System Design for Pot-pulator

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1 Revision History

Date	Version	Notes
2023-01-18	Juan Moncada, Aaron Billones, Steven Ramundi, Gillian Ford	Initial release
2023-04-05	Juan Moncada, Aaron Billones, Steven Ramundi, Gillian Ford	Final documentation system design updates

2 Reference Material

This section records information for easy reference.

2.1 Abbreviations and Acronyms

symbol	description
CR	Conveyor Functional Requirement
NFR	Non-Functional Requirement
PDR	Pot Dispensing Functional Requirement
SRS	Software Requirements Specification
TDR	Tray Dispensing Functional Requirement
VR	Verification Functional Requirement
MIS	Module Interface Specification
MG	Module Guide
LED	Light-Emitting Diode
CAD	Computer-Aided Design

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3 Introduction

The Pot-pulator is a machine with purpose of aiding Sheridan Nurseries in populating their trays with pots, in order to prepare them for filling with soil and seeds.

Their current method of populating the trays with pots is a process with little to no automation, requiring many manual hours of labour. Each year, 250,000 annual plants need to be produced by the nursery. Recently, the supervisors have found it increasingly more difficult to fill positions with enough workers to run the operation smoothly and meet production demand. The Pot-pulator will alleviate the large reliance on manual labour and improve the overall efficiency of the nursery.

This document consists of a detailed design overview of the Pot-pulator. The system overview, system variables, user interfaces, hardware design and electrical design will be presented in this document.

4 Purpose

This document describes the overall system functionality and the design overview of the Pot-pulator. It will describe how the mechanical, electrical, and software components will interact with each other, and the various design decisions made within the system. The Module Guide (MG) and Module Interface Specification (MIS) are additional design documents that provide a further in depth design of the components in each module of the system.

5 Scope

The following figure shows the boundary between the Pot-pulator device and its functionality within the given environment.

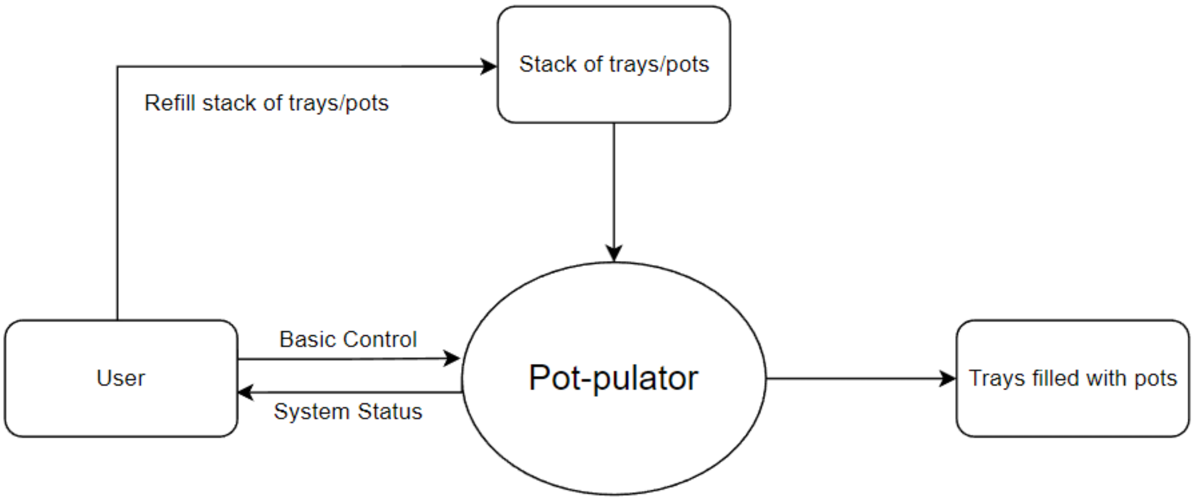

Figure 1: System Context Diagram

6 Project Overview

6.1 Normal Behaviour

The Pot-pulator needs to be filled with empty pots and trays by the user. Upon pressing the "start" button, the Pot-pulator begins its operation with no further interaction required by the user. Under normal operation, the ideal behaviour of the Pot-pulator will be as follows:

