



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 4, April 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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# Jatayu-The Great Ornithopter

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**ABSTRACT:** Ornithopters, aircraft that achieve flight by flapping their wings, have garnered significant interest due to their potential for efficient and versatile aerial maneuverability. This paper presents the design and analysis of an ornithopter aimed at achieving optimal flight performance. The design process integrates principles from biology, aerodynamics, and mechanical engineering to develop a functional and efficient ornithopter prototype.

The paper begins with a comprehensive review of ornithopter history, current research, and relevant biological insights into avian flight. Drawing inspiration from natural avian flight mechanisms, the ornithopter's wing design is optimized for lift generation and thrust production during both flapping and gliding phases.

Furthermore, the aerodynamic performance of the ornithopter is evaluated using computational fluid dynamics (CFD) simulations to analyse lift, drag, and overall efficiency. These simulations inform the design refinement process, leading to improvements in flight characteristics and energy consumption.

Additionally, the mechanical components of the ornithopter, including the wing mechanism, actuation system, and control mechanisms, are discussed in detail. Emphasis is placed on lightweight materials, efficient transmission systems, and precise control mechanisms to maximize flight efficiency and maneuverability.

Finally, experimental validation of the ornithopter prototype is conducted through flight testing, assessing its stability, maneuverability, and overall performance. Results from these tests provide valuable insights for further refinement and optimization of the ornithopter design.

Overall, this paper contributes to the advancement of ornithopter technology by presenting a systematic approach to design and analysis, resulting in a functional prototype capable of efficient and maneuverable flight. The findings presented here pave the way for future developments in ornithopter design for various applications, including surveillance, environmental monitoring, and search and rescue operations.

**KEYWORDS:** ORNITHOPTER, MANEUVERABILITY, AERODYNAMIC, COMPUTATIONAL FLUID DYNAMICS (CFD), SURVEILLANCE.

## I. INTRODUCTION

The dream of human flight has long captivated the imagination, leading to a myriad of innovations and endeavors to conquer the skies. Among these, the concept of an ornithopter, an aircraft emulating the flight of birds by flapping its wings, has remained a tantalizing prospect. With its potential for agile, energy-efficient flight, ornithopters offer a unique avenue for exploration in aerospace engineering.

The fascination with ornithopters traces back centuries, with Leonardo da Vinci famously envisioning machines that mimicked avian flight. Despite centuries of progress in aviation, ornithopters have remained on the periphery of mainstream aircraft design, often overshadowed by more conventional fixed-wing and rotary-wing aircraft. However,

recent advancements in materials, propulsion systems, and aerodynamics have reignited interest in these bio-inspired flying machines.

This paper embarks on a journey to explore the design and analysis of an ornithopter, blending insights from biology, aerodynamics, and mechanical engineering. By drawing inspiration from the remarkable efficiency and maneuverability of birds, we aim to develop a functional ornithopter prototype capable of achieving sustained flight with optimal performance.

Through a thorough examination of historical precedents, current research, and biological principles underlying avian flight, we lay the foundation for our ornithopter design. By understanding the intricacies of wing morphology, flapping kinematics, and aerodynamic forces at play, we seek to harness nature's wisdom to inform our engineering endeavors. Central to our approach is the integration of advanced computational tools, such as computational fluid dynamics (CFD) simulations, to refine and optimize the ornithopter's aerodynamic performance. These simulations allow us to explore a vast design space, fine-tuning wing profiles, kinematic patterns, and control strategies to achieve efficient and stable flight.

Moreover, we delve into the mechanical intricacies of ornithopter design, addressing challenges related to wing actuation, transmission systems, and control mechanisms. By leveraging lightweight materials, innovative actuation systems, and precise control algorithms, we aim to create a nimble and responsive ornithopter capable of executing complex flight maneuvers.

Ultimately, through a combination of theoretical analysis, computational modeling, and experimental validation, we aspire to demonstrate the viability and potential of ornithopters as a novel class of aerial vehicles. Beyond mere engineering curiosity, ornithopters hold promise for diverse applications, including surveillance, environmental monitoring, and search and rescue missions, where their unique flight capabilities offer distinct advantages.

In the pages that follow, we invite the reader to join us on this exploration of ornithopter technology, where nature's elegance converges with human ingenuity to unlock new frontiers in flight.

