Project Document
Laser Painter

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Section 1: Overview
1.1 Executive Summary

The laser painter is a device designed to implement a system that will draw onto a surface with the utilization of a laser. The predominant goal is to have an image projected in a clear manner and by having it look like the original picture that was chosen by the user. All members of the team have coalesced and determined the most efficient route to assemble a more state of the art and advanced technology by making the laser painter more intriguing. Our primary objective is to ensure that the safety of those who come in contact with the device such as those who are working on the project and to those who are utilizing the device will be safe as it remains the top priority, while making certain that the laser painter can be enjoyed by others. We have taken into consideration the intensity and the power of the beams to ensure that the resolution of the images that are generated are visible and can be seen clearly. Furthermore, with the established safety protocol, the appropriate intensity and power of the beams will be selected by guaranteeing that it is regulated and approved by the FDA and to prevent damage to the eyes because we don't want anyone to get hurt or to become blind.

The laser painter has been constructed in the past and has been successfully completed; however, it is very limited to creating a few simple patterns. In order to meet higher expectations and push the boundaries of creativity, we plan to utilize the laser painter to generate more complex graphics, such as animal contours and emojis. Having the ability to draw more complex patterns will provide a better user experience. All of these key features will be more beneficial to the stakeholders, who are the users and customers that will be utilizing these devices because there will be more functionalities implemented. This will ultimately impact our design process because we want to deliver a more modern and polished version of the laser painter compared to the one that was accomplished six years ago. As we perused the internet and utilized several sources, we were able to garner a lot of inspiration for the project, which includes the use of the Arduino as the processor for the system, along with the selection of circuit operational amplifiers. Additionally, the usage of the galvanometers will be crucial and the process on how to generate a laser source.

1.2 Team Communication Protocols and Standards

Table 1: Team members' contact information and the project roles

Member Name	Email Address	Phone Number	Project role and expected contribution
Alex Greiner	greinera@oregonstate.edu	5039492612	Mirror controls, documenting schematics, design power supply.
Gregory Del Sta…	stapleyg@oregonstate.edu	9712738743	Design/Print case, code, build circuits, writing, schematics.

Nathan A Rasch…	raschken@oregonstate.edu	5038565392	Technical documentation, designing block diagrams and schematics
Yuhao Su	suyuh@oregonstate.edu	5412484630	Provide professional knowledge, draw PCB boards for the project, write and edit project-related documents.

(Table 1: Portrays the contact information for each team member and the role that's being executed by each individual.)

Table 2: Team communication protocol and standard

Topic	Protocol	Standard
Weekly Meeting	The team will hold weekly meetings on Friday at noon via zoom to discuss the progress of the project.	All members should attend the team meeting on time. If a member cannot attend, he should inform the other members in advance to determine the new meeting time.
Task Management	The team will carry out task assignments and progress feedback at weekly meetings.	During the meeting, each member should demonstrate the progress made in the past week, and other members should give appropriate feedback. Discuss the issues that the project still needs to solve, assign tasks for the new week and make sure everything is on track.
On-time Deliverables	All teamwork documents should be completed before the set deadline.	The team file should contain all the required content and meet the correct format requirements.
Google Team Drive	All project files should be uploaded to Google Drive Folder and be named correctly.	All members should share the new progress of the project with other members in a timely manner, and any form

		of files will be uploaded to the shared Google Drive Folder.
Respectful Communication	Team members should respect the ideas and suggestions of other members.	Every member of the team has an equal right to speak. When a member shows views and opinions, other members should show sufficient respect. When team members have disagreements, they should negotiate friendly and seek common ground while reserving differences.

(Table 2: Depicts the established protocols, standards and the agreements that the entire team has adhered to.)

Table 3: Project Parner Point of Contact

Person	Contact Information	Resource For	Communication
Donald Heer	heer@eecs.oregonstate.edu	EE technical advice, project scope.	Email every three weeks with project progress
Ingrid Scheel	scheeli@oregonstate.edu	Project assignment clarification and guidance.	Meet twice a term regarding technical advice
Rachael Cate	cater@oregonstate.edu	Professional development, project impact advice.	Meet during recitation to evaluate project impacts

(Table 3: Illustrates our communication analysis on how we plan to reach out and connect with our project partner.)

1.3 Gap Analysis

The purpose of this project is to provide a device that can project images with the usage of a laser that would make the experience more compelling and enjoyable for all of the users who are interested in laser painting. We will know when that goal is completed when the user is having a good time and by finding the device irresistible.

The project will allow users to upload the pictures they want to draw through the user interface. The system will analyze and process the pictures uploaded by the users and then automatically draw them on the canvas using a laser source. This project was conducted six years ago by seniors in the electrical and computer engineering field and what was accomplished back then were simple figures such as squares and circles.

After communicating with the project partners, we plan to make the system more advanced and sophisticated so that it's able to provide more complex images such as animals and emojis. Likewise, another upgrade that will be implemented to the system would be to add more functionalities to the system such as a timer to govern how long the image will be projected. Another example of what the laser painter will be able to do is to authorize the users the capability to draw the outlines of some animals and emojis on the canvas. In order to ensure the safety of the users and the people around the device, we will also add an automatic power-off function to the laser source of the system. After the laser source completes the painting task on the canvas, the power supply of the laser source will be automatically powered off. At the same time, in order to provide users with a richer and interesting experience, we will also try to add a variety of interface options to the system, for example, the users can use a controller or mouse to control the movement of the laser source on the canvas.

1.4.1 Timeline/Proposed Timeline

Fall

Weeks 1-3

- Team introduction
- Define project objectives
- Contact the project partners
    - Contact Don Heer - refer to section 1.2 for contact information
- Clarify expectations of project partners
- Environment Analysis
    - Contact Rachael Cate - refer to section 1.2 for contact information
- Order test parts (receive by 10/28/2021)
    - Assigned to Greg Stapley
    - Parts BOM Resource

Weeks 4-7

- Research
    - Refer to sections 1.5, 2.4, 3.4 for project resources
- Design impact assessment on users/customers and society
    - Assigned individually
- Craft the project document
- Block diagram draft
    - Assigned to team, see section 3.1 - 3.3

Weeks 8-10

- Receive all of the components that were ordered
- Continue to do more research
- Define engineering requirements
  - Assigned to team, see section 2.1
  - Contact Ingrid Scheel for clarification
- Block diagram

Current point in timeline

Winter

Weeks 1-3

- Start the physical building process
  - Assigned to team
- Test the circuit components and what has been built so far
  - Assigned Nathan Raschkes
- Design the PCB board of the system
  - Deliverable
  - Assigned to Yuhao Su
    - May need postponed due to chip shortage

Weeks 4-7

- Modify the physical laser painter
- Add functionalities/features
- Combine the blocks together
  - Assigned to Alex Greiner
- Design the 3D modeling enclosure
  - Assigned to Greg Stapley
  - Deliverable

Weeks 8-10

- Continue to build the physical laser painter
  - Assigned to team
- Revise the project documentation

Spring

Weeks 1-3

- Add any last-minute features and implementations to the project
  - Assigned to team
  - Deliverable

