suggestions

4.2.2 MAVLink COMMUNICATION INTERFACE

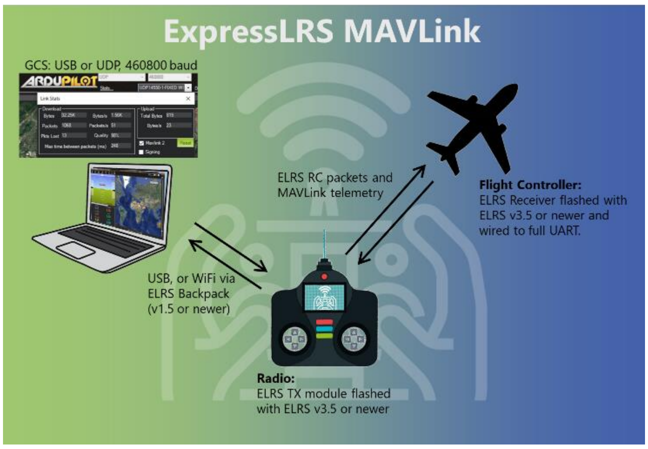

Fig 4.13: MAVLink Communication Interface

The Micro Air Vehicle Link (MAVLink) is a lightweight, open-source communication protocol designed for unmanned aerial vehicles (UAVs) and robotic platforms. It is used to exchange telemetry data, navigation commands, and system status between the flight controller, onboard systems, and ground control stations (GCS). MAVLink is widely supported by autopilot systems such as PX4, ArduPilot, Pixhawk, and compatible hardware like ESP8266, Raspberry Pi, and Jetson modules.

MAVLink supports both unidirectional streaming and bidirectional command-based communication, enabling real-time mission planning, data logging, and autopilot control. It is highly efficient and suitable for low-bandwidth communication channels such as RF telemetry modules, Wi-Fi, 4G/5G IoT modules, and UART interfaces.

Features of MAVLink

- Lightweight Protocol: Optimized message size for low-power embedded systems.
- Real-Time Telemetry: Sends attitude, GPS, speed, battery, and sensor data continuously.
- Bidirectional Commanding: Allows waypoint upload, mission updates, and control actions.
- Custom Message Support: Enables adding new commands for payloads or sensors.
- Secure Communication: MAVLink 2.0 supports encrypted message signing for safety.

Installation and Setup

- Install Ground Control Software such as QGroundControl or Mission Planner
- Configure communication port (UART/Wi-Fi/Telemetry Radio)
- Select autopilot firmware (PX4/ArduPilot) and enable MAVLink support
- Connect drone hardware to software interface

Connecting MAVLink

- Use UART/Wi-Fi to connect flight controller to GCS
- Open GCS → Select COM port or network connection
- Configure baud rate (typically 57600 or 115200) for stable telemetry

Basic MAVLink Message Structure

- Heartbeat: Identifies system status and component type
- Telemetry Messages: Provide real-time flight metrics
- Command Messages: Control motors, missions, or payloads
- Mission Protocol: Upload and execute waypoint mission

Key Components

- Control Station (GCS): User interface for drone control
- Telemetry Link: Transfers commands and data wirelessly
- Flight Controller: Executes MAVLink instructions and responds with telemetry
- Uploading / Executing Missions
- Define mission in GCS
- Start mission → GCS monitors real-time drone status

Integration With Other Software

- ROS (MAVROS): Enables AI, path planning, and autonomy
- Python/C++ APIs: Used for custom scripting and automation
- Companion Computers: Enable advanced applications (AI vision, fire detection, etc.)

Limitations

- Requires configuration for compatibility with different hardware
- Limited debugging tools compared to full IDEs
- Message structure can be complex for beginners

CHAPTER 5

RESULTS

The AetherResQ firefighting and rescue drone prototype was successfully assembled, configured, and tested under controlled indoor and outdoor conditions. The key modules of the system—flight control, sensor detection, telemetry, and extinguishing mechanism—were evaluated to verify their functionality and performance.

During testing, the Pixhawk flight controller initialized correctly, establishing stable communication with Mission Planner through MAVLink telemetry. GPS acquisition was successful, with the module consistently locking onto the required number of satellites, ensuring accurate positional tracking for autonomous missions. Manual flight tests using the FlySky FS-i6 transmitter demonstrated stable lifting, maneuverability, and controlled hovering, confirming the proper integration of motors, ESCs, and power systems.

The sensing components were evaluated using real fire and human-motion simulation. The flame sensor detected fire reliably within the effective range, and the PIR sensor accurately identified human movement, validating the system's ability to support emergency detection requirements. The relay-controlled fire extinguisher mechanism was activated successfully during trials, releasing suppressant material promptly after signal triggering, confirming the operational readiness of the actuation subsystem.

Telemetry data—including altitude, battery voltage, GPS position, and mode status—was received in real time on Mission Planner, enabling continuous monitoring of the drone during testing. Payload handling and flight stability were assessed with the mounted extinguisher, and the drone was able to maintain stable flight under the configured load.

Overall, the results demonstrate that the essential firefighting and sensing capabilities of the system function as intended. The prototype meets the core objectives of the project by achieving stable flight, reliable hazard detection, real-time monitoring, and successful activation of the extinguishing mechanism. The autonomous flight capability is fully supported by the Pixhawk system, with manual mode used during the prototype demonstration for safety. These results validate the successful development of the AetherResQ firefighting and rescue drone

Fig 5.1: Project Output

Fig 5.2: Project Model

Fig 5.3: Group Photo with Model

Parameter	Unit	Expected Value	Observed Value	Performance
Motor Response	kv	700kv-1600kv	1000kv	36%
Hover Stability Drift	cm	10cm	20-40cm	60%
GPS Satellite Lock count	count	25 satellites	15 satellites	90%
Flame Detection Range	cm	30-50cm	5cm	80%
PIR Human Detection Range	m	3-10m	6m	90%
PSI Coverage	feet	5-8 feet	3feet	60%
Telemetry Signal Strength	km	0.5-2km	0.85km	80%
Battery Backup (Payload On)	minutes	30min	10-12 min	70%
Payload Handling Stability	kg	2kg	½ kg	70%

Manual Flight Control Accuracy	%	100%	92%	70%

Table 1: Technical Performance Data Table

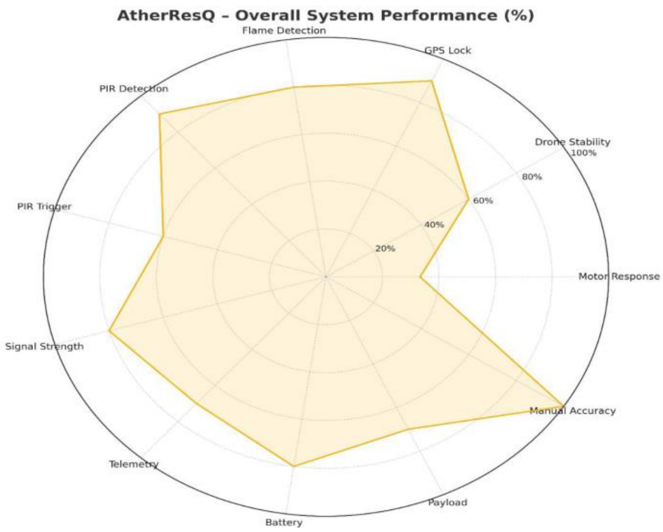

Fig 5.4: Radar Chart

CHAPTER 6

ADVANTAGES AND DISADVANTAGES

6.1 ADVANTAGES

- **Autonomous Operation and Smart Control:** The integration of the Pixhawk flight controller with MAVLink telemetry enables fully autonomous flight modes such as Auto, Loiter, Position Hold, and RTL. This significantly reduces manual intervention during fire suppression and rescue missions, ensuring consistent and reliable operation.

- **Real-Time Fire and Human Detection:** The flame sensor (IR-based) and PIR sensor enable rapid and accurate detection of fire energy and human presence. This allows the drone to perform independent decision-making for activating the fire extinguisher or initiating rescue procedures.

- **High Stability Through PID-Based Control:** The use of PID algorithms in Pixhawk ensures precise stabilization and attitude control even during dynamic operations such as spraying extinguishing agents. This improves flight accuracy and mission safety.

- **Efficient Propulsion System:** Brushless DC motors (2212, 920 KV) paired with 30A ESCs offer high thrust, low power loss, and reduced heat generation. This enhances the drone's payload handling and propulsion efficiency.

- **Long-Range Communication and Telemetry:** MAVLink-supported ground control systems (Mission Planner/QGroundControl) provide real-time monitoring of flight parameters, mission status, battery health, and sensor alerts. This ensures high reliability in remote operations.

- **Modular Hardware Architecture:** The system follows a modular design where sensors, extinguishing modules, rescue harnesses, and cameras can be individually replaced or upgraded without affecting the main flight controller. This improves maintainability and scalability.

- **Immediate Fire Response Capability:** The onboard fire extinguisher module allows rapid suppression of small and medium-sized fires—crucial in the early stages before escalation. This provides a significant technical edge over manual firefighting approaches.

- **Lightweight and Energy-Efficient Electronics:** The Arduino-based sensor subsystem, GPS module, and relay circuits consume minimal power, enabling longer flight durations.

6.2 DISADVANTAGES

- **Limited Payload Capacity:** The drone can carry only around 10 kg, which restricts the amount of fire-extinguishing agent and rescue equipment that can be deployed during operations.
- **Short Flight Duration**: High power consumption of BLDC motors and the extinguisher pump reduces overall battery backup, limiting mission time.
- **Environmental Sensitivity:** Strong winds, rain, dense smoke, and extreme temperatures can affect flight stability, sensor accuracy, and GPS performance.
- **Complex Setup and Calibration:** Proper PID tuning, ESC calibration, and sensor alignment require technical expertise, making the system challenging for beginners.
- **Limited Sensor Intelligence:** Flame and PIR sensors perform only threshold-based detection and cannot classify fire severity or identify multiple hazards without advanced vision systems.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

The AetherResQ firefighting and rescue drone was successfully designed, developed, and tested as an innovative solution for emergency response applications. The integration of Pixhawk-based autonomous flight capability, flame and PIR detection modules, telemetry communication, and a relay-controlled fire extinguisher validated the core objectives of the project.

The prototype demonstrated stable manual flight, reliable hazard detection, and effective activation of the extinguishing mechanism. The drone also proved capable of lifting the payload and maintaining flight stability, making it suitable for small-scale firefighting scenarios. Although the advanced AI-based smart surveillance module is part of the system architecture, it remains a future enhancement due to hardware and time limitations.

Overall, the project successfully showcases the potential of unmanned aerial systems in reducing human risk, improving response efficiency, and automating critical emergency functions. The developed system provides a strong foundation for further research and real-world implementation.

7.2 FUTURE SCOPE

1. AI-Based Smart Surveillance:

   Integration of a camera module with computer vision algorithms (YOLO, thermal imaging) to identify fire intensity, humans, or hazardous objects in real time.

2. Full Autonomous Navigation:

   Implementation of onboard companion computers (Raspberry Pi/Jetson Nano) to enable complete autonomous decision-making without manual control.

3. Improved Fire Suppression Mechanism:

   Use of higher-capacity extinguishers, pump-based spraying systems, or fire-retardant powder tanks for tackling medium-scale fires.

4. Advanced Sensor Fusion:

   Combining gas sensors, temperature sensors, and thermal cameras to increase detection accuracy and reliability.

5. Swarm Coordination:

   Multiple drones can collaborate using mesh communication for large-area firefighting or search-and-rescue missions.

6. Enhanced Battery Performance:

   Upgrading to high-capacity Li-Po or Li-ion batteries, or integrating solar-assisted charging to extend flight duration.

7. Payload Rescue Mechanism:

   Development of a lightweight rescue harness or delivery system to assist trapped individuals by carrying medical kits or essential supplies.

8. Weather-Resistant Frame:

   Strengthening the drone frame with carbon fiber and heat-resistant materials for better survival in harsh environments

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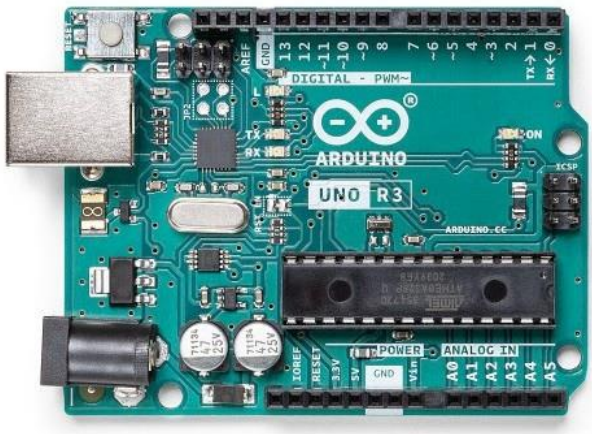
APPENDIX A

DATASHEETS

User Manual
SKU: A000066



Description

The Arduino® UNO R3 is the perfect board to get familiar with electronics and coding. This versatile development board is equipped with the well-known ATmega328P and the ATMega 16U2 Processor.

This board will give you a great first experience within the world of Arduino.

