3D Printer and Application Interface

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MIDTERM REPORT

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CONCEPT OF OPERATIONS

REVISION – 0.1
14 September 2022

CONCEPT OF OPERATIONS
FOR
3D Printer and Application Interface

TEAM 21

APPROVED BY:

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Cody Hutchison Date

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Prof. Lusher Date

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1. Executive Summary

Common 3D printers require local, in-person interaction to start/stop, format settings, or even insert memory devices to upload files. The sponsor for this project, Dalton Cyr, desires a 3D printer capable of printing files with the portability and ease of using a mobile device from any location. With a thoroughly designed phone application and Wi-Fi capability, this 3D printer will have similar features to other standard 3D printers and can also be controlled from any location with internet access. To print, while away from the 3D printer, it must have a server, and to preserve security, the 3D printer will access a web server provided by Amazon Web Services which has a reputation for customer security and satisfaction. This project will highlight the pleasing and straightforward user experience of printing 3D designs with the speed and quality of other printers through a mobile phone application.

2. Introduction

This document will review the concepts of operation for a 3D printer and its application interface. While many 3D printers require users to handle their operation in person, this 3D printer will solve this issue with a mobile phone application allowing the user to print from their current location. To achieve this task, the project will be broken down, researched, and executed in several subsystems: power supply, microcontroller unit, dedicated web server, and mobile phone application.

2.1. Background

The combination of a mobile phone application and the dedicated web server will not only provide ease of use, away from the 3D printer but will also act as a simple form of security and solution for transferring large print files. Using the mobile phone application will minimize the need for a user interface on the printer. The only printer control will be the main power switch placing the printer in a standby state. Physical interactions with the 3D printer consist of the initial setup and powering on, adding PLA rolls to the printer, and removing completed prints.

2.2. Overview

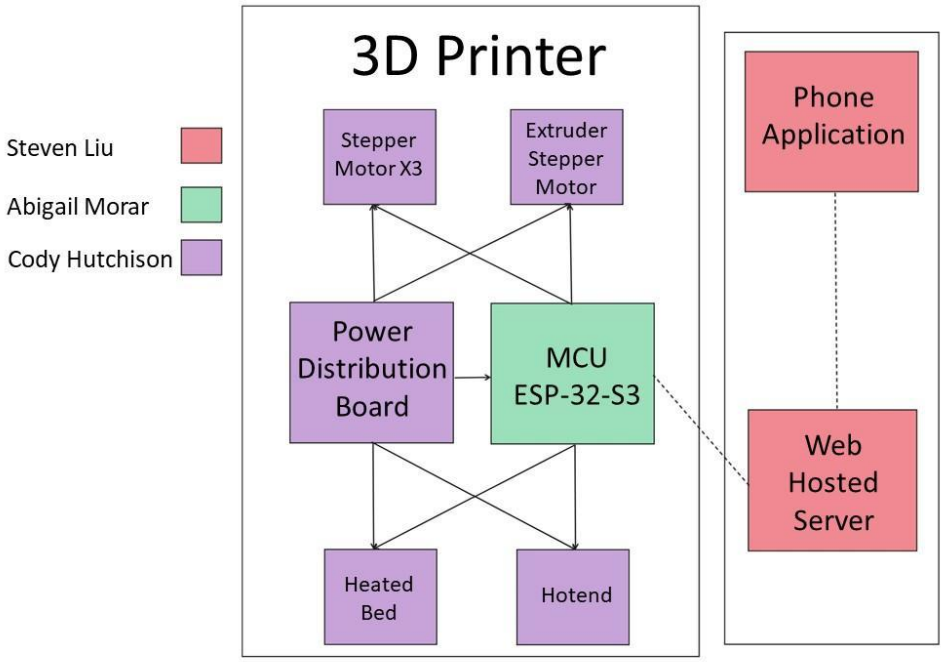

Figure 1. 3D Printer Block Diagram

This 3D printer will be designed to work exclusively through a mobile phone application. The application will receive commands and files and send them to the web-based server setup for the printer. Once uploaded, the server will store the files in the cloud and pass on commands to the motherboard in the 3D printer, if any are received. The motherboard will

then read the codes in order of the most recent upload and begin heating the heated bed and hot head. Once the hot head and heated bed are at the required temperature set by the user, the motherboard will start reading the G-code from the server and initiate printing. The motherboard will also send a code to the server that will be forwarded to the application to start the timer. Another transmitted command would be to cancel/end the print in a situation where there is an issue with the print job, an issue with the design and the person does not want to waste PLA, or the user realized there would not be enough filament to complete the job. Once printing is finished, the printer will send a complete command to the server that will be forwarded to the application to notify the individual that the print is done and the timer will be stopped. Power will be distributed to the motherboard, the stepper motors, the hot head, the heated bed, and the extruder for operation and communication between subsystems.