Weeks 4-7

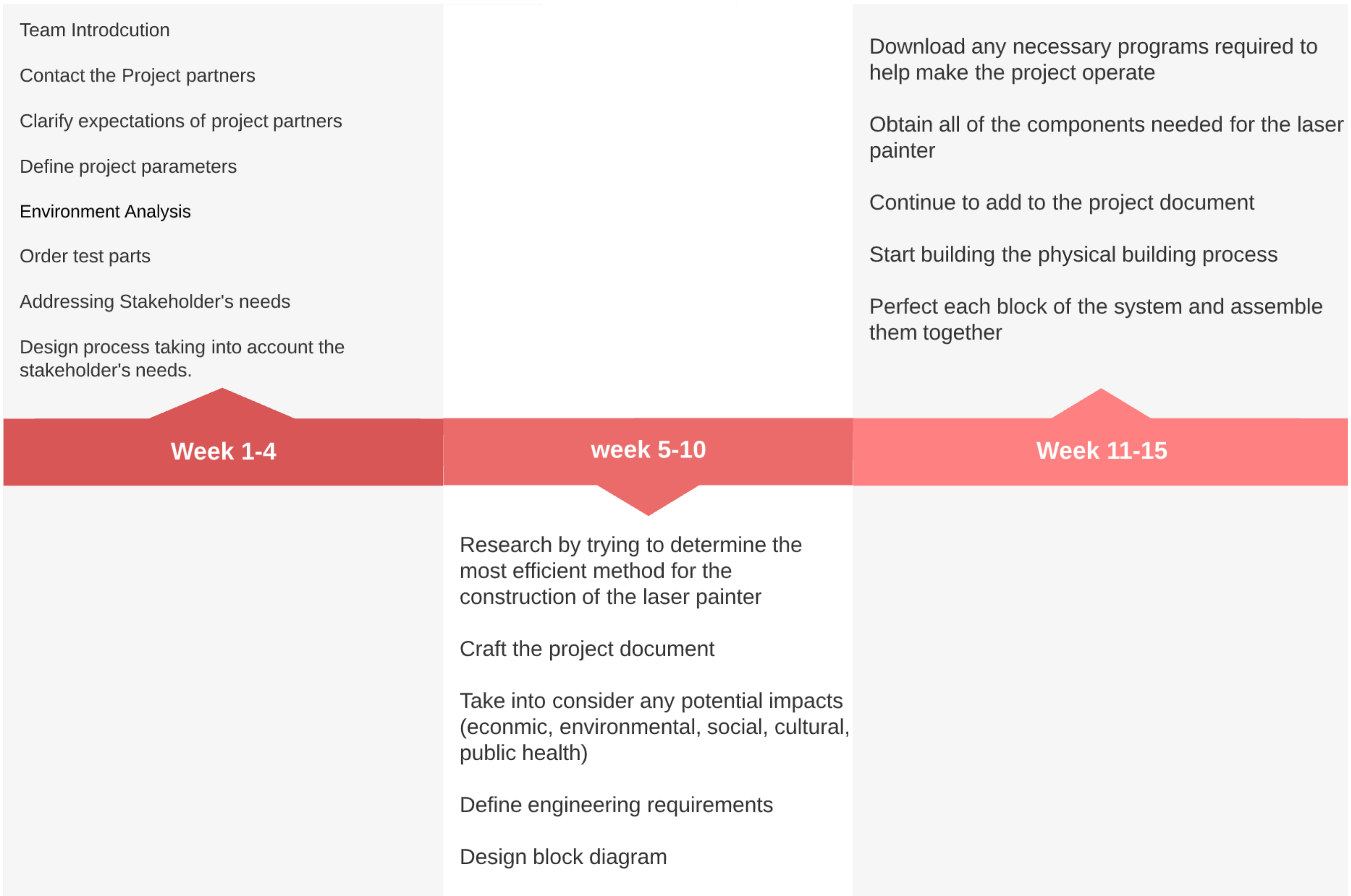
- Polish the laser painter
- Do any last-minute touches to project documentation

Weeks 8-10

- Prepare for the Project Showcase Expo
- Present the laser painter
    - Deliverable
- Submit the project document

1.4.2 - Visual Timeline Chart

Figure 1: Timeline Part 1



(Figure 1: Represents part one of the timeline of how the laser painter will be developed over the three terms.)

Figure 2: Timeline Part 2

(Figure 2: Represent part 2 of the timeline of how the laser painter will be developed over the three terms)

1.4.3 - Critical Path

Week 1-3
- Team introduction and project partner contact

Week 4-7
- Engineering Requirements and risk assessment

Week 8-10
- Block diagram, interface definitions

Week 11-13
- One block completed and tested by each team member

Week 14-17
- Additional block completed by each team member and integrate functional blocks

Week 18-20
- Additional block completed for a total of 12 blocks completed, tested, and integrated

Week 21-23
- Finalize testing, verify system meets all engineering requirements

Week 23-27
- Finalize project documentation

Week 28-30
- Project expo

1.5 References and File Links

General Internet Site

[1] DeltaFlo, "Arduino Laser Show With Real Galvos," *Instructables.com.* [Online]. Available: https://www.instructables.com/Arduino-Laser-Show-With-Real-Galvos/. [Accessed Oct. 17, 2021]

[2] S. Morales and Instructables, "Laser painting," *Instructables*, 08-Oct-2017. [Online]. Available: https://www.instructables.com/Laser-Painting/. [Accessed: 17-Oct-2021].

Online Videos

[1] X-lasers USA, "How laser projectors work," YouTube, 13-Feb-2019. [Online]. Available: https://www.youtube.com/watch?v=jscpGsmAEmE.[Accessed: 17-Oct-2021].

[2] Styropyro, "Building a burning laser from an old computer!!!," *YouTube*, 19-Mar-2015. [Online]. Available: https://www.youtube.com/watch?v=fj7EcDA73Bs. [Accessed: 17-Oct-2021].

1.6 Revision Table

Date	Name	Description
11/28/2021	Team	- Revised timeline based on instructor and student feedback
11/26/2021	Alex Greiner	- Added project partner point of contact - Resources for timeline, critical path
10/27/2021	Yuhao Su	-Adjusted gap analysis, timeline, visual timeline chart and revision table.
10/26/2021	Nathan Raschkes	-Clarified whose safety is involved and what kind of safety. -Added a comma splice to the draft over the feedback that was provided. -I edited the section by providing a more precise verb and sentence. -Elaborated more on what higher user needs are. - Explained how the goal is defined. -Added labels and information to the table in section 1.2. -Added more insights and information to the first sentence. -Added a cover page -Addressed who this is and what project this is. -Add labels and information to the timeline. -Adjusted the size of the timeline. -Modified one of the bullet points in the winter term phase for weeks 1-3. -Clarified who the stakeholders are and the significance of the project will be for them and how it will impact our design.
10/23/2021	Alex Greiner	-Put timeline chart on a horizontal page
10/20/2021	Yuhao Su	-Adjusted the timeline and add a visual timeline chart
10/20/2021	Nathan Raschkes	-Added to the executive summary, gap analysis and to the timeline
10/17/2021	Yuhao Su	-Adjusted Team Communication Protocol and Standard
10/17/2021	Greg Stapley	-Adjusted executive summary
10/15/2021	Alex Greiner	-Added Basic Formatting (headers, team name, etc.)