Target areas:

Maker, introduction, industries

Features

- **ATMega328P** Processor
  - **Memory**
    - AVR CPU at up to 16 MHz
    - 32 kB Flash
    - 2 kB SRAM
    - 1 kB EEPROM
  - **Security**
    - Power On Reset (POR)
    - Brown Out Detection (BOD)
  - **Peripherals**
    - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
    - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
    - 1x USART with fractional baud rate generator and start-of-frame detection
    - 1x controller/peripheral Serial Peripheral Interface (SPI)
    - 1x Dual mode controller/peripheral I2C
    - 1x Analog Comparator (AC) with a scalable reference input
    - Watchdog Timer with separate on-chip oscillator
    - Six PWM channels
    - Interrupt and wake-up on pin change
  - **ATMega16U2 Processor**
    - 8-bit AVR® RISC-based microcontroller
  - **Memory**
    - 16 kB ISP Flash
    - 512B EEPROM
    - 512B SRAM
    - debugWIRE interface for on-chip debugging and programming
  - **Power**
    - 2.7-5.5 volts

CONTENTS

1 The Board

1.1 Application Examples

The UNO board is the flagship product of Arduino. Regardless if you are new to the world of electronics or will use the UNO R3 as a tool for education purposes or industry-related tasks, the UNO R3 is likely to meet your needs.

First entry to electronics: If this is your first project within coding and electronics, get started with our most used and documented board; UNO. It is equipped with the well-known ATmega328P processor, 14 digital input/output pins, 6 analog inputs, USB connections, ICSP header and reset button. This board includes everything you will need for a great first experience with Arduino.

Industry-standard development board: Using the UNO R3 board in industries, there are a range of companies using the UNO R3 board as the brain for their PLC's.

Education purposes: Although the UNO R3 board has been with us for about ten years, it is still widely used for various education purposes and scientific projects. The board's high standard and top quality performance makes it a great resource to capture real time from sensors and to trigger complex laboratory equipment to mention a few examples.

1.2 Related Products

- Arduino Starter Kit
- Arduino UNO R4 Minima
- Arduino UNO R4 WiFi
- Tinkerkit Braccio Robot

2 Ratings

2.1 Recommended Operating Conditions

Symbol	Description	Min	Max
	Conservative thermal limits for the whole board:	-40 °C (-40 °F)	85 °C (185 °F)

NOTE: In extreme temperatures, EEPROM, voltage regulator, and the crystal oscillator, might not work as expected.

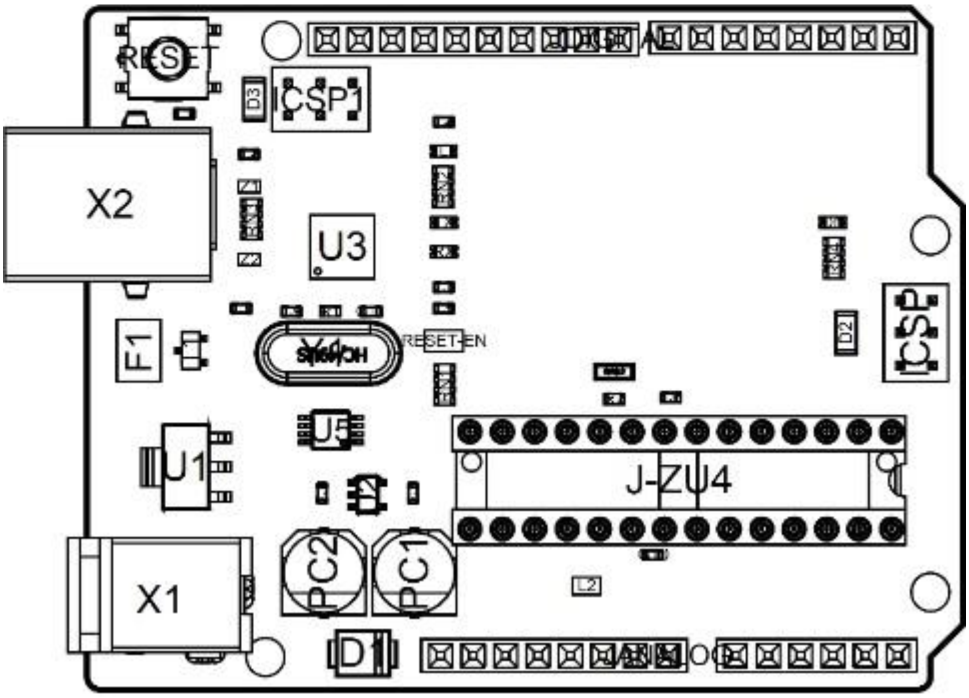
2.2 Power Consumption

Symbol	Description	Min	Typ	Max	Unit
VINMax	Maximum input voltage from VIN pad	6	-	20	V
VUSBMax	Maximum input voltage from USB connector		-	5.5	V
PMax	Maximum Power Consumption	-	-	xx	mA

3 Functional Overview

3.1 Board Topology

Top view



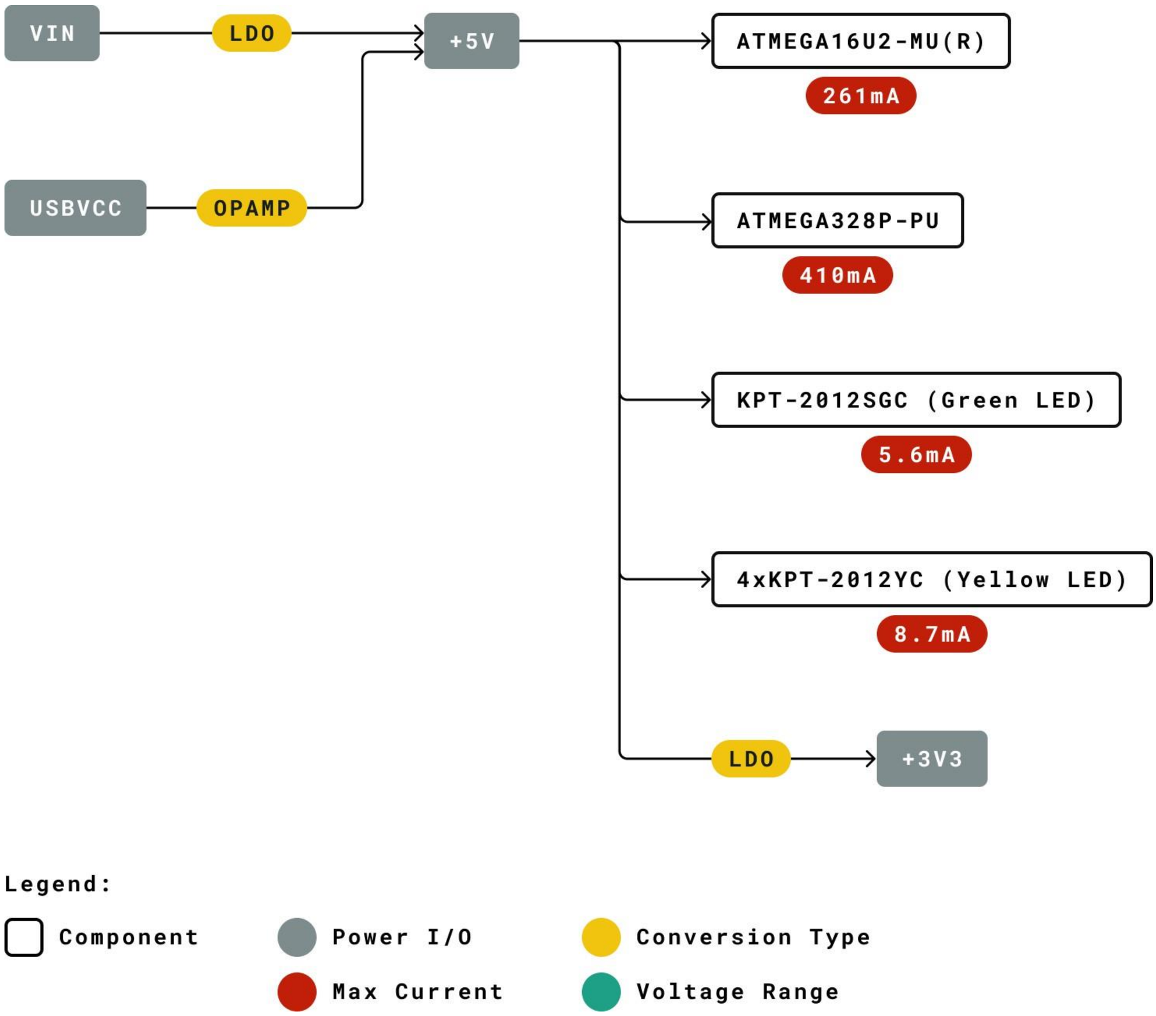
Board topology

Ref.	Description	Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3	ATMEGA16U2 Module
PC1	EEE-1EA470WP 25V SMD Capacitor	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through hole 6)
J-ZU4	ATMEGA328P Module	ICSP1	Pin header connector (through hole 6)
Y1	ECS-160-20-4X-DU Oscillator		

3.2 Processor

The Main Processor is a ATmega328P running at up to 20 MHz. Most of its pins are connected to the external headers, however some are reserved for internal communication with the USB Bridge coprocessor.

3.3 Power Tree



Power tree

4 Board Operation

4.1 Getting Started - IDE

If you want to program your UNO R3 while offline you need to install the Arduino Desktop IDE [1] To connect the UNO R3 to your computer, you'll need a USB-B cable. This also provides power to the board, as indicated by the LED.

4.2 Getting Started - Arduino Cloud Editor

All Arduino boards, including this one, work out-of-the-box on the Arduino Cloud Editor [2], by just installing a simple plugin.

The Arduino Cloud Editor is hosted online, therefore it will always be up-to-date with the latest features and support for all boards. Follow **[3]** to start coding on the browser and upload your sketches onto your board.

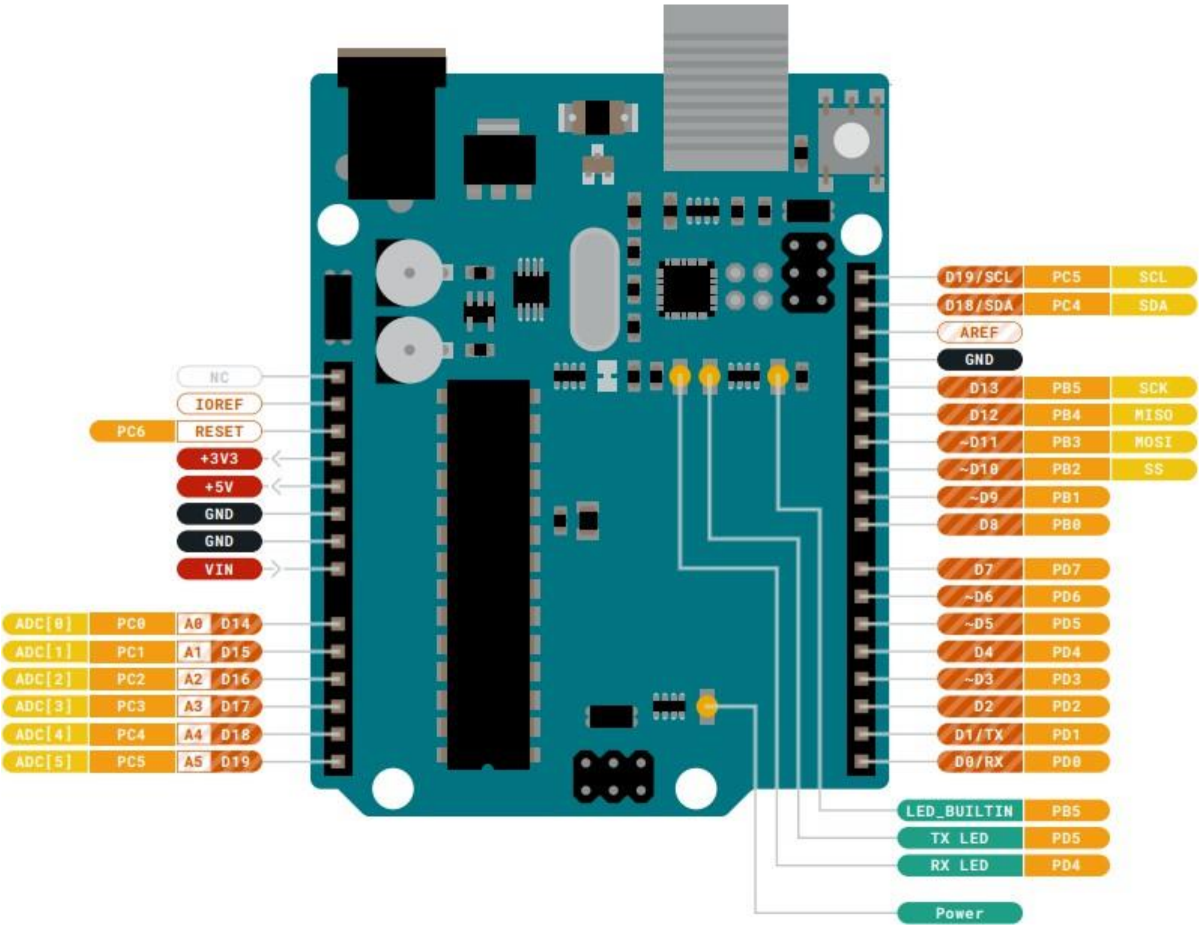
4.3 Sample Sketches

Sample sketches for the UNO R3 can be found either in the "Examples" menu in the Arduino IDE or in the "Documentation" section of the Arduino website [4].

4.4 Online Resources

Now that you have gone through the basics of what you can do with the board you can explore the endless possibilities it provides by checking exciting projects on Arduino Project Hub [5], the Arduino Library Reference [6] and the online Arduino store [7] where you will be able to complement your board with sensors, actuators and more.