## II. LITERATURE SURVEY

Ornithopters, aircraft that achieve flight by flapping their wings, have captivated the imagination of scientists, engineers, and aviation enthusiasts for centuries. The concept of emulating avian flight has spurred a rich body of research encompassing diverse disciplines including biology, aerodynamics, robotics, and materials science. In this literature survey, we explore key advancements, insights, and challenges in ornithopter design and analysis.

**Historical Precedents:** The history of ornithopters dates back to ancient times, with early attempts to replicate bird flight recorded in the works of ancient Greek and Chinese scholars. Leonardo da Vinci's sketches of ornithopter-like flying machines in the 15th century exemplify early attempts to translate biological principles into mechanical designs. Subsequent centuries witnessed sporadic efforts to build ornithopters, with notable figures such as Otto Lilienthal and Samuel Langley contributing to the field.

**Biological Insights:** A fundamental understanding of avian flight mechanics has been essential for informing ornithopter design. Biological studies have elucidated the complex interactions between wing morphology, flapping kinematics, and aerodynamic forces in birds. High-speed photography, motion capture, and anatomical studies have provided valuable insights into the intricacies of avian flight, guiding the development of biomimetic ornithopter designs.

**Aerodynamics and Fluid Dynamics:** The aerodynamic principles governing ornithopter flight have been extensively studied using computational and experimental techniques. Computational fluid dynamics (CFD) simulations have enabled researchers to analyse flow patterns around flapping wings, optimize wing shapes, and assess the aerodynamic efficiency of ornithopter configurations. Wind tunnel experiments, wing load tests, and flight trials have provided empirical validation of theoretical predictions, highlighting the importance of aerodynamic design in achieving stable and efficient flight.

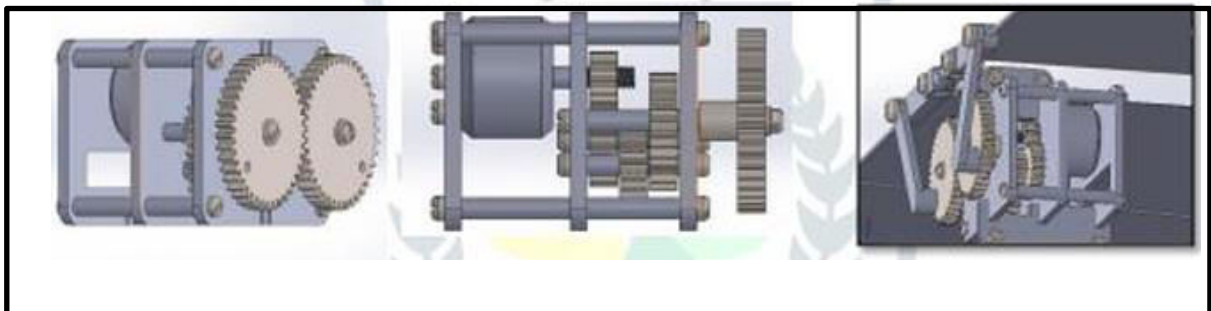
**Mechanical Design and Actuation:** The mechanical design of ornithopters presents unique challenges related to wing articulation, propulsion systems, and control mechanisms. Early ornithopter prototypes often relied on cumbersome mechanisms and inefficient power sources, limiting their practicality. Advances in lightweight materials, miniaturized actuators, and microelectronics have enabled the development of more agile and responsive ornithopter platforms. Novel actuation systems, such as piezoelectric actuators, smart materials, and bio-inspired mechanisms, hold promise for enhancing the agility and energy efficiency of ornithopters.

**Control and Stability:** Achieving stable and controllable flight poses significant challenges for ornithopter design. Control algorithms must account for the nonlinear dynamics of flapping-wing systems, rapid changes in aerodynamic forces, and environmental disturbances. Feedback control strategies, biomimetic control laws, and sensor fusion techniques have been investigated to improve the stability and maneuverability of ornithopters. Real-time sensor data, onboard processing capabilities, and autonomous control algorithms are essential for enabling autonomous flight and mission planning in ornithopter applications.

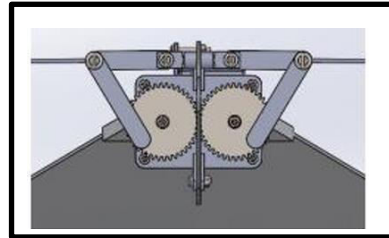
In summary, the literature survey underscores the multidisciplinary nature of ornithopter research, drawing upon insights from biology, aerodynamics, mechanics, and control theory. By synthesizing knowledge from diverse fields and leveraging advancements in technology, researchers continue to push the boundaries of ornithopter design, paving the way for innovative solutions to challenges in aerial robotics and aviation.