Section 2: Requirements Impacts and Risks

2.1 Requirements

2.1.1

Customer Requirement 1:

The system should turn off when left unattended.

Engineering Requirement 1:

The system lets users define timeout durations of 30, 60, and 90 seconds.

Tests for Requirement 1:

1. Turn on the power switch for the system
2. Open the GUI
3. Connect the GUI to the system's bluetooth using the bluetooth selector button in the GUI
4. Select one of the three auto timeout durations (30, 60, or 90 seconds) through the GUI.
5. Select "on" to project an image with the system.
6. Leave the system idle for the selected duration.

Verification for Requirement 1:

The system no longer displays a laser projected image after the auto timeout duration.

2.1.2

Customer Requirement 2:

The system should have an upload image option.

Engineering Requirement 2:

The system lets the user control the system via a user scanned image from the user interface.

Tests for Requirement 2:

1. Turn on the power switch for the system
2. Open the GUI
3. Connect the GUI to the system's bluetooth using the bluetooth selector button in the GUI
4. Select the "Upload From Camera" option
5. If prompted, allow the GUI to use the access the Android camera
6. Point the camera to view the desired scan image
7. Press the "Scan" button on the GUI
8. Select "Go To Data Menu"
9. Select "on" to project an image with the system

Verification for Requirement 2:

The system will display the word of the scanned image from the image database

2.1.3

Customer Requirement 3:

The system should have an option for the user to control the image being displayed.

Engineering Requirement 3:

The system lets the user control the system using control knobs to adjust the X and Y location of the image, and the size of the image.

Tests for Requirement 3:

1. Use the laser painter to display an image
2. Turn the x-axis potentiometer clockwise
    a. Verify the image translated to the right
3. Turn the y-axis potentiometer counterclockwise
    a. Verify the image translated to the left
4. Turn the y-axis potentiometer clockwise
    a. Verify the image translated up
5. Turn the y-axis potentiometer counterclockwise
    a. Verify the image translated downwards

Verification for Requirement 3:

The display image moves and scales with the turning of the control knobs.

2.1.4

Customer Requirement 4:

The system should not overheat.

Engineering Requirement 4:

The system will turn on an intake and an exhaust fan if the internal components are greater than or equal to 75 degrees fahrenheit.

Tests for Requirement 4:

1. Use the laser system to display an image
2. Use a temperature measurer to measure the temperature at the thermistor location
3. Verify that the intake and exhaust fans turn on when the temperature gun reads 75 +/- 5 degrees fahrenheit or greater.

Verification for Requirement 4:

The intake and exhaust fans turn on when the system is greater than or equal to 75 degrees fahrenheit. The fans turn off when the system is less than 75 degrees fahrenheit.

2.1.5

Customer Requirement 5:

The system should not blind people.

Engineering Requirement 5:

A receptor will run parallel to the laser beam and the laser will turn off if an object crosses the laser system's path.

Tests for Requirement 5:

1. Power on the laser system.
2. Turn the laser on with the GUI.
3. Move an object between the laser system and the surface the laser is projecting onto.

Verification for Requirement 5:

A red laser boundary displays for the perimeter of the operating range, indicating to not step within this range. The image stops being displayed when an object is within the user defined operating range.

2.1.6

Customer Requirement 6:

The system will project a word.

Engineering Requirement 6:

The system will display an identifiable and readable word as identified by the course evaluator.

Tests for Requirement 6:

1. Turn on the power of the system
2. Using the GUI, connect to the system bluetooth
3. On the GUI, select "Upload From Camera"
4. On the GUI, select "scan"
5. On the GUI, select "Go To Data Menu"
6. Ensure the distance sensor is not obstructed measured from the start up distance
7. On the GUI, select "ON"

Verification for Requirement 6:

The word projected by the laser painter is identifiable and readable as determined by the course evaluator.

2.1.7

Customer Requirement 7:

The system should be portable

Engineering Requirement 7:

The system is within the following parameters:

- The system is less than 30 pounds
- The system is less than 1.5 cubic feet
- All connectors are removable

- The system can shook with intensity equal to a car transportation and still operate afterwords

Tests for Requirement 7:

1. Use a scale to weigh the laser system excluding all external cables
2. User a measuring tape to measure the length, width, and height of the laser system in feet
    a. Multiply the length, width, and height to get the total cubic feet of the laser system
3. Verify that the power cable can be removed from the laser system

Verification for Requirement 7:

The system weighs less than 30 pounds, less than 1.5 cubic feet, the connectors can be removed, and the system operates after being shook.

2.1.8

Customer Requirement 8:

System parameters (light level, internal temperature, and display distance, will be displayed to the user.

Engineering Requirement 8:

An OLED display will show the following system parameters:

- The display distance in meters +/- 0.1 meter
- Temperature in fahrenheit +/- 5 degrees
- Lux +/- 10%

Tests for Requirement 8:

1. Use the laser painter to display an image
2. Use a tape measure to measure the distance between the laser system and the display surface.
3. Use a temperature meter to measure the temperature at the internal thermistor
4. Uses a lux meter to measure the light level at the photoresistor.
5. Verify the measurements from steps 2-4 are within the specified range displayed on the OLED

Verification for Requirement 8:

The display distance is displayed in meters +/- 0.1 meter.
The internal temperature is displayed in fahrenheit +/- 5 degrees
The external lux is displayed +/- 10%

2.2 Design Impact Statement

2.2.1. Introduction

With the construction of the laser painter, it is crucial that the information is transparent and that it takes into consideration any potential negative consequences. Taking into account these possible negative ramifications into our design process ensures that the project was executed adequately because we want to build a device that doesn't harm or offend anyone. We are constructing the laser painter to make it enjoyable for everyone by making it as inclusive as possible. As the design engineers, we have to look into these aspects by researching it thoroughly by seeing the implementations of how it could impact the public health, safety, environment, economic and cultural aspects. This is significant to the project contributor because they want to invest and be part of a project that's constructed appropriately and they also don't want to face any sorts of liability issues. The goal is to convey the unvarnished truth, which is a vital key to ensure that the project is safe and reliable for everyone that decides to come in contact with the device. Parenthetically, by taking into account these concerns, it will make certain that the project was built appropriately.

We will be exploring the potential impacts that are associated with the laser painter, along with any negative connotations or any preconceived notions. We will be addressing these possible ramifications, such as the public health, safety, and welfare impacts. Furthermore, cultural and social impacts will be taken into account as well. Likewise, another aspect that will be inspected will be any environmental and economical concerns. All of those aspects will be examined in an objective light which will help remove any biases towards any certain groups of people and it will reduce any damages towards the environment.

