UNIT II - DRONE DESIGN, FABRICATION AND PROGRAMMING

Classifications of the UAV - Overview of the main drone parts - Technical characteristics of the parts - Function of the component parts -Assembling a drone - The energy sources - Level of autonomy - Drones configurations - The methods of programming drone - Download program - Install program on computer - Running Programs - Multi rotor stabilization - Flight modes- Wi-Fi connection.

2.1 CLASSIFICATIONS OF THE UAV

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are classified based on several factors, including their size, weight, range, flight altitude, and purpose. Below is a general classification of UAVs:

1. Classification by Size and Weight

UAVs can be classified by their physical dimensions and weight into several categories:

a. Micro and Nano UAVs:

- **Weight:** Less than 2 kg
- **Uses:** Indoor surveillance, hobby flying, close-range photography
- **Examples:** DJI Mini-series, Parrot Mambo

b. Mini UAVs:

- **Weight:** 2–20 kg
- **Uses:** Photography, recreation, environmental monitoring, agriculture
- **Examples:** DJI Phantom, Parrot Anafi, fixed-wing mini drones

c. Small UAVs:

- **Weight:** 20–150 kg
- **Uses:** Industrial inspections, advanced surveillance, scientific research
- **Examples:** AeroVironment RQ-11 Raven

d. Medium UAVs:

- **Weight:** 150–600 kg
- **Uses:** Military surveillance, border patrol, tactical missions
- **Examples:** Boeing ScanEagle

e. Large UAVs:

- **Weight:** Over 600 kg
- **Uses:** Military strike missions, long-range surveillance, high-altitude research

- **Examples:** General Atomics MQ-9 Reaper, Northrop Grumman Global Hawk

2. Classification by Range

Based on the operational range, UAVs are classified as:

a. Very Close-Range UAVs:

- **Range:** Up to 5 km
- **Flight Duration:** Less than 1 hour
- **Uses:** Short-range monitoring, indoor missions
- **Examples:** Mini drones, hobby drones

b. Close-Range UAVs:

- **Range:** 5–50 km
- **Flight Duration:** 1–6 hours
- **Uses:** Industrial inspection, tactical operations
- **Examples:** Parrot Disco, DJI Matrice series

c. Short-Range UAVs:

- **Range:** 50–150 km
- **Flight Duration:** 6–12 hours
- **Uses:** Border patrol, surveillance, environmental monitoring
- **Examples:** AeroVironment Puma

d. Mid-Range UAVs:

- **Range:** 150–650 km
- **Flight Duration:** 12–24 hours
- **Uses:** Military reconnaissance, scientific data gathering
- **Examples:** IAI Heron, Turkish Bayraktar TB2

e. Endurance/Long-Range UAVs:

- **Range:** Over 650 km (up to thousands of km)
- **Flight Duration:** Over 24 hours
- **Uses:** Strategic intelligence, combat missions, long-distance logistics
- **Examples:** Northrop Grumman Global Hawk, General Atomics MQ-1 Predator

3. Classification by Altitude

UAVs are also classified based on the altitude they can achieve:

a. Low-Altitude UAVs (Up to 5,000 feet):

- **Uses:** Agriculture, environmental surveys, firefighting
- **Examples:** DJI Agras, SenseFly eBee

b. Medium-Altitude UAVs (5,000–30,000 feet):

- **Uses:** Surveillance, scientific missions, mapping
- **Examples:** MQ-9 Reaper, Turkish Anka

c. High-Altitude UAVs (Above 30,000 feet):

- **Uses:** Strategic military surveillance, atmospheric studies, communication relays
- **Examples:** Global Hawk, Boeing Phantom Eye

4. Classification by Purpose

UAVs are categorized by their primary mission:

a. **Civilian/Commercial UAVs:

- **Uses:** Aerial photography, agriculture, delivery services, mapping, research
- **Examples:** DJI Inspire, Amazon Prime Air drones

b. **Military UAVs:

- **Uses:** Intelligence, surveillance, reconnaissance (ISR), combat missions
- **Examples:** MQ-1 Predator, MQ-9 Reaper, Wing Loong

c. **Special-Purpose UAVs:

