MAE 3260

Professor Campbell

Final Groupwork: The Drone Zone

Kasper Atkinson (kna37)
Ava Farkash (ajf245)
Gabrielle Garra (gmg96)
Joseph Rachiele (jar574)

General Overview:

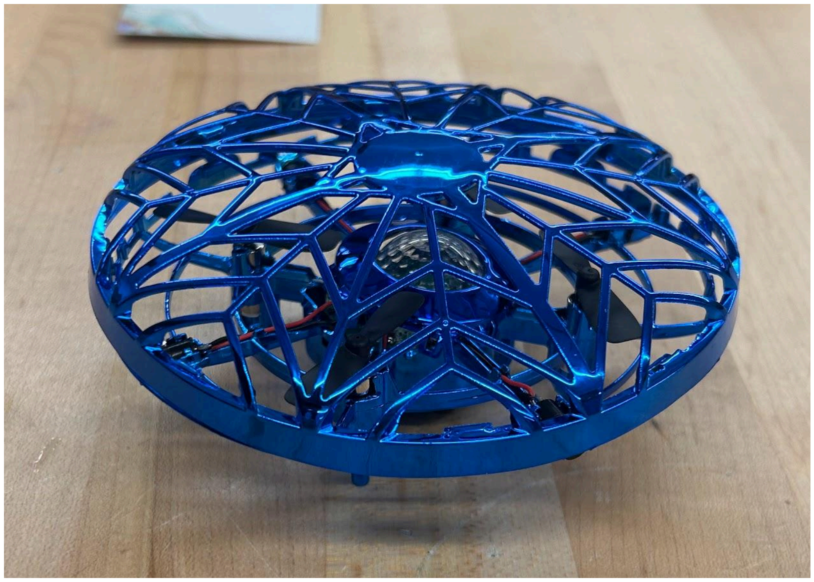


Image 1: Full drone

Our drone is battery powered with four rotating blades. The battery also powers the LED light in the center of the drone. To start the drone, press the power button which activates the LED and indicates that the drone is on. To activate the propellers and get the drone to fly, the drone must be tossed into the air. The drone's sensor will detect its downward motion and the propellers will rapidly accelerate to propel the drone up and maintain itself in the air.

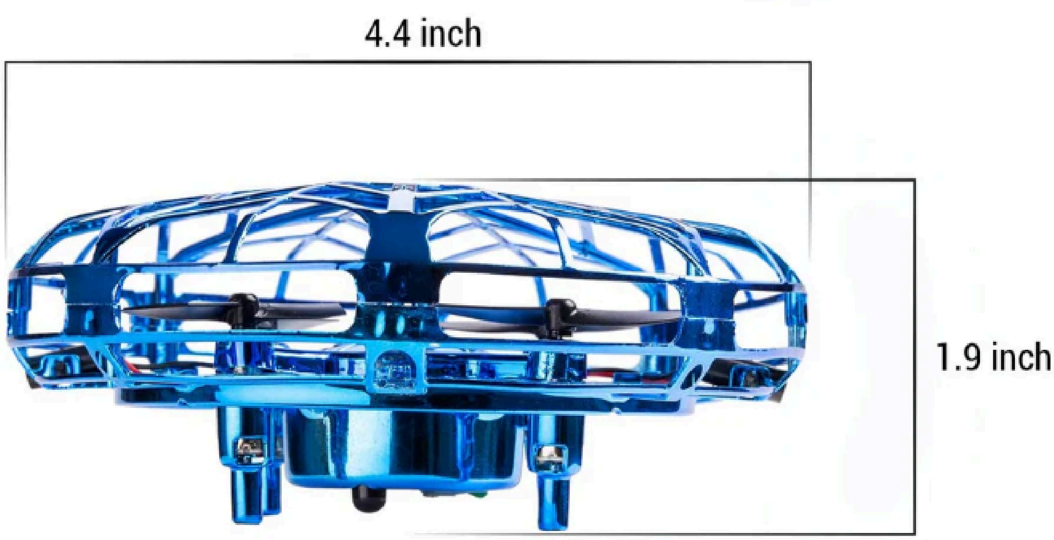


Image 2: Dimensions of Drone

Once in the air, the drone will then respond to motion and objects detected by its sensors. There is a sensor that will detect any objects below it and will send more power to the propellers causing them to accelerate and generate a lift force to propel the drone higher. The instructed way to fly the drone is by moving your hand towards the drone from below it, which will accelerate the propellers and cause the drone to lift.