The safety of all individuals that come in contact with the laser painter will be our highest priority, whether that is the person operating the device and to those who are watching. The proper gear will be handed out, such as safety glasses. The safety protocols will be addressed at the beginning just to ensure awareness which will help promote safety. We don't want anyone to be harmed while enjoying the laser painter, which is why we'll be monitoring the laser intensity and by carefully watching the user interact with the device.

2.2.2. Public Health, Safety and Welfare Impacts

With regards to safety and the health of individuals, an issue that arises with lasers is the known capabilities of causing blindness. A typical laser pointer can produce a range of one to five milliwatts of power which can damage the retina in our eyes after merely ten seconds of exposure. A laser can burn through paper at 3,500 milliwatts and can be purchased online for two hundred dollars. Unfortunately, that means those who acquire these unregulated lasers that have the capability of producing higher power would need to be exposed to the light for less than ten seconds to sustain permanent damage [1]. It is important when the laser painter is being assembled that the intensity of the brightness won't damage the eyes of the viewers while ensuring that it is bright enough that it can be seen and enjoyed. Likewise, in order to mitigate this particular risk, we all want to make certain that the selected laser is safe, regulated and approved by the FDA because having reputable brands that are well known and that are reliable will help protect and build trust to the public. The FDA has been regulating lasers and the powers that are being emitted. It’s worth pointing out that there are unregulated lasers that are being sold into the marketplace that have the ability to generate higher levels of power than what is set by the FDA. Lastly, providing safety goggles to those who are watching and using the laser painter will help reduce the risks of any eye injuries.

Another harmful effect that is associated with lasers is the shear powers being emitted that can lead to burnings. The higher the power that’s being generated, the stronger the laser intensity will be. Lasers can be potent enough to pop a balloon, even light a match and it can also severe an electrical tape. In order for a laser to conduct those operations, it will require at least 200mW or 300mW. Several lasers that can be handheld often come with a fixed focus beam which means that the intensity of the width of the beam cannot be modified. Obtaining a focusable adjustment lens will provide more control over the beam and permit the ability to increase the intensity of the laser by decreasing the size of the beam [2]. It’s paramount that the focus adjustment option is considered in the development phase because it enables more leverage over the intensity which makes it easier to control the power that’s being generated from the laser. This can be done through purchasing a laser that has that specific feature and by ensuring that the selected laser is regulated by the FDA so that the laser intensity isn’t super strong like the ones that are unregulated that are being sold in the marketplace. This is a good safety precaution because if a user decides to act foolishly by engaging in unsafe manners, those around them will be safer because the unregulated lasers have a stronger intensity which means it takes less exposure to cause any damages to the eyes.

2.2.3. Cultural and Social Impacts

Lasers have largely become more affordable over time to the point that they are being brought to protest events. Many demonstrators bring lasers to garner attention by trying to push for changes in policies while trying to convey their messages to the public. Social movements see lasers as an important tool because they see it as a form of self defense, along with how it can provide distractions and how it has the capability to interfere with drones that are being utilized by law enforcement. It’s worth acknowledging that lasers aren’t always used by peaceful protesters who are advocating for social change. Lasers can provoke a reaction from the police which can very easily lead to a confrontation. According to HarvardPolitics, they articulated that “When asked how police would respond to the hypothetical use of lasers in protests, Officer Robert Rueca, a spokesperson for the San Francisco Police Department, said that police are trained to respond to certain threats, but that their response depends on the nature of the threat. If protesters began to use lasers to blind police or create disorder, patrol officers would likely respond by treating lasers as a dangerous weapon” [3]. Lasers are a powerful tool; unfortunately, bad actors with malevolent intent do get a hold of such devices and use it irresponsibly. Ultimately, it’s up to the groups to make the calls on whether utilizing a laser provides more benefits by outweighing the harm. During the event, if someone decides to mess around and act carelessly, we will make the determination by telling them politely to not utilize the laser painter and if they are causing a ruckus, then they will be asked to leave.

Another societal impact that lasers can have a negative outcome is that it can cause confusion and provide scare. People might think that they are being targeted or that a gun is being pointed at them. There will also be confusion because it can be perceived as a threat or someone just playfully pointing the light in an amicable fashion [4].

When the presentation or event occurs, we'll make sure that the images that are being projected won't display any offensive pictures or messages. There will not be any illustrations depicting stereotypes of any groups. Additionally, the visuals won't showcase anything that is malicious based on any individuals' race, origin, gender, religion, sexual orientation, economic status, etc. Likewise, there won't be any political images or messages being projected. The overall goal is to have an inclusive project where everyone feels welcomed and can enjoy the laser creation that has been developed.

2.2.4. Environmental Impacts

Lasers, such as laser pointers are comprised of a variety of electronic components, metals and plastics. In those individual industries, they have particular waste byproducts like lead, chemicals, solvents, and halocarbon gases. While laser pointer assembly doesn't have any particular wastes until it is being disposed of. Devices like a laser pointer are constituted of small quantities of hazardous materials like lead and some toxic semiconductors. An approach that would be more amicable and safer towards the environment would be to recycle the parts, specifically in places that reuse electronic components. Laser diodes are made in a semiconductor factory where the materials are generated in very pristine and carefully managed conditions. The article continues to proclaim on the process on how the laser diodes are produced in a clean notion and what elements are utilized "The substrate is the base material on which other materials will be deposited. A wafer of the substrate is produced, cleaned, and prepared. Then it goes through several steps where layers of material are deposited on it. Some of these layers are only several atoms thick. These layers can be conductive (metals such as aluminum and gold) or semiconductors" [5]. When it comes to electronic components, certain elements like aluminum and gold would need to be extracted from the Earth. Fortunately, lasers don't utilize a plethora of materials from the environment and its parts can be reused. With our project, we will choose a laser that is environmentally friendly by making sure that it is comprised of the least amount of elements and we'll also make sure that it can be reused when it is being disposed of.

An energy efficient laser such as the CQD (Center for Quantum Devices) which is being carried out by Razeghi, Walter P. Murphy Professor of Electrical Engineering and Computer Science at the McCormick School of Engineering and Applied Science showcases that the design, material growth and laser fabrications have significantly improved the output power, along with the efficiency of the wall-plug which involves the capability to alter electrical power into light. The CQD has shown that individual lasers can fit on a penny, while emitting wavelengths of 4.5 microns and have the ability to generate over 700 milliwatts of uninterrupted output power in room temperature. Likewise, it can also produce more than a Watt of output power in smaller temperatures. Additionally, the article declares how very efficient these lasers are by stating that "these lasers are extremely efficient in converting electricity to light, having a 10 percent wall-plug efficiency at room temperature and more than 18 percent wall-plug efficiency at lower temperatures. This represents a factor of two increase in laser performance, which is far superior to any competing laser technology at this wavelength" [6]. In order to ensure an energy efficient laser, we'll incorporate a laser that is able to generate enough milliwatts to produce a readable resolution of the images while keeping the energy consumption as low as possible.