### III. METHODOLOGY

A) **Gear box:** Spur gearbox the most critical part of the ornithopter is the drive mechanism that converts the electric power from the battery to the flapping motion of the wings. This system is the most complex to design and fabricate because it must withstand very large forces that reverses direction several times a second while at the same time it needs to be extremely light and durable. Because of the loads, it must be made from durable material which makes it beneficial to perform careful analysis and trim as much weight as possible.

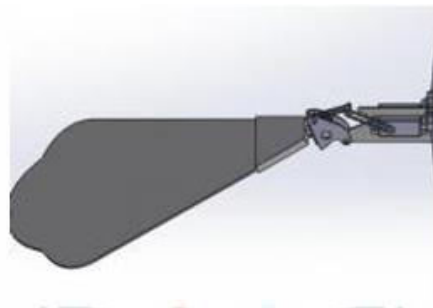


B) **Flapping mechanism:** Dual Gear Crank Mechanism The flapping wing mechanism function is to convert the motor's rotary motion into flapping motion. It is the most important component of the ornithopter thus much research was done to assess the many different designs available. Generally, the mechanism design is about the same to each other with only slight modifications. This design features two gears that control each wing hinges separately. A simulation test was done using the Ansys and it showed that it could hold at high frequency flapping and the flapping movement is synchronized.



C) **Wing Design:** Flexible wing Ornithopter wings can be flexible or rigid. The rigid wing design is much more complicated. Each cross section of the rigid wing has a real aviation wing profile. These wings require a frame system and accurate geometry. Furthermore, ornithopter with a rigid wing is bigger and heavier which is complicated to make. So, we decided to keep the wings of our ornithopter flexible. Flexible wings are like a stretched fabric that forms a membrane made from lightweight, tear resistant material. Also, the material must not allow to pass air through. The membrane wing consists of a spar, at the leading edge of the wing and a wing membrane which extends backward from the spar and attaches to the body of the ornithopter. The rigid structure is concentrated at the front of the wing.

D) **Tail:** Steering is usually done by the tail. The wings can be used for steering, but this is less consistently successful and more difficult to implement. A simple elevator and rudder system is very effective for ornithopter steering. For a more birdlike appearance, though, a flat, triangular tail is more often used. The tail may swing out to the left and right sides so that the downforce of the tail causes a rolling moment on the ornithopter. Alternatively, the tail may rotate about its long axis. In this case, the downforce is redirected in a way that provides yaw control. Flat v shape design is used since it is consistently successful. Material selection for the tail: • Spar – Carbon Fiber • Membrane – Nylon Fabric



E) **Main Frame:** The mainframe of the ornithopter is a surprisingly simple component from a design standpoint. Because the flapping mechanism is contained fully within the gearbox frame. The frame design is a single flat plate which relies on its thickness for stiffness. The mainframe of the ornithopter serves the purpose of providing the mounting locations for the wing mounts, electronic components, battery, and tail assembly. The frame design is a single flat plate which relies on its thickness for stiffness. Material selection for mainframe – Reinforced Glass Fiber plastic Reinforced Glass Fiber plastic is a composite material formed by reinforcing plastic material with glass fibres in a matrix form. It is light weight material also can withstand sudden impact during any failure of ornithopter.