- **Uses:** Search and rescue, disaster relief, medical supply delivery
- **Examples:** Zipline drones for medical supply, UAVs for firefighting

d. **Recreational UAVs:

- **Uses:** Hobby flying, drone racing, personal use
- **Examples:** DJI Mavic, Parrot Bebop

5. Classification by Type of Flight

UAVs are also classified based on the mechanism they use for flying:

a. Fixed-Wing UAVs:

- **Characteristics:** Airplane-like structure, wings provide lift, long-range, high speed
- **Uses:** Long-distance missions, mapping, surveying
- **Examples:** Boeing Insitu ScanEagle

b. Rotary-Wing UAVs (Multicopters):

- **Characteristics:** Helicopter-like design, rotors provide lift, VTOL (Vertical Takeoff and Landing) capability
- **Uses:** Close-range aerial photography, inspections
- **Examples:** DJI Phantom, DJI Matrice

c. Hybrid UAVs:

- **Characteristics:** Combine fixed-wing and rotary-wing features for both VTOL and long-range flying
- **Uses:** Flexible missions requiring vertical takeoff and long endurance
- **Examples:** Quantum Systems Vector

6. Classification by Autonomy

UAVs are also divided based on their level of autonomy:

a. Remotely Piloted UAVs:

- **Characteristics:** Fully controlled by a human operator from a remote station
- **Examples:** Many consumer drones

b. Autonomous UAVs:

- **Characteristics:** Operate independently using pre-programmed routes, AI, and advanced sensors
- **Examples:** Some military drones, advanced research drones

c. Semi-Autonomous UAVs:

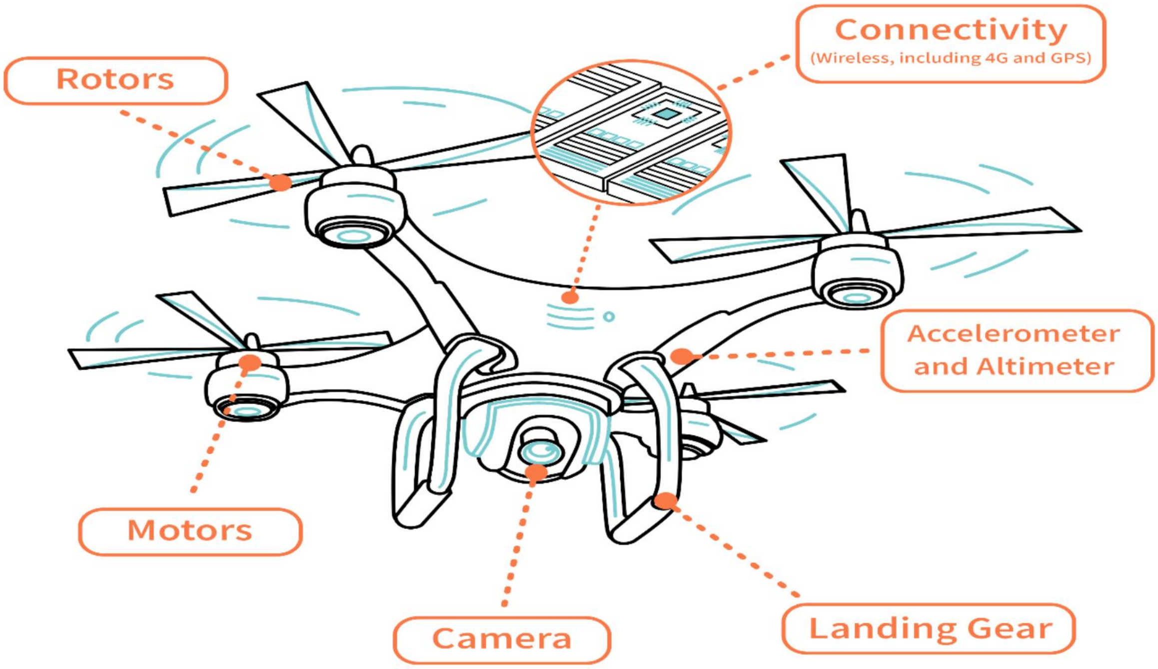
- **Characteristics:** Can perform autonomous functions but require occasional human intervention
- **Examples:** Many drones used for commercial purposes like agriculture or mapping

Conclusion

UAV classification varies depending on factors like size, range, altitude, purpose, flight mechanism, and level of autonomy. Each type serves specific needs, from recreational use to highly specialized military and scientific applications.