5 Connector Pinouts



Pinout

5.1 JANALOG

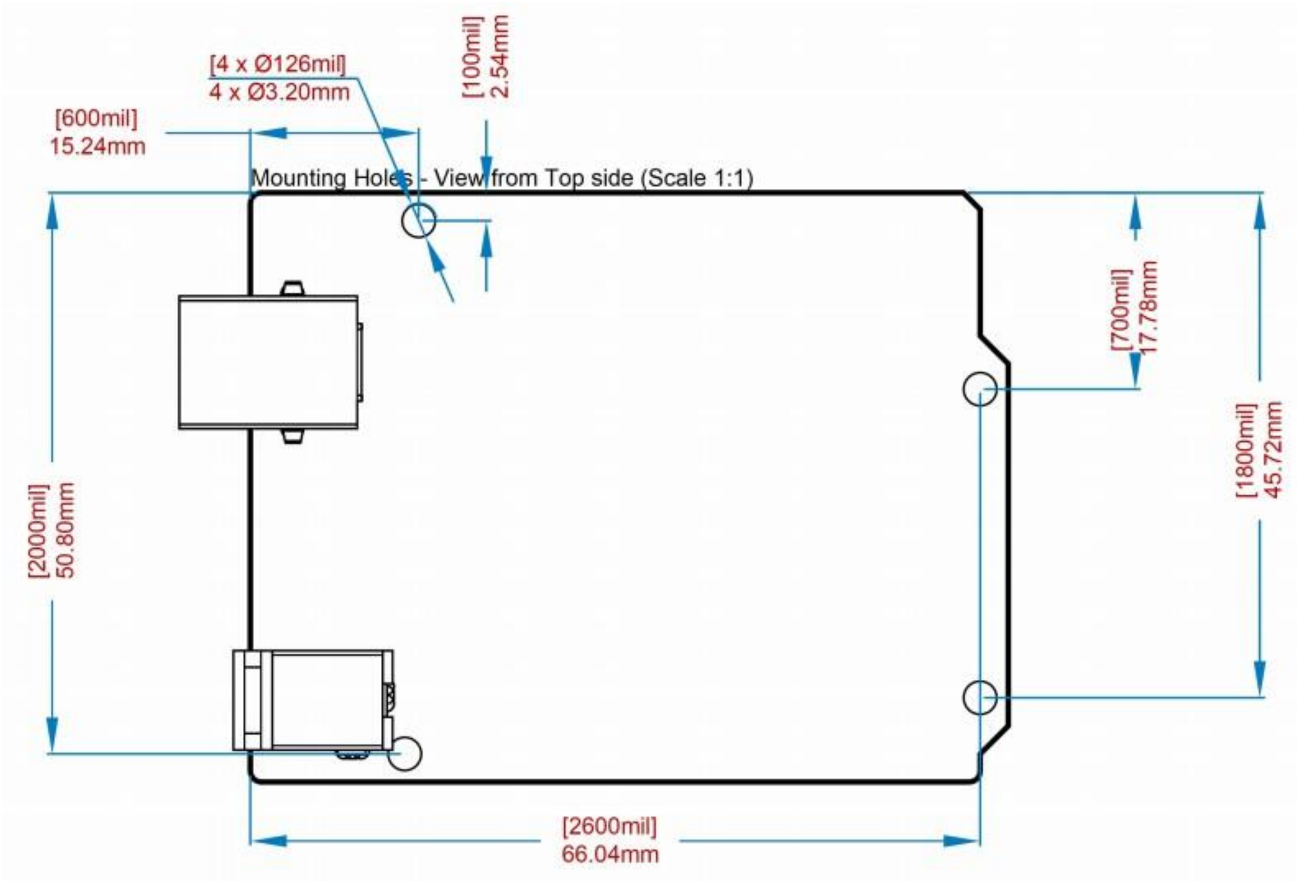
Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

5.3 Mechanical Information

5.4 Board Outline & Mounting Holes



Board outline

6 Certifications

6.1 Declaration of Conformity CE DoC (EU)

We declare under our sole responsibility that the products above are in conformity with the essential requirements of the following EU Directives and therefore qualify for free movement within markets comprising the European Union (EU) and European Economic Area (EEA).

ROHS 2 Directive 2011/65/EU	
Conforms to:	EN50581:2012
Directive 2014/35/EU. (LVD)	
Conforms to:	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
Directive 2004/40/EC & 2008/46/EC & 2013/35/EU, EMF	
Conforms to:	EN 62311:2008

6.2 Declaration of Conformity to EU RoHS & REACH 211 01/19/2021

Arduino boards are in compliance with RoHS 2 Directive 2011/65/EU of the European Parliament and RoHS 3 Directive 2015/863/EU of the Council of 4 June 2015 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Substance	Maximum limit (ppm)
Lead (Pb)	1000
Cadmium (Cd)	100
Mercury (Hg)	1000
Hexavalent Chromium (Cr6+)	1000
Poly Brominated Biphenyls (PBB)	1000
Poly Brominated Diphenyl ethers (PBDE)	1000
Bis(2-Ethylhexyl} phthalate (DEHP)	1000
Benzyl butyl phthalate (BBP)	1000
Dibutyl phthalate (DBP)	1000
Diisobutyl phthalate (DIBP)	1000

Exemptions: No exemptions are claimed.

Arduino Boards are fully compliant with the related requirements of European Union Regulation (EC) 1907 /2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). We declare none of the SVHCs (https://echa.europa.eu/web/guest/candidate-list-table), the Candidate List of Substances of Very High Concern for authorization currently released by ECHA, is present in all products (and also package) in quantities totaling in a concentration equal or above 0.1%. To the best of our knowledge, we also declare that our products do not contain any of the substances listed on the "Authorization List" (Annex XIV of the REACH regulations) and Substances of Very High Concern (SVHC) in any significant amounts as specified by the Annex XVII of Candidate list published by ECHA (European Chemical Agency) 1907 /2006/EC.

6.3 Conflict Minerals Declaration

As a global supplier of electronic and electrical components, Arduino is aware of our obligations with regards to laws and regulations regarding Conflict Minerals, specifically the Dodd-Frank Wall Street Reform and Consumer Protection Act, Section 1502. Arduino does not directly source or process conflict minerals such as Tin, Tantalum, Tungsten, or Gold. Conflict minerals are contained in our products in the form of solder, or as a component in metal alloys. As part of our reasonable due diligence Arduino has contacted component suppliers within our supply chain to verify their continued compliance with the regulations. Based on the information received thus far we declare that our products contain Conflict Minerals sourced from conflict-free areas.

7 FCC Caution

Any Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference

(2) this device must accept any interference received, including interference that may cause undesired operation.

FCC RF Radiation Exposure Statement:

1. This Transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
2. This equipment complies with RF radiation exposure limits set forth for an uncontrolled environment.
3. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

English: User manuals for license-exempt radio apparatus shall contain the following or equivalent notice in a conspicuous location in the user manual or alternatively on the device or both. This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:

(1) this device may not cause interference

(2) this device must accept any interference, including interference that may cause undesired operation of the device.

French: Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

(1) l' appareil nedoit pas produire de brouillage

(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC SAR Warning:

English This equipment should be installed and operated with minimum distance 20 cm between the radiator and your body.

French: Lors de l' installation et de l' exploitation de ce dispositif, la distance entre le radiateur et le corps est d 'au moins 20 cm.

Important: The operating temperature of the EUT can't exceed 85℃ and shouldn't be lower than -40℃.

Hereby, Arduino S.r.l. declares that this product is in compliance with essential requirements and other relevant provisions of Directive 2014/53/EU. This product is allowed to be used in all EU member states.

8 Company Information

Company name	Arduino S.r.l
Company Address	Via Andrea Appiani 25 20900 MONZA Italy

9 Reference Documentation

Reference	Link
Arduino IDE (Desktop)	https://www.arduino.cc/en/Main/Software
Arduino Cloud Editor	https://create.arduino.cc/editor
Arduino Cloud Editor - Getting Started	https://docs.arduino.cc/arduino-cloud/guides/editor/
Arduino Website	https://www.arduino.cc/
Arduino Project Hub	https://create.arduino.cc/projecthub?by=part&part_id=11332&sort=trending
Library Reference	https://www.arduino.cc/reference/en/
Arduino Store	https://store.arduino.cc/

10 Revision History

Date	Revision	Changes
25/04/2024	3	Updated link to new Cloud Editor
26/07/2023	2	General Update
06/2021	1	Datasheet release

中文 (ZH)

描述

Arduino UNO R3 是熟悉电子技术和编码的完美开发板。这款多功能开发板配备了著名的 ATmega328P 和 ATMega 16U2处理器。该开发板将为您带来 Arduino 世界绝佳的初次体验。

目标领域:

创客、介绍、工业领域

特点

- **ATMega328P** 处理器
  - 内存
    - AVR CPU 频率高达 16 MHz
    - 32KB 闪存
    - 2KB SRAM
    - 1KB EEPROM
  - 安全性
    - 上电复位 (POR)
    - 欠压检测 (BOD)
  - 外设
    - 2x 8 位定时器/计数器，带专用周期寄存器和比较通道
    - 1x 16 位定时器/计数器，带专用周期寄存器、输入捕获和比较通道
    - 1x USART，带分数波特率发生器和起始帧信号检测功能
    - 1x 控制器/外设串行外设接口 (SPI)
    - 1x 双模控制器/外设 I2C
    - 1 个模拟比较器
    - (AC)，带可扩展参考输入看门狗定时器，带独立的片上振荡器
    - 6 通道 PWM
    - 引脚变化时的中断和唤醒
  - **ATMega16U2** 处理器
    - 基于 AVR® RISC 的 8 位微控制器
  - 内存
    - 16 KB ISP 闪存
    - 512B EEPROM
    - 512B SRAM

    - 用于片上调试和编程的 debugWIRE 接口
- 电源
    - 2.7-5.5 伏特

目录

11 电路板简介

11.1 应用示例

UNO 电路板是 Arduino 的旗舰产品。无论您是初次接触电路板产品，还是将 UNO 用作教育或工业相关任务的工具，UNO都能满足您的需求。

初次接触电子技术**:** 如果这是您第一次参与编码和电子技术项目，那么就从我们最常用、记录最多的电路板 Arduino UNO开始吧。它配备了著名的 ATmega328P 处理器、14 个数字输入/输出引脚、6 个模拟输入、USB 连接、ICSP 接头和复位按钮。该电路板包含了您获得良好的 Arduino 初次体验所需的一切。

** 行业标准开发板:** 在工业领域使用 Arduino UNO R3 开发板，有许多公司使用 UNO 开发板作为其 PLC 的大脑。

教育用途**:** 尽管我们推出 UNO R3 电路板已有大约十年之久，但它仍被广泛用于各种教育用途和科学项目。该电路板的高标准和一流性能使其成为从传感器采集实时数据和触发复杂实验室设备等各种应用场合的绝佳资源。

11.2 相关产品

- Starter Kit
- Arduino UNO R4 Minima
- Arduino UNO R4 WiFi
- Tinkerkit Braccio Robot

12 额定值

12.1 建议运行条件

符号	描述	最小值	最大值
	整个电路板的保守温度极限值：	-40 °C (-40°F)	85 °C (185°F)

注意： 在极端温度下，EEPROM、电压调节器和晶体振荡器可能无法正常工作。

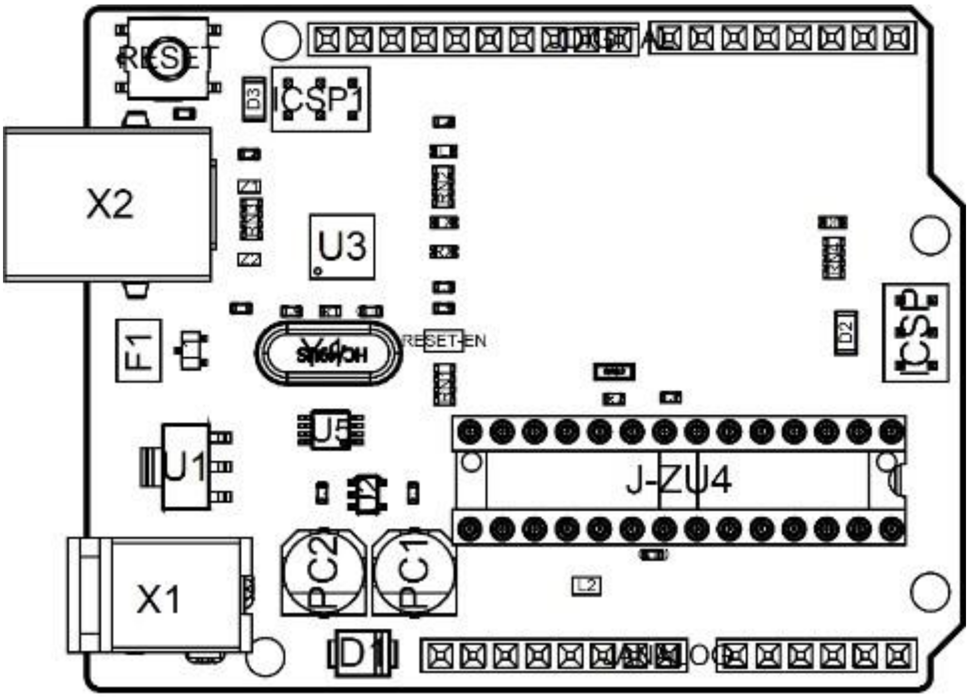
12.2 功耗

符号	描述	最小值	典型值	最大值	单位
VINMax	来自 VIN 焊盘的最大输入电压	6	-	20	V
VUSBMax	来自 USB 连接器的最大输入电压		-	5.5	V
PMax	最大功耗	-	-	xx	mA