### 1. Component Description:

- **Servo Motor(SG90):**-A servomotor (or servo motor or simply servo (to be differentiated from servomechanism, which may also be called a servo)) is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity, and acceleration in a mechanical system. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor,
- **Transmitter (FS) & Receiver (FS)(8 Channel) :-** A transmitter can be a separate piece of electronic equipment, or an electrical circuit within another electronic device. A transmitter and a receiver combined in one unit is called a transceiver. The term transmitter is often abbreviated "XMTR" or "TX" in technical documents. The purpose of most transmitters is radio communication of information over a distance. The information is provided to the transmitter in the form of an electronic signal called the modulation signal, such as an audio (sound) signal from a microphone, a video (TV) signal from a video camera, or in wireless networking devices, a digital signal from a computer. The transmitter generates a radio frequency signal which when applied to the antenna produces the radio waves, called the carrier signal. It combines the carrier with the modulation signal, a process called modulation. The information can be added to the carrier in several different ways, in different types of transmitters.
- **BLDC Motor(1400KV):** - A brushless DC electric motor (BLDC), also known as an electronically commutated motor, is a synchronous motor using a direct current (DC) electric power supply. It uses an electronic controller to switch DC currents to the motor windings producing magnetic fields that effectively rotate in space and which the permanent magnet rotor follows. The controller adjusts the phase and amplitude of the DC current pulses to control the speed and torque of the motor. This control system is an alternative to the mechanical commutator (brushes) used in many conventional electric motors. The construction of a brushless motor system is typically similar to a permanent magnet synchronous motor (PMSM), but can also be a switched reluctance motor, or an induction (asynchronous) motor. They may also use neodymium magnets and be outrunners (the stator is surrounded by the rotor), inrunners (the rotor is surrounded by the stator), or axial (the rotor and stator are flat and parallel).
- **LIPO Battery(1000mah) Single Cell:-** A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated as LiPo, LIP, Li poly, lithium-poly and others), is a rechargeable battery of lithium ion technology using a polymer electrolyte instead of a liquid electrolyte. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, such as mobile devices, radio-controlled aircraft and some electric vehicles.
- **LIPO Battery Charger:-** A battery charger, recharger, or simply charger,[1][2] is a device that stores energy in a battery by running an electric current through it. The charging protocol (how much voltage or current for how long, and what to do when charging is complete) depends on the size and type of the battery being charged. Some battery types have high tolerance for overcharging (i.e., continued charging after the battery has been fully charged) and can be recharged by connection to a constant voltage source or a constant current source, depending on battery type. Simple chargers of this type must be manually disconnected at the end of the charge cycle.

#### IV. WORKING

The working principle of an ornithopter revolves around emulating the flapping flight of birds to achieve sustained aerial locomotion. Unlike conventional fixed-wing aircraft or rotorcraft, which rely on steady airflow over rigid airfoils or rotating blades, ornithopters generate lift and thrust through the rhythmic flapping motion of their wings. This section outlines the key components and mechanisms involved in the operation of an ornithopter:

##### 1. **Wing Design and Morphology:**

- The wings of an ornithopter are designed to closely mimic the shape, size, and movement of avian wings. They typically feature lightweight, flexible structures with airfoil cross-sections optimized for aerodynamic efficiency.
- Wing morphing technologies may be employed to adjust wing shape and camber during different phases of the flapping cycle, enabling control over lift and thrust generation.

##### 2. **Flapping Mechanism:**

- The flapping motion of the ornithopter's wings is powered by onboard propulsion systems, such as electric motors, internal combustion engines, or pneumatic actuators.
- Mechanical linkages and transmission systems convert rotary motion from the propulsion source into reciprocating motion of the wings, driving them through a prescribed flapping trajectory.
- The flapping motion typically involves a combination of translational and rotational movements, with variations in amplitude, frequency, and phase to achieve desired aerodynamic effects.

##### 3. **Aerodynamic Forces:**

- During the flapping cycle, the ornithopter's wings generate aerodynamic forces, including lift, thrust, drag, and moment, through interaction with the surrounding airflow.
- The flapping motion creates unsteady flow patterns around the wings, inducing dynamic changes in pressure distribution and aerodynamic forces.
- Lift is primarily generated during the downstroke phase of the flapping motion, while thrust is produced during both the downstroke and upstroke phases.

##### 4. **Control Systems:**

- Control mechanisms are essential for regulating the flapping motion, adjusting wing kinematics, and stabilizing the ornithopter's attitude and trajectory.
- Control surfaces such as flaps, ailerons, and elevators may be incorporated into the wing design to modulate lift, drag, and pitching moments.
- Onboard sensors, including accelerometers, gyroscopes, and airspeed sensors, provide real-time feedback on the ornithopter's orientation, velocity, and environmental conditions.
- Flight control algorithms process sensor data and execute control commands to maintain stability, achieve desired flight trajectories, and respond to user inputs or external disturbances.

##### 5. **Energy Management:**

- Efficient energy management is critical for achieving sustained flight with limited onboard power sources.
- Lightweight construction materials, streamlined aerodynamic profiles, and optimized wing kinematics help minimize energy consumption during flight.