Reference Link:
https://www.e-education.psu.edu/geog892/node/5

2.2 OVERVIEW OF THE MAIN DRONE PARTS



Here is an overview of the **main parts of a drone**:

1. Frame

- **Purpose**: The frame is the body or skeleton of the drone. It holds all the components together.
- **Materials**: Commonly made from carbon fiber, plastic, or aluminum for lightweight and durability.

2. Motors

- **Purpose**: The motors power the propellers, allowing the drone to lift and maneuver. Most drones have four motors (quadcopter), but there are hexacopters (six motors) and octocopters (eight motors) as well.
- **Type**: Brushless motors are most commonly used for efficiency and long life.

3. Propellers

- **Purpose**: Propellers generate the lift needed for flight. Each motor drives a propeller, and their coordinated speeds control the drone's movement.
- **Shape**: They are often bi-bladed or tri-bladed, with different designs for optimizing flight performance.

4. Electronic Speed Controllers (ESCs)

- **Purpose**: ESCs control the speed and direction of the motors by regulating power input. They take signals from the flight controller and adjust motor speeds accordingly.
- **Location**: Usually mounted on the arms of the drone near the motors.

5. Flight Controller

- **Purpose**: The brain of the drone, responsible for stabilizing and controlling the drone's flight. It processes input from the user and onboard sensors to manage motor speeds, flight path, and orientation.
- **Features**: Includes a gyroscope, accelerometer, and sometimes a barometer, GPS, and compass.

6. Battery

- **Purpose**: The primary power source for the drone. Most drones use lithium polymer (LiPo) batteries due to their high energy density and lightweight design.
- **Voltage**: The voltage (number of cells) determines the power available for the motors and flight time.

7. GPS Module

- **Purpose**: Provides location data to the flight controller. Essential for autonomous flight, return-to-home features, and positioning.
- **Optional**: Found in more advanced drones for precise navigation.

8. Transmitter (Remote Controller)

- **Purpose**: The user interface that sends signals to the drone, controlling its movement, speed, and orientation. It communicates with the drone's receiver.
- **Frequency**: Commonly uses radio frequencies like 2.4 GHz or 5.8 GHz.

9. Receiver

- **Purpose**: Installed in the drone to receive commands from the transmitter. It sends these commands to the flight controller for execution.

10. Camera (Optional)

- **Purpose**: Allows for aerial photography or videography. Some drones have built-in cameras, while others support external mounts like GoPro.
- **Gimbal**: Often paired with a gimbal to stabilize the camera during flight for smooth footage.

11. Landing Gear

- **Purpose**: Protects the drone's body, especially during takeoff and landing. Some drones have retractable landing gear, while others have fixed legs.

12. Antennas

- **Purpose**: Used for communication between the drone and the controller, as well as for video transmission if a camera is used.
- **Types**: FPV (First Person View) drones have antennas for real-time video streaming to the user.

13. FPV (First Person View) System (Optional)

- **Purpose**: Provides a live video feed to the user, giving a real-time view from the drone's perspective. Often used in racing or for cinematic drone shots.
- **Components**: Includes a camera, video transmitter (VTX), and video receiver (VRX), usually integrated into goggles or screens.