2.3. Referenced Documents and Standards

- IEEE Wi-Fi Std 802.11-2020
- IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz, ANSI C95.1-2019
- Android App Development, “Core App Quality” https://developer.android.com/docs/quality-guidelines/core-app-quality

3. Operating Concept

3.1. Scope

The goal is to develop a 3D printer that is controlled by a phone application that stores the G-code files on an internet server and allows the printing of the G-code files from anywhere that has internet access.

3.2. Operational Description and Constraints

This 3D printer system requires internet access from both the 3D printer and mobile device. Before using the 3D printer, the microcontroller unit will require an initial connection to the web-hosted server and local network at its location with its main power switch on standby. The user will send G-code files and printer commands from the mobile phone application to the server. On the printer side, the microcontroller will send pull requests in intervals receiving packets of the files/commands to control the 3D printer while also sending push requests of collected data to the server. This data is displayed through the mobile application allowing the user to monitor the 3D printer’s progress. The 3D printer design must meet the following criteria:

- Operate within 10-15% speed of the initial hardware and software used for the Ender 3 3D printer
- Print area of 220mm x 220mm x 250mm
- Print height of 0.2 mm per layer
- Use 1.75mm PLA for print material
- The heated bed must reach a maximum temperature of 80℃
- The hot head must reach a maximum temperature of 220 ℃

The printer will have an input of 120V 60Hz AC power that will be converted to 24V 15A. The system will use an ESP32 microcontroller to communicate with the host server and provide commands to the motherboard. The interface for the 3D printer will be through an android mobile application with the host server designed through Amazon Web Services.

3.3. System Description

There are three main subsystems for the 3D printer and mobile phone application. The first subsystem is the interface consisting of the mobile phone application and the web server. The mobile phone application will take G-code files and upload them to a web server and allow the initiation and shutdown of the 3D printer. The application will also handle initializing specific printing specifications desired by the user such as heated bed/hot head temperatures and stepper motor adjustments. Other features of the application are keeping track of print progress, the amount of material used, and housing a library of prints sent from the phone. The web host server will act as an intermediary for file transfer and controls between the phone application and the 3D printer while also housing previous 3D print files.

The second subsystem is the microcontroller for the 3D printer. While in standby mode, the microcontroller will send requests in specified intervals to take in commands from the cloud server and send them to the motherboard. Such commands may include the starting/stopping of printing, the control over fan speed, the location of the hot head, the amount of extruded material, the retraction of filament, and the temperature of the heated components. The motherboard will process and distribute these commands whether in standby or active printing. The movement of the stepper motors will be communicated to the stepper motor control board, and adjusting the temperature of the heated bed and hot head will be communicated to their boards, respectively. The microcontroller will also collect information to be sent back to the phone application allowing the user to monitor the printing progress and selected print settings.

The third subsystem will be the motor controller boards, temperature controlling boards, and a power distribution board. The motor controller boards will take commands from the microcontroller and send power to the stepper motors by use of dual H-bridges. The temperature control board will also send power to the heated bed and hot head by the use of MOSFETs and signals from the microcontroller. The power distribution board will take the 24V 15A, split it up, and send 5V 1.5A to all 4 stepper motors; 5V 0.5A to the microcontroller, 24V 9.167A to the heated bed, and 24V 1.67A to the hot head.

3.4. Modes of Operations

There is a single planned mode of operation for the 3D printer electronic system. That operation is to control the 3D printer through a mobile phone application that requires only a main power switch on the printer to stop all external power.

3.5. Users

This 3D printing system is aimed toward hobbyist 3D printers. The setup requires basic knowledge to connect the printer's built-in microcontroller to the web server and local network by following the instructions in the manual. After the server's setup is complete, anyone with proper G-code files and an internet connection can use the printer.