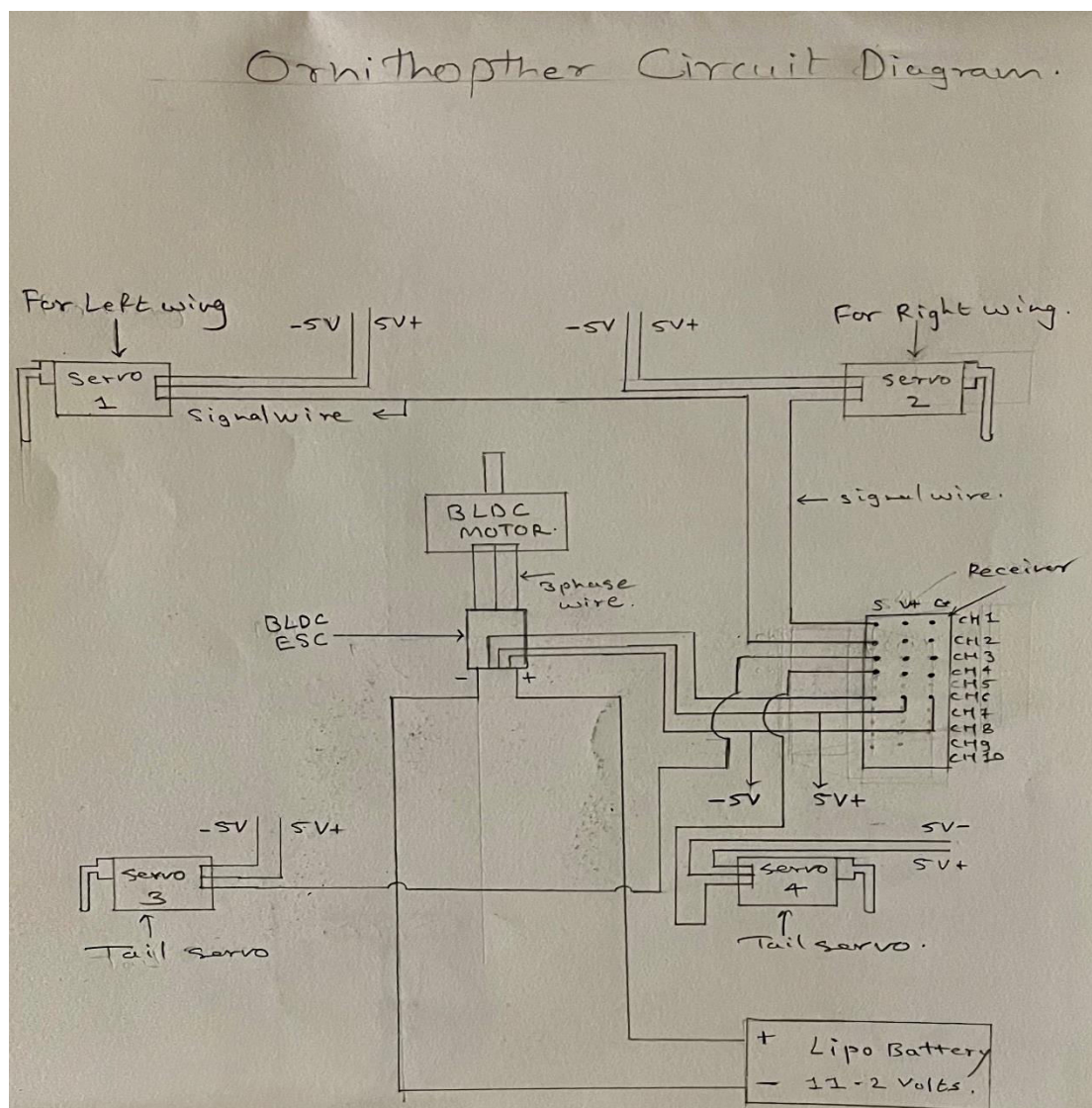
- Battery or fuel cell systems provide electrical or chemical energy to power propulsion systems, with considerations for weight, energy density, and endurance influencing design decisions.

6. **Flight Dynamics and Maneuverability:**

- The flight dynamics of an ornithopter are characterized by complex interactions between aerodynamic, inertial, and control forces.
- Maneuverability is achieved through coordinated adjustments in wing motion, control surface deflections, and propulsion thrust, enabling the ornithopter to perform agile maneuvers such as turns, climbs, and descents.

