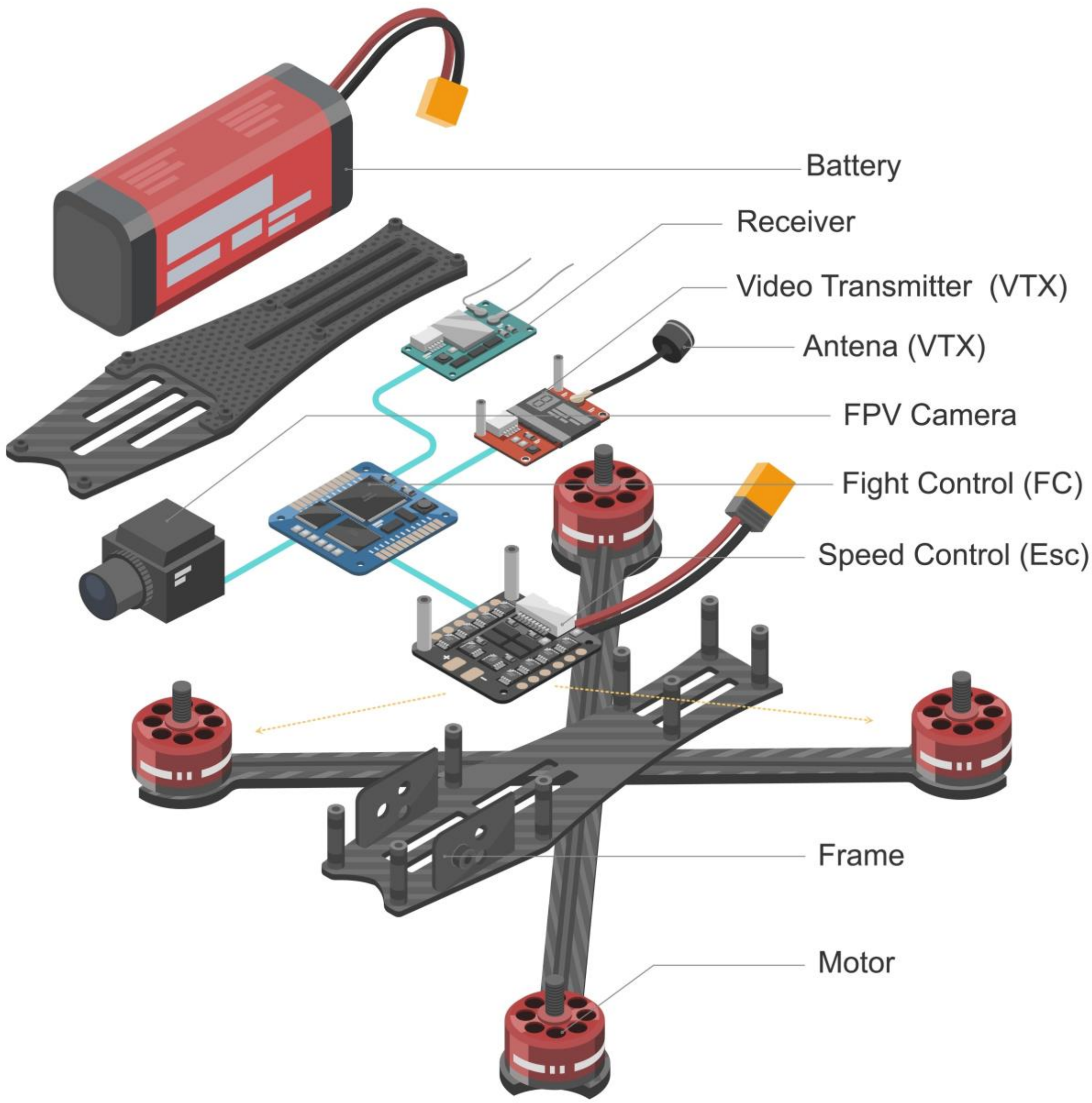
TASK 2-Basic Electronic Components



2.1 Electronic Components

Flight Controllers

The Flight Controller is the **"Brain"** (specifically the *cerebellum* or "reflex center") of the drone. It is the central hub where all hardware connects.