13 功能概述

13.1 电路板拓扑结构

俯视图



电路板拓扑结构

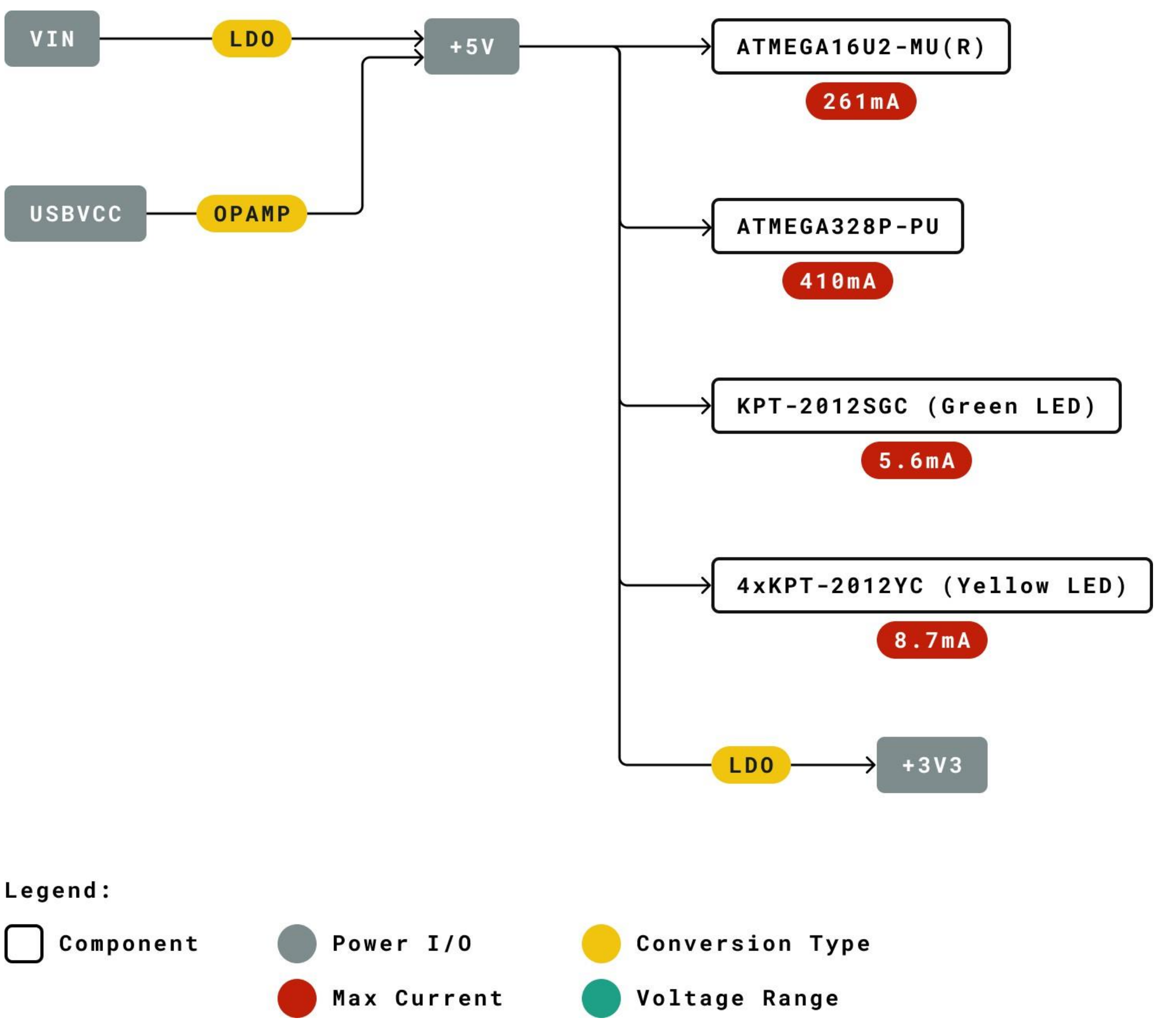
编号	描述	编号	描述
X1	电源插孔 2.1x5.5 毫米	U1	SPX1117M3-L-5 调节器

编号	描述	编号	描述
X2	USB B 连接器	U3	ATMEGA16U2 模块
PC1	EEE-1EA470WP 25V SMD 电容器	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD 电容器	F1	片式电容器，高密度
D1	CGRA4007-G 整流器	ICSP	引脚接头连接器（通过 6 号孔）
J-ZU4	ATMEGA328P 模块	ICSP1	引脚接头连接器（通过 6 号孔）
Y1	ECS-160-20-4X-DU 振荡器		

13.2 处理器

主处理器是 ATmega328P，运行频率高达 20 MHz。它的大部分引脚都与外部接头相连，但也有一些引脚用于与 USB 桥协处理器进行内部通信。

13.3 电源树



电源树

14 电路板操作

14.1 入门指南 - IDE

如需在离线状态下对 Arduino UNO R3 进行编程，则需要安装 Arduino Desktop IDE [1] 若要将 Arduino UNO 连接到计算机，需要使用 USB-B 电缆。如 LED 指示灯所示，该电缆还可以为电路板供电。

14.2 入门指南 - Arduino Cloud Editor

包括本电路板在内的所有 Arduino 电路板，都可以在 Arduino Cloud Editor [2]

上开箱即用，只需安装一个简单的插件即可。

Arduino Cloud Editor
是在线托管的，因此它将始终提供最新功能并支持所有电路板。接下来**[3]**开始在浏览器上编码并将程序上传到您的电路板上。

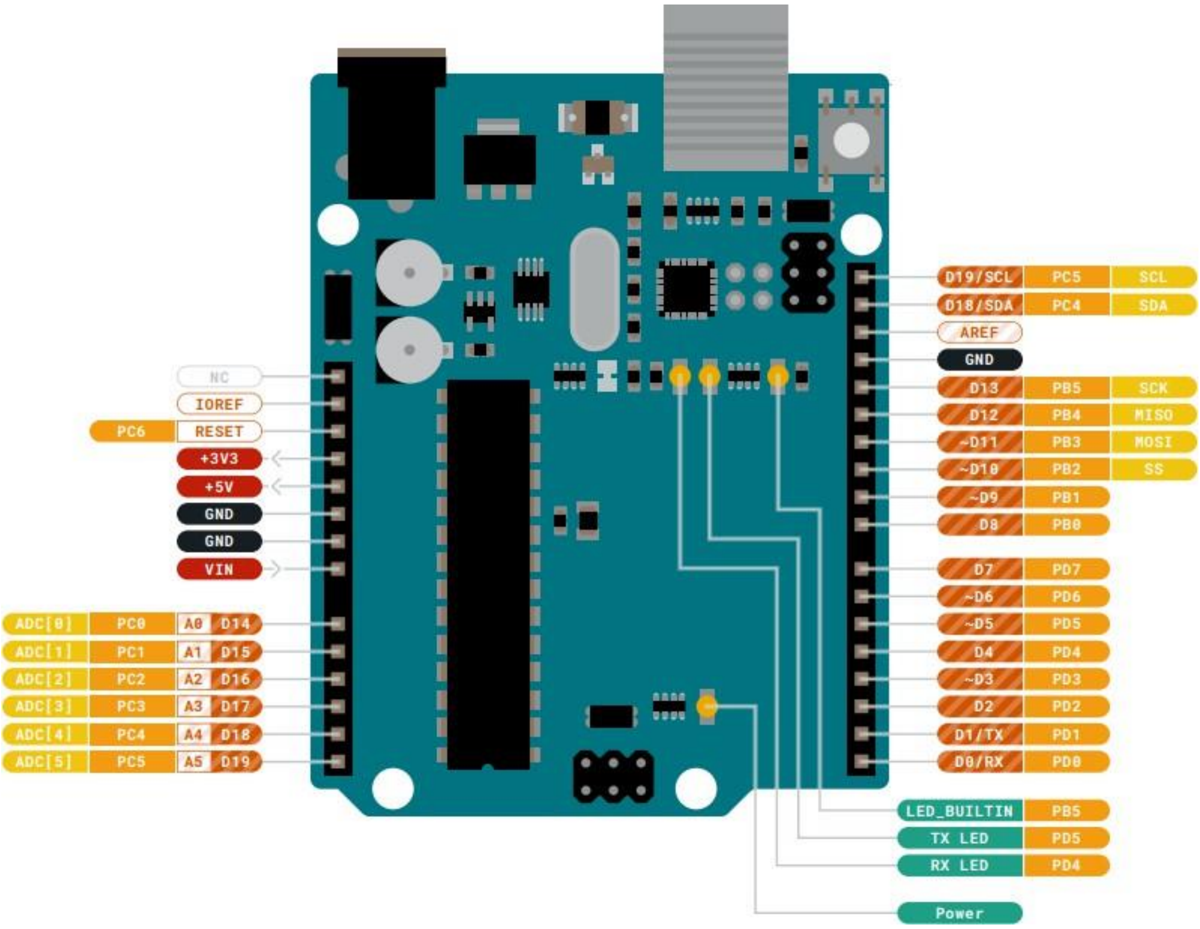
14.3 示例程序

Arduino UNO R3 的示例程序可以在 Arduino IDE 的“示例”菜单或 Arduino 网站 [4] 的“文档”部分找到

14.4 在线资源

现在，您已经了解该电路板的基本功能，就可以通过查看 Arduino Project Hub **[5]**、Arduino Library Reference **[6]**以及在线 Arduino 商店 **[7]**上的精彩项目来探索它所提供的无限可能性；在这些项目中，您可以为电路板配备传感器、执行器等。

15 连接器引脚布局



布局

15.1 JANALOG

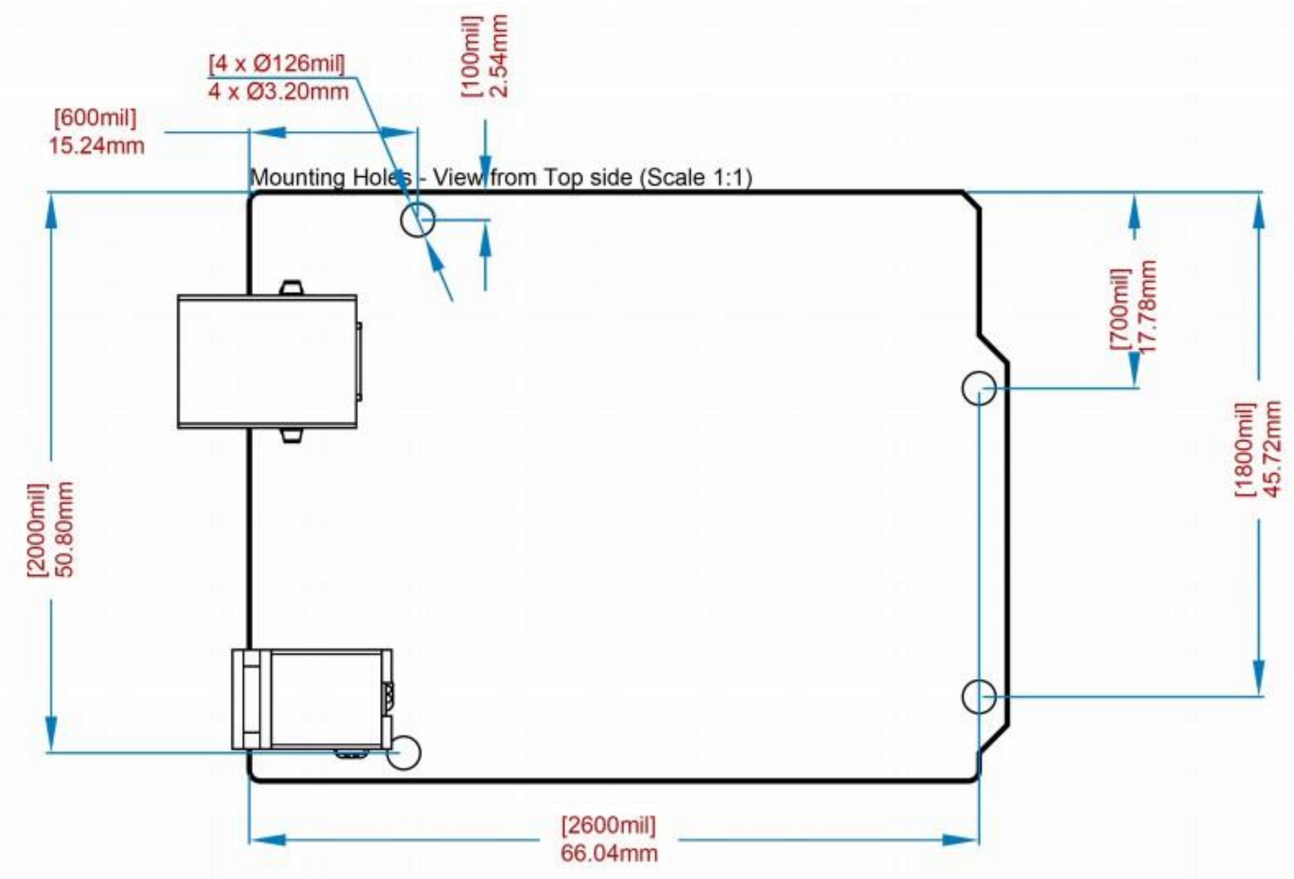
引脚	功能	类型	描述
1	NC	NC	未连接
2	IOREF	IOREF	数字逻辑参考电压 V - 连接至 5V
3	复位	复位	复位
4	+3V3	电源	+3V3 电源轨
5	+5V	电源	+5V 电源轨
6	GND	电源	接地
7	GND	电源	接地
8	VIN	电源	电压输入
9	A0	模拟/GPIO	模拟输入0 / GPIO
10	A1	模拟/GPIO	模拟输入1 / GPIO
11	A2	模拟/GPIO	模拟输入2 / GPIO
12	A3	模拟/GPIO	模拟输入3 / GPIO
13	A4/SDA	模拟输入/I2C	模拟输入 4/I2C 数据线
14	A5/SCL	模拟输入/I2C	模拟输入 5/I2C 时钟线