3.6. Support

The manual will provide assembly instructions for the 3D printer as well as instructions to set up the connection to the web server and local network. The manual will also display the mobile application name and link to download it. The app will provide a walkthrough of all its features along with how to send print files, adjust heating components or extruder positioning, and start or stop a print design.

4. Scenario(s)

4.1. Parts Rush

- Parts rush required due to competition schedule and broken parts so prints may be initiated while traveling from a competition.

4.2. 3D Printing Business

- Need to start a print order while out of the office to meet customer deadlines.

4.3. Work Prototyping

- Modifications are required on a prototype 3D print that cannot be finished at work. Allows employees to finish adjustments and initiate printing from home.

4.4. Hobby Printing

- Allows hobbyists to print from any location as long as there is internet connection.

5. Analysis

5.1. Summary of Proposed Improvements

Improvements include user-friendly setup, ease of feature adjustments, print progress notifications, the ability to start and stop jobs remotely, virtually infinite file storage, faster auto-home command, and convenient communication between devices.

5.2. Disadvantages and Limitations

Feeding issues could be a major disadvantage to this system. This would be caused by a clog in the extruder or the 3D printer running out of filament. The limitation of having only a phone application to communicate with the 3D printer would prove to be a problem if the local network is ever down since the device can only print files when connected over the internet.

5.3. Alternatives

One alternative is that the printer could be controlled through Bluetooth instead of a network connection to the server. A drawback to that would be the need for users to stay within range of the printer to control and operate it.

5.4. Impact

Possible impacts:

1. The capability to 3D print from anywhere, allows people to be more social and not be confined to their homes to print an item.
2. With the freedom of not having to constantly monitor the printer, the individual can now volunteer to clean up around their neighborhood, town, or city.
3. By making the 3D printer user-friendly, it allows people who are not technically inclined to a platform to perform 3D printing.
4. An ethical issue would be leaving the printer to run unattended with the 80℃ heated bed and a 200℃ hot head. A fire could occur if a flammable item fell onto the hot head or heated bed. Without supervision, these heated components could cause dangerous outcomes such as a major injury to another person or pet.

3D Printer and Application Interface

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Abigail Morar

FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – 0.0
3 October 2022

FUNCTIONAL SYSTEM REQUIREMENTS
FOR
3D Printer and Application

TEAM 21

_____
Author Date

APPROVED BY:

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Cody Hutchison Date

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John Lusher, P.E. Date

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Dalton Cyr Date

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1. Introduction

1.1. Purpose and Scope

The 3D Printer will provide an efficient solution to users who desire to 3D print remotely. This project shall incorporate the use of a mobile application, AWS cloud computing service, and onboard internet capabilities along with common 3D printing hardware to achieve this goal. The 3D printer shall retain the same options as the printer's original hardware and software offered. The project will be divided into several subsystems listed below in Table 1.

Figure 1. Ender 3 3D printer

1.2. Responsibility and Change Authority

The team leader, Cody Hutchison, will ensure all project requirements will be met and that the team will keep to the planned schedule. All subsystems and respective responsibilities are listed below in Table 1. Any and all changes must be approved by the team leader and Sponsor, Dalton Cyr. Cody Hutchison is responsible for the stepper motor controller, the heating elements of the hot head and hot bed, and the correct power distribution to all the required hardware components. Steven Liu is in charge of the development of the 3D printer application and making sure it connects to the web-hosted server. He is also responsible for the development of the server which will communicate with the MCU. Abigail Morar is responsible for the microcontroller and ensuring that it is sending and receiving signals appropriately, as well as communicating between each component and subsystem effectively.

Subsystem	Responsibility
Power Distribution	Cody Hutchison
Onboard Hardware	Cody Hutchison
Onboard Software	Abigail Morar
AWS Server	Steven Liu
Mobile Application	Steven Liu

Table 1. Subsystems and Responsibilities

2. Applicable and Reference Documents

2.1. Applicable Documents

Document Number	Revision/Release Date	Document Title
Ender 3 Printer Manual		Ender 3 Printer Manual
ESP32-S3 Series	V1.3	ESP32-S3 Series Datasheet
802.11-2020	08 October 2021	IEEE Standard of for Information Technology

Table 2. Applicable Documents

2.2. Reference Documents

Document Number	Revision/Release Date	Document Title
N/A	N/A	Android App Development

Table 3. Reference Documents

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings, or other documents that are invoked as "applicable" in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

3.1. System Definition

The project is to design a control system and application that allows the printer to be operated by an application from anywhere there is internet access.

