BID4R Project - Engineering Notebook

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September 23, 2024: Initial Meeting with the Customer

- **Objective**: Understand project scope and gather requirements.
- **Details**: Attended an initial meeting with the customer to discuss the BID4R project's scope. Key areas of focus included the development of a distributed power management system, wiring design, and component integration. The customer emphasized the importance of battery management, cooling during charging, and ensuring safe, efficient integration of components. We also clarified that autonomous docking for charging was out of scope, meaning the operator would manually place the robot in the charging station when the battery is low.

September 26, 2024: Received Components List

- **Objective**: Begin component review and analysis.
- **Details**: The team received an Excel file that included a list of all components we would use in the BID4R project. Each component's link was provided, allowing us to access their specifications directly. This enabled us to assess their suitability based on factors such as voltage, current requirements, and safety features, ensuring they aligned with the project's technical needs.

September 28, 2024: Team Meeting to Draft the Proposal

- **Objective**: Collaborate with the team to structure the project proposal and backlog.
- **Details**: Participated in a team meeting where we began drafting the project proposal and outlining the backlog. My contributions involved defining key milestones, such as power management and wiring integration, and ensuring we had a clear understanding of each task's dependencies. The backlog was populated with high-level tasks that we planned to break down into more detailed steps as the project progressed.

September 29, 2024: Submission of Project Proposal

- **Objective**: Finalize and submit the project proposal.
- **Details**: Met again with the team to submit the project proposal. My assigned task was to research existing and alternative components to ensure the project used suitable parts that meet the project goals.

5. October 1, 2024: Stakeholder Meeting

- **Objective**: Officially receive the robot for development work.
- **Details**: Met with stakeholders and received the physical robot, which marked the start of the component integration process.

October 2, 2024: Component Specification and Suitability Check

- **Objective**: Begin detailed analysis of component specifications and evaluate their suitability for the BID4R system.
- **Details**:

1. **Component Specification Review**:
    a. I began by carefully reviewing the technical specifications of each component in the system, including power requirements, dimensions, and connectivity. The focus was on ensuring that all components could function within the power limits provided by the system's power supply, and that each part could integrate smoothly with others. This analysis was compiled into a **Component Specification Review** file, which included detailed documentation on the specifications of components like the PowerBoost 1000C, Arduino Nano 33 IoT, sensors, and the Qi charging modules.
    b. The review covered components such as:
        i. **PowerBoost 1000C**: Its input and output voltage (3.7V from the LiPo battery, outputting 5V) and its continuous current capacity of 1A were verified. The goal was to ensure it could power all sensors and the Arduino without risk of overloading.
        ii. **Motors**: Checked voltage range (3-6V), current draw, and the potential for stall currents that could exceed safe operating limits.
        iii. **Batteries and Charging Components**: The compatibility of the 3.7V LiPo battery with other components, especially in terms of voltage and capacity, was analyzed.
2. **Suitability Check of PowerBoost 1000C and Sensors/APA106 LEDs**:
    a. I examined the **PowerBoost 1000C** and its ability to power the sensors and LEDs within the system. The PowerBoost provides a stable 5V output, which is necessary to power components such as the **Pixy2 Smart Vision Sensor** (5V, 140mA) and the **VCNL4010 Proximity/Light Sensor** (3.3-5V, 8mA).

Additionally, two **APA106 Addressable RGB LEDs** were evaluated, each drawing 20mA.

b. The total current draw from these components was calculated to be around 188mA, well within the PowerBoost's continuous output capacity of 1A. This provided ample headroom for other components, like the Arduino Nano 33 IoT, to operate safely. I confirmed that the PowerBoost 1000C was suitable for powering these components without the risk of overload, and this analysis was documented in the **Suitability Check for Existing Components** file.

3. **Suitability Check of Arduino Nano 33 IoT and Sensors**:
   a. I evaluated the **Arduino Nano 33 IoT**, which serves as the main processing unit in the system, for compatibility with connected sensors such as the **Pixy2 Smart Vision Sensor** and the **VCNL4010 Proximity/Light Sensor**. The Arduino operates at 3.3V logic, which matches the I2C logic level of both sensors, ensuring no need for additional logic level conversion.
   b. The **Pixy2 Smart Vision Sensor** requires 5V power but communicates using 3.3V logic, making it fully compatible with the Arduino. The **VCNL4010 Proximity Sensor** can operate between 3.3V and 5V, further aligning with the Arduino Nano 33 IoT. I confirmed that both sensors could be powered directly by the Arduino and operate within their expected parameters. This verification was summarized in the **Suitability Check for Existing Components** file.
4. **Suitability Check of Motors, Motor Controller, and Battery**:
   a. For the **DC Motors** in the **Mini 3-Layer Round Robot Chassis Kit**, I reviewed their voltage requirements (3-6V) and current draw (200-400mA under normal operation, 1.5A during stall conditions). I determined that the **3.7V LiPo battery** would provide adequate power, though the motors might operate with slightly reduced performance compared to a 6V supply. However, this was deemed acceptable for the project's needs.
   b. I also evaluated the **Adafruit DRV8833 Motor Driver**, which controls the motors and has a continuous current limit of 1.2A per channel, with a peak limit of 2A. Given that the motors can draw up to 1.5A during a stall, I recommended installing **1.5A fuses** in series with the motors to protect the motor controller from potential damage caused by overcurrent.
   c. The **3.7V, 3000mAh LiPo battery** was analyzed for capacity and safety. The battery's capacity was deemed sufficient to power the entire system for an extended period. However, I identified the need for a **Battery Management System (BMS)** to prevent overcharging, over-discharging, and short circuits,

thus ensuring the battery's long-term health and safe operation. These protective measures were critical to ensuring the safe functioning of the system. The findings were summarized in the **Suitability Check for Existing Components** file.