The lateral and forward-backwaerd motion of the drone is dependent upon an uneven rotation of the blades which is dictated by a feedback system dynamic. When your hand goes under the drone and also moves forward the back propellers will accelerate more than the front propellers. This feedback will push the drone forward. The same and opposite can be done to push the drone backwards. The drone will also move laterally away from objects or your hand. The drone will also react after hitting objects, thus there is a protective plastic shell to shield the propellers from its semi-frequent crashes (shown in image 3).

Image 3: Drone shell

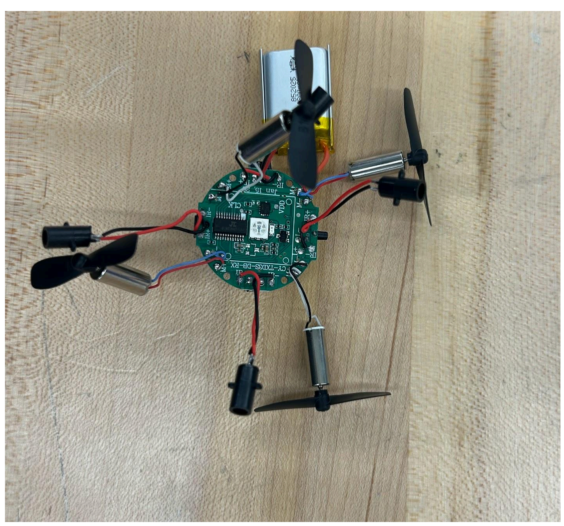


Image 4: Internal components

Another feature of the drone is its ability to do a flip. If the drones lateral sensors detect your hands waving on either side of the drone (left and right), then the LED light will begin to flash. This flash indicates to the user that upon the next detection of a hand underneath the drone, the drone will complete a 360 degree flip.