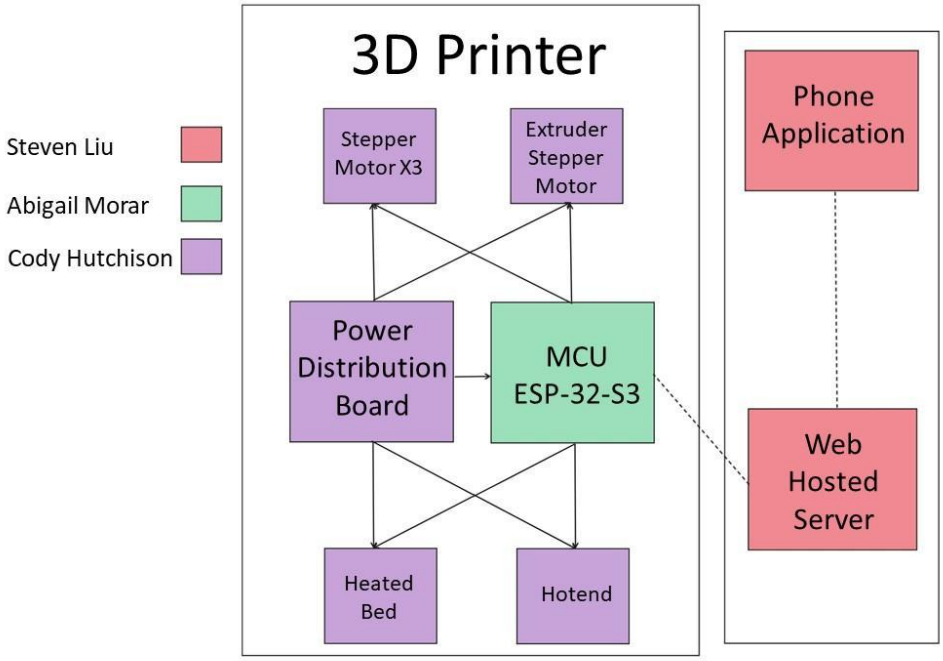

Figure 2. Block Diagram of System

The three main subsystems are the MCU programming, the android application and web server, and finally the control and power distribution board. The reason for changing the 3D printer design is to convert it from being manually operated through the application only. The original hardware was all combined into two boards which is the reason for building all the different boards.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Print Time

Constraining the print time within 10-15% of the time it takes to print with the original hardware and software.

Rationale: This is a requirement specified by the customer to meet the capabilities set by the old software.

3.2.1.2. Axis Speed

Increase the Z-axis speed so that it is closer to the speed of the X and Y-axis.

Rationale: By increasing the Z-axis speed allows the movement of the hotend and home return.

3.2.1.3. Temperature Control

The heated bed needs to be controllable from 0-80℃ and the hot end needs to be controllable from 0-220℃.

Rationale: This is a requirement specified by the customer to have the heated components be heated enough for PLA filament to be properly used. These temperature ranges allow adjustability for different brands of PLA.

3.2.1.4. Printing Layer Height

Each layer will have a height of 0.2mm.

Rationale: This is a requirement specified by the customer since this is the common printing height of the filament.

3.2.2. Physical Characteristics

3.2.2.1. Print Area

The printing area will be 220mm x 220mm x 250mm.

Rationale: This is a requirement specified by the customer due to the printing area of the original 3D printer base/frame being used.

3.2.2.2. Printing Material

The printing material needs to be 1.75mm PLA.

Rationale: This is a requirement specified by the customer since this printing material is common and affordable.

3.2.3. Software Characteristics

3.2.3.1. Mobile Application

The mobile application shall be developed for Android devices.

Rationale: The application is done for Android devices due to an accessible developmental environment and available tools.

3.2.3.2. Mobile Application Software

The mobile application software shall be developed using the Kotlin programming language.