1. User fills the machine with empty pots and trays
2. User presses the start button
3. Raise the platform containing the trays until the stack reaches the top
4. Take the top tray off of the stack and place it on the conveyor belt
5. Proceed to move the conveyor and position the tray correctly to prepare for pot insertion
6. Stop the conveyor when pots and drop the pots 2 at a time in the tray
7. Continue moving the conveyor to the next available slots in the tray
8. Repeat steps 6 and 7 until the entire tray is filled with pots (10 pots)
9. Once the tray is filled with pots, the verification subsystem determines if all the pots have been placed correctly in the tray

Throughout the opreation of the device, the user interface displays the current status of the machine.

6.2 Undesired Event Handling

The Pot-pulator is vulnerable to many undesired events during operation. The user will be notified should anything go wrong with the system via the user interface, LEDs, and sound.

6.2.1 Pot/Tray Misalignement

A very common issue that could arise with the Pot-pulator is that there is the possibility of a pot not being placed correctly in the tray due to misalignement. To mitigate this risk, the verification subsystem was implemented to ensure that there are pots in all of the tray slots. If there are missing pots, the user will be notified and the tray may be removed from the conveyor by hand.

6.2.2 Motor Jam/Malfunction

If a motor is unable to turn or fails, the system comes to a stop and the user is notfied about the issue. The user is then expected to remove the object that is blocking the motor from moving. If the motor refuses to turn even without obstruction, the motor will most likely need to be replaced by a qualified individual.