15.2 JDIGITAL

引脚	功能	类型	描述
1	D0	数字引脚/GPIO	数字引脚 0/GPIO
2	D1	数字引脚/GPIO	数字引脚 1/GPIO
3	D2	数字引脚/GPIO	数字引脚 2/GPIO
4	D3	数字引脚/GPIO	数字引脚 3/GPIO
5	D4	数字引脚/GPIO	数字引脚 4/GPIO
6	D5	数字引脚/GPIO	数字引脚 5/GPIO
7	D6	数字引脚/GPIO	数字引脚 6/GPIO
8	D7	数字引脚/GPIO	数字引脚 7/GPIO
9	D8	数字引脚/GPIO	数字引脚 8/GPIO
10	D9	数字引脚/GPIO	数字引脚 9/GPIO
11	SS	数字	SPI 芯片选择
12	MOSI	数字	SPI1 主输出副输入
13	MISO	数字	SPI 主输入副输出
14	SCK	数字	SPI 串行时钟输出
15	GND	电源	接地
16	AREF	数字	模拟参考电压
17	A4/SD4	数字	模拟输入 4/I2C 数据线（重复）
18	A5/SD5	数字	模拟输入 5/I2C 时钟线（重复）

15.3 机械层信息

15.4 电路板外形图和安装孔



电路板外形图

16 认证

16.1 符合性声明 CE DoC（欧盟）

我们在此郑重声明，上述产品符合以下欧盟指令的基本要求，因此有资格在包括欧盟（EU）和欧洲经济区（EEA）在内的市场内自由流通。

RoHS 2 指令 2011/65/EU	
符合：	EN50581:2012
指令 **2014/35/EU**。 **(LVD)**	
符合：	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
指令 **2004/40/EC & 2008/46/EC & 2013/35/EU, EMF**	
符合：	EN 62311:2008

16.2 声明符合欧盟 RoHS 和 REACH 211 01/19/2021

Arduino 电路板符合欧洲议会关于限制在电子电气设备中使用某些有害物质的 RoHS 2 指令 2011/65/EU 和欧盟理事会于 2015 年 6 月 4 日颁布的关于限制在电子电气设备中使用某些有害物质的 RoHS 3 指令 2015/863/EU。

物质	最大限值 **(ppm)**
铅 (Pb)	1000
镉 (Cd)	100
汞 (Hg)	1000
六价铬（Cr6+）	1000
多溴联苯（PBB）	1000
多溴联苯醚（PBDE）	1000
邻苯二甲酸二(2-乙基己)酯 (DEHP)	1000
邻苯二甲酸丁苄酯 (BBP)	1000
邻苯二甲酸二丁酯（DBP）	1000
邻苯二甲酸二异丁酯（DIBP）	1000

豁免：未申请任何豁免。

Arduino 电路板完全符合欧盟法规 (EC) 1907/2006 中关于化学品注册、评估、许可和限制 (REACH) 的相关要求。我们声明，所有产品（包括包装）中的 SVHC (https://echa.europa.eu/web/guest/candidate-list-table),（欧洲化学品管理局目前发布的《高度关注物质候选授权清单》）含量总浓度均未超过 0.1%。据我们所知，我们还声明，我们的产品不含 ECHA（欧洲化学品管理局）1907/2006/EC 公布的候选清单附件 XVII 中规定的“授权清单”（ REACH 法规附件 XIV）和高度关注物质 (SVHC) 所列的任何物质。

16.3 冲突矿产声明

作为电子和电气元件的全球供应商，Arduino 意识到我们有义务遵守有关冲突矿产的法律法规，特别是《多德-弗兰克华尔街改革与消费者保护法案》第 1502 条。Arduino 不直接采购或加工锡、钽、钨或金等冲突矿物。冲突矿物以焊料的形式或作为金属合金的组成部分存在于我们的产品中。作为我们合理尽职调查的一部分，Arduino 已联系供应链中的元件供应商，以核实他们是否始终遵守法规的相关规定。根据迄今收到的信息，我们声明我们的产品中含有来自非冲突地区的冲突矿物。

17 FCC 警告

任何未经合规性负责方明确批准的更改或修改都可能导致用戶无权操作设备。

本设备符合 FCC 规则第 15 部分的规定。操作须满足以下两个条件：

(1) 此设备不会造成有害干扰

(2) 此设备必须接受接收到的任何干扰，包括可能导致不良操作的干扰。

FCC 射频辐射暴露声明**:**

1. 此发射器不得与任何其他天线或发射器放置在同一位置或同时运行。
2. 此设备符合为非受控环境规定的射频辐射暴露限值。
3. 安装和操作本设备时，辐射源与您的身体之间至少应保持 20 厘米的距离。

English: User manuals for license-exempt radio apparatus shall contain the following or equivalent notice in a conspicuous location in the user manual or alternatively on the device or both. This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:

(1) this device may not cause interference

(2) this device must accept any interference, including interference that may cause undesired operation of the device.

French: Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

(1) l' appareil nedoit pas produire de brouillage

(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC SAR警告**:**

English This equipment should be installed and operated with a minimum distance of 20 cm between the radiator and your body.

French: Lors de l' installation et de l' exploitation de ce dispositif, la distance entre le radiateur et le corps est d 'au moins 20 cm.

重要提示： EUT 的工作温度不能超过 85°C，也不能低于 -40°C。

Arduino S.r.l. 特此声明，本产品符合 2014/53/EU 指令的基本要求和其他相关规定。本产品允许在所有欧盟成员国使用。

18 公司信息

公司名称	**Arduino S.r.l**
公司地址	Via Andrea Appiani 25 20900 MONZA Italy

19 参考资料

参考资料	链接
Arduino IDE (Desktop)	https://www.arduino.cc/en/Main/Software
Arduino IDE (Cloud)	https://create.arduino.cc/editor
Cloud IDE 入门指南	https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editor-4b3e4a
Arduino 网站	https://www.arduino.cc/
Arduino Project Hub	https://create.arduino.cc/projecthub?by=part&part_id=11332&sort=trending
库参考	https://www.arduino.cc/reference/en/
在线商店	https://store.arduino.cc/

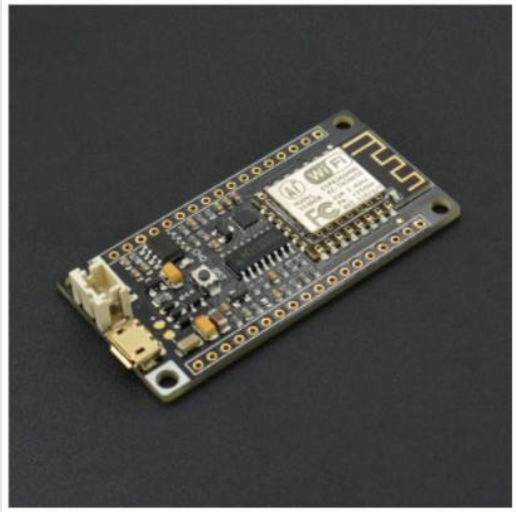
20 修订记录

日期	版次	变更
2023/07/26	2	一般更新
2021/06	1	数据表发布

FireBeetle ESP8266 IOT Microcontroller SKU: DFR0489

(http://www.dfrobot.com/) **Home** (https://www.dfrobot.com/) > **Arduino** (https://www.dfrobot.com/index.php?route=product/category&path=35) > **Microcontroller** (https://www.dfrobot.com/index.php?route=product/category&path=35_104)

Contents



(https://www.dfrobot.com/product-1634.html)
FireBeetle ESP8266 IOT Microcontroller (https://www.dfrobot.com/product-1634.html)

Introduction

DFRobot FireBeetle is a series of low-power-consumption development hardware designed for Internet of Things (IoT). Firebeetle ESP8266 is a development board integrated with IoT WiFi, TCP/IP, 32-bit MCU, 10-bit ADC and multiple interfaces such as HSPI, UART, PWM, I2C and I2S. In DTIM10, the full power consumption to maintain WiFi connection reached to 1.2mW. Equipped with 16MB outer SPI flash memory, ESP8266 is available for programs and firmware storage.
Compatible with Arduino programming enables Firebeetle ESP8266 to lower the barrier of programming. Operator can implement Arduino programming codes directly onto ESP8266 to reduce the difficulty of operating and increase the stability of board.

(/wiki/index.php/File:Warning_yellow.png)

NOTE: There still remains some bugs to be detected and fixed by developers. In some cases some peripherals may not work perfectly by embedding Arduino sample codes in ESP8266. Much more functions implemented in Arduino are still under development and improvement. An alternative way is to change development tool such as RTOS and MicroPython towards a more operating-friendly experience in some conditions.

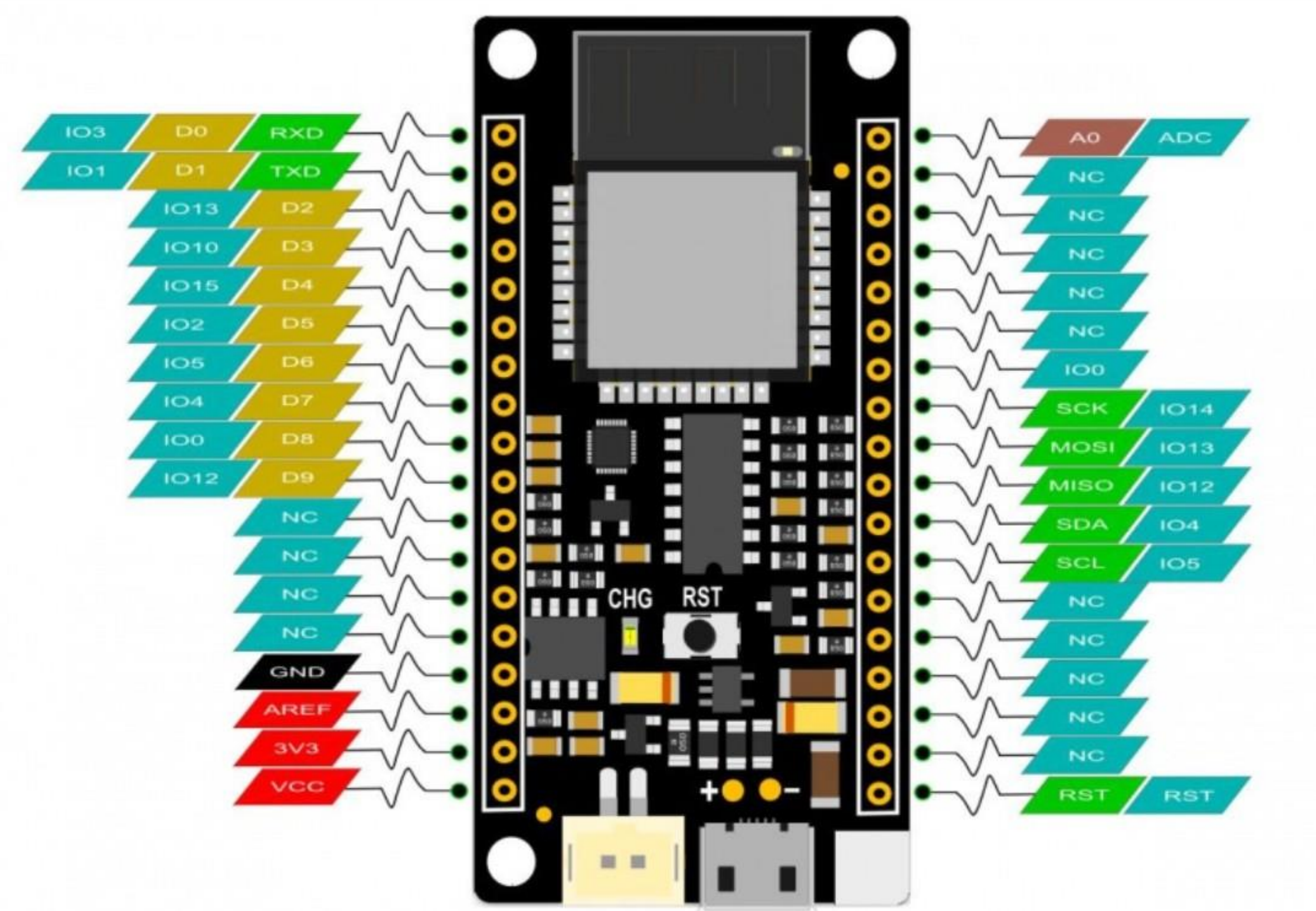
Specification

- Operating Voltage: 3.3V
- Input Voltage (limits): 3.3~5V (Lithium Battery:3.7V & USB:5V)
- Microcontroller: Tensilica L106 (32-bit MCU)
- Clock Speed: 80MHz (Maximum: 160MHz)
- SRAM：50KB
- External Flash Memory: 16MB