Rationale: The Kotlin language is chosen due to its compatibility with android application development.

3.2.3.3. Web-Hosted Server

The intermediary server shall be developed using Amazon Web Services.

Rationale: AWS is chosen for its reputable performance, quality and security. AWS has a wide variety of integrable services that meet the needs of the customer.

3.2.4. Electrical Characteristics

3.2.4.1. System Power

3.2.4.1.1 Power Consumption

The total power consumption shall not exceed 360 W.

Rationale: The maximum amount of power consumption was below 360 Watts and the maximum output of our power supply is 360 Watts.

3.2.4.2. Outputs

3.2.4.2.1 Data Output

The 3D Printing System shall include an interface to view the printing progress.

Rationale: The 3D printer sends progress data back to the user through the server and mobile application.

3.2.5. Failure Propagation

The 3D Printing System shall not allow failure propagation beyond the server.

3.2.5.1. Failure Detection

The 3D Printing System shall have a software subsystem in the server to check if the G-code files to be printed will fit within the 3D printing size constraints and if the heated elements are within proper printing temperatures.

Rationale: This is a requirement to avoid oversized prints due to large print designs and poor adhesion of print layers due to inadequate extrusion and hot bed temperatures.

3.2.5.2. Failure Warning

The 3D Printing System will record how much filament has ever been used to notify the user of potential print failure when filament is estimated to run out.

Rationale: Users will be able to account for and resolve problems when they are planning to print remotely.

4. Support Requirements

The 3D printer and application will require an internet connection and access to 120VAC 60Hz power. The web-hosted server will also require an initial setup through the amazon web-hosted server website. The 3D printer will require some assembly. If taken to a new location where the local network is changed, a new connection setup with the web-hosted server will have to take place. The phone application will need to be downloaded onto an android device with Wi-Fi/internet connection capability.

- # Appendix A: Acronyms and Abbreviations

3D	3 Dimensional
A	Amperage
AWS	Amazon Web Services
C	Celsius
G-code	Geometric Code
GHz	Gigahertz
Hz	Hertz
MHz	Megahertz
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronic Engineers
MCU	Microcontroller Unit
mm	Millimeter
oz	Ounce
PCB	Printed Circuit Board
PLA	Polylactic Acid
V	Voltage
VAC	Volts Alternating Current
W	Watts

- # Appendix B: Definition of Terms

Appendix C: Interface Control Documents

3D Printer and Application Interface

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INTERFACE CONTROL DOCUMENT

REVISION – 0.0
3 October 2022

INTERFACE CONTROL DOCUMENT
FOR
3D Printer and Application

TEAM 21

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Author Date

APPROVED BY:

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Cody Hutchison Date

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John Lusher II, P.E. Date

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Dalton Cyr Date

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1. Overview

The interface control document details how the microcontroller is interfacing with all the other control boards, the web-hosted server, and the application.

2. References and Definitions

2.1. References

Refer to section 2.2 of the Functional System Requirements document.

2.2. Definitions

Refer to Appendix A of the Functional System Requirements document.

3. Physical Interface

3.1. Weight

Component	Weight (oz)	Number of Items	Total Weight
ESP32-S3	TBD	1	TBD
Stepper Motor Control Board	TBD	4	TBD
Heated Bed Control Board	TBD	1	TBD
Hotend Control Board	TBD	1	TBD
Power Distribution Board	TBD	1	TBD

Table 1. PCB Dimension

3.2. Dimensions

Component	Length (mm)	Width (mm)
ESP32-S3	62.74	25.4
Stepper Motor Control Board	TBD	TBD
Heated Bed Control Board	TBD	TBD
Hotend Control Board	TBD	TBD
Power Distribution Board	TBD	TBD