6.3 Component Diagram

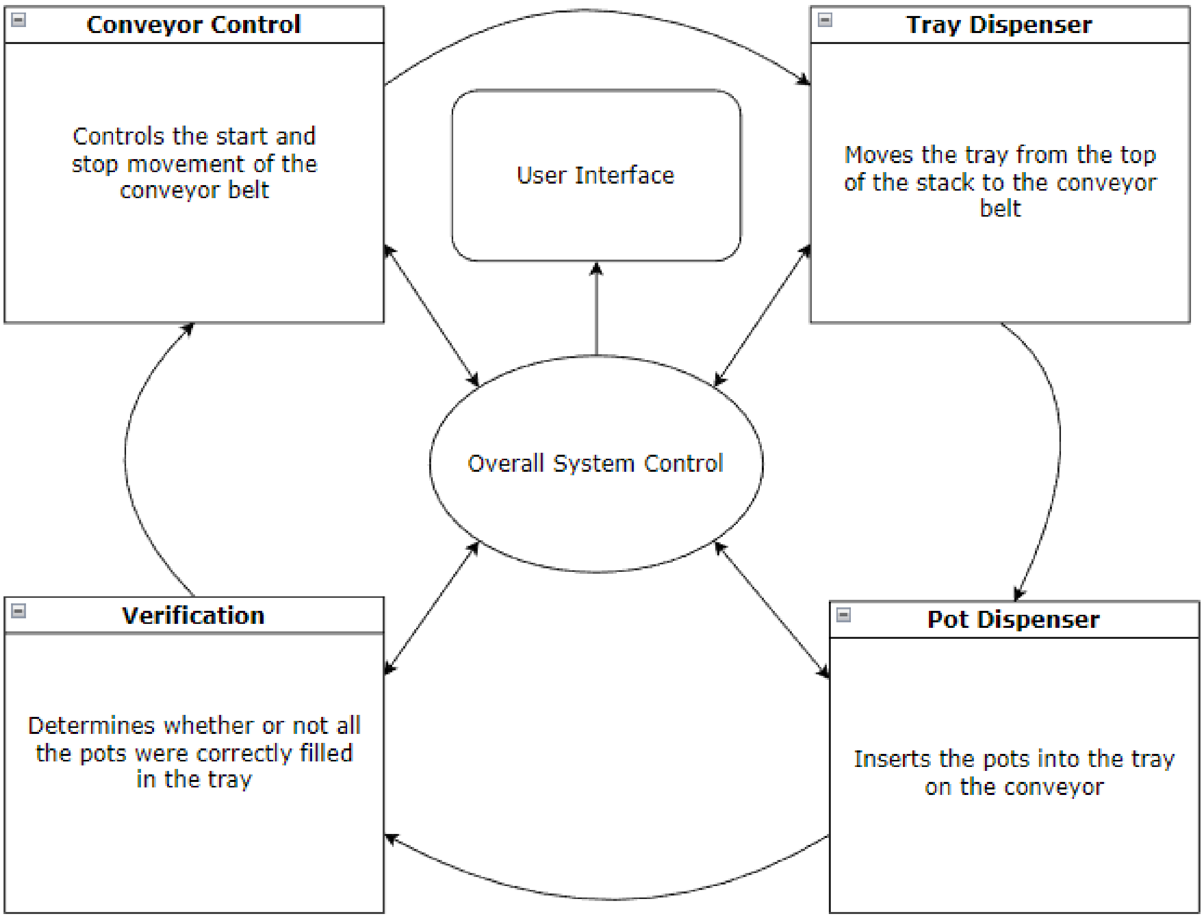

Figure 2: Component Diagram

6.4 Connection Between Requirements and Design

The table below shows the traceability between design components and requirements specified in the SRS.

Table 1: Requirements and System Design

Component	**Corresponding Requirement**
Overall System Control	NFR11, NFR12
Conveyor Control	CR1, CR2, CR3, CR4, CR5, CR6, NFR8
Tray Dispenser	TDR1, TDR2, TDR3, TDR4, TDR5, TDR6, TDR7, NFR4, NFR10, NFR13, NFR16
Pot Dispenser	PDR1, PDR2, PDR3, PDR4, PDR5, PDR6, PDR7, PDR8, NFR4, NFR9, NFR14, NFR15
Verification	VR1, VR2, NFR5
User Interface	NFR7

7 System Variables

7.1 Monitored Variables

Table 2: Monitored Variables

Variable	Description	Type	Units
Sensor Distances	Measured distances that the sensor identifies	Distance	mm
System State	Determines the state of the system (ie. Ready, Running, Error, Success)	State	N/A
Tray/Pot Weight	Weight of the trays/pots to verify number in the stack	Weight	kg
Tray/Pot Height	Height of the trays/pots to verify number in the stack	Height	m

7.2 Controlled Variables

Table 3: Controlled Variables

Variable	Description	Type	Units
Motor Speeds	The speeds at which the motors in the system will turn	Speed	rad/s
Voltage In	Voltage going into the system	Voltage	V
Current In	Current going into the system	Current	A
LEDs	LED status lights	Boolean	N/A

7.3 Constants Variables

Table 4: Constants Variables

Variable	Description	Type	Units
Motor Acceleration	The acceleration at which the motors in the system will turn	Acceleration	rad/s^2
Pots Dispensed	Pots dispensed by the system per cycle	Quantity	pots per cycle
Trays Dispensed	Trays dispensed by the system per cycle	Quantity	trays per cycle
Total Distance	Total distance travelled by trays	Distance	m

8 User Interfaces

The User Interface will consist of a set of buttons to allow the operator to safely interact with the machine. It will also consist of audible and visual signals to alert the operator of any action required (e.g. tray/pot restock, verification error, etc.). See Appendix A for interface layout concept.

9 Design of Hardware

9.1 Conveyor

The conveyor subsystem is comprised of:

- 1 conveyor (including belt, motor, gear box and framing)
- 1 Arduino Uno microcontroller

The conveyor has been acquired from Sheridan Nurseries and will not require fabrication.

9.2 Pot Dropper

The pot dropper subsystem is comprised of:

- 4 stepper motors
- 4 stepper motor drivers

- 1 Arduino Uno microcontroller
- 4 pot dropper screws
- 1 ultrasonic range finder

The pot dropper is fabricated with steel framing to support the mechanism. The stepper motors are attached to the frame, and the pot dropper screws are attached to the shaft of the stepper motors. See Appendix B.1 for a CAD diagram of the pot dropper screw.