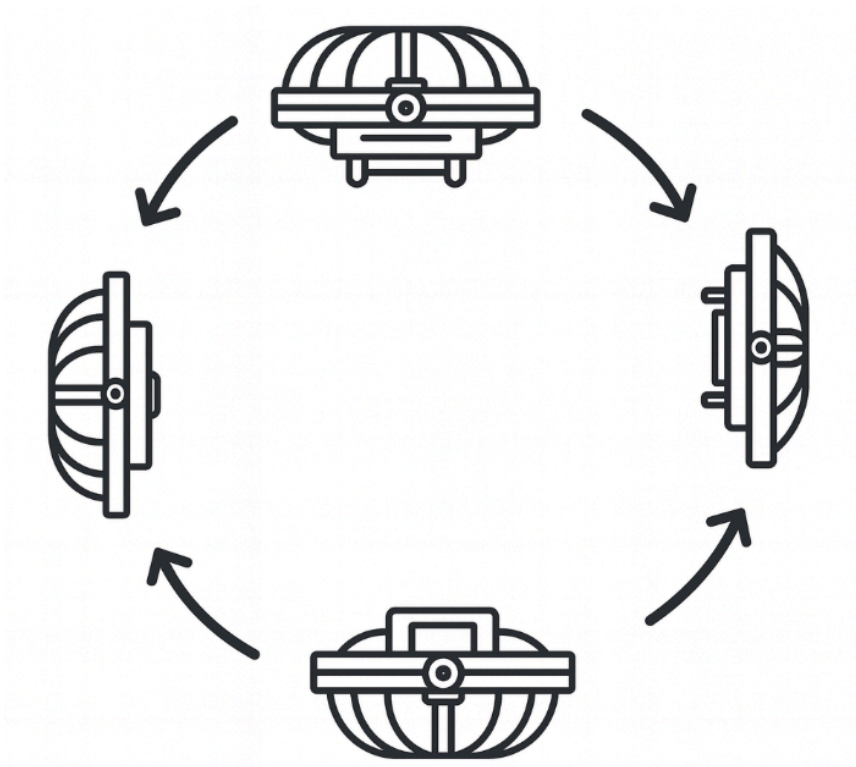


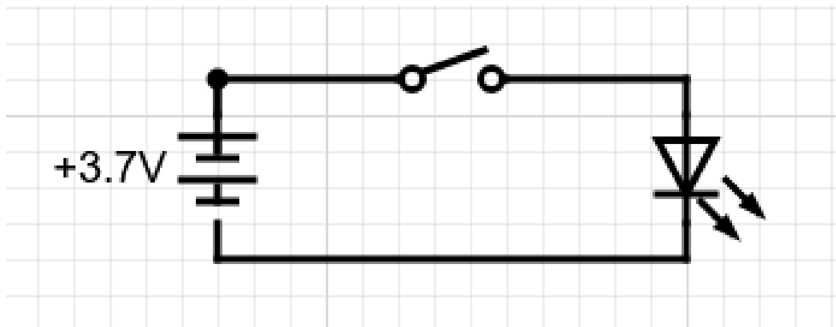
Image 5: Visualization of 360° Spin

Flashing LED Analysis

The drone features one main LED soldered to the top of its circuit board covered with a glossy, dimpled, plastic. The covering divides the LED light and creates a disco-like pattern around the drone. Dissecting the drone further, a small lithium-polymer battery consisting of a single cell and 300mAh capacity was also found. Testing the system under various conditions, four key behaviors were identified.

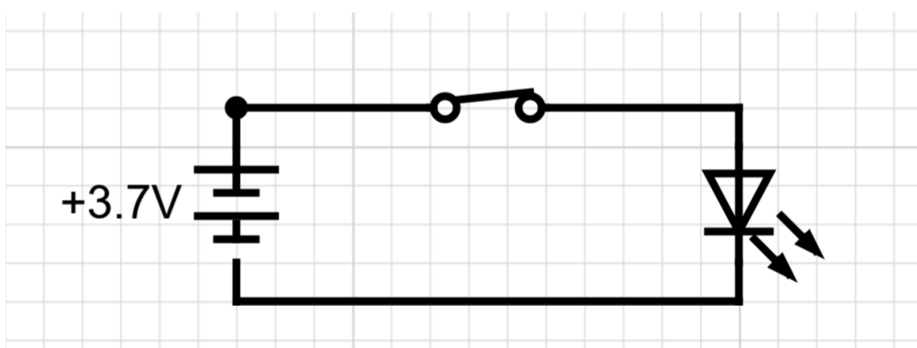
- Drone-off: no light emitted.
- Drone-on: green, persistent light.
- Low battery: red, pulsing light.
- In flight: multiple flashing colors.

To further understand the dynamics of this electrical circuit, four models were constructed. The first describes purely the drone-off state and can therefore be represented as an open circuit with a battery and LED. For the purpose of further analyses, an LED is treated as a simple resistor. Because the circuit is open, current and voltage will both be zero and constant throughout time.



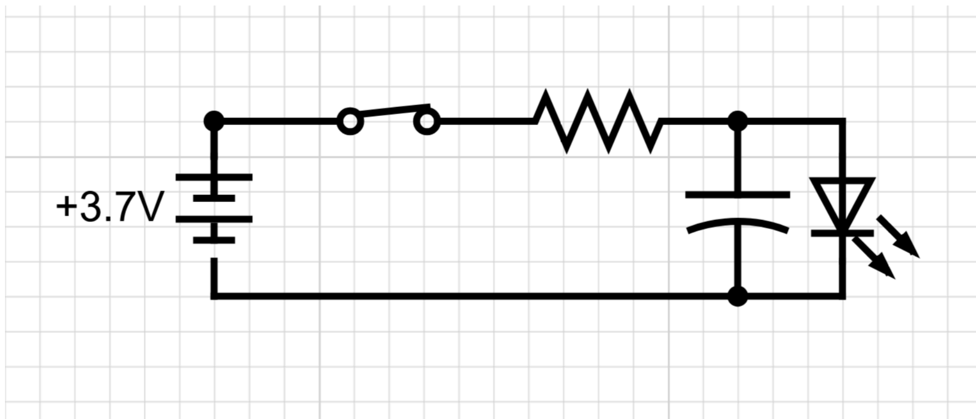
$$I(t) = 0 \qquad\qquad V(t) = 0$$

The drone-on state when not flying can have its dynamics modeled with the help of a voltage step input when the circuit is initially connected. In this simplified LED model, the circuit current instantaneously changes with the step input, u(t). Assuming a perfect, resistanceless wire, the voltage drop across the LED would be the same as the battery.