- **What it does:** It takes inputs from the pilot (via the receiver) and sensors, calculates what the motors need to do, and sends orders to the ESCs.
- **How it stays stable (The IMU):** Inside every FC is a tiny chip called an **IMU (Inertial Measurement Unit)**. This contains:
  - **Gyroscope:** Measures rotational speed (how fast is it spinning?).
  - **Accelerometer:** Measures gravity and acceleration (which way is down?).
- **Working Principle:** The FC runs software (like **Betaflight** or **ArduPilot**) that loops thousands of times per second. It compares "Where the pilot wants to be" vs. "Where the drone actually is" and corrects the error instantly.

Working Principle of FCs

The flight controller runs a special software (ArduPilot or Betaflight) that reads data from its sensors. It then processes the data several times to understand the drone's orientation. This orientation is then compared to the desired state and then the drone makes the necessary adjustments to achieve the desired state.

Use-Cases

- Stabilizing flight
- Autonomous Navigation
- Acrobatic Maneuvers

Advantages

- Provides stability needed for flight

- Able to integrate multiple sensors in one drone
- Highly configurable

Limitations

- Limited processing power for high-level tasks
- Sensitive to vibrations which can reduce performance

Integration Challenges

- Connecting all peripherals such as ESC,GPS and OC to correct ports can be complex
- Figuring out dampening techniques to reduce impact of vibrations (as sensitive to it)

Electronic Speed Controller

If the FC is the brain, the ESC is the **"Muscle & Nerve"** system.

- **What it does:** The Flight Controller cannot power motors directly (it only has 5V logic signals). The ESC takes the massive power from the battery and the delicate signal from the FC to spin the motor at the *exact* speed requested.
- **AC vs. DC:** Batteries provide **DC** (Direct Current), but drone motors are typically **Brushless** (which act like 3-phase AC). The ESC rapidly switches the power on and off (Pulse Width Modulation) to convert DC into the precise pulses needed to spin the motor.
- **Key Insight:** You will see **3 wires** connecting an ESC to a Motor. These correspond to the 3 phases of power that drive the motor coils

Working Principle

The ESC works by switching the flow of power to the motor on and off. This process is known as Pulse Width Modulation which allows precise control over the motor's speed. The longer the pulses of electricity, the faster the motor will spin and faster the drone will fly.

Use-Cases

- Maintaining the motor on a multirotor at a precise speed
- Changing the speed of rotor

Advantages

- Makes the motor control and management efficient
- Modern ESC can provide data such as RPM, Temp and current back to FC

Limitations

- Can overheat under high loads thus requires ventilation
- Low computational capacity which affects the maximum achievable speed of motors

Integration Challenges

- Must be calibrated so that FC's signal is interpreted precisely.
- Managing increased moment of inertia due to ESCs being mounted away from the center of the drone

Radio Receiver (Rx)

The Receiver is the drone's **"Ears."**

- **What it does:** It listens for invisible radio waves sent by your handheld remote controller (Transmitter).
- **Frequencies:**
  - **2.4GHz:** Standard for most drones (good range, decent penetration).
  - **900MHz (ELRS/Crossfire):** Used for long-range flying (can fly for kilometers).
- **Telemetry:** Modern receivers also have a "mouth"—they can send data (battery voltage, signal strength) *back* to your remote control.

LiPo Battery (Lithium Polymer)

The battery is the **"Heart"** pumping energy through the system. LiPo batteries are used because they are lightweight but pack a huge punch. You must understand two ratings written on every battery:

- **Cell Count ("S" Rating):** This defines the **Voltage** (Power/Speed).
    - $1S = 3.7V$ (Tiny drones)
    - $4S = 14.8V$ (Standard racing drones)
    - $6S = 22.2V$ (High-performance drones)
- **Discharge Rate ("C" Rating):** This defines the **Amperage** (Torque/Punch). A higher "C" number means the battery can dump energy faster without overheating.