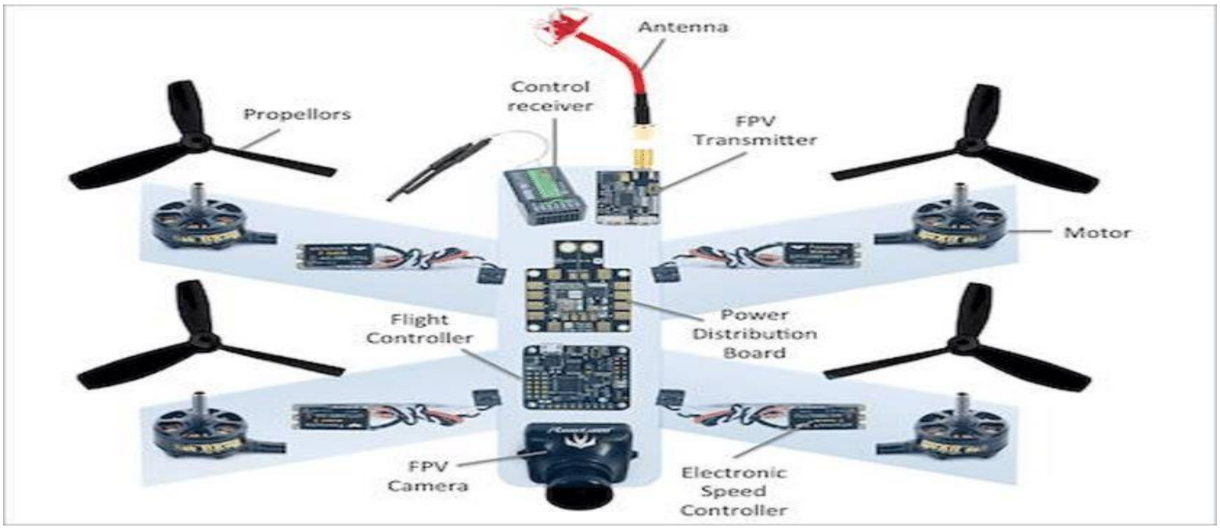
14. Sensors

- **Purpose**: Drones often include additional sensors like:
    - **Ultrasonic sensors**: For altitude control and obstacle detection.
    - **Infrared sensors**: For detecting heat or object proximity.
    - **Barometer**: For measuring altitude by detecting air pressure.

15. Power Distribution Board (PDB)

- **Purpose**: Distributes power from the battery to the motors, ESCs, and other components like the flight controller and sensors.

These are the essential parts of a drone, each contributing to its flight, control, and functionality.



2.3 TECHNICAL CHARACTERISTICS OF THE PARTS

Here are the **technical characteristics** of the main drone parts, covering specifications that affect performance, efficiency, and capabilities:

1. Frame

- **Material**: Carbon fiber, aluminum, plastic
- **Weight**: Ranges from 50g to 300g (for small to mid-sized drones)
- **Size**: Measured in millimeters between motor mounts (e.g., 250mm, 450mm)
- **Durability**: Must withstand impacts and resist bending
- **Type**: Quadcopter, Hexacopter, or Octocopter configuration
- **Arm Length**: Affects stability and agility during flight

2. Motors

- **Type**: Brushless motors (most common) or brushed (less efficient)
- **KV Rating**: Measured in RPM/Volt (e.g., 2300 KV)
  - Higher KV = more RPM, more speed but less torque.
  - Lower KV = more torque, better for lifting heavy loads.
- **Thrust**: Motor thrust output measured in grams or pounds.
- **Voltage Compatibility**: Typically 3S (11.1V), 4S (14.8V), or 6S (22.2V) batteries.
- **Power Output**: 100W to 2000W per motor for high-performance drones.

3. Propellers

- **Diameter**: Measured in inches, ranging from 3” to 10” or more.
  - Larger propellers generate more lift but reduce agility.
  - Smaller propellers offer faster acceleration and maneuverability.
- **Pitch**: Refers to the angle of the blades (e.g., 5x3 means 5” diameter, 3” pitch).
- **Material**: Plastic, carbon fiber, or nylon composite for strength and lightness.
- **Number of Blades**: More blades (e.g., tri-blades) offer more stability, while fewer blades are more efficient and faster.

4. Electronic Speed Controllers (ESCs)

- **Current Rating**: Measured in Amps (e.g., 20A, 30A, 40A).
  - Higher amp rating supports more powerful motors.
- **Voltage Rating**: Typically supports 2S to 6S LiPo batteries (7.4V to 22.2V).
- **Protocol Support**: DShot, PWM, Oneshot, or Multishot protocols for motor communication.
- **BEC (Battery Elimination Circuit)**: Optional; supplies power to the flight controller and other systems (e.g., 5V output).