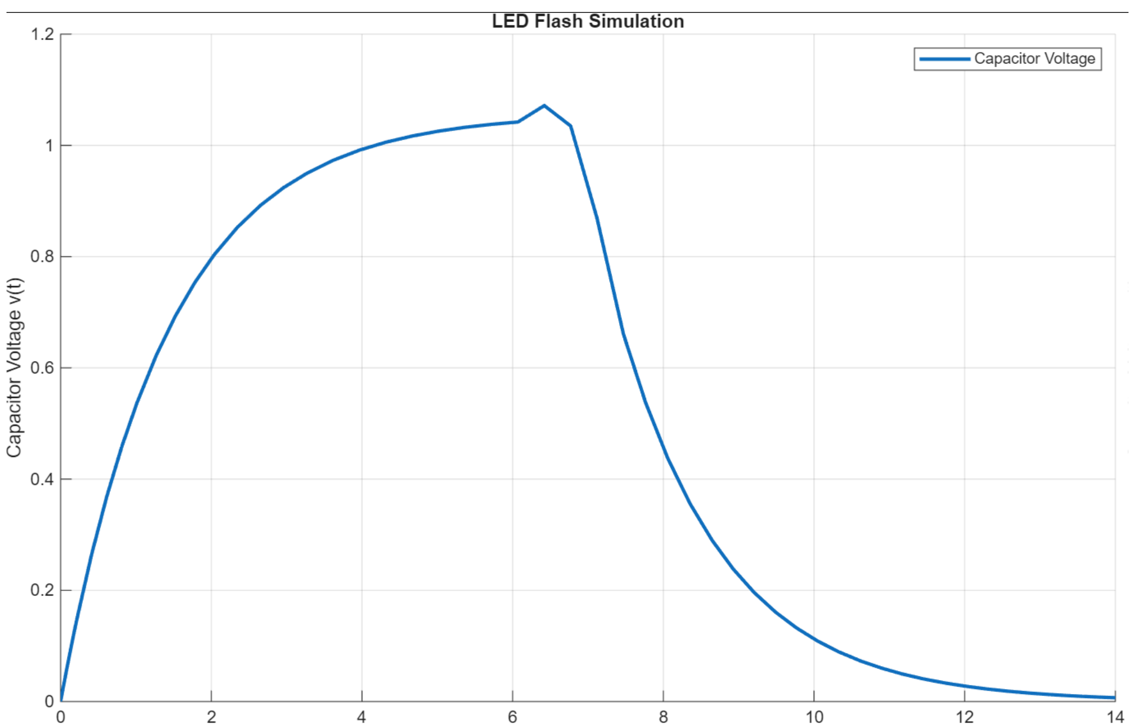
$$I(t) = \frac{V_{bat}}{R_{LED}} \times u(t) \qquad\qquad V(t) = 3.7V$$

The third, red slow pulsing state, utilizes a different LED circuit which relies on the gradual raising and lowering of the voltage across it. The toggling on and off of a switch with a capacitor and LED in-line can roughly emulate this effect. With the switch closed, the charge on the capacitor starts at zero and the LED is a resistor, so the capacitor will take most of the current. After a while, the charge on the capacitor grows until its voltage is equal to the drop across the LED and current flows equally through both. When the switch is disconnected, the built up charge on the capacitor powers the LED until it runs out. To capture the mathematics of the response, capacitor and Kirchhoff law equations were taken from the course slide notes [1] to construct the governing ODE and accompanying solution.



$$R_{LED}C\frac{dV}{dt} + V = \frac{R_{LED}}{R}\left(V_{bat}u(t) - V\right)$$

To directly illustrate the time dependence of this system, these equations were plotted in MATLAB [2] using ode45 and the ODE established above. The switch signal u(t) was changed from 1 to 0 at t=7, representing the slow frequency of the flashing LED.