Warning: LiPo batteries are volatile. If punctured or overcharged, they can catch fire. Always use a proper balance charger.

Power Distribution Board (PDB)

The PDB is the **"Arteries"** of the drone.

- **Function:** It is a circuit board that takes the thick wires from the battery and splits the power into smaller channels for the ESCs, Flight Controller, and Camera.
- **BEC (Battery Eliminator Circuit):** A built-in feature on PDBs that steps down the high battery voltage (e.g., 22V) to safe levels (5V or 12V) for delicate electronics like the GPS or Camera.

Global Positioning System

GPS is the system that is used in drones to allow it to navigate its environment and determine their precise geographical location.

In today's world GPS is extremely common, being used in apps like Google Maps, Order Tracking and Ride services. With the help of GPS, a drone can fly with complete freedom, follow predefined routes with precision and maintain a stable flight.

Working Principle

The GPS works due to a network of satellites orbiting the Earth that transmits signals to receiving devices, which use these signals to determine the exact location on the planet.

Use-Cases

- Navigating the way in unknown environments
- Determining the location of the drone

Advantages

- Enables autonomous flight over large distances.
- Important for recovery if drone is lost

Limitations

- Requires a clear signal from satellites
- Standard accuracy can be several meters

Integration challenges

- The GPS system can be affected by electromagnetic interference from wires in drones
- The drone must be still for a period of time to acquire signal from the satellite

Onboard Computer (NVIDIA Jetson)

Onboard computers (or also known as Companion computers) is a device whose role is very similar to the flight controller. It processes data from GPS, cameras, and other sensors to control flight paths, stability, and mission-specific tasks.

A Flight controller is responsible for the fundamental aspects of flight: stability, navigation, and responding to pilot commands whereas much complex tasks require companion computer systems.

Among the most powerful and popular of these is the NVIDIA Jetson series, which brings the power of Artificial Intelligence and computer vision to the skies.

Working Principle

The onboard computer runs a software (Linux) on it just like the flight controller and takes in data from sensors (like LiDARs, Depth Cameras and Optical Flow Sensors), processes this data accordingly and then sends commands to FC for execution.

Use-Cases

- Drone can avoid obstacles due to sensors detecting it
- Using camera to navigate in case GPS is not working

Advantages

- Brings desktop-like computing power in a drone.

Limitations

- OCs generally consume a lot of power which affects flight time
- Since they are power hungry, they also generate a lot of heat

Integration Challenges

- Requires a reliable communication with the FC
- Needs a good and reliable power source

2.2 Sensors

LiDARs

LiDAR (also known as Light Detection and Ranging) is a sensing technology that uses lasers to measure distances and created detailed 3D models of the surroundings. When used in a drone, it becomes a handy tool for capturing precise spatial data.

It works by emitting a pulse of laser towards a target and measuring the time it takes for the light to reflect and return to the sensor. These pulses are emitted in a sweeping pattern in a circular radius to get an accurate data.

Depth Cameras

Depth Camera is an important tool in drones where it captures a 2D image where each pixel stores a value which represents the distance of that pixel from the camera. This gives the drone an idea of how far each point in the image is.

Depth Cameras are crucial for navigating in a cluttered environment and in environments where GPS is not available.

Optical Flow Sensors

An Optical Flow Sensor allows a drone to hold its position relative to the ground without a GPS. It works with the help of a small, low resolution camera pointed downwards that captures the images of the ground and tracks the movement of drone relative to it. It then calculates the speed and distance needed to maintain that position relative to the ground. This tool is important for maintaining height and low-altitude flights(GPS signal might be weak at low altitude).

IR Sensors (from Oscar Liang's Articles)

An Infrared Sensor consists of an emittor and a detector. The emittor sends out IR beam of light which bounces back after reflecting off a surface and then is detected by the detector that calculates the distance between the sensor and the surface based on the time taken by the beam of light to reflect. This working principle is very similar to the one seen in LiDARs.