BID4R Project - Final Power-Flow Calculations

1. Power Consumption of Each Component

We calculate the power consumption using the formula: $P = V \times I$

Where:

- P is power in watts (W)

- V is voltage in volts (V)

- I is current in amps (A)

Motors (powered directly by LiPo):

Normal operation (per motor): P = 3.7V × 0.3A = 1.11W
For two motors: 1.11W × 2 = 2.22W
Stall condition (per motor): P = 3.7V × 1.5A = 5.55W
For two motors: 5.55W × 2 = 11.1W

Pixy2 Camera (powered by PowerBoost 1000C): P = 5V × 0.14A = 0.7W

VCNL4010 Proximity Sensor (powered by PowerBoost 1000C): P = 5V × 0.008A = 0.04W

Arduino Nano 33 IoT (powered by PowerBoost 1000C): P = 5V × 0.16A = 0.8W

APA106 LED (powered by PowerBoost 1000C): P = 5V × 0.06A = 0.3W

DS18B20 Temperature Sensor (powered by PowerBoost 1000C): P = 5V × 0.0015A = 0.0075W

Adafruit Power Relay FeatherWing (powered by PowerBoost 1000C): P = 5V × 0.02A = 0.1W

2. Total Power Consumption

The total power consumption is the sum of the motors and the PowerBoost-powered components:

Normal operation:

Power consumption of the motors: 2.22W

Power consumption of the components powered by the PowerBoost:
- Pixy2 Camera: 0.7W
- VCNL4010 Proximity Sensor: 0.04W
- Arduino Nano 33 IoT: 0.8W
- APA106 LED: 0.3W
- DS18B20 Temperature Sensor: 0.0075W
- Power Relay FeatherWing: 0.1W

Summing up the PowerBoost components: P_PowerBoost (normal) = 1.9475W

Thus, the total power consumption during normal operation is:

P_total (normal) = 2.22W + 1.9475W = 4.1675W

Stall condition:

Power consumption of the motors: 11.1W

Power consumption of the components powered by the PowerBoost remains the same:
P_PowerBoost (stall) = 1.9475W

Thus, the total power consumption during stall condition is:

P_total (stall) = 11.1W + 1.9475W = 13.0475W

3. PowerBoost Efficiency

The PowerBoost 1000C operates at 90% efficiency. The power drawn from the battery by the PowerBoost is:

P_battery for PowerBoost = P_PowerBoost / Efficiency

For both normal and stall conditions, the PowerBoost is drawing the same power:

P_battery for PowerBoost = 1.9475W / 0.9 ≈ 2.16W

4. Battery Capacity and Energy Stored

The energy stored in the LiPo battery is calculated as:

E_battery = Capacity (Ah) × Voltage (V)

For a 3Ah, 3.7V battery: E_battery = 3Ah × 3.7V = 11.1Wh

5. Battery Runtime Estimate

We estimate the battery runtime using: Runtime = E_battery / P_total

For normal operation: Runtime (normal) = 11.1Wh / 4.1675W ≈ 2.66 hours ≈ 159 minutes

For stall conditions: Runtime (stall) = 11.1Wh / 13.0475W ≈ 0.85 hours ≈ 51 minutes

6. Current Draw Monitoring

We ensure the PowerBoost 1000C's current draw is within the 1A limit. The total current draw is:

I_total PowerBoost = I_Pixy2 + I_VCNL4010 + I_Arduino + I_LED + I_DS18B20 + I_Relay

Substituting values: I_total PowerBoost = 0.14A + 0.008A + 0.16A + 0.06A + 0.0015A + 0.02A = 0.3895A

This is within the 1A limit of the PowerBoost.

7. Charging Time for the Battery

The time required to charge the battery using the Qi wireless charging system is estimated using the following formula:
Charging Time = E_battery / P_charging
Given the Qi charger provides 5W with 80% efficiency, the power delivered to the battery is:
P_charging = 5W × 0.8 = 4W
Thus, the charging time is:
Charging Time = 11.1Wh / 4W ≈ 2.78 hours ≈ 2 hours and 47 minutes

8. (BMS and Fuses)

The Battery Management System (BMS) included in the design will not significantly affect the power consumption or runtime calculations, as its primary function is to protect the battery from overcharging, over-discharging, and short circuits. Similarly, the use of fuses will not impact the overall power consumption, as fuses are passive components that only interrupt the circuit when the current exceeds the specified limit. Under normal operating conditions, both the BMS and fuses function as safety mechanisms without drawing significant power.

Formula for Operating Time Based on Load Conditions:

T_operation = E_battery / [(f_heavy × P_heavy) + (f_normal × P_normal)]

Variables Explained:

T_operation: Total operating time of the robot (in hours).

E_battery: Energy stored in the battery, in watt-hours (Wh).

- Example: For a 3Ah, 3.7V LiPo battery, E_battery = 11.1Wh.

f_heavy: Fraction of time the robot spends under heavy load (as a decimal).

- Example: If the robot operates under heavy load 10% of the time, f_heavy = 0.1.

P_heavy: Power consumption during heavy load (in watts, W).

- Example: P_heavy = 13.05W (including motor and other components).

f_normal: Fraction of time the robot spends under normal load (as a decimal).

- Example: If the robot operates under normal conditions 90% of the time, f_normal = 0.9.

P_normal: Power consumption during normal load (in watts, W).

- Example: P_normal = 4.17W (including motor and other components).