2.2.5. Economic Factors

Depending on the power and intensity that an individual is seeking, that will have an impact on the price which will broaden the range by having the prices range from very cheap to extremely expensive. The small handheld and portable lasers such as the laser pointers are relatively cheap and can be purchased at a price fewer than fifty dollars. These lasers are very durable, high quality and can produce amazing beams. A blue and violet laser pointer can be bought from Laserpointerpro at $17.79 with a power level of 20mW. Furthermore, a Zeus Pocket Red Laser Pointer can be purchased at a higher price of $46.20 from Zeus Lasers, with a power level of 300mW. This specific laser can generate a powerful beam that can light a match in seconds and it's sold at a reasonable cost. Additionally, it's also fully adjustable with exceptional battery duration and has a sturdy design [7].

According to the U.S Bureau of Labor Statistics, there have been more than 20,000 eye injuries that occur every year in the workforce. Eye injuries in the workforce usually require at least one or more days missed from work just for recovery. OSHA concedes that injuries involving the eyes cost around $300 million per year that is lost in productivity, worker compensation and medical treatment [8]. The intensity and the beams that the laser is emitting are powerful enough to blind anyone. It's vital that businesses prioritize safety over monetary profits because sloppy handling and negligence in certain situations would not only cause harm to those who are working in the field, it would also cost these businesses a significant amount of money as well. Having safety protocols with the proper training would decrease the chance of an accident taking place. During the presentation and event, we'll be distributing the appropriate gear such as safety glasses, which can help protect the eyes against potential injuries. Our project can be used as a prime example of what safety precautions looks like by modeling good behaviors.

2.2.6. Conclusion

While the laser painter is a very fascinating and intriguing concept that's being conducted, clearly there are some aspects that need to be investigated further. There are ethical dilemmas that need to be addressed to ensure that no one is harmed and that the safety of the individuals remains the top priority. We don’t want to impair any eyes, especially those with sensitive eyes and we also don’t want any retinas to be damaged in the process that could lead to permanent blindness. Likewise, we need to carefully monitor the power that’s being generated to thwart any potential fires or burning of any objects. All of these things will be taken into serious consideration as we thoroughly explore all of our options when it comes down to selecting the appropriate laser that meets our safety requirements. Our predominant objective is to make certain that it’s as safe as possible while certifying that the intensity of the beams and the power that is being emitted from the laser is projecting a clear resolution of the pictures that can be seen and enjoyed by others.

2.2.7. References

[1] Ceenta, “Can a laser pointer blind you?,” *Charlotte Eye Ear Nose & Throat Associates*, 28-Oct-2020. [Online]. Available: https://www.ceenta.com/news-blog/can-a-laser-pointer-blind-you. [Accessed: 20-Oct-2021].

[2] Biglasers, “Which laser pointers can burn?,” *BigLasers.com*, 25-Aug-2021. [Online]. Available: https://biglasers.com/blog/2018/09/28/which-laser-pointers-can-burn/. [Accessed: 20-Oct-2021].

[3] J. Kim, By, J. Kim, Mary Cipperman - October 18, M. C. -, Prince Williams - October 15, P. W. -, Iqra Noor - October 10, I. N. -, Aidan Scully - October 10, A. S. -, Sawyer Taylor-Arnold - October 9, S. T.-A. -, Rosanna Kataja - July 25, R. K. -, Corbin Duncan - April 6, C. D. -, Andre Ferreira - March 6, A. F. -, Ilana Cohen - March 23, I. C. -, Chloe E.W. Levine - March 8, C. E. W. L. -, Jeremiah Kim - March 19, and J. K. -, “Lasers: The future of protests,” *Harvard Political Review*, 20-Oct-2020. [Online]. Available: https://harvardpolitics.com/lasers/. [Accessed: 20-Oct-2021].

[4] Author(s) Eugene Nielsen, “Laser sights provide a tactical advantage,” *Laser Sights Provide a Tactical Advantage | Office of Justice Programs*. [Online]. Available: https://www.ojp.gov/ncjrs/virtual-library/abstracts/laser-sights-provide-tactical-advantage. [Accessed: 20-Oct-2021].

[5] “Laser pointer,” *How Products Are Made*. [Online]. Available: http://www.madehow.com/Volume-7/Laser-Pointer.html. [Accessed: 20-Oct-2021].

[6] “Laser sets records in power and Energy Efficiency,” *Phys.org*, 24-Jul-2007. [Online]. Available: https://phys.org/news/2007-07-laser-power-energy-efficiency.html. [Accessed: 20-Oct-2021].

[7] A. J. Ward, “Best cheap laser pointers of 2020,” *Optics Advisors*, 17-Dec-2020. [Online]. Available: https://opticsadvisors.com/best-cheap-laser-pointers/. [Accessed: 20-Oct-2021].

[8] Ishn.com. 2021. [online] Available at: <https://www.ishn.com/articles/106278-eye-injuries-cost-business-300-million-annually> [Accessed 20 October 2021].

2.3 Risks

Table 4: Risk Assessment and Action Plan

Risk ID	Risk Description	Risk category	Risk probability	Risk impact	Performance indicator	Responsible party	Action Plan
R1	Taking into account the intensity of the laser beams by trying to prevent objects from catching on fire and by making certain that people's eyes aren't getting damaged.	Public Health	80%	H	Accessibility of safe testing sites decreases over project life cycle	Alex Greiner	Reduce -- The system will be designed with safety goals in mind, such as a designated operation zone.
R2	Vendor delay	Timeline	30%	M	Parts are received by a determined deadline per part	Greg Stapley	Retain -- Order parts 2 times earlier than needed given the longest estimated shipping time.
R3	No energy efficient hardware is available	Environmental	60%	L	The project is energy efficient and has a default timeout setting	Yuhao Su	Reduce -- Integrate a default timeout setting and verify the efficiency of the selected components will combine for a desired efficiency prior to integration.

R4	No compatible software is available	Team Collaboration	20%	L	Ensure all software used is accessible by all group members	Alex Greiner	Avoid -- Before a new software is used to develop a system block, confirm that the software is openly available for other OSU students to use.
R5	Faulty Components	Timeline	10%	H	All individual components should be thoroughly tested for functionality prior to integration	Nathan Raschkes	Retain -- Test all components for fundamental functionality prior to system block being developed.
R6	Faulty PCB board	Technical	30%	M	The designed PCB board does not behave as expected	Yuhao Su	Reduce -- Test the PCB board for full functionality prior to system integration.
R7	Available products are prone to high heat	Technical	20%	H	The system and the specified components won't reach high temperatures.	Greg Stapley	Reduce -- Verify prior to ordering parts that the components either run at a desired temperature, or can operate at the highest run temperature of a given system component.
R8	Communication disruption	Communication	10%	M	The team is unable to	Nathan Raschkes	Reduce -- Coordinate team meetings and ensure

					show the progress of the project to the project partners in time or make changes based on feedback from the project partners		that deadlines are met within two days of the deadline to ensure that every group member is able to revise the assignment prior to submission.

(Table 4: Describes the type of risk, the probability of occurrence and the level of risk impact of the project.

