42: Multi-Axis Cobot For Factory Automation

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**Interface Control Document**

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Interface Control Document

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42: Multi-Axis Cobot For Factory Automation

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# Overview

This document provides an overview of the integration between the different subsystems. The four subsystems are split into power, MCU/processing, wireless, and motor driving. The power subsystem will deliver accurate power to components, MCU/processing will ensure signals are sent from MCU, wireless will communicate with the cobot via Bluetooth, and motor driving will create motor movement. In this document, you will find the necessary system requirements to achieve this integration for the cobot. This document includes necessary references and definitions as well as physical, thermal, and electrical interfaces.

# References and Definitions

## References

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| IEEE 802.15 | June 2005 | IEEE Standard for Information Technology |
| TMS320F28004x | January 2023 | TMS320F28004x Real-Time Microcontrollers |
| DRV816x | July 2024 | DRV816x 100V Half-Bridge Smart Gate Driver with Integrated Protection and Current Sense Amplifier |
| ESP-32 | September 2024 | ESP-32 Series |

*Table 1: References*

## Definitions

Cobot Collaborative Robot

MCU Microcontroller Unit

mA Milliamp

mW Milliwatt

in Inch

lb Pound

PCB Printed Circuit Board

PMS Power Management System

TBD To Be Determined

V Volt

# Physical Interface

## Weight

### Weight of Cobot Apparatus

This section covers the weight of physical components and the design of the cobot. Encompassed in this section are the motor driving subsystem, MCU and processing subsystem, power management subsystem, and wireless communication subsystem. While we have not confirmed exact weights, we roughly estimate the cobot apparatus will weigh 10 pounds, not including the physical design and base.

| **Component** | **Weight** | **Number of Items** | **Total Weight** |
| --- | --- | --- | --- |
| Motors | ~ .4lb - 2.6lb | 5 | TBD |
| Motor Drivers | ~ 0.22lb | 15 | TBD |
| Pincher | 0.121lb | 1 | 0.121lb |
| ESP-32 | 0.121lb | 1 | 0.121lb |
| Physical Design and Base | TBD | 1 | TBD |
| Associated PCB’s | TBD | TBD | TBD |

*Table 2: Weight of Cobot Components*

* + 1. **Weight of Battery Management**

The battery management system is weighed separately because, in the final design, the battery and its charging system will be removable. While we have not confirmed exact weights, we roughly estimate the battery management system will weigh 4 pounds.

| **Component** | **Weight** | **Number of Items** | **Total Weight** |
| --- | --- | --- | --- |
| Battery | ~4lb | 1 | ~4lb |
| Associated PCB’s | TBD | TBD | TBD |

*Table 3: Weight of Battery Management Components*

## Dimensions

### Dimension of Motor Driving Subsystem

Each motor will have different specifications. For each motor to function, it will have a PCB with 3 DRV8161 Motor Drivers. We estimate the PCB alongside each motor will be at least 1.18 inches by 1.18 inches.

| **Component** | **Length** | **Width** | **Height** |
| --- | --- | --- | --- |
| Motors | ~ 1.57 - 3.15in | ~ 1.18 - 3.15in | ~ 1.57 - 3.94in |
| Motor Drivers | ~ 0.2in | ~ 0.12in | TBD |
| Associated PCB’s | ~ 1.18in | ~ 1.18in | TBD |

*Table 4: Motor Driving Subsystem Dimensions*

### Dimension of MCU/Processing Subsystem

The MCU subsystem will consist of a PCB that holds the F280049CPZS microcontroller which has dimensions 0.63 inches by 0.63 inches. Furthermore, with other ICs and passive components integrated into the PCB, we estimate it will be at least 3.94 inches by 3.94 inches.

| **Component** | **Length** | **Width** | **Height** |
| --- | --- | --- | --- |
| F280049CPZS | ~ 0.63in | ~ 0.63in | TBD |
| Associated PCB’s | ~ 3.94in | ~ 3.94in | TBD |

*Table 5: MCU and Signals Processing Subsystem Dimensions*

### Dimension of Power/Battery Management Subsystem

The power and battery management subsystem envelops the battery, which we estimate will be 48 volts, alongside the PCBs that are needed to run the PMS. We estimate the battery will be around 10.63 inches by 3.15 inches by 2.76 inches and the PCBs needed will be around 3.34 inches by 3.34 inches.

| **Component** | **Length** | **Width** | **Height** |
| --- | --- | --- | --- |
| Battery | ~ 10.63in | ~ 3.15in | ~ 2.76in |
| Associated PCB’s | ~ 3.34in | ~ 3.34in | TBD |

*Table 6: Power and Battery Management Subsystem Dimensions*

### Dimension of Wireless Communication Subsystem

The wireless communication subsystem is built around an ESP-32 board. The ESP-32 typically comes in size 0.71 inches by 1.00 inches by 0.12 inches. Including the size of the ESP-32 board and associated ICs, we estimate the dimensions of the PCB will be 2.76 inches by 2.76 inches.

| **Component** | **Length** | **Width** | **Height** |
| --- | --- | --- | --- |
| ESP-32 | ~ 0.71in | ~ 1.00in | ~ 0.12in |
| Associated PCB’s | ~ 2.76in | ~ 2.76in | TBD |

*Table 7: Wireless Communication Subsystem Dimensions*

## Mounting Locations

### Motor Mounting

Each motor will need to be mounted and secured to the robotic arm apparatus. To prevent sag and weight issues, the mountings will have to be strong enough to support the weight of the motor under maximum load.

