Battery Selection and Power Analysis

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1 Introduction

This report presents the process of selecting the most suitable power source for our mobile robot. The robot consists of several components, including motors, sensors, and microcontrollers, all of which have specific power requirements. The objective is to identify a battery that can meet these requirements in both typical and worst-case scenarios. The report covers power calculations, battery selection, and a comparative analysis of different power sources. By understanding the robot's energy needs, we ensure optimal performance and efficiency.

2 Component Specifications

To calculate the total power requirements, we first identify the operating voltage and current consumption of each component in the robot. The table below summarizes the typical and peak current consumption values for each component:

Component	**Operating Voltage (V)**	**Typical Current Consumption (mA)**	**Peak Current Consumption (mA)**
TCS34725 RGB Color Sensor	5	0.235	0.330
N20 Motor (x2)	6	70 - 100	300
Magnetic Encoder (x2)	3.3	10	20
8-Array IR Sensors	3.3 - 5	100	100
GY-US42 Ultrasonic Sensor	5	9	9
ToF Sensor	3.3	20	30
Servo Motor	5 - 6	600	600
ESP32	3.3	250	250
DRV8833 Motor Driver	2.7 - 10.8	1.7	3

Table 1: Component Specifications: Voltage and Current Consumption

3 Total Current Calculation

The total current consumption is calculated for both typical and worst-case (peak) scenarios:

$$I_{\text{total, typical}} = 0.235 + (2 \times 70) + (2 \times 10) + 100 + 9 + 20 + 600 + 250 + 1.7 = 1140.935\,\text{mA}$$

$$I_{\text{total, worst}} = 0.330 + (2 \times 300) + (2 \times 20) + 100 + 9 + 30 + 600 + 250 + 3 = 1632.33\,\text{mA}$$

4 Battery Capacity Calculation

The required battery capacity is determined by the total current consumption and the desired operating time (2 hours). The battery capacity is calculated for both the typical and worst-case scenarios:

$$\text{Capacity}_{\text{typical}} = 1140.935\,\text{mA} \times 1\,\text{hours} = 1140.935\,\text{mAh}$$

$$\text{Capacity}_{\text{worst}} = 1632.33\,\text{mA} \times 1\,\text{hours} = 1632.33\,\text{mAh}$$

5 Battery Selection

A suitable battery must meet the following requirements:

- **Voltage**: At least 6V to match the N20 motors and DRV8833 motor driver.
- **Capacity**: At least 3264.66 mAh for 2 hours of worst-case operation.

Selection: A **2-cell 3.7V Lithium-Ion Battery (2200 mAh)** in series provides 7.4V and a capacity of 2200 mAh. Two such batteries can meet the voltage and energy requirements of the robot.

Specifications of Li-ion Battery:

- **Voltage**: 3.7V (per cell)
- **Capacity**: 2200 mAh
- **Max Charging Current**: 2.2A
- **Max Discharging Current**: 4.3A
- **Size**: 18650 (Cylindrical)

6 Power Distribution

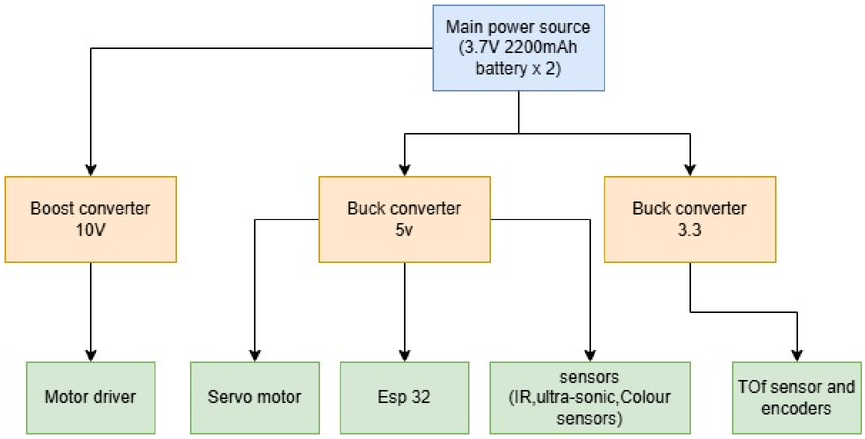

Figure 1: Power Distribution Circuit Diagram

Description:

The power distribution circuit uses two 3.7V batteries, providing a total of 7.4V. It consists of multiple power pathways:

- **Boost Converter (10V)**: Powers the motors driver.
- **Motor Controller (6V)**: Powers the motors directly.
- **Buck Converter (5V)**: Steps down voltage for the servo motor,Sensors and Micro controller(ESP 32)
- **Buck Converter (3.3V)**: Reduces voltage for the TOF sensors and magnetic encoders.

Alternative Battery Options

The following are alternative battery types along with their specifications, discharge rates, pros, and cons:

- **Lead-Acid Battery**
  - Voltage: 12 V
  - Capacity: 1000 - 20000 mAh
  - Discharge Rate: Typically around 1C
  - Key Features: Economical, high power output, heavy, limited cycle life (200-300 cycles)
  - Pros: Cost-effective, reliable for high power applications
  - Cons: Heavy, lower energy density, limited cycle life
- **Nickel-Cadmium (NiCd)**
  - Voltage: 1.2 V
  - Capacity: 600 - 1200 mAh
  - Discharge Rate: Up to 10C
  - Key Features: Long cycle life (up to 1500 cycles), robust, toxic materials, lower energy density
  - Pros: Excellent cycle life, can deliver high discharge rates
  - Cons: Contains toxic materials, memory effect, lower energy density
- **Nickel-Metal Hydride (NiMH)**
  - Voltage: 1.2 V
  - Capacity: 1000 - 3000 mAh
  - Discharge Rate: Typically 1C to 2C
  - Key Features: Higher energy density than NiCd, less toxic, suffers from self-discharge
  - Pros: Higher energy density than NiCd, less environmental impact
  - Cons: Self-discharge is higher than Li-Ion, moderate cycle life
- **Lithium-Ion (Li-Ion)**
  - Voltage: 3.7 V
  - Capacity: 1800 - 3500 mAh
  - Discharge Rate: 1C to 3C
  - Key Features: High energy density, lightweight, complex management systems needed

  - Pros: High energy density, lightweight, low self-discharge rate
  - Cons: Requires protective circuits, sensitive to temperature extremes

- **Lithium Polymer (LiPo)**
  - Voltage: 3.7 V
  - Capacity: 1000 - 5000 mAh
  - Discharge Rate: Can be 5C to 30C or higher
  - Key Features: Similar to Li-Ion, lightweight, flexible shapes, requires protective circuitry
  - Pros: Lightweight, flexible form factors, high discharge rates
  - Cons: Requires careful charging/discharging, sensitive to punctures and temperature

- **LiFePO4 (Lithium Iron Phosphate)**
  - Voltage: 3.2 V
  - Capacity: 1000 - 4000 mAh
  - Discharge Rate: Typically 1C to 2C
  - Key Features: Very stable chemistry, good thermal stability, lower energy density than Li-Ion
  - Pros: High thermal stability, long cycle life
  - Cons: Lower energy density compared to other Li-Ion chemistries, heavier

7 Conclusion

After analyzing the power requirements of the robot, two 3.7V 2200 mAh Li-ion batteries connected in series are selected as the optimal power source. This setup provides a voltage of 7.4V and meets both the typical and worst-case current demands. The power distribution circuit ensures that all components receive the appropriate voltage, enhancing the robot's operational efficiency.