2.4 References and File Links

General Internet Site

[1] Primerobotics and Instructables, "Controlling LED by Potentiometer With Arduino Uno R3," *Instructables*, 31-May-2019. [Online]. Available: https://www.instructables.com/Controlling-LED-by-Potentiometer-With-Arduino-Uno-/. [Accessed: 23-Oct-2021].

[2] Paschotta, D., 2021. *Optical Intensity*. [online] Rp-photonics.com. Available: https://www.rp-photonics.com/optical_intensity.html. [Accessed 23 October 2021].

[3] Environmental Health and Safety. 2021. *Laser Hazards-General*. [online] Available at: https://ehs.oregonstate.edu/laser/training/laser-hazards. [Accessed 23 October 2021].

[4] How to Electronics. 2021. *TEMT6000 Ambient Light Sensor & Arduino – Measure Illuminance & Light Intensity*. [online] Available at: https://how2electronics.com/temt6000-ambient-light-sensor-arduino-measure-light-intensity/. [Accessed 23 October 2021].

Online Videos

[1] "Tutorial 01: How to Prepare Picture for Laser Engraving with Corel Draw," *YouTube*, 24-Dec-2017. [Online]. Available: https://www.youtube.com/watch?v=h4Pg-NU8qaA&t=5s. [Accessed: 23-Oct-2021].

[2] "Android Studio Tutorial - Upload Picture Part 1 - user interface," *YouTube*, 22-Jun-2015. [Online]. Available: https://www.youtube.com/watch?v=e8x-nu9-_BM. [Accessed: 23-Oct-2021].

[3] "Arduino Tutorial: Arduino Auto Power off. Make Arduino power off itself!" *YouTube,* 22-Mar-2016. [Online]. Available: https://www.youtube.com/watch?v=L55QrKQQZJk. [Accessed: 23-Oct-2021].

2.5 Revision Table

Date	Name	Description
11/28/2021	Team	- Revised engineering requirements based on instructor and student feedback
11/26/21	Alex Greiner	- Added action plan for risks. Made interface options two requirements. Removed burning requirement.

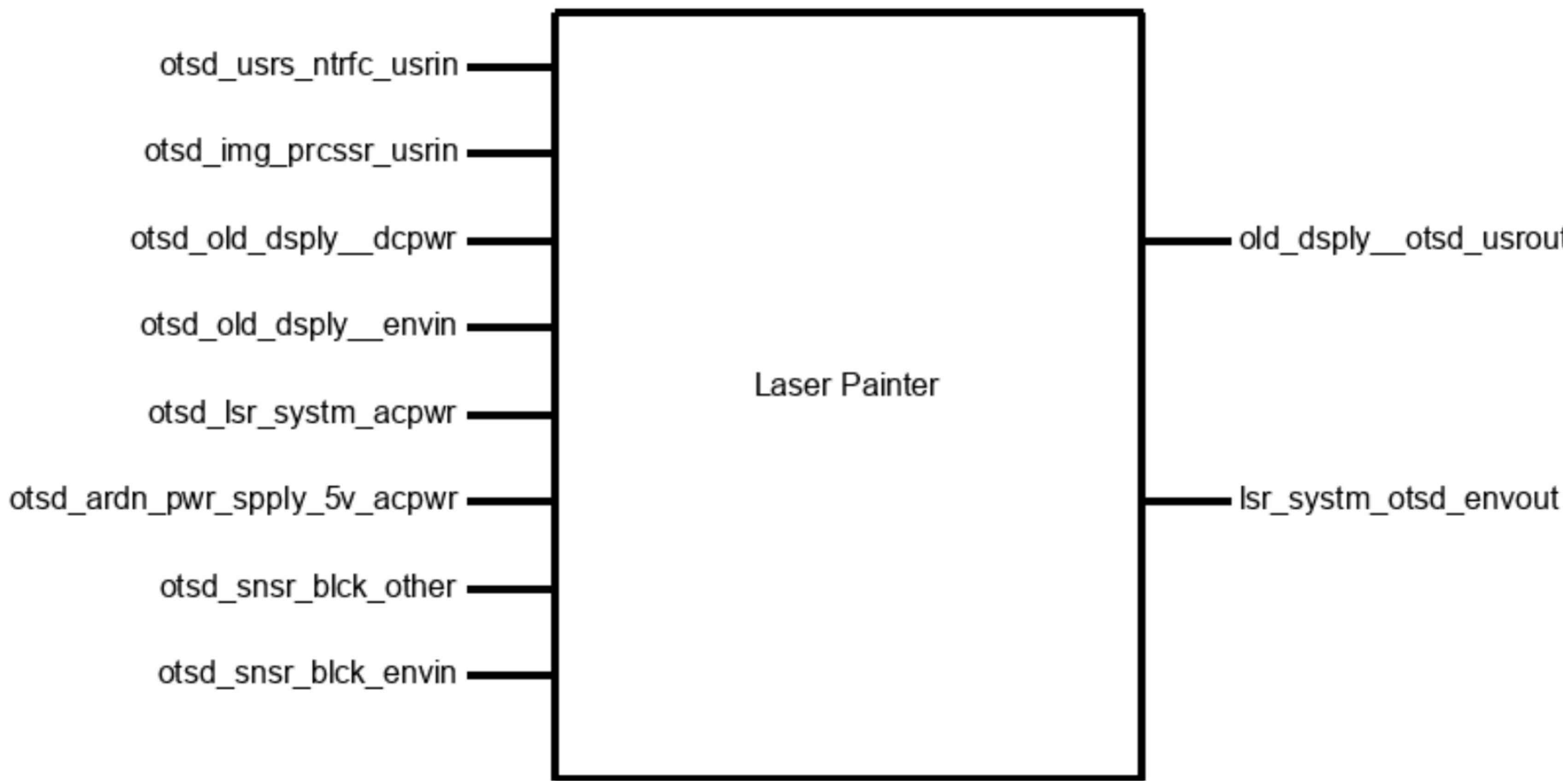
11/10/21	Alex Greiner	-Revised requirements and risks
11/5/21	Nathan Raschkes & Greg Stapley	-Revised Section 1 and Section 2 based off of the professor's comments
10/27/21	Yuhao Su	-Adjusted the revision table -Added label to the risk table
10/23/21	Yuhao Su	-Added risks, reference, and file links
10/23/21	Greg Stapley	-Added references, risks, risk testing
10/23/21	Nathan Raschkes	-Added to the draft requirements, along with the references and file links.
10/22/21	Alex Greiner	-Added risks, drafted requirements