5. Flight Controller

- **Processor**: ARM-based microcontroller (e.g., STM32 series).
  - Faster processors enable smoother flight and more complex tasks.
- **Sensors**: Gyroscope (6-axis), accelerometer, barometer (altimeter), magnetometer (compass), GPS, and IMU (Inertial Measurement Unit).
- **Firmware**: Runs software like Betaflight, Ardupilot, or INAV.
- **Ports**: Multiple UART, I2C, and PWM ports for connecting sensors, GPS, ESCs, and telemetry.
- **Integrated OSD (On-Screen Display)**: Displays flight data in real-time on FPV goggles or screen.

6. Battery

- **Type**: Lithium Polymer (LiPo) or Lithium-Ion (Li-ion).
- **Capacity**: Measured in milliamp-hours (mAh). Common capacities are 1000mAh to 5000mAh.
  - Larger capacity = longer flight time, but also more weight.
- **Voltage (Cell Count)**: Typically 2S (7.4V), 3S (11.1V), 4S (14.8V), 6S (22.2V).
  - Higher voltage provides more power but requires compatible ESCs and motors.
- **C-Rating**: Indicates the battery's discharge rate (e.g., 30C, 50C).
  - Higher C-rating = better for high-performance drones, faster energy delivery.
- **Weight**: Affects flight time and performance (e.g., 100g to 400g depending on size).

7. GPS Module

- **Position Accuracy**: Generally within 1-2 meters for consumer GPS units.
- **Refresh Rate**: 5Hz to 10Hz (number of updates per second).
- **GNSS Support**: Can support GPS, GLONASS, Galileo, or BeiDou satellite systems.
- **Cold Start/Hot Start Time**: Time to acquire signal, cold start usually takes longer (30-60 seconds).

8. Transmitter (Remote Controller)

- **Frequency**: 2.4 GHz or 5.8 GHz for control and communication.
  - Higher frequencies (e.g., 5.8 GHz) provide better range but may face interference.
- **Channels**: Ranges from 4 to 16 channels, with more channels providing better control over extra functions (e.g., gimbal control).
- **Range**: Typically 1km to 5km, with extended range systems reaching up to 10km or more.
- **Latency**: Measured in milliseconds (lower latency is better for responsive control).

9. Receiver

- **Frequency Compatibility**: 2.4 GHz or 5.8 GHz, matching the transmitter.
- **Protocol**: FrSky, FlySky, Spektrum, or Crossfire (for long-range) protocols.
- **Antenna Configuration**: Single or dual antenna for better signal reception.

10. Camera

- **Resolution**: Common resolutions are 1080p, 2.7K, and 4K, with higher resolutions offering better image quality.
- **Frame Rate**: 30fps, 60fps, or 120fps, with higher frame rates used for smoother or slow-motion footage.
- **Field of View (FOV)**: Measured in degrees (e.g., 90° to 170°), affecting how much the camera can see.
- **Sensor Type**: CMOS or CCD sensor, affecting image quality and low-light performance.

11. Gimbal

- **Axis Stabilization**: 2-axis or 3-axis stabilization to counteract drone movement.
- **Control Precision**: Usually around ±0.02° for smooth stabilization.
- **Weight**: Ranges from 100g to 300g, affecting overall drone payload.

12. Landing Gear

- **Material**: Plastic, carbon fiber, or aluminum for lightweight and durability.
- **Height**: Usually around 100-150mm to protect the camera and body.
- **Weight**: 50g to 200g depending on design and material.

13. Antennas

- **Frequency Range**: 2.4 GHz or 5.8 GHz (control) and 5.8 GHz for FPV video.
- **Polarization**: Linear or circular polarization; circular provides better signal stability.
- **Gain**: Measured in dBi; higher gain (e.g., 5dBi) extends range but narrows the beam width.

14. FPV System

- **Camera Resolution**: Typically low-latency analog video feed (600TVL, 800TVL).
- **Video Transmitter (VTX) Power**: Ranges from 25mW to 800mW; higher power increases range.
- **Frequency Bands**: 5.8 GHz is common for FPV video.
- **Latency**: Critical for FPV racing, usually under 20ms.
- **Display**: FPV goggles or screens with low latency and high refresh rates.