### Cobot to Base Mounting

To ensure a strong center of gravity when lifting and moving a payload, the bottom (Base) of the cobot will be mounted to a baseboard or metal sheet. This allows for the cobot to have a designated location on a square surface to support the weight of the robotic arm with and without a load. By securing the cobot to a base plate, we can better control the lean and influence the movement of the cobot on its center of gravity.

### Base to Table Mounting

To ensure the cobot does not tip over if its center of gravity changes, the base plate the cobot is mounted to will also be mounted to a table. The base plate can clamp onto the outside lip of the table it is placed on, which ideally means the table size is the size of the base plate. By clamping the base plate to the table, we eliminate the center of gravity changing due to the base plate lifting and leaning during movement.

# Thermal Interface

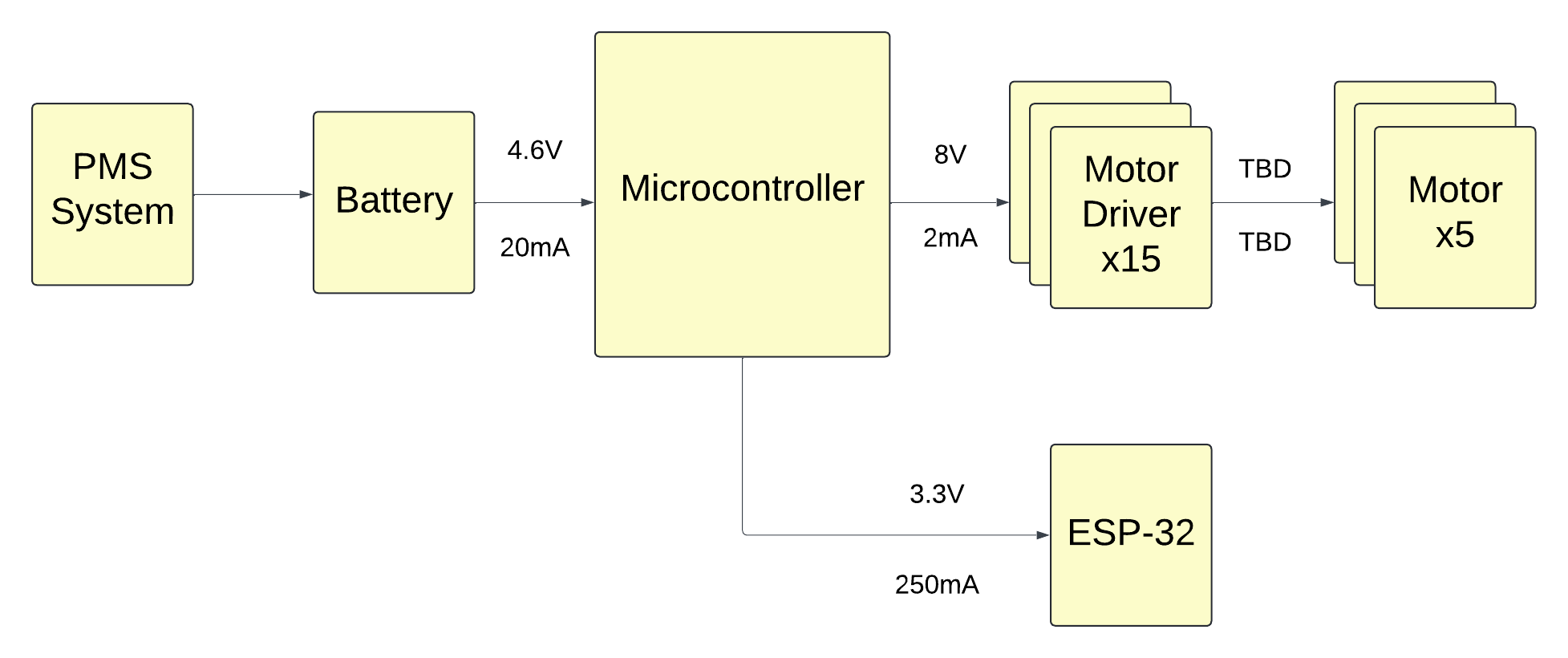
Our project involves working with high voltage and current, which means cooling will be essential for the PCBs, motors, and other components to prevent overheating. Depending on the power draw and consumption, many of these parts will require adequate thermal management. Since the cobot is not designed for continuous operation over extended periods, a heatsink in the form of a metal heat dissipation plate, along with proper airflow, should be sufficient to maintain safe operating temperatures.