- DC Current in the Low-Power-Consumption: 46uA
- Average Operating Current: 80mA
- Maximum Discharging Current: 600mA (LDO-3.3 Output)
- Maximum Charging Current: 500mA
- Digital Pin x10
- Analog Pin x1
- SPI interface x1
- I2C interface x1
- IR interface x1
- I2S interface x1
- Interface: XH2.54mm Pin (No soldering default)
- In Combination of Wi-Fi MAC/ BB/RF/PA/LNA
- WiFi: IEEE802.11 b/g/n (2.4 GHz~2.5 GHz), not support 5GHz WiFi
- Operating Temperature: -10℃~+55℃
- Dimension: 58 × 29(mm)
- Weight: 24g

Board Overview

FireBeetle Board - ESP8266 is not only compatible with ESP8266 PinMap, but also make a special compatible with Arduino IDE PinMap. Dx (x=0,1,2,3...9)



(/wiki/index.php/File:DFR0489_pinout.jpg)

Fig1: FireBeetle Board-ESP8266 PinOUT

- **CHG** Blink = not connect battery; Light on = Charging; Light off = Charge complete

(/wiki/index.php/File:Warning_yellow.png) Note: NC = Empty; VCC = VCC (5V under USB power supply, Around 3.7V under 3.7V lipo battery.power supply)

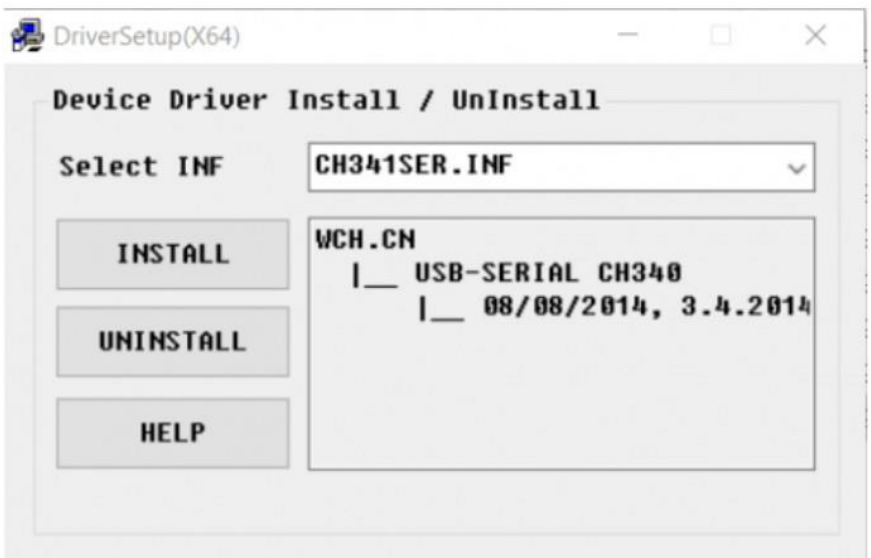
Tutorial

In this tutorial, we'll show you some basic operation with FireBeetle-ESP8266 Microcontroller.

Requirements

- **Hardware**
  - FireBeetle ESP8266 IOT Microcontroller x 1
  - Micro USB Cable x1
- **Software**
  - Arduino IDE (newest), Click to Download Arduino IDE from Arduino® (https://www.arduino.cc/en/Main/Software%7C)
  - Download CH340 FireBeetle ESP8266 Window Driver (https://github.com/Arduinolibrary/DFRobot_FireBeetle_ESP8266_DFR0489/raw/master/CH340%20Driver.zip)

Note: CH340 driver is free to install for most of Windows OS, if you find there is no COM Port in Device Manager, please download the driver and install it.

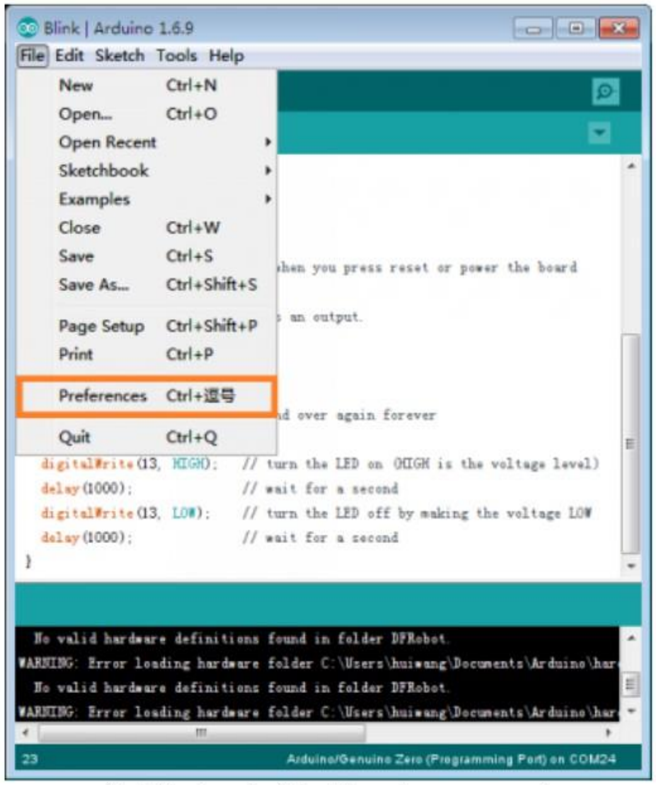


(/wiki/index.php/File:CH340_Driver_install.png)

Setup Arduino IDE Development Environment

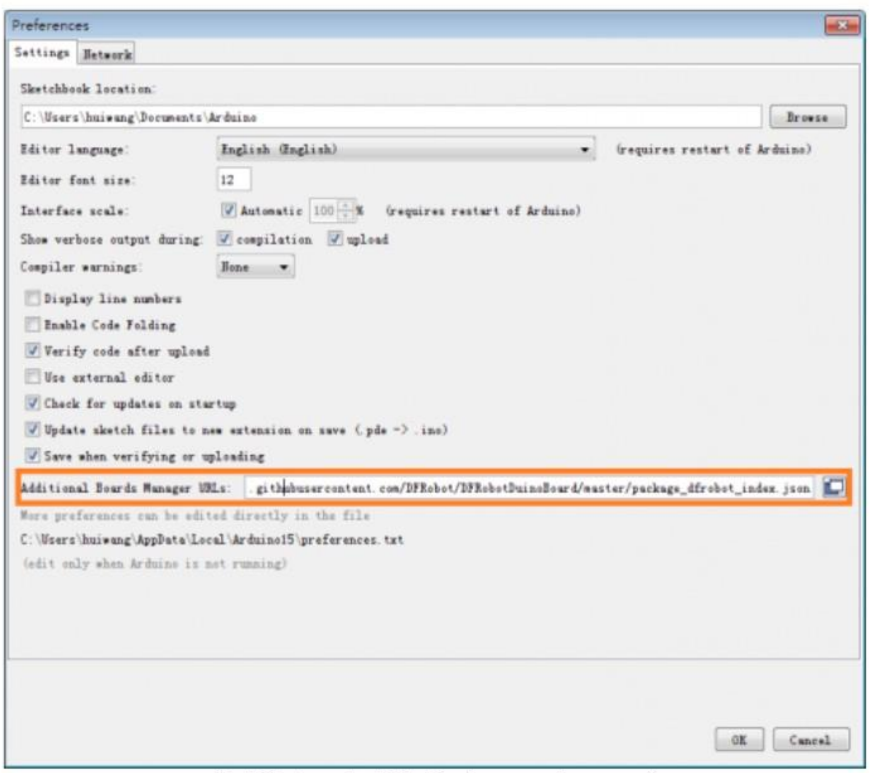
- Plug FireBeetle to your computer, install the driver manually.
- Add FireBeetle Board URL to Arduino IDE
- Open Arduino IDE, **File->Preferences**, find **Additional Boards Manager URLs**, copy the below link, and paste in the blank.

https://raw.githubusercontent.com/DFRobot/FireBeetle-ESP8266/master/package_firebeetle8266_index.json (https://raw.githubusercontent.com/DFRobot/FireBeetle-ESP8266/master/package_firebeetle8266_index.json)



(/wiki/index.php/File:Filepreferences.png)

File->Preferences

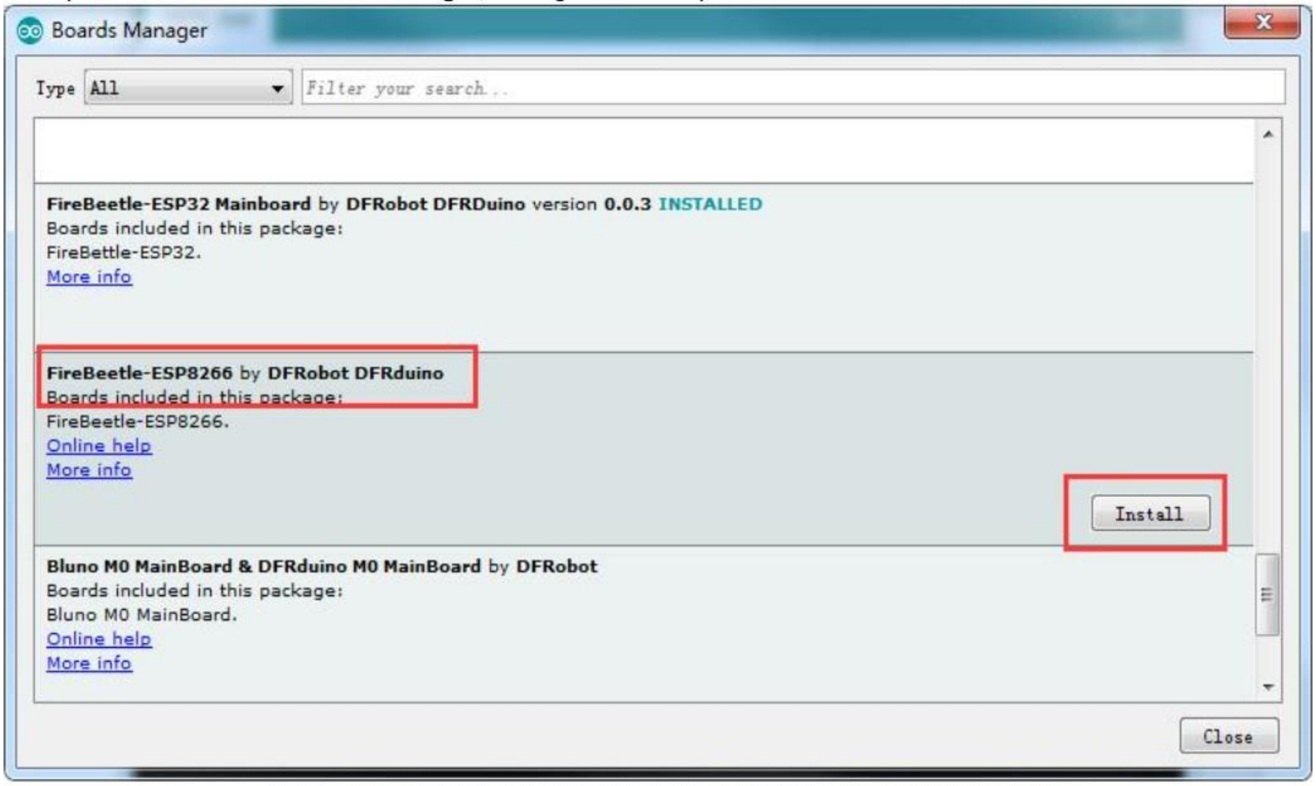


(/wiki/index.php/File:Preferencesjson.png)

paste url here

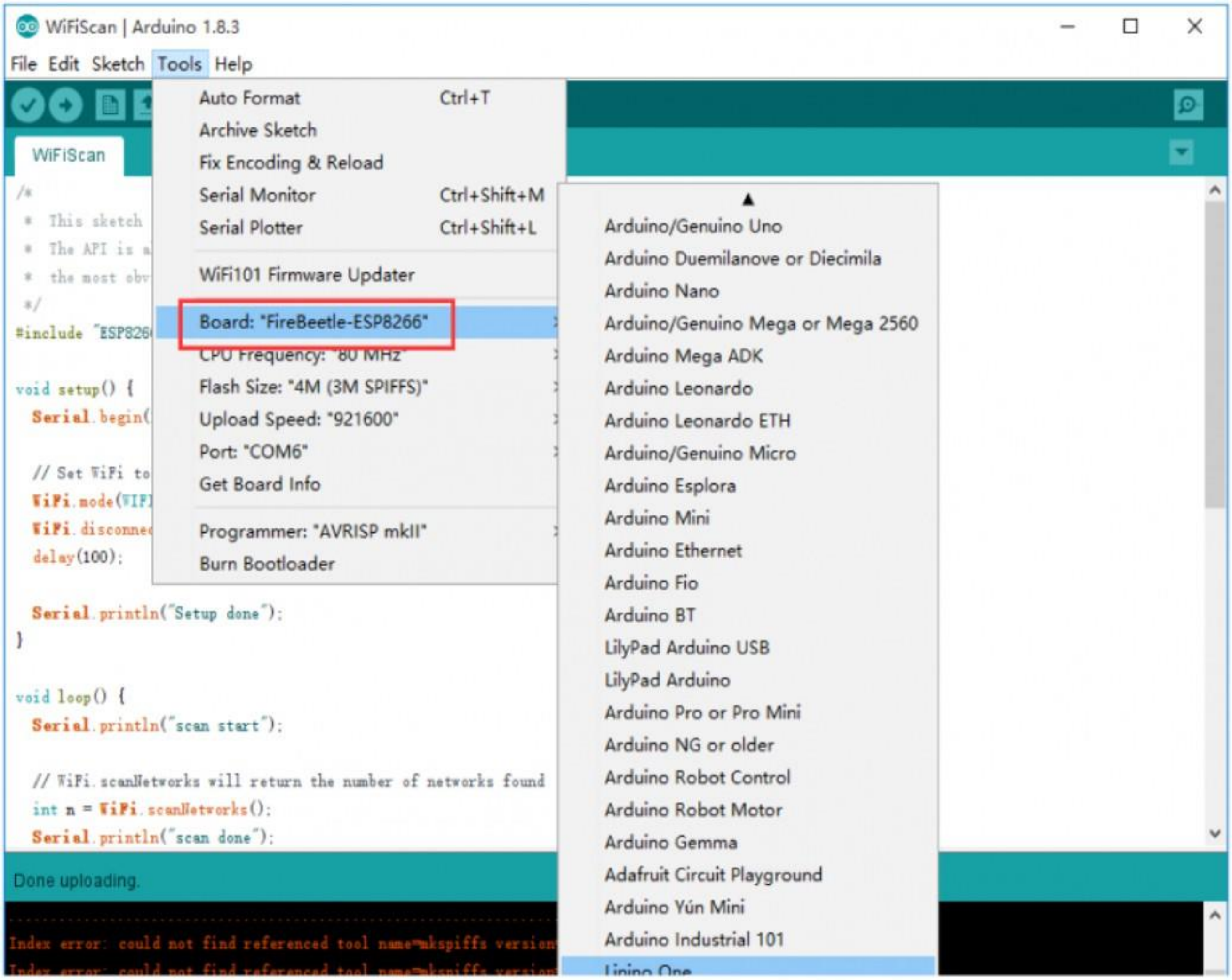
- Click **OK**

- Open **Tools->Board->Boards Manager**, waiting automatic update. You'll find **FireBeetle-ESP8266**



(/wiki/index.php/File:DFR0489_FireBeetle_ESP8266_BoardManager.jpg)

Now, the development environment has been installed, you can use it like a normal Arduino board.