Section 3: Top-Level Architechture

3.1 Block Diagram

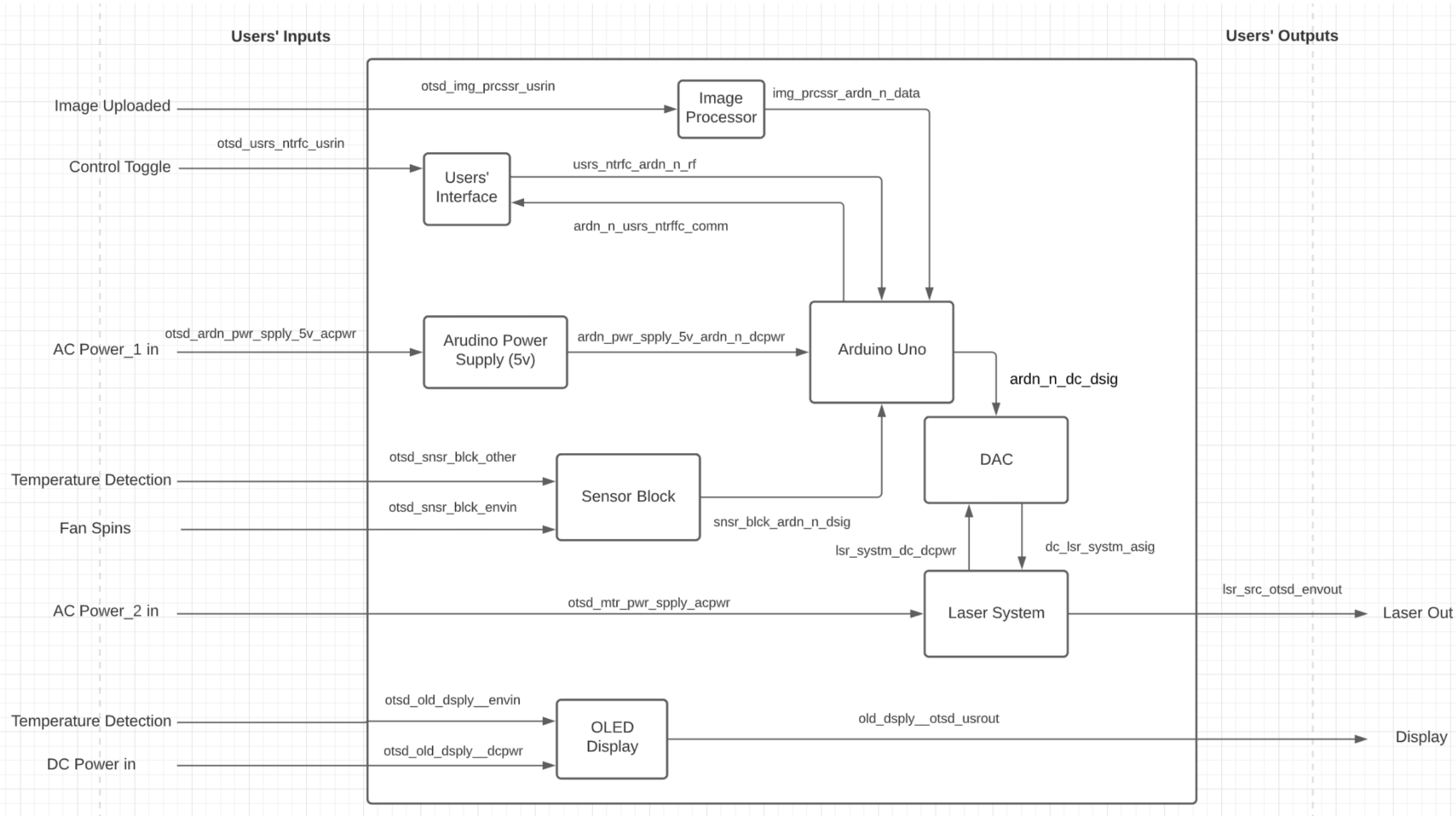
3.1.1 Black Box Diagram

Figure 3: Black box diagram of the laser painter



3.1.2 Block Diagram

Figure 4: Block Diagram of the laser painter



3.2 Block Descriptions

Block name	Block description
Users' Interface Champion: Alex Greiner	The users' interface will be an Android phone APP. The users can upload an image via the users' interface block.
Image Processor Champion: Alex Greiner	The Image Processor block will process the user uploaded image into a a word for the system to display. The word is pulled from an online database.
OLED Display Champion: Nathan Raschkes	An OLED display along with the distance sensor is implemented in our system to illustrate the distance that the laser is being emitted at. The OLED display and the distance sensor will operate simultaneously by working with one another so that the user knows how far the laser is being projected. A buzzer will be implemented and it will be activated when it is out of the range that has been set. For the verification process, I had the range set to 7cm to 30cm. This is an important concept because the safety of the users and the people around the laser painter remains the top priority. We don't want to damage any retinas and cause permanent blindness. We want to make certain that the laser painter can be enjoyed by others without getting harmed in any way.
Laser System Champion: Yuhao Su	The Laser System block includes an AC/DC switching power supply, a motor driver, a galvanometer, and a laser source. The inputs of this block are a 120V AC voltage and an analog signal. An Arduino will generate digital signals based on the code and send the digital signals to a DAC (digital-analog converter) block. The converted digital signal will go into the input of the motor driver, and then the motor driver will drive the motors of the galvanometer to adjust the two mirrors as expected. This block also contains a laser transmitter module, the DAC block has a 5V active high signal to turn the laser on and off.

Arduino Power Supply (5V) Champion: Greg Stapley	This block will provide a stable 5V DC voltage to the Arduino Uno.
Arduino Uno Champion: Greg Stapley	The Uno will take data from external sensors (temp, light) and adjust the system accordingly. It will receive data from the android app, namely what to display. In addition, data from the Uno will be displayed in the android app (system temp, ambient light levels).
Sensor Block Champion: Nathan Raschkes	A fan is implemented in our system to assist in regulating the temperature. The objective is to ensure that the system doesn't overheat or become too hot. When the system reaches a specific temperature, the fan will be activated by cooling the system. Likewise, when the fan has been turned on, another feature that will be applied to the system is the ability to govern the speed of the fan. The sensor block will be executing this feature based off of the temperature readings in Celsius. Once 28 degrees Celsius has been achieved, the fan will be activated and the speed of the fan will be displayed. Furthermore, we don't want the system to utilize the fan when it isn't necessary and to consume too much power. It's vital that the fan isn't blowing at a speed that's too rapid because it would create a lot of noise and blow a lot of dust. The speed that has been established will make certain that a lot dust won't get blown because I implemented a fan that isn't too powerful so that once the fan speed reaches 100%, it won't generate a lot of dust. Additionally, it's crucial that the fan doesn't operate at a speed that is too slow because if the system is overheated, it won't be cooled down fast enough which could potentially affect the quality and performance of the system. Another primary objective is to ensure energy efficiency. Controlling the speed of the fan and having the ability to trigger the fan both play important roles on making certain that the energy efficiency is maintained.

DAC Champion: Yuhao Su	The DAC (Digital to Analog Converter) block is powered by an Arduino and a +/- 15V AC/DC switching power supply. The DAC block is between an Arduino and a motor driver in the whole system. The function of this block is to convert the digital signal generated by an Arduino into an analog signal and input the analog signal to a motor driver. In order to implement this function, the main chip of the block is MCP4822 (8 pins). The DAC block also has two op-amps corresponding to the X and Y channels on the motor driver and TL082 (8 pins) is chosen for the operational amplifier in this block to provide voltage gain.