9.3 Tray Dropper

The tray dropper subsystem is comprised of:

- 2 stepper motors
- 2 stepper driver boards
- 2 D-shafts
-
- 1 steel extrusion frame
- 2 tray dropper end-effectors

The tray dropper is fabricated with steel framing to support the mechanism. The stepper motors and shaft connectors are attached to the framing, and the shafts are secured to the shaft connectors. See Appendix B.2 for a CAD diagram of the tray dropper assembly and a CAD diagram of the tray dropper gear.

9.4 Verification

The verification subsystem will be comprised of:

- 2 ultrasonic range finders

10 Design of Electrical Components

The Pot-pulator has a number of electrical components in the system. A complete overview of the circuit diagram can be found in section C of the appendix. To improve modularity and for easier troubleshooting, the electrical components were divided in to 4 subsystems based on the control of the system: conveyor control, pot control, tray control, and verification. These subsystems are each controlled using an Arduino Uno while being monitored by the main microcontroller (STM32F429I-DISC1). For each subsystem, its respective Arduino controls the motors and reads sensor/switch/button values in order to ensure smooth operation. The

Arduino relays the operation status to the STM32F429I-DISC1 via status bits, that are sent from each of the subsystems to the STM32F429I-DISC1 at all times. If an error were to occur in one of the subsystems, the STM32F429I-DISC1 will be notified and tell all other subsystems to pause operation.

11 Timeline

Table 5: Timeline

Task	Description	Team Member(s)	Deadline
Pot Dropper Design	Design of pot dropper hardware and software	Juan Moncada and Gillian Ford	Juanuary 23, 2023
Tray Dropper Design	Design of tray dropper hardware and software	Steven Ramundi and Aaron Billones	January 23, 2023
Pot Dropper Fabrication	Fabrication of pot dropper frame and apparatus	Juan Moncada	January 31, 2023
Tray Dropper Fabrication	Fabrication of tray dropper and elevator frame and apparatus	Steven Ramundi and Aaron Billones	January 31, 2023
Verification Fabrication	Fabrication of verification System	Gillian Ford	January 31, 2023
Electrical Fabrication	Fabrication and assembly of all electrical components	All members	February 2, 2023
Testing	Testing of all subsystems and components	All members	February 6, 2023

A Interface

Figure 3: Example of Interface

The above figure shows an example of a status message alerting the machine operator that the pot dispenser requires refill. This would be accompanied by an audible alert.

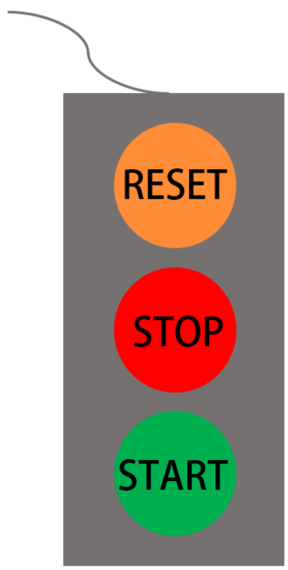

Figure 4: Example of Button Controls

Concept of the button interface used by the operator to control the machine. Handheld as to mitigate any safety concerns with a machine-mounted apparatus.