October 3, 2024: Identifying Additional Components and Initial Power Calculations

- **Objective**: Identify necessary additional components and perform initial power calculations for the robot's operation.
- **Details**:

1. **Identifying Additional Components**:

   After reviewing the existing component specifications and suitability, I listed the **Battery Management System (BMS)** and **fuses** as additional components required for the project. The BMS is essential for managing the LiPo battery, ensuring protection against overcharging, over-discharging, and short circuits, which are critical to battery longevity and safety. The fuses, particularly the 1.5A slow-blow fuses, are necessary to protect the motor controller from overcurrent situations that could occur during motor stalls.

October 4, 2024: Initial Power Calculations

- **Objective**: Calculate how long the robot would operate under both normal and stall conditions.
- **Details**:

  I worked with Belal to begin the initial calculations to determine how long the robot would operate under both normal conditions and during stall conditions. We used the formula $P = V \times I$ to calculate the power consumption for each component.

  Motors: Under normal conditions, each motor draws 0.3A, resulting in a total power consumption of 2.22W for both motors. During stall conditions, the current draw increases to 1.5A per motor, resulting in 11.1W for both motors.

  Other Components: We calculated the power consumption of the Pixy2 Camera, VCNL4010 Proximity Sensor, Arduino Nano 33 IoT, and APA600 LEDs, which are powered by the PowerBoost 1000C. The total power consumption from these components was 1.72W.

Total Power Consumption: For normal operation, the total system power consumption was calculated to be 3.94W, while during stall conditions, it increased to 12.82W.
Battery Runtime: We used the energy stored in the LiPo battery (11.1Wh) to estimate the runtime. For normal operation, the robot can run for approximately 2.82 hours (169 minutes). In stall conditions, the runtime drops to about 0.87 hours (52 minutes).

These calculations were essential for estimating the robot's battery life and ensuring the power system could handle peak loads without overloading.

We also applied a more detailed formula to calculate the operating time based on different load conditions:

$$T_{\text{operation}} = \frac{E_{\text{battery}}}{(f_{\text{heavy}} \times P_{\text{heavy}}) + (f_{\text{normal}} \times P_{\text{normal}})}$$

This formula allows us to estimate the total operating time based on how frequently the robot operates under normal or heavy (stall) conditions. For example, if the robot operates under heavy load for 10% of the time and normal load for 90%, we can calculate how long the battery will last under these conditions. This formula is crucial for understanding the robot's overall runtime in mixed operating scenarios and helps in optimizing power management.

October 17, 2024: Stakeholder Meeting to Review Charging Station and Additional Components

- **Objective**: Review the charging station design and additional components list with stakeholders.
- **Details**:

During a meeting with the stakeholders, we reviewed the charging station design and the additional components list that I provided on **October 15**. The key discussions included the need for a **Battery Management System (BMS)** and **fuses** for the BID4R project.

- **BMS Approval**: The stakeholders agreed to provide the BMS for the project, acknowledging its importance in ensuring safe operation of the LiPo battery, particularly in managing overcharging, over-discharging, and short circuits.

- **Fuse Discussion**: While the stakeholders accepted the BMS, there was some uncertainty regarding the necessity of the **1.5A fuses** I had recommended. They were unsure if the fuses were needed to protect the motor driver during stall conditions.

October 18, 2024: Finalization of Power Calculations

- **Objective**: Finalize power calculations after adding resistors for new components.
- **Details**:

  I finalized the power calculations after we added two resistors to the system—one for the **DS18B20 Temperature Sensor** and one for the **Adafruit Power Relay FeatherWing**.

  These updates were necessary to ensure proper operation and voltage regulation for the new components.
- **Updated Power Consumption**:
  - The **DS18B20 Temperature Sensor** draws 0.0075W.
  - The **Adafruit Power Relay FeatherWing** draws 0.1W.
- **Total Power Consumption**: With these additions, the total power consumption during normal operation was recalculated to be 4.17W, and during stall conditions, it increased to 13.05W.
- **Battery Runtime**: After the adjustments, the estimated runtime for the robot was about 2.66 hours under normal conditions and 0.85 hours during stall conditions.
- **Current Draw**: The total current draw from the PowerBoost 1000C was calculated to ensure it remained within the 1A limit, and the system was confirmed to be well within this limit at 0.39A.
- This final calculation provided a more accurate estimate of the robot's performance under various conditions and ensured that the power system could handle the additional components efficiently.

October 18, 2024: provide feedback of Wiring Diagram

- **Objective**: Provide feedback on the wiring diagram and ensure correct component connections.
- **Details**:

Turki started working on the wiring diagram in fritzing for the BID4R project. I provided feedback on how the components should be connected. Key points included:

- **Resistor Placement**: I highlighted that we needed two resistors for monitoring the battery and one additional resistor between the Arduino and the LED to ensure proper voltage and current regulation.
- **Sensor Power Source**: I also checked to ensure that all sensors were being powered by the PowerBoost, and I confirmed that this was done correctly. The sensors were successfully powered by the PowerBoost, ensuring the system would function as intended.

The wiring diagram was progressing well, and the connections appeared to be set up effectively.

October 24, 2024: Stakeholder Meeting to Print Charging Station and Review Calculations

- **Objective**: Print the charging station and discuss the power calculations.
- **Details**:

During a meeting with the stakeholders, we printed the charging station and reviewed the final power calculations. I provided a detailed explanation of the **stall condition**, clarifying its impact on the robot's operation and why the motor's current spikes during these situations.

The stakeholders mentioned that they would review the calculations once more and provide additional feedback. However, they decided not to order the **fuses**, expressing that they did not believe the system would need them, as they were confident that overcurrent situations during stall conditions were unlikely to occur.