Table 2. PCB Weights

4. Electrical Interface

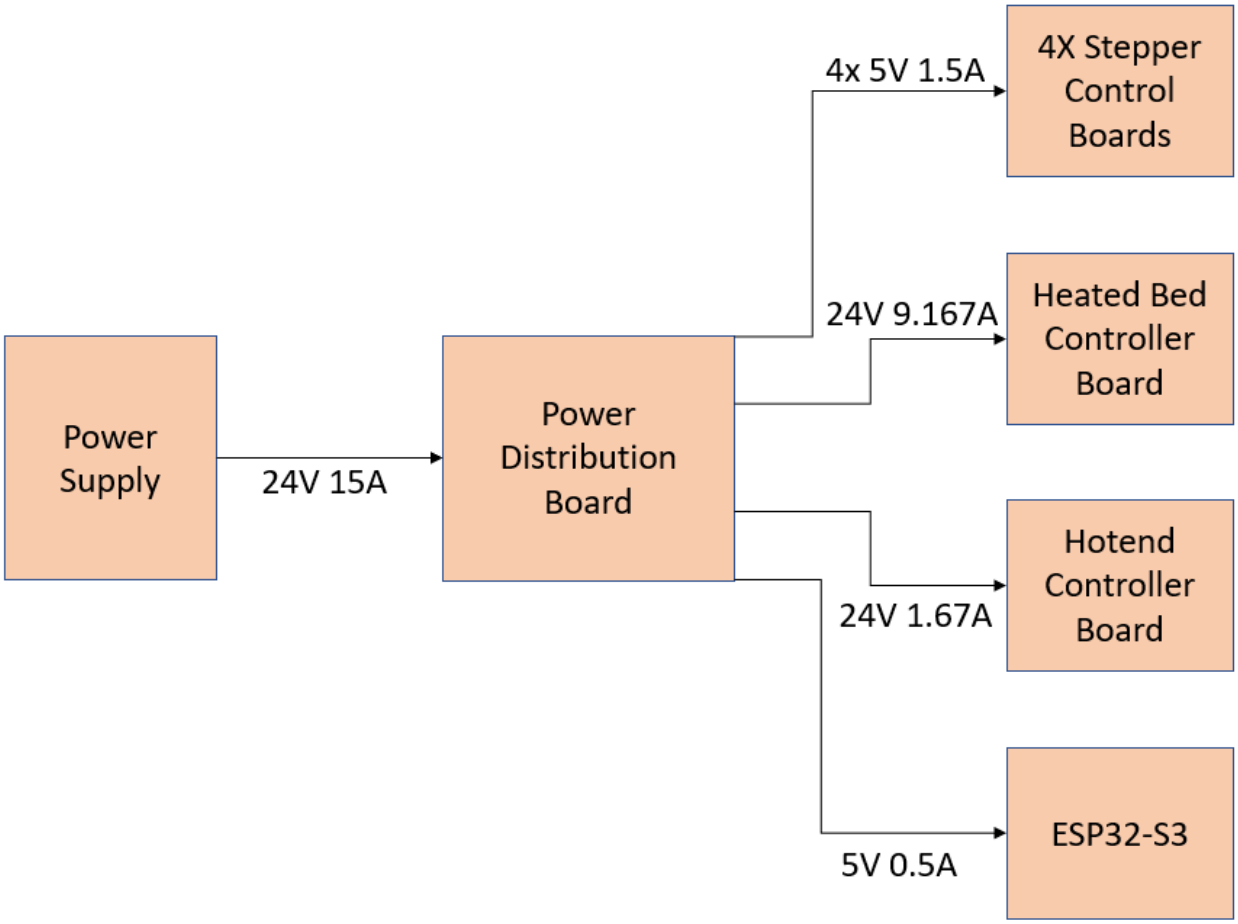

Figure 1. Electrical Interface Diagram

4.1. Primary Input Power

4.1.1. Power Supply

The power supply coming in will be 24V 15A and is the original power supply that the 3D printer had.

4.1.2. Power Distribution

The power distribution board will take the 24V 15A and distribute the power required to each board.

4.2. Voltage and Current Levels

Components	Voltage (V)	Current (A)	Power (W)
ESP32-S3	5	0.5	2.5
Stepper Motor Control Board	5	1.5	7.5
Heated Bed Control Board	24	9.167	220
Hotend Control Board	24	1.67	40
Power Distribution Board	24	15	360

Table 3. Component power usage

4.3. Signal Interfaces

4.3.1. ESP32-S3 Signal Interface

The ESP32-S3 will be controlled by a built-in 802.11 b/g/n 2.4 GHz Wi-Fi + Bluetooth module. It will be connected to the server and motherboard.

