Cálculos para estos componentes

Qué tenemos?

Motor brushless A22-12:

- 1000KV -> Cada voltio girará 1000 rpm
- 22mm width of the stator
- 13mm height of the rotor

ESC (Electrónic Speed Controller):

- 30A

Propeller 10-45:

- Diameter: 10 inches → 25,4 cm
- Pitch 4.5 inches → 11.43

Battery 2 options:

- Batería Lipo 3500mAh 2S 25C, 7.4V
    - 3500mAh
    - 7,4V
    - 2s
    - 25C → 3,5A*25(1/h) = 87,5A (Max Amp output)
    - Energia = 3.5 Ah * 7.4V = 25.9 Wh
- Lipo Batería 5200mAh 2S 50C 7.4V
    - 5200mAh
    - 7,4V
    - 2s
    - 50C → 5,2A*50(1/h) = 260A (Max Amp output)
    - Energia = 5.2 Ah * 7.4V = 38.48 Wh

Weight: 1kg

¿Volará?

Peso del dron

Componente	Peso
RaspBerry pi 4	10g
Cámara con autofocus 12MP IMX477	5g
Motor brushless * 4	120*4 = 480g
Batería Lipo 3500mAh 2S 25C, 7.4V	215g
Omnibus F4V3S F4 V3 V3S PLUS FC	18g
Carcasa	250g
TOTAL:	978 - aprox 1 kg

Thrust-to-Weight Ratio (T:W)

Thrust:

1. Determine motor rpm:
   - KV: Motor KV Rating
   - V: Battery voltage

   Formula: KV · V = RPM → KV = 1000kv · 7,4V = 7400RPM

2. Calculate propeller thrust

   $T \approx C_T \cdot \rho \cdot n^2 \cdot D^4$

   Where:

   - T: Thrust in Newtons
   - C_T: Thrust coefficient (typically ranges from 0.1 to 0.2 for common hobby props)
   - *ρ: Air density (approx 1.225 kg/m3 at sea level)*
   - *n: Rotational speed in revolutions per second (RPS)*
   - *D: Propeller diameter in meters*

RPM to RPSecond = 7400/60 = 123,33

Ct = 0.15
p = 1.225
n = 123
D = 0.25

T = 0,15 * 1.225 * 123 ^ 2 * 0.25 ^ 4 = 11,57 N

Convert thrust to kilograms (1Kg = 9.81N)
14,47 / 9,81 = 1,179kg

Total thrust for 4 motors = 1,352kg * 4 = 4.6996kg

Thrust to weight ratio = 4.6kg / 1kg = 4.6kg

Induced Velocity at Hover ($v_{i,h}$)

Weight (m): 1kg *(*1000g *from our example above)*

Propeller Radius (r_{prop}): 0.125 *(0.25 diameter from our 10" example above/2)*

Air Density (ϱ): 1.225 kg/m^3 *(approx at sea level)*

Gravitational Force (g): 9.81 m/s^2 *(constant)*

Number of Rotors (N_r): 4 *(4 total motors)*

Step-by-step calculation:

Formula: $v_{i,h} = \sqrt{\,(T_h / 2\varrho A_{prop})} = \sqrt{\,(mg / 2\varrho\pi r^2_{prop} N_r)}$

1. Calculate the Thrust Required to Hover (T_h):

$T_h = mg = 1 \cdot 9.81 \approx \mathbf{9.81\ N}$

2. Calculate the Propeller Area (A_{prop}):

$A_{prop} = \pi r^2_{prop} = \pi(0.125)^2 \approx \pi \cdot 0.015625 = \mathbf{0.049087\ m^2}$

3. Insert the Values into the Formula:

$v_{i,h} = \sqrt{\ } 9.81/ 2 \cdot 1.225 \cdot \pi \cdot 0.015625 \cdot 4$

Simplify for Induced Velocity at Hover:

$v_{i,h} = \sqrt{\ } 6.867 / 0.48105 \approx \sqrt{16.81} \approx \mathbf{4.51\ m/s}$