While a cold wall isn’t necessary due to the intermittent operation of the system, heatsinks will still be required for most, if not all, of the motors in the robotic arm. These motors, subjected to high voltage and current, will generate heat more rapidly than lower-power alternatives. However, given the cobot's non-continuous, human-triggered operation, we believe that proper ventilation and airflow should be enough to manage any potential heat issues, even with the higher power motors.

In summary, the use of simple metal heat dissipation plates combined with adequate ventilation should address all thermal concerns without the need for more complex cooling solutions like a cold wall.

# Electrical Interface

Provide details on the electrical interface. Examples are:



*Figure 1: Electrical Interface Diagram*

## Primary Input Power

* + 1. **Primary Power Source for Cobot**

All power for the cobot will be supplied by an external, rechargeable battery. The voltage rating for the battery is 48V, and the amp-hour specification is currently TBD as we are finalizing parts selection. Our battery will be connected to a battery management system, which will include regulators and buck converters to deliver power to all subsystems in the required amounts.

* + 1. **Battery Charging**

Our team will also be developing a charging unit for the battery. Because we are using a large, multi-cell battery, this system will include safeguards and associated components to ensure when the battery is charging, cells are charged in a balanced way, and potential faults are detected.

* + 1. **Microcontroller**

The cobot will be using the F280049CPZS microcontroller from the C2000 family at Texas Instruments. This MCU has a 32-bit CPU at 100 Mhz and includes 356 KB of on chip memory. There is no BLE module, hence an ESP-32 will be required externally.

## Signal Interfaces

* + 1. **DRV8161 Pulse Width Modulation Signals**

The communication between the motor drivers and motors will be facilitated through 3-phase Pulse Width Modulation (PWM), utilizing a C2000 MCU to generate the necessary control signals. This setup ensures precise and efficient control over the motor phases.

* + 1. **Digital Signals Between Mobile App and Cobot**

The cobot will use an ESP-32 to connect the user’s mobile app to the cobot through Bluetooth. The ESP-32 for use with Bluetooth is compliant with Bluetooth v4.2 BR/EDR and Bluetooth LE specifications, and has +9 dBm transmitting power.

## User Control Interface

Users will be able to operate the cobot using a wireless mobile application that will be developed using FlutterFlow. This mobile app will include dialogs and menus which will allow the user to complete training videos and modules, connect to the cobot via Bluetooth, and receive error messages from the cobot.

## Voltage and Current Levels

* + 1. **Maximum Voltage and Current**

| Component | Voltage [V] | Current [mA] | Power [mW] |
| --- | --- | --- | --- |
| Motor Driver | 20 | 2 | 40 |
| MCU | 3.3 | 20 | 92 |
| ESP-32 | 3.6 | 250 | 900 |
| Motors | TBD | TBD | TBD |

*Table 8. Maximum Voltage, Current, and Power Levels*

The table above outlines the maximum ratings for voltage and current consumption of each component. Operating under maximum conditions will not be done frequently, however, it is important to take into consideration when designing safety and sizing our battery.

* + 1. **Typical Voltage and Current**

| Component | Voltage [V] | Current [mA] | Power [mW] |
| --- | --- | --- | --- |
| Motor Driver | 8 | 2 | 16 |
| MCU | 3.3 | 20 | 66 |
| ESP-32 | 3.3 | 250 | 825 |
| Motors | TBD | TBD | TBD |

*Table 9. Typical Operating Voltage, Current, and Power*

The table above shows a more accurate representation of the power needs of each component during operation. While most of the components are relatively low-power, we anticipate our motors will have a much larger power requirement.

# Communications / Device Interface Protocols

## Wireless Communications (Bluetooth)

**6.1.1. Bluetooth**

The cobot uses Bluetooth v4.2 for wireless communication between the mobile app and the cobot's microcontroller unit (MCU). Since the C2000 MCU does not have a built-in Bluetooth module, an ESP-32 is employed for this purpose. The ESP-32 complies with the IEEE 802.15.1 standard, which ensures low-power, short-range wireless communication.

## Host Device

* + 1. **C2000 Microcontroller Unit (MCU)**

The C2000 serves as the primary Host Device for the cobot, as it is responsible for real-time processing and motor control. The C2000 will receive signals from the ESP-32, which communicates with the user’s controller. Then, the C2000 will generate PWM signals to send to the Motor Drivers for precise Motor control.

## Device Peripheral Interface

* + 1. **ESP-32 Connection with User Interface**

The ESP-32 serves as the wireless communication interface between the User Interface and the C2000. Using Bluetooth, the ESP-32 transits signals and commands from the Interface to the C2000. The communication is handled through UART.

* + 1. **Motor Driver and Motor Communication**

The communication between the C2000 MCU and the motor drivers is managed through 3-phase Pulse Width Modulation (PWM) signals. These PWM signals control the motor phases to regulate speed, torque, and positioning. The C2000 MCU outputs these PWM signals directly to the motor drivers, ensuring precise control.

* + 1. **Micro-USB**

A Micro-USB port will be needed to interface between the computer and the MCU. The MCU offers I2C, CAN, SPI, UART, and FSI. The communication protocol to use for micro-USB is still to be determined.