15. Power Distribution Board (PDB)

- **Current Rating**: Supports up to 100A or more, depending on the drone's power requirements.
- **Voltage Input**: Supports 2S to 6S LiPo batteries (7.4V to 22.2V).
- **Outputs**: Provides power to ESCs, flight controller, camera, and other components.

These technical characteristics dictate how efficiently and effectively a drone can fly, perform maneuvers, and carry out specialized tasks such as aerial photography or racing.

2.4 FUNCTION OF THE COMPONENT PARTS

Here's a breakdown of the **functions** of the various drone components:

1. Frame

- **Function**:
  - The frame serves as the skeleton of the drone. It supports and holds all other components together, such as motors, propellers, and the flight controller.
  - It provides structural integrity and rigidity to withstand forces during flight, landing, or collisions.

2. Motors

- **Function**:
  - Motors are responsible for rotating the propellers, which generates thrust to lift the drone off the ground.
  - They work in pairs, with two rotating clockwise (CW) and two counterclockwise (CCW), providing stability and control for movement.
  - Motor speed changes to control the drone's orientation, pitch, yaw, and roll.

3. Propellers

- **Function**:
  - Propellers create lift by displacing air downward, allowing the drone to rise, hover, or descend.
  - By varying the speed of individual propellers, the drone can move in different directions (forward, backward, sideways) and maintain stability.
  - Propellers' size and pitch affect the drone's agility, speed, and efficiency.

4. Electronic Speed Controllers (ESCs)

- **Function**:
  - ESCs regulate the speed of each motor by controlling the electrical power supplied from the battery.
  - They receive signals from the flight controller to increase or decrease motor speed for stable flight, maneuvers, and directional changes.
  - ESCs ensure smooth acceleration and deceleration of motors to avoid instability during rapid movements.

5. Flight Controller

- **Function**:
  - The flight controller is the brain of the drone, processing data from sensors (gyroscope, accelerometer, GPS) and user input to maintain balance and control.

- It adjusts the speed of each motor through the ESCs, ensuring the drone can hover, climb, descend, or maneuver correctly.
- The controller ensures stability during flight and manages auto-pilot features like return-to-home and waypoint navigation.

6. Battery

- **Function**:
  - The battery is the main power source for the entire drone, providing electrical energy to the motors, ESCs, flight controller, and other components like cameras and sensors.
  - The size and capacity of the battery directly influence flight time and overall power available for high-performance tasks.
  - A balanced power distribution ensures efficient use and longevity of drone operations.

7. GPS Module

- **Function**:
  - The GPS module provides the drone's precise location and altitude data to the flight controller for autonomous flight, navigation, and geo-fencing.
  - It enables features like return-to-home (RTH), waypoint navigation, and precise hovering in one place without drifting.
  - GPS is crucial for outdoor flights and tracking the drone's location for safety.

8. Transmitter (Remote Controller)

- **Function**:
  - The transmitter is the handheld device used by the pilot to send control signals (throttle, yaw, pitch, and roll) to the drone's receiver.
  - It enables the pilot to manage flight direction, speed, camera angle, and other functions in real-time.
  - Advanced transmitters offer telemetry data, allowing the pilot to monitor flight status such as battery levels, GPS location, and signal strength.

9. Receiver

- **Function**:
  - The receiver in the drone collects signals from the transmitter and forwards them to the flight controller.
  - It decodes the pilot's commands for flight adjustments, such as motor speed changes for direction and altitude control.
  - The receiver ensures real-time communication for responsive and stable drone operation.

10. Camera

- **Function**:
  - The camera captures aerial photos and videos during flight, providing the drone's visual capabilities.
  - It can be used for FPV (First Person View) to stream real-time video to the pilot, giving them a live perspective of what the drone sees.
  - In professional drones, cameras are used for tasks like surveying, photography, videography, and inspections.

11. Gimbal

- **Function**:
  - The gimbal stabilizes the camera during flight, ensuring smooth video capture and eliminating jitter caused by drone movement.
  - It provides 2-axis or 3-axis stabilization to maintain a steady camera angle, even when the drone changes orientation or experiences turbulence.
  - Gimbals often allow the pilot to tilt or rotate the camera remotely.