3.3 Interface Definitions

Name	Properties
otsd_usrs_ntrfc_usrin	• **Type:** User uploaded image • **Type:** User uploaded drawing • **Type:** User set system parameter (on time duration)
otsd_img_prcssr_usrin	• **Timing:** 2 seconds minimum time between user upload images • **Type:** User uploaded image • **Usability:** Android camera
otsd_old_dsply__dcpwr	• **Inominal:** 5-8mA • **Ipeak:** 6-10mA • **Vmax:** 5.1 volts • **Vmin:** 4.5 volts
otsd_old_dsply__envin	• **Other:** Object input #3: Having the magazine being detected • **Other:** Object input #2: Having the construction paper being detected

	Other: Object input #1: Having the DY3700-628 Static Shielding Zip Lock Bag being detected
otsd_lsr_systm_acpwr	**Inominal:** 100mA. **Ipeak:** 150mA **Vnominal:** 120V AC voltage.
otsd_ardn_pwr_spply_5v_acpwr	**Inominal:** 0.5 A **Ipeak:** 1 A **Vnominal:** 115V AC
otsd_snsr_blck_other	**Other:** Temperature sensor **Other:** Temperature gun **Other:** Feeling the heat with your hand
otsd_snsr_blck_envin	**Other:** The blades on the fan will move by spinning in a circular motion. **Other:** A piece of toilet paper could be put near the fan to prove that the fan is working, which will result in the paper getting sucked closer to the fan. **Other:** The cooling fan will draw in room air. The fan will activate once it reaches the specified temperature.
usrs_ntrfc_ardn_n_rf	**Datarate:** Maximum 1 char per second **Messages:** single char type indicating user control option **Protocol:** bluetooth protocol between Arduino and Android

img_prcssr_ardn_n_data	**Datarate:** Maximum 19 byte word (19 characters) every 2 seconds **Messages:** User uploaded image data base resulting text **Messages:** Maximum word size of 19 characters **Protocol:** Bluetooth protocol from GUI (Tx) to Arduino (Rx)
old_dsply__otsd_usrout	**Other:** Have the buzzer activate when the objects (DY3700-628 Static Shielding Zip Lock Bag, construction paper and magazine) are out of range that has been set (7cm -30 cm) **Other:** Show that objects (DY3700-628 Static Shielding Zip Lock Bag, construction paper and magazine) are within the given range of 7cm to 30 cm **Other:** Display distance value in centimeters and inches
lsr_systm_otsd_envout	**Other:** At 3 feet: Laser dot is no larger than 1cm **Other:** At 3 feet: laser can sweep between +/-3 inches horizontal **Other:** At 3 feet: laser can sweep between +/-10 inches vertical
lsr_systm_dc_dcpwr	**Inominal:** 0.1-1A at +15V and 0.1-0.5A at-15V. **Ipeak:** 1A at +15V and 0.5A at -15V. **Vmax:** Vmax: +/- 15V. **Vmin:** Vmin: +/- 5V.
ardn_n_usrs_ntrfc_comm	**Datarate:** maximum 15 char array per second **Messages:** array of char of format

	"temp|light|ontime" ● **Protocol:** bluetooth protocol between Arduino and Android
snsr_blck_ardn_n_dsig	● **Other:** A heat source will be used to apply simulated heat around the temperature probe, as the fan turns on when the threshold is reached, the temperature sensor will show a decrease of 4 degrees F in ambient temp over a minutes time. ● **Other:** Display Light in Lux and percent total ● **Other:** AC Fan turns on at 24 degrees Celsius or 75 degrees F. ● **Other:** Display temperature in Celsius and F.
dc_lsr_systm_asig	● **Other:** Has a single active high 500mV signal to turn laser off and on ● **Vmax:** 10V(The analog signals converted by the DAC block will have a 10V maximum voltage to drive the motors) ● **Vrange:** 0 to +/- 10V
otsd_usrs_ntrfc_usrin	● **Type:** User uploaded image ● **Type:** User uploaded drawing ● **Type:** User set system parameter (on time duration)
otsd_img_prcssr_usrin	● **Timing:** 2 seconds minimum time between user upload images ● **Type:** User uploaded image ● **Usability:** Android camera

otsd_old_dsply__dcpwr	• **Inominal:** 5-8mA • **Ipeak:** 6-10mA • **Vmax:** 5.1 volts • **Vmin:** 4.5 volts

3.4 Reference and File Links
No references used for this section.

3.5 Revision Table

Date	Name	Description
3/27/22	Yuhao Su	- Updated block diagram
3/5/22	Yuhao Su	- Updated black box diagram, block description and interface properties.
12/3/21	Yuhao Su	- Adjusted black box diagram. - Adjusted block diagram. - Adjusted block description. - Adjusted interface properties.
11/28/21	Team	- Adjusted the description of the Motor Power Supply block. - Adjusted the interface properties based on instructor and student feedback.
11/11/21	Team	- Added interface definitions, added black box diagram. Revised block diagram.
11/6/21	Team	- Added block diagram, block descriptions, interface definition and revision table.

Section 4: Block Validations

4.1. DAC Block

4.1.1 Description

The DAC (Digital to Analog Converter) block is powered by an Arduino and a +/- 15V AC/DC switching power supply. The DAC block is between an Arduino and a motor driver in the whole system. The function of this block is to convert the digital signal generated by an Arduino into an analog signal and input the analog signal to a motor driver. In order to implement this function, the main chip of the block is MCP4822 (8 pins) [1]. The DAC block also has two op-amps corresponding to the X and Y channels on the motor driver and TL082 (8 pins) [2] is chosen for the operational amplifier in this block to provide voltage gain.

4.1.2 Design

Figure 5: Black Box for DAC

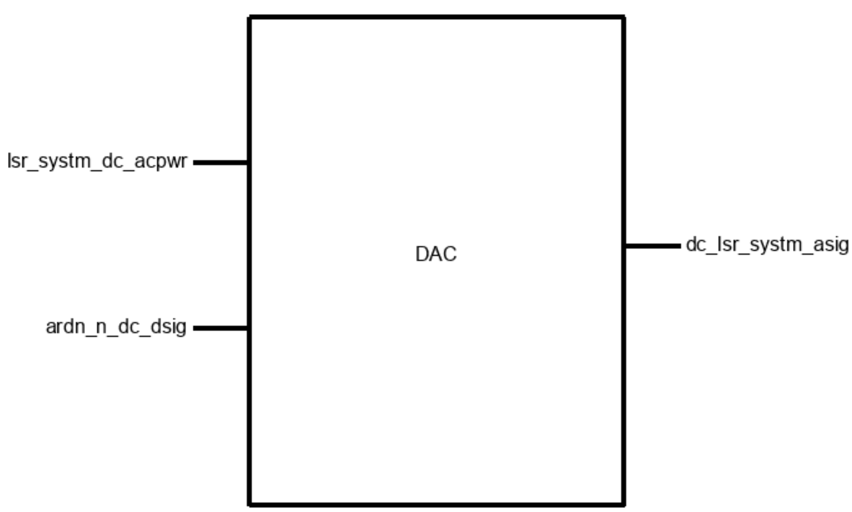


Figure 6: Schematic of the DAC block