3. Hover Power (P_h)

What variables do you need:

Weight *(m): 1 (1000g from our example above)*

Gravitational Force *(g): 9.81 m/s^2 (constant)*

Air Density *(ϱ): 1.225 kg/m^3 (approx at sea level)*

Propeller Radius *(r_{prop}): 0.125 (0.13 diameter from our 5" example above/2)*

Number of Rotors *(N_r): 4 (4 total motors)*

Propeller Efficiency *(η_P): 0.6 (typical assumption for small multicopter propellers)*

Thrust Required to Hover *(T_h): 9,81N (calculated from previous formula)*

Induced Velocity at Hover *($v_{i,h}$): 4.51 m/s (calculated from previous formula)*

Step-by-step calculation:

Formula: $P_h = T_h v_{i,h} N_r / \eta_P$

1. Insert Values into the Formula:

$P_h = (9{,}81 \cdot 4.51 \cdot 4) / 0.6$

2. Simplify for Hover Power:

$P_h = 176.97 / 0.6 \approx$ ***294.95 W***

4. Power at Optimal Endurance (P_e) and Optimal Range (P_r)

Hover power: *294.95W (calculated above)*

Power consumption for optimal endurance: *91.4% (constant derived from studies and experiments on multicopter performance)*

Power consumption for optimal range: *109.2% (constant derived from studies and experiments on multicopter performance)*

Step-by-step calculation:

1. Calculate Power at Optimal Endurance *(P_e)**:***

$P_e = 0.914 \cdot 294.95 \approx \mathbf{269.58\ W}$

2. Calculate Power at Optimal Range *(P_r)**:***

$P_r = 1.092 \cdot 294.95 \approx \mathbf{322.08\ W}$

5. Electric Power Demand ($P_{mot,e}$), ($P_{mot,r}$)

What variables do you need:

Power at Optimal Endurance *(P_e):* ***269.58*** *W (calculated above)*

Power at Optimal Range *(P_r):* ***322.08*** *W (calculated above)*

Motor Efficiency *(ηM): 0.75 (assumed, typical value for electric motors)*

Step-by-step calculation:

1. Calculate Electric Power Demand at Optimal Endurance *($P_{mot,e}$)**:***

Formula: *($P_{mot,e}$) = P_e / ηM*

Insert values into formula:

($P_{mot,e}$) = 269.58 / 0.75 ≈ ***359.44 W***

2. Calculate Electric Power Demand at Optimal Range *($P_{mot,r}$)**:***

Formula: *($P_{mot,r}$) = P_r / ηM*

Insert values into formula:

($P_{mot,r}$) = 322.08 / 0.75 ≈ ***429.44 W***

6. Normalized Power Consumption ($P_{cell,e}$), ($P_{cell,r}$)

What variables do you need:

Power Demand at Optimal Endurance *($P_{mot,e}$): 359.44W (calculated above)*

Power Demand at Optimal Range *($P_{mot,r}$): 429.44 W (calculated above)*

Battery Cell Count *(N_{cell}): 2 (based on the battery we picked)*

Battery Capacity *(C_{batt}): 3500 mAh (based on the battery we picked)*

Step-by-step calculation:

1. Convert Battery Capacity from mAh to Ah:

C_{batt} = 3500 mAh / 1000 = ***3.5 Ah***

2. Calculate Normalized Power Consumption at Optimal Endurance *($P_{cell,e}$):*

Formula: $P_{cell,e} = P_{mot,e} / (N_{cell} \cdot C_{batt})$

Insert values into formula:

$P_{cell,e}$ = 359.44 / (2 · 3.5) = 359.4/ 7 ≈ ***51.34 W / Ah***

3 . Calculate Normalized Power Consumption at Optimal Range *($P_{cell,r}$):*

Formula: $P_{cell,r} = P_{mot,r} / (N_{cell} \cdot C_{batt})$

Insert values into formula:

$P_{cell,r}$ = *429.44/ (2 · 3.5) = 429.44 / 7 ≈* ***61.34 W / Ah***

7. Effective Battery Capacity (κ_e), (κ_r)

What variables do you need:

Normalized Power Consumption at Optimal Endurance ($P_{cell,e}$)*:* 51.34 W / Ah *(calculated above)*

Calculate Normalized Power Consumption at Optimal Range ($P_{cell,r}$)*:* 61.34 W / Ah *(calculated above)*

Polynomial coefficients for effective capacity *(assumed, based on empirical data)*
d_0: Constant term = 1.0
d_1: Linear term coefficient = -0.01
d_2: Quadratic term coefficient = 0.0005
d_3: Cubic term coefficient = -0.00001

Step-by-step calculation:

1. Calculate Battery Capacity at Optimal Endurance (κ_e)*:*

Formula: $\kappa_e = d_0 + d_1 P_{cell,e} + d_2 P^2_{cell,e} + d^3_{cell,e}$

Insert values into formula:
κ_e = *1.0* + *(-0.01* · 51.34) + (0.0005 · 51.34^2) + (-0.00001 · 51.34^3)

Simplify:
κ_e = *1 - 0.*5134 + *1.3178 - 1.3532≈* **0.4512**

2. Calculate Battery Capacity at Optimal Range (κ_r)*:*

Formula: $\kappa_r = d_0 + d_1 P_{cell,r} + d_2 P^2_{cell,r} + d^3_{cell,r}$

Insert values into formula:
κ_r = *1.0* + *(-0.01* · 61.34) + (0.0005 · 61.34^2) + (-0.00001 · 61.34^3)

Simplify:
κ_r = *1 -0.*6134 + *1.8813.- 2.3079*≈ **-0.04**

8. Maximum Endurance and Flight Time (t_e), (t_r)

What variables do you need:

Effective Battery Capacity at Optimal Endurance (κ_e): 0.4512 *(calculated above)*

Effective Battery Capacity at Optimal Range (κ_r): -004*(calculated above)*

Electric Power Demand at Optimal Endurance ($P_{mot,e}$): 359.44 W *(calculated above)*

Electric Power Demand at Optimal Range ($P_{mot,r}$): 429.44 W *(calculated above)*

Battery Cells (N_{cell}): 2 *(based on the battery we picked)*

Battery Capacity (C_{batt}): 3500 mAh *(based on the battery we picked)*

Nominal Cell Voltage: 3.7 V *(constant)*

Step-by-step calculation:

1. Convert Battery Capacity from mAh to Ah:
C_{batt} = *3500 mAh / 1000 =* ***3.5 Ah***

2. Calculate Total Effective Battery Capacity in Watt-hours (Wh):

For Endurance:

Formula: $C_{eff,e} = \kappa_e \cdot C_{batt} \cdot N_{cell} \cdot 3.7$ V
$C_{eff,e} = 0.4512 \cdot 3.5 \cdot 2 \cdot 3.7 \approx$ **11.68 Wh**

For Range:

Formula: $C_{eff,r} = \kappa_r \cdot C_{batt} \cdot N_{cell} \cdot 3.7\ \mathrm{V}$
$C_{eff,r} = 0.01 \cdot 1.5 \cdot 4 \cdot 3.7 \approx$ **14.13 Wh**

3. Calculate Maximum Endurance (t_e):

Formula: $t_e = (C_{eff,e} \cdot 3600$ seconds in an hour) / $P_{mot,e}$
$t_e = 11.68 \cdot 3600 / 359.44 \approx 116.98$ seconds ≈ **1.94 minutes**

4. Calculate Flight Time at Maximum Range (t_r):

Formula: $t_r = (C_{eff,r} \cdot 3600$ seconds in an hour) / $P_{mot,r}$
$t_r = 14.13 \cdot 3600 / 273.40 \approx 186$ seconds ≈ **3.1 minutes**