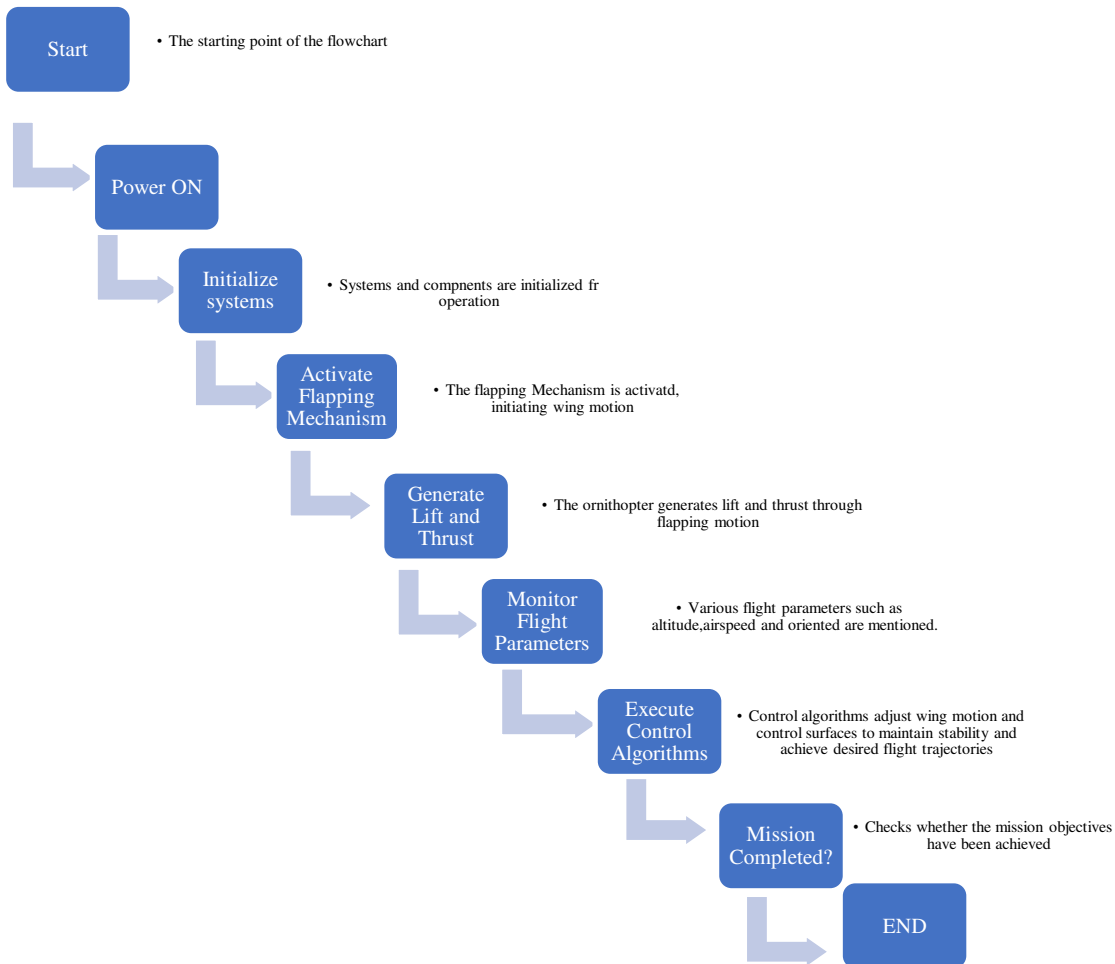
In summary, the working of an ornithopter involves a synergistic interplay between aerodynamic principles, mechanical systems, control algorithms, and energy management strategies to achieve sustained, controlled flight through biomimetic flapping motion. By harnessing the elegance of avian flight, ornithopters offer unique capabilities for applications ranging from aerial surveillance and environmental monitoring to search and rescue missions.

**CIRCUIT DIAGRAM:**





## V. FLOW CHART



## VI. CONCLUSION

In conclusion, the ornithopter represents a promising paradigm in aerial robotics, offering distinct advantages in agility, efficiency, and versatility over conventional aircraft. Continued research and development in ornithopter technology hold the potential to unlock new capabilities and applications, from urban aerial transportation to disaster response and beyond.

As we look to the future, interdisciplinary collaboration and innovation will be key drivers in advancing ornithopter technology and harnessing its full potential for addressing real-world challenges in aerospace engineering and beyond.

## REFERENCES

1. <https://www.jetir.org/papers/JETIR2005250.pdf>
2. <https://en.wikipedia.org/wiki/Ornithopter>
3. [https://web.ics.purdue.edu/~rmanish/report/ornithopter\\_report.pdf](https://web.ics.purdue.edu/~rmanish/report/ornithopter_report.pdf)
4. <https://www.ornithopter.org/how.flap.shtml>
5. <http://fab.cba.mit.edu/classes/863.17/EECS/people/akaspar/project/>



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