B Mechanical Hardware

B.1 Pot Dropper

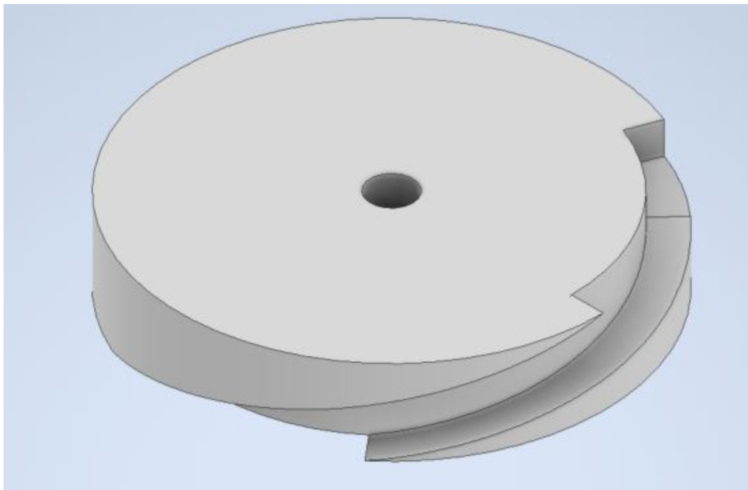

Figure 5: Pot Dropper Screw

B.2 Tray Dropper

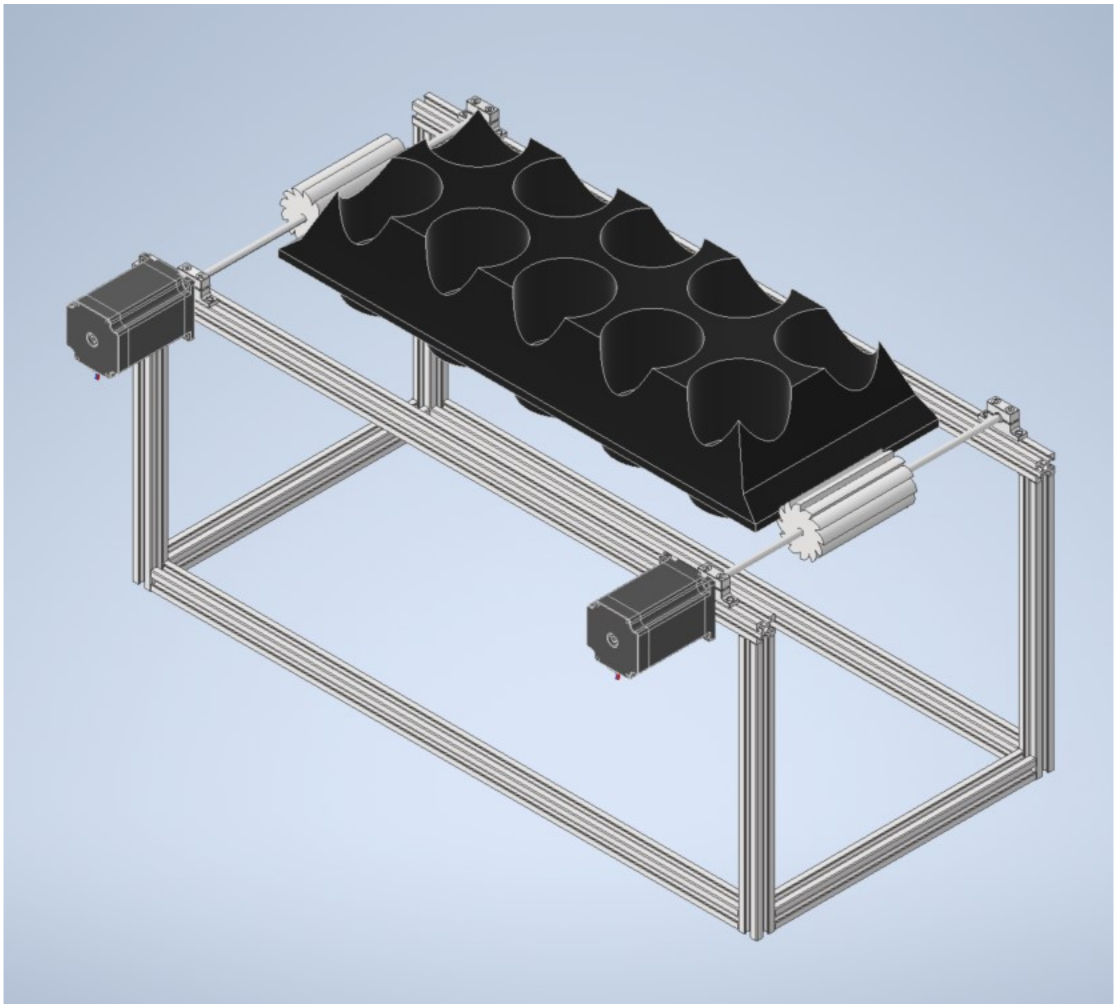

Figure 6: Tray Dropper Assembly

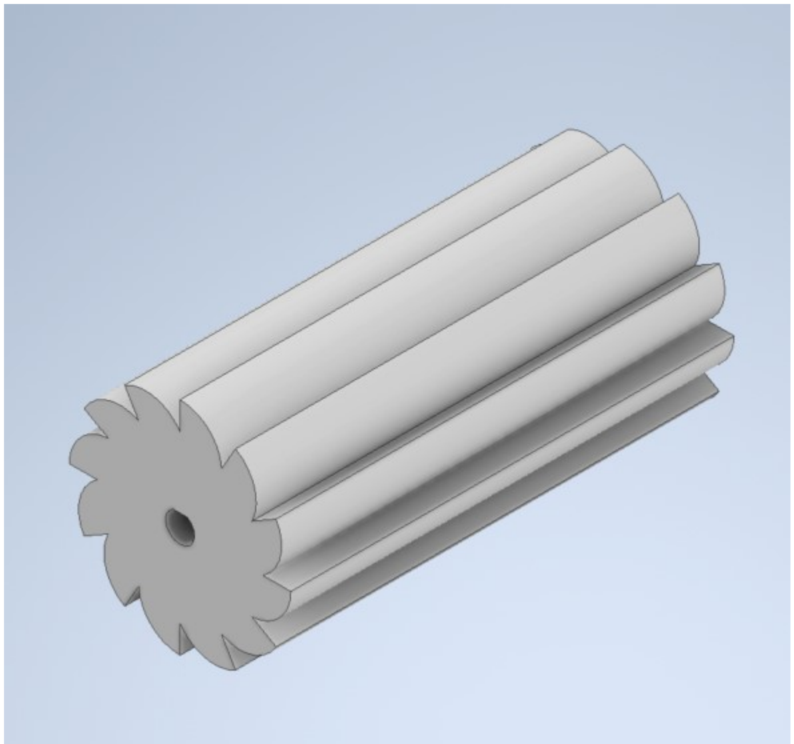

Figure 7: Tray Dropper Gear

C Electrical Components

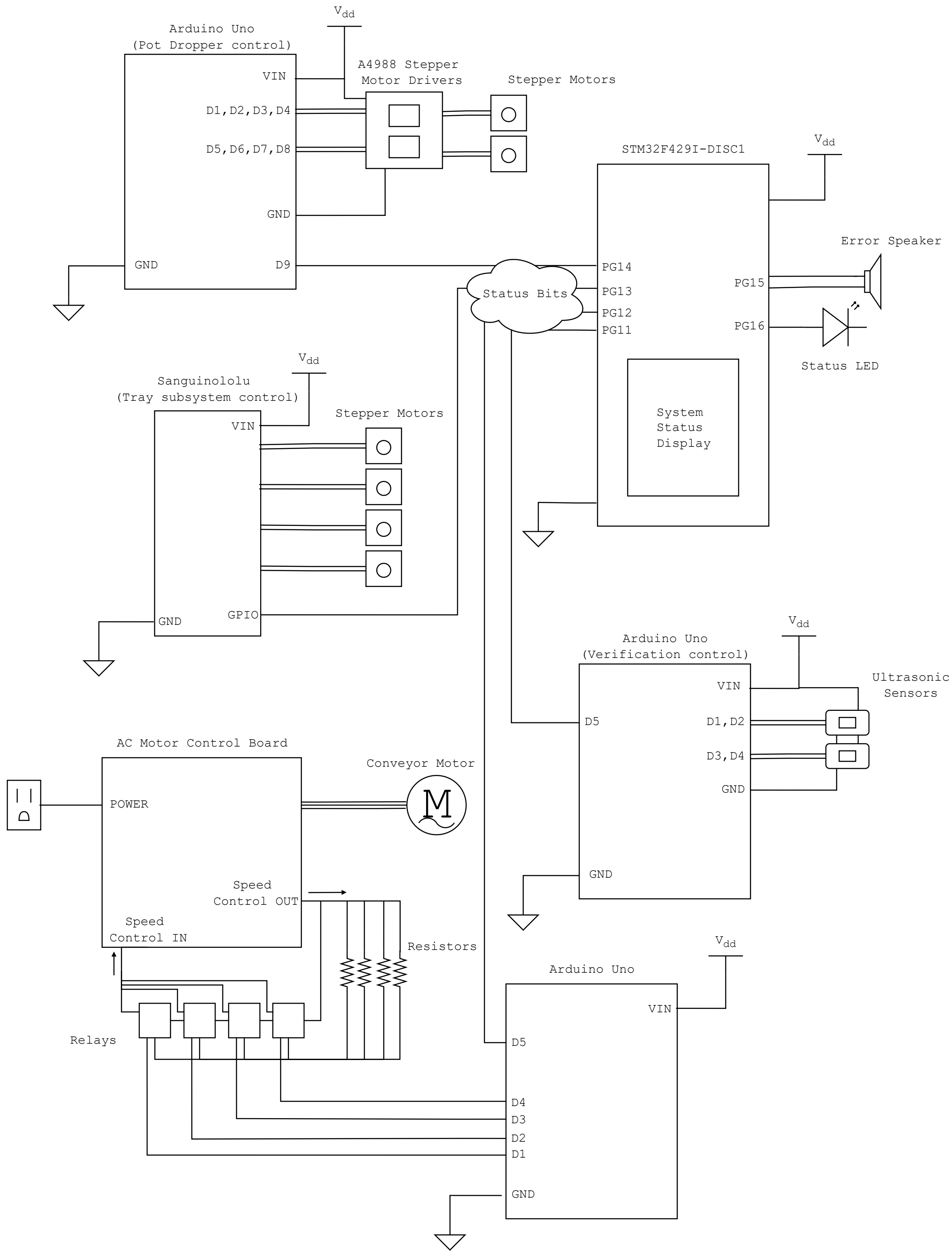

Figure 8: Circuit Diagram

D Communication Protocols

E Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Problem Analysis and Design. Please answer the following questions:

1. What are the limitations of your solution? Put another way, given unlimited resources, what could you do to make the project better?

   One limitation of our solution would be the overall load capacity of the system. We are constrained by the space where the pots and trays are being stored in the device that makes it difficult to upsize. Another limitation of our solution is that there are only a set number of speeds we can make the conveyor move at relative to the number of relays we use. This is because we used the existing AC motor that came with the conveyor and its control board rather than designing a control board from scratch. We still wanted to control the AC motor with an Arduino in some way with digital signals. This created some issues in controlling the motor to an exact speed we wanted. Given unlimited resources, we would ideally get a conveyor system that had a DC motor and could seemlessly be controlled using digital signals. We would also create more robust mounts and obtain more accurate sensors in order to mitigate risks during operation.

2. Give a brief overview of other design solutions you considered. What are the benefits and tradeoffs of those other designs compared with the chosen design? From all the potential options, why did you select documented design?

   We considered a number of design solutions on each subsystem of our device. For controlling the AC motor (conveyor), we considered purchasing a digital potentiometer. This option would give us more precise control over the motor, but was much more expensive that using relays. Another design option we considered was using a pully system to lift the trays into position in preparation for dispensing. We opted out of this option because the pully system would be less accurate and reliable than our rack and pinion design. We considered dispensing the trays in a simiar way to the pots using a threaded dropping system. However, given the shape and flexibility of the trays, we determined that this would be a unreliable way of getting the trays on the conveyor. The gantry method of moving the tray is much more reliable.