(/wiki/index.php/File:DFR0489_IDE_DFRduino_FirBeetle_ESP8266.png)

Sample Code - **Blink**

The default LED for FireBeetle Board-ESP8266 is D5 (IO2), input following code:

```
// GPIO 2 (D5) has a LED_BLINK attached to it. Give it a name:
int LED_BLINK = 2;
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BLINK, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BLINK, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);                       // wait for a second
  digitalWrite(LED_BLINK, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);                       // wait for a second
}
```

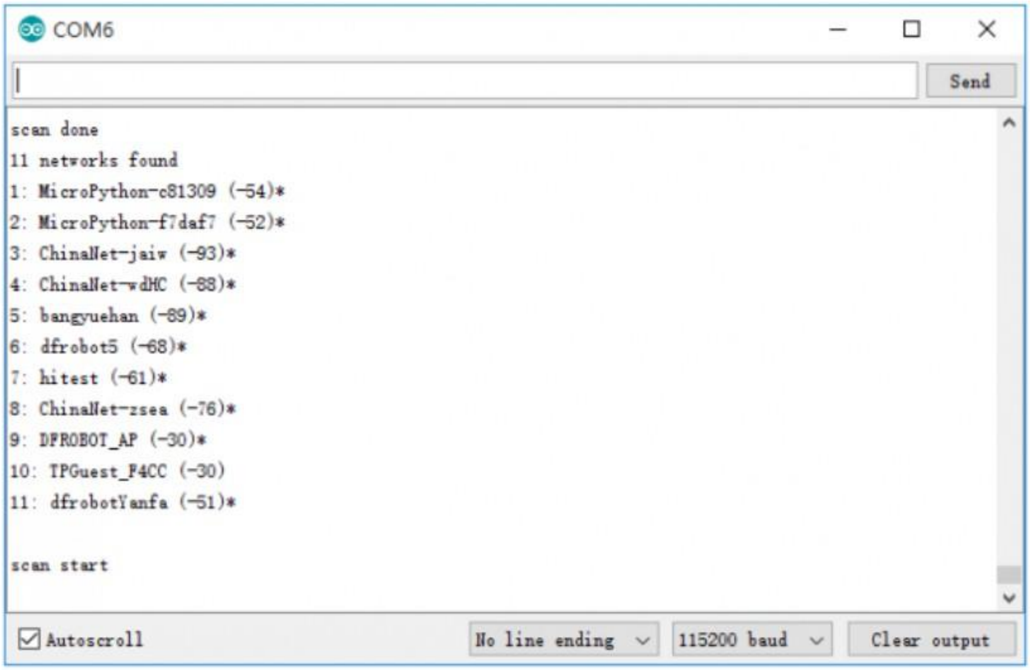
Note: ESP8266 has different pinmap in different development environment, For example: the LED connects IO2, which maps **D5** in Arduino IDE It is totally different mean with **2** and **D2** !

Sample Code - **Scan WiFi**

After you have installed the FireBeetle ESP8266 development environment, it will comes with a lot of sample code in Arduino IDE, you can find them in **File > Examples**. The follow sample code scans the around WiFi:

```
/*
 *  This sketch demonstrates how to scan WiFi networks.
 *  The API is almost the same as with the WiFi Shield library,
 *  the most obvious difference being the different file you need to include:
 */
#include "ESP8266WiFi.h"

void setup() {
  Serial.begin(115200);

  // Set WiFi to station mode and disconnect from an AP if it was previously connected
  WiFi.mode(WIFI_STA);
  WiFi.disconnect();
  delay(100);

  Serial.println("Setup done");
}

void loop() {
  Serial.println("scan start");

  // WiFi.scanNetworks will return the number of networks found
  int n = WiFi.scanNetworks();
  Serial.println("scan done");
  if (n == 0)
    Serial.println("no networks found");
  else
  {
    Serial.print(n);
    Serial.println(" networks found");
    for (int i = 0; i < n; ++i)
    {
      // Print SSID and RSSI for each network found
      Serial.print(i + 1);
      Serial.print(": ");
      Serial.print(WiFi.SSID(i));
      Serial.print(" (");
      Serial.print(WiFi.RSSI(i));
      Serial.print(")");
      Serial.println((WiFi.encryptionType(i) == ENC_TYPE_NONE)?" ":"*");
      delay(10);
    }
  }
  Serial.println("");

  // Wait a bit before scanning again
  delay(5000);
}
```

Open your Arduino IDE serial monitor:



(/wiki/index.php/File:DFR0489_FireBeetle_WiFi_Scan.png)

FAQ

For any questions, advice or cool ideas to share, please visit the **DFRobot Forum** (http://www.dfrobot.com/forum/).

More Documents

- Schematic (https://github.com/Arduinolibrary/DFRobot_FireBeetle_ESP8266_DFR0489/raw/master/FireBeetle%20Board-ESP8266%20Schematic.pdf)
- Dimension (https://github.com/Arduinolibrary/DFRobot_FireBeetle_ESP8266_DFR0489/raw/master/FireBeetle%20Board-ESP8266%20Dimension.pdf)
- Datasheet (https://github.com/Arduinolibrary/DFRobot_FireBeetle_ESP8266_DFR0489/raw/master/esp-wroom-02_datasheet_en.pdf)
- Hardware Design (https://github.com/Arduinolibrary/DFRobot_FireBeetle_ESP8266_DFR0489/raw/master/esp-wroom-02_pcb_design.pdf)
- Espressif Download (http://espressif.com/en/support/download/documents)

APPENDIX B

JOURNAL PAPERS

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:02/February-2025 Impact Factor- 8.187 www.irjmets.com

AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER

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DOI : https://www.doi.org/10.56726/IRJMETS68081

ABSTRACT

Fire incidents in residential, industrial, and forest environments often require rapid intervention under conditions that pose serious risks to human responders. To enhance safety and response efficiency, this paper presents **AetherResQ**, an autonomous unmanned aerial system designed to support firefighting and rescue operations through intelligent sensing, aerial surveillance, and onboard fire suppression. The proposed drone platform utilizes a Pixhawk flight controller to achieve stable autonomous navigation and waypoint-based mission execution. Flame sensors and passive infrared (PIR) sensors are integrated to detect active fire sources and human presence in real time. Continuous telemetry and command exchange with the Ground Control Station are achieved using the MAVLink communication protocol. Upon confirmation of fire detection, the system automatically activates an onboard fire extinguishing unit while maintaining flight stability. Experimental evaluations demonstrate reliable flight performance, accurate fire detection, and effective suppression in controlled environments. The proposed system highlights the potential of autonomous UAV-based solutions to reduce firefighter exposure, improve response time, and enhance operational effectiveness in emergency and disaster management scenarios.

Keywords: UAV , Firefighting drone , Autonomous systems , Artificial intelligence , Disaster management.

I. INTRODUCTION

Fire-related emergencies continue to pose a critical challenge to public safety, infrastructure protection, and environmental preservation. In densely populated urban regions, industrial zones, and forested areas, fire outbreaks can escalate rapidly due to unpredictable flame propagation, limited accessibility, and delayed situational awareness. Conventional firefighting practices depend heavily on human intervention, often requiring personnel to operate in environments characterized by extreme heat, dense smoke, toxic gases, and structural instability. These conditions significantly increase the likelihood of injury and operational failure during emergency response.

Recent advancements in unmanned aerial vehicles (UAVs), embedded electronics, and intelligent sensing technologies have opened new opportunities for improving emergency response systems. UAV platforms are capable of rapid deployment, aerial monitoring, and real-time data transmission, making them suitable for operations in hazardous or inaccessible locations. By integrating sensors, communication modules, and autonomous control algorithms, drones can assist responders by providing early fire detection, continuous surveillance, and critical information for decision-making without direct human exposure to danger.

In this context, the **AetherResQ** project focuses on the development of an AI-assisted autonomous firefighting and rescue drone that combines aerial mobility with intelligent sensing and automated suppression capabilities. The system is designed to navigate autonomously toward fire-affected regions using GPS-based waypoint control while continuously monitoring environmental conditions through onboard flame and PIR sensors. A Pixhawk flight controller ensures stable flight dynamics, whereas MAVLink-based telemetry facilitates real-time communication with a Ground Control Station for mission supervision and data analysis.

In addition to fire detection, the system supports rescue-oriented functionality by identifying human presence and transmitting location data to ground operators. An integrated fire extinguishing mechanism allows the drone to respond immediately upon detecting a fire source, thereby minimizing response delay. Through the combination of autonomous navigation, real-time sensing, and onboard actuation, the proposed system aims to enhance firefighting efficiency, reduce risks to emergency personnel, and demonstrate the applicability of intelligent UAV platforms in modern disaster management operations.

II. LITERATURE SURVEY

Recent research efforts have explored the application of unmanned aerial vehicles, Internet of Things (IoT) frameworks, and intelligent sensing techniques to improve fire detection, monitoring, and emergency response. Several studies emphasize early fire identification using distributed sensor networks, where temperature and gas sensors are integrated with wireless communication modules to provide remote alerts through cloud platforms. While such IoT-centric approaches enable wide-area surveillance at low cost, their functionality is largely limited to detection and notification, lacking autonomous navigation and active fire suppression capabilities.

UAV-based fire detection systems have gained attention due to their mobility and ability to operate in hazardous environments. Some quadcopter designs utilize infrared and PIR sensors to distinguish fire sources from human movement, improving detection reliability in indoor and cluttered settings. Although these systems demonstrate effective sensing performance, they generally rely on manual control and do not incorporate automated firefighting or rescue mechanisms, restricting their use in large-scale emergency scenarios.

Autonomous firefighting drones capable of deploying suppression agents have been investigated to address response delays in conventional firefighting. These systems typically combine thermal or optical sensors with waypoint-based navigation to approach fire zones and release extinguishing materials. Experimental results confirm the feasibility of aerial fire suppression; however, limitations such as restricted payload capacity, limited extinguishing agent volume, and reduced endurance affect long-duration operations and rescue-oriented missions.

Thermal imaging–based fire detection using UAV platforms has also been widely studied. Advanced image processing techniques applied to thermal infrared data enable accurate identification of fire hotspots, even in smoke-filled or low-visibility environments. Despite high detection accuracy, these approaches require significant onboard computational resources and increased power consumption, which can be challenging for lightweight UAV platforms intended for extended missions.

The Pixhawk flight control system has emerged as a widely adopted open-source solution for autonomous UAV operation. It supports GPS-based navigation, inertial stabilization, and modular sensor integration, making it suitable for research and real-world applications. While Pixhawk provides reliable flight control and mission execution, additional external controllers and actuators are required to support application-specific tasks such as firefighting payload control and intelligent sensing.

Communication protocols play a critical role in UAV coordination and monitoring. MAVLink has been extensively studied for its lightweight design, real-time telemetry support, and compatibility with popular ground control stations. Although communication reliability may be affected in harsh or signal-degraded environments, MAVLink remains a practical choice for real-time UAV operations in emergency response scenarios.

More recent studies have focused on multi-sensor fusion techniques combining visible cameras, infrared imaging, and environmental sensors to enhance fire detection accuracy and reduce false alarms. While such systems improve robustness, they often involve complex calibration, higher costs, and increased payload weight. Additionally, many existing solutions prioritize detection accuracy rather than integrating suppression and rescue functionalities into a unified platform.

Overall, existing research demonstrates significant progress in UAV-assisted fire detection and monitoring. However, gaps remain in developing compact, autonomous systems that combine intelligent sensing, real-time communication, fire suppression, and human detection within a single platform. The proposed AetherResQ system addresses these limitations by integrating autonomous navigation, multi-sensor fire and human detection, and onboard extinguishing capabilities to support comprehensive firefighting and rescue operations

III. HARDWARE DESCRIPTION

The AetherResQ firefighting and rescue drone is an integrated system that uses a comprehensive set of hardware components to detect fire, identify human presence, perform autonomous navigation, and carry out fire suppression operations. The system is designed to reduce human risk and improve emergency response efficiency by leveraging unmanned aerial technology, sensors, and intelligent control units.