Although this report will not detail the process directly, this system model can be extrapolated to the fourth observed behavior of flight, where multiple LEDs alternate in flashing at a much higher frequency.

Rotors

The Fly and Spin UFO Drone features four rotors each connected to the main circuit board (shown in image 1). This central circuit board distributes power and control signals. The rotors commence spinning when the drone is tossed upwards. The sensors initiate motor activation and the rotors rapidly accelerate. This most closely resembles the fast spinning blades and redirected downward push to generate lift in a helicopter. Additionally, the spinning mass contributes to stability, so the system behaves quite similarly to a gyroscope, a concept further discussed in MAE 4060. The angular momentum generated during spin results in stuffiness which will help the drone remain upright and resist disturbances.

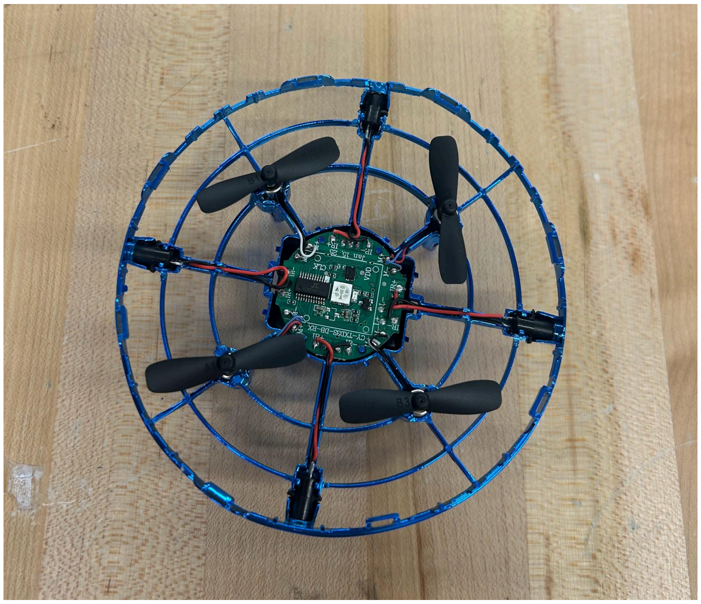


Image 6: Rotors connected to main circuit board

To characterize rotational performance, we measured the rotor speed using a high speed camera. To achieve this result, we colored one of the rotors with a silver sharpie to track the rotations on the high speed camera (shown in image 2). The TA in charge of the high speed camera was able to identify 5 frames per rotation and calculated the result of 1000RPM for our drone. This observational method served as a practical application of motion tracking and rotational kinematics which further enforced the relationships between angular frequency and image rate.

Thrust Tests

To better understand the lifting capabilities of the drone, multiple thrust test trials were conducted. Thrust was measured in grams using a calibrated force scale while the drone operated at a steady state. The results of our four trials are shown below.

Trial #	Thrust (g)
1	250
2	250
3	175
4	200

These results show a small degree of variability which is likely due to differences in the battery charge, rotor spin up behavior, airflow disturbances, and human error. Trials 1 and 2 demonstrated the highest lift at 250g while trial 3 was noticeably lower. This could indicate insufficient rotational speed or decreased voltage delivery. Trial 4 fell in between these results, making our best thrust estimate 200g.

PID Control System

Our fly-and-spin UFO-style drone relies on basic PID control to maintain stable hover, attitude, and rotational motion despite disturbances and rapidly changing aerodynamic forces. At its core, the controller continuously compares the drone's measured state—roll, pitch, yaw rate, and altitude—to its desired set points. The proportional term provides the immediate corrective action by producing control outputs proportional to the instantaneous error, helping counter deviations in attitude or altitude. The integral term accumulates long-term error, correcting slow drifts caused by sensor bias, uneven thrust, or minor asymmetries in the rotor/propeller system. The derivative term damps oscillations by responding to the rate at which the error is changing, providing predictive stabilization that is particularly important for a lightweight spinning platform with high moment of inertia about the vertical axis. These three components combine to drive motor speed adjustments that control lift and spin rate, ensuring that the drone can hold a commanded rotation without destabilizing its vertical flight. In practice, the PID loops for altitude and attitude interact: changes in spin rate can introduce gyroscopic effects and cross-coupled motions, making careful tuning essential to avoid oscillations, overshoot, or sluggish response. Through iterative tuning, typically using step-response characterization and frequency-domain analysis, the drone achieves a balance between responsiveness and stability. Ultimately, PID control provides a simple and reliable framework enabling the UFO drone to hover steadily, execute controlled spins, and respond predictably to hand commands.