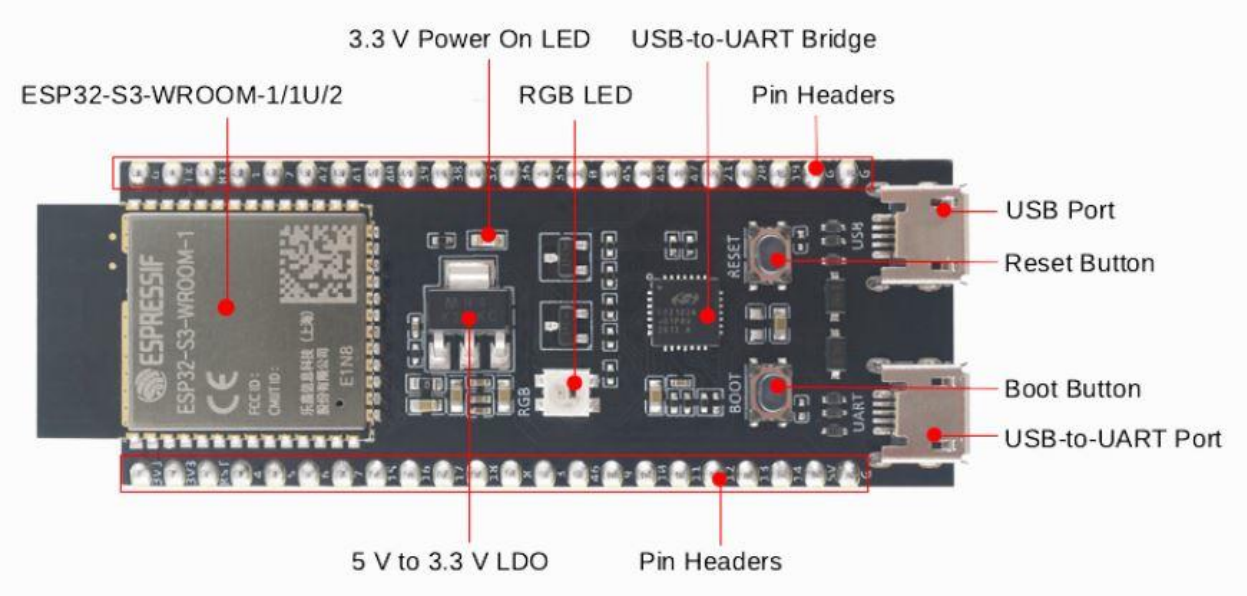

Figure 2. ESP32-S3 Layout

5. Communications / Device Interface Protocols

5.1. Wireless Communications (Wi-Fi)

The ESP32-S3 has a Wi-Fi module built into the board that follows the IEEE 802.11 b/g/n standard protocol. This will allow the microcontroller to be controlled by the application through the Wi-Fi and web-hosted server.

3D Printer and Application Interface

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SCHEDULE AND VALIDATION PLAN

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3 October 2022

SCHEDULE AND VALIDATION PLAN
FOR
3D Printer and Application

TEAM 21

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Author Date

APPROVED BY:

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Cody Hutchison Date

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John Lusher, P.E. Date

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1. Execution Plan

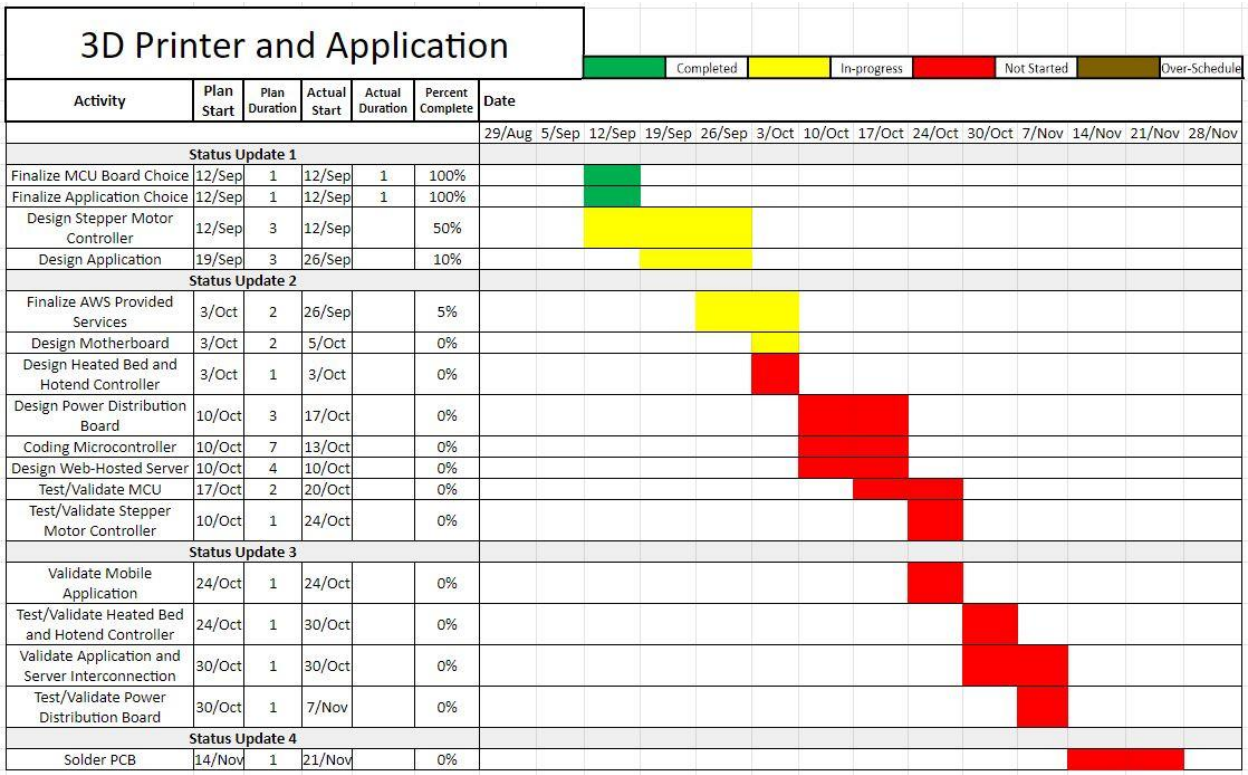

Table 1. Gantt Chart

2. Validation Plan

Validation	Success Criteria	Test Bench	Status	Responsible
Stepper Motor Board	Output of 5V 1.5A on specific outputs with specific controller inputs	Use coded inputs and multimeter to validate output requirements.	Untested	Cody Hutchison
Heated Bed Board	Output of 24V 1.67A when controller input is made	Use coded inputs and multimeter to validate output requirements.	Untested	Cody Hutchison
Hotend Board	Output of 24V 1.67A when controller input is made	Use coded inputs and multimeter to validate output requirements.	Untested	Cody Hutchison
Power Distribution Board	Output of four 5V 1.5A, one 5V 0.5A, one 24V 9.167A, and one 24V 1.67A outputs that will come from a 24V 15A power supply	Use multimeter to validate all output possiblilites and connections.	Untested	Cody Hutchison
Mobile Application	Downloadable and user interactable application	Download from app store, open app, and check all possible settings are functioning and adjustable.	Untested	Steven Liu
Web-Hosted Server/Application Connection	Viewable files in mobile application of the server library after files are uploaded	Open app, upload G-code, and check if files are stored on server.	Untested	Steven Liu
Communication of ESP32	Check incoming transmission from server	Connect MCU to network and send pings to server.	Untested	Abigail Morar
Extruder	Ensure printer is extruding and retracting the proper amount of filament	Feed filament through opening and send code to force filament through nozzle by specified amounts.	Untested	Abigail Morar
Motherboard	Can communicate correctly with motors and heated components	Sending inputs through every channel to show everyhting is connected and operating correctly.	Untested	Abigail Morar
Stepper Motors	Function smoothly and rotate accordingly by required distance	Various input cases will be used to track movement of the motors. This will be tested to ensure correct communication between board and device.	Untested	All
Heated Bed Temperature	Can reach 220°C	Use infrared thermometer to check surface temperature.	Untested	All
Hot Head Temperature	Can reach 80°C	Use infrared thermometer to check surface temperature.	Untested	All
Extruder Location	Can reach the full printing area of 220x220x250 (mm)	Set extrusion nozzle head to every possible coordinate.	Untested	All

Table 2. Validation Table