A. Block Diagram

The block diagram illustrates the overall hardware architecture and functional flow of the AetherResQ system. It shows how sensor data from flame, PIR, and gas sensors is processed by the Arduino controller and transmitted to the Pixhawk flight controller through MAVLink telemetry. The Pixhawk manages autonomous flight, navigation, and stability, while communication with the Ground Control Station enables real-time monitoring and control. Based on detection logic, the fire extinguishing mechanism is activated using relay and solenoid valve control.

B. Components

1. **PIXHAWK FLIGHT CONTROLLER:**
• Acts as the main control unit of the UAV.
• Handles flight stabilization, altitude control, and autonomous navigation.
• Supports waypoint missions and failsafe operations.

2. **GPS MODULE:**
• Provides real-time latitude, longitude, and altitude data.
• Enables autonomous navigation and return-to-launch functionality.

3. **FLYSKY TRANSMITTER AND RECEIVER:**
• Allows manual control during testing and emergency situations.
• Acts as a safety override for autonomous operation.

4. **SAFETY SWITCH:**
• Prevents accidental arming of the drone.
• Ensures safe handling and transportation.

5. **BUZZER:**
• Provides audible alerts for system status and warnings.
• Useful in noisy and emergency environments.

6. **PIR SENSOR:**
• Detects human presence based on infrared radiation.
• Assists in identifying trapped individuals during rescue operations.

7. **FLAME SENSOR:**
• Detects infrared radiation emitted by fire sources.
• Enables early fire detection in low-visibility environments.

8. **GAS SENSOR:**
• Detects harmful gases generated during combustion.
• Enhances safety and environmental monitoring.

9. **ARDUINO UNO BOARD:**
• Processes sensor data from flame, PIR, and gas sensors.
• Controls relay and solenoid valve for fire suppression.

10. **I2C COMMUNICATION PORT:**
• Enables communication between sensors and controllers.
• Reduces wiring complexity.

11. **BRUSHLESS DC MOTORS:**
• Provide required thrust for lift and maneuverability.
• Offer high efficiency and reliability.

12. **ELECTRONIC SPEED CONTROLLERS (ESCS):**
• Regulate motor speed based on flight controller commands.
• Ensure smooth and precise motor operation.

13. **PROPELLERS:**
• Convert motor rotation into lift and thrust.
• Designed for balanced and stable flight.

14. **DRONE FRAME:**
• Provides mechanical support for all components.
• Designed to withstand vibration and payload weight.

15. **LIPO BATTERY:**
• Supplies power to all onboard components.
• High energy density suitable for UAV applications.

16. **POWER DISTRIBUTION BOARD:**
• Distributes power evenly to motors, controllers, and sensors.
• Ensures stable voltage levels.

17. **RELAY MODULE:**
• Enables low-power control of high-power devices.
• Used to activate the fire extinguisher.

18. **ELECTRONIC SOLENOID VALVE**:
• Controls the release of the extinguishing agent.
• Ensures controlled fire suppression.

19. **FIRE EXTINGUISHER:**
• Suppresses detected fire automatically.
• Mounted onboard the UAV.

20. **SPRAY NOZZLE:**
• Directs the extinguishing agent accurately toward the fire source.
• Improves suppression effectiveness.

C.Working Process

The working process of the proposed system, AetherResQ, begins with system initialization, where the Pixhawk flight controller, Arduino Uno, sensors, and communication modules are powered on and checked for proper operation. A communication link between the drone and the Ground Control Station is established using MAVLink for real-time monitoring and control.After initialization, the drone performs autonomous takeoff and navigates to the target area using GPS-based waypoint navigation. During flight, the flame sensor continuously monitors for fire sources, while the PIR sensor detects human presence by sensing body heat. The sensor data is processed by the Arduino controller and shared with the Pixhawk flight controller for decision-making.When fire is detected beyond a predefined threshold, the system automatically triggers the fire extinguishing mechanism through a relay and solenoid valve. The spray nozzle directs the extinguishing agent accurately toward the fire source while the Pixhawk maintains flight stability. If human presence is detected, the location information is transmitted to the ground station to assist rescue operations. Throughout the mission, telemetry data such as position, altitude, battery status, and sensor readings are sent to the ground control interface for real-time supervision. After completing the firefighting or surveillance task, the drone autonomously returns to the launch point and performs a safe landing, completing the mission successfully.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
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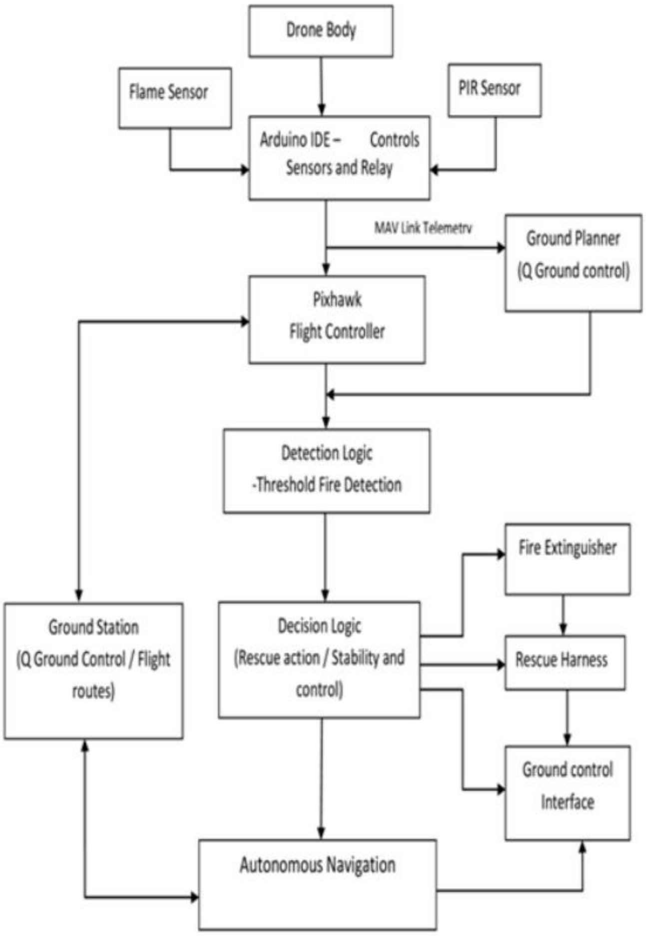

Fig 3: Block Diagram for AtherResQ

IV. EXPERIMENTAL RESULT

The AetherResQ firefighting and rescue drone was fabricated and evaluated through a series of controlled indoor and outdoor experiments to assess its flight stability, sensing accuracy, communication reliability, and fire suppression performance. All system components, including the Pixhawk flight controller, Arduino-based sensor module, and onboard extinguishing unit, were integrated and tested prior to mission execution.

During initial trials, stable communication between the drone and the Ground Control Station was successfully established using the MAVLink protocol. The system consistently achieved GPS lock, enabling reliable execution of waypoint-based autonomous navigation. Both manual and autonomous flight tests demonstrated smooth takeoff, stable hovering, responsive maneuvering, and safe landing under varying operating conditions.

Fire detection experiments confirmed that the flame sensor was able to identify active fire sources within its effective detection range. In parallel, the PIR sensor reliably detected human movement during simulated rescue scenarios, indicating its suitability for identifying trapped individuals. Sensor data processing and decision-making were performed without noticeable delay, ensuring timely system response.

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International Research Journal of Modernization in Engineering Technology and Science
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Volume:07/Issue:02/February-2025 Impact Factor- 8.187 www.irjmets.com

Upon confirmation of fire detection, the relay-controlled fire extinguishing mechanism was automatically activated. The solenoid valve and spray nozzle operated as intended, allowing accurate deployment of the extinguishing agent toward the fire source while maintaining flight stability. Telemetry parameters such as altitude, position, battery status, and sensor readings were continuously monitored using Mission Planner, providing real-time feedback throughout the mission.

The experimental results validate the operational reliability of the proposed system in terms of autonomous navigation, fire detection, human presence identification, and suppression functionality. These observations demonstrate that the AetherResQ platform can effectively support firefighting and rescue tasks in controlled environments, highlighting its potential for deployment in real-world emergency response scenarios.

Fig 4: Model picture of flying AtherResQ

Fig 5: Model picture of complete setup of AtherResQ

V. CONCLUSION

This work presented AetherResQ, an AI-assisted autonomous firefighting and rescue drone developed to support emergency response operations in hazardous environments. The proposed system integrates autonomous flight control, intelligent fire detection, human presence identification, real-time telemetry, and an onboard fire suppression mechanism into a single unmanned aerial platform. By employing a Pixhawk-based flight controller in combination with Arduino-driven sensor processing and MAVLink communication, the system demonstrated stable flight performance and reliable coordination between sensing, navigation, and actuation modules.

Experimental evaluations conducted under controlled conditions confirmed the drone's ability to detect fire sources accurately, identify human movement using PIR sensing, and activate the extinguishing mechanism with minimal response delay. The use of real-time telemetry and ground station monitoring enhanced situational awareness and allowed effective supervision of autonomous missions. The results indicate that UAV-assisted firefighting systems such as AetherResQ can significantly reduce direct human involvement in high-risk scenarios while improving operational efficiency and response speed. Overall, the project validates the feasibility of integrating autonomous aerial platforms into modern firefighting and rescue frameworks and highlights their potential role in next-generation disaster management systems.

VI. FUTURE SCOPE

The operational capabilities of the AetherResQ system can be further enhanced through several future improvements. Advanced computer vision techniques using thermal cameras and deep learning–based fire and victim detection models can be incorporated to improve detection accuracy in complex and low-visibility environments. The addition of onboard companion computers such as Raspberry Pi or NVIDIA Jetson modules would enable higher-level autonomous decision-making without continuous dependence on ground control communication.Fire suppression performance may be improved by integrating higher-capacity extinguishing systems, pump-assisted spray mechanisms, or fire-retardant agents suitable for medium-scale fire scenarios. Multi-sensor fusion involving thermal, gas, and temperature sensors can further increase system reliability under dynamic environmental conditions. Additionally, coordinated multi-UAV swarm operation using mesh-based communication protocols could enable large-area coverage for forest fire monitoring and disaster response missions. Improvements in energy storage technology, including high-density lithium-ion batteries or hybrid solar-assisted charging systems, may extend flight endurance and mission duration. Structural enhancements using lightweight, heat-resistant materials and the inclusion of modular rescue payload mechanisms would further improve durability, scalability, and adaptability. These future developments can transform AetherResQ into a more robust, intelligent, and field-deployable platform for advanced firefighting and search-and-rescue applications.

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IRJMETS
e-ISSN: 2582-5208
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Volume:07/Issue:02/February-2025 Impact Factor- 8.187 www.irjmets.com

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APPENDIX C

CERTIFICATES

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International Research Journal Of Modernization in Engineering Technology and Science

(Peer-Reviewed, Open Access, Fully Refereed International Journal)

e-ISSN: 2582-5208

Ref: IRJMETS/Certificate/Volume 07/Issue 12/71200107514

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Certificate of Publication

*This is to certify that author "**Arthi. S**" with paper ID "**IRJMETS71200107514**" has published a paper entitled "**AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER**" in International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), Volume 07, Issue 12, December 2025*

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e-ISSN: 2582-5208

Ref: IRJMETS/Certificate/Volume 07/Issue 12/71200107514

Date: 21/12/2025

Certificate of Publication

*This is to certify that author "**Vedha. D**" with paper ID "**IRJMETS71200107514**" has published a paper entitled "**AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER**" in International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), Volume 07, Issue 12, December 2025*

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e-ISSN: 2582-5208

Ref: IRJMETS/Certificate/Volume 07/Issue 12/71200107514

Date: 21/12/2025

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e-ISSN: 2582-5208

Ref: IRJMETS/Certificate/Volume 07/Issue 12/71200107514

Date: 21/12/2025

Certificate of Publication

*This is to certify that author "**Varsha. KG**" with paper ID "**IRJMETS71200107514**" has published a paper entitled "**AETHERRESQ: AI DRIVEN FIREFIGHTING RESCUE DRONE WITH SMART SURVEILLANCE AND AUTONOMOUS FIRE EXTINGUISHER**" in International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), Volume 07, Issue 12, December 2025*

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Organizer	Dean, Academics	Principal

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Organizer	Dean, Academics	Principal

1st

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Organizer | Dean, Academics | Principal

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K. Ananth	[signature]	HG [signature]
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This is to certify that Mr./Ms./Prof./Dr. Arthi S from Sambharam IT participated in titled fire fighting Rescue Drone during **National Level Project Expo 2025**, organized by Department of Information Science & Engineering and Department of Computer Science & Engineering in associate with ISTE, at HKBK College of Engineering, Nagawara, Bengaluru on 4th & 5th of December 2025.

Dr. Smitha Kurian	Dr.A.Syed Mustafa	Dr. Mohammed Riyaz Ahmed
Convener, Head - CSE	Convener, Head – ISE	Principal

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This is to certify that Mr./Ms./Prof./Dr. Vedha D from Sambaram IT participated in titled Fire fighting Rescue Drone during **National Level Project Expo 2025**, organized by Department of Information Science & Engineering and Department of Computer Science & Engineering in associate with ISTE, at HKBK College of Engineering, Nagawara, Bengaluru on 4th & 5th of December 2025.

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