12. Landing Gear

- **Function**:
  - The landing gear supports the drone during takeoff and landing, preventing damage to the body and sensitive components like the camera.
  - It keeps the drone elevated above the ground, particularly if equipped with a bottom-mounted camera.
  - Some drones have retractable landing gear that folds during flight to reduce drag and improve aerodynamics.

13. Antennas

- **Function**:
  - Antennas enable communication between the drone and the transmitter/receiver for control and telemetry.
  - FPV antennas transmit live video feed to the pilot, providing a real-time view for navigation or aerial imaging.
  - High-gain antennas improve signal range and reliability, especially in long-distance flights.

14. FPV (First Person View) System

- **Function**:
  - The FPV system provides a live video feed from the drone's camera to the pilot, typically through FPV goggles or a screen.
  - It allows the pilot to fly the drone as if they are in the cockpit, crucial for racing, aerial cinematography, and navigating tight spaces.

- The FPV system enables precise control, especially in situations where direct line-of-sight is not possible.

15. Power Distribution Board (PDB)

- **Function**:
  - The PDB distributes electrical power from the battery to various components like the ESCs, flight controller, and other electronics.
  - It ensures that each component receives the appropriate voltage and current, preventing overload or underpowering of critical parts.
  - The PDB simplifies wiring by centralizing the power supply to all parts of the drone.

These components work together to achieve flight, stability, navigation, and control of the drone. Each plays a crucial role in ensuring smooth and safe operation.

2.5 ASSEMBLING A DRONE

Assembling a drone involves carefully combining all its components to ensure proper functionality. Here's a general guide on how to assemble a drone:

1. Prepare the Parts

- **Drone frame**
- **Motors**
- **Electronic Speed Controllers (ESCs)**
- **Propellers**
- **Flight controller**
- **Power distribution board (PDB)**
- **Battery**
- **Receiver and Transmitter**
- **GPS module (if needed)**
- **Camera and Gimbal (optional)**
- **Landing gear**
- Tools: Soldering iron, screwdrivers, wire cutters, heat shrink, electrical tape, and screws.

2. Assemble the Frame

- Start by laying out the **drone frame** and assembling the main body according to the kit's instructions.
- Attach the **arms** to the central hub (for quadcopters, there are typically four arms). Use screws to fasten everything securely.

3. Install the Motors

- Attach the **motors** to the ends of the frame arms. Most drone motors are either clockwise (CW) or counterclockwise (CCW) to ensure balanced flight.
- Ensure the motors are properly secured to prevent vibrations that could destabilize the drone.
- Verify the wiring of each motor matches the ESC placement.

4. Mount the ESCs

- Install the **Electronic Speed Controllers (ESCs)** near each motor on the frame. Use zip ties or electrical tape to secure them in place.
- Solder the ESC wires to the corresponding motor wires. Usually, there are three wires from each ESC to each motor.
- Cover the solder joints with **heat shrink** to prevent short circuits.

5. Connect the Power Distribution Board (PDB)

- Attach the **Power Distribution Board (PDB)** to the frame's central hub. This board distributes power from the battery to all components.
- Solder the power leads from each **ESC** to the PDB. Ensure the connections are solid and covered with heat shrink.
- Connect the battery leads to the PDB.

6. Install the Flight Controller

- Mount the **flight controller** in the center of the drone, using rubber or foam pads to reduce vibrations.
- Connect the **ESCs** to the flight controller using the signal wires. Each motor has a designated position on the controller, usually marked 1, 2, 3, 4 for quadcopters.
- Connect any additional sensors, such as a GPS or barometer, to the flight controller.

7. Attach the Receiver

- Install the **receiver** on the drone frame, and connect it to the flight controller using the appropriate wires.
- Ensure the receiver is securely placed and antennas are oriented properly to avoid signal loss.

8. Install the Battery

- Place the **battery** on the bottom or center of the frame, depending on the design. Most frames have a battery tray or compartment.
- Use velcro straps or clips to secure the battery, ensuring it won't shift during flight.
- Connect the battery leads to the power distribution board.