Infrared Sensors

The Fly and Spin UFO Drone uses infrared sensors to detect hand motion and gauge distance. This feature is how the drone is flown without a controller. Each sensor has an infrared light and a photodiode. These work together to transmit and receive the light after it reflects off of objects. This explains how the drone will fly away from the walls or floor. These sensors do not calculate distance, but they send a signal to the drone that allows it to react in an opposite motion to the direction of the light [4]. The rotor speed will also increase as objects come closer. This allows the drone to react quickly to any possible collisions.

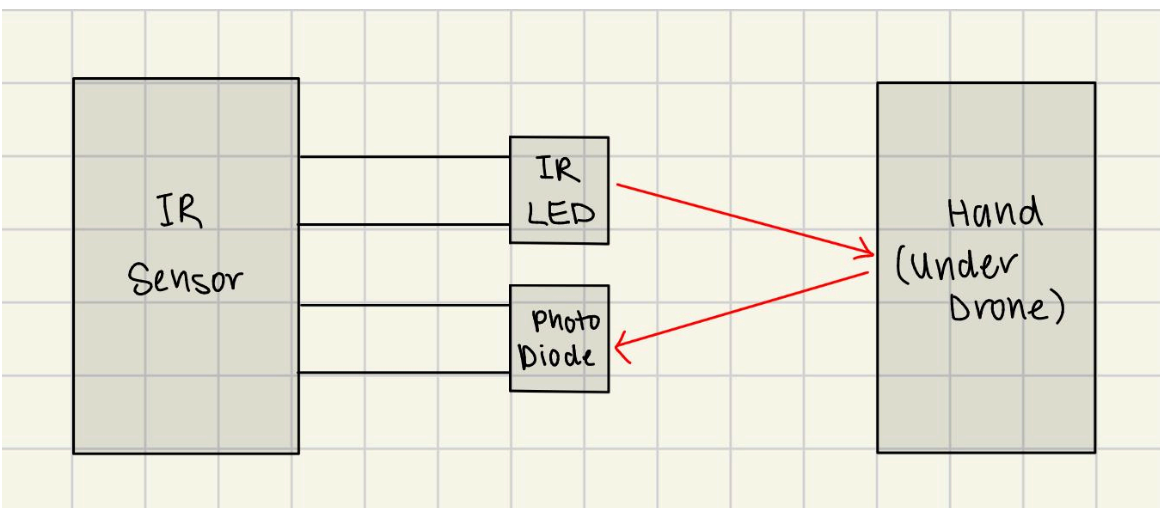


Image 7: Infrared Sensor Diagram

References

[1] MAE_Lecture_3M_(annotated). Campbell, Mark. Accessed 6 Dec. 2025.

[2] MATLAB. (2025a). Natick, Massachusetts: The MathWorks Inc. Accessed 6 Dec. 2025.

YouTube, YouTube, www.youtube.com/watch?v=DCLlmegK3d8. Accessed 5 Dec. 2025.

[3] Bitriá, R., & Palacín, J. (2022). *Optimal PID Control of a Brushed DC Motor with an Embedded Low-Cost Magnetic Quadrature Encoder for Improved Step Overshoot and Undershoot Responses in a Mobile Robot Application. Sensors, 22*(20), 7817. https://doi.org/10.3390/s22207817

[4] tariq epazz. "A Guide to Learning Infrared Drones." ZenaTech, 21 Apr. 2025, www.zenatech.com/a-guide-to-learning-infrared-drones/. Accessed 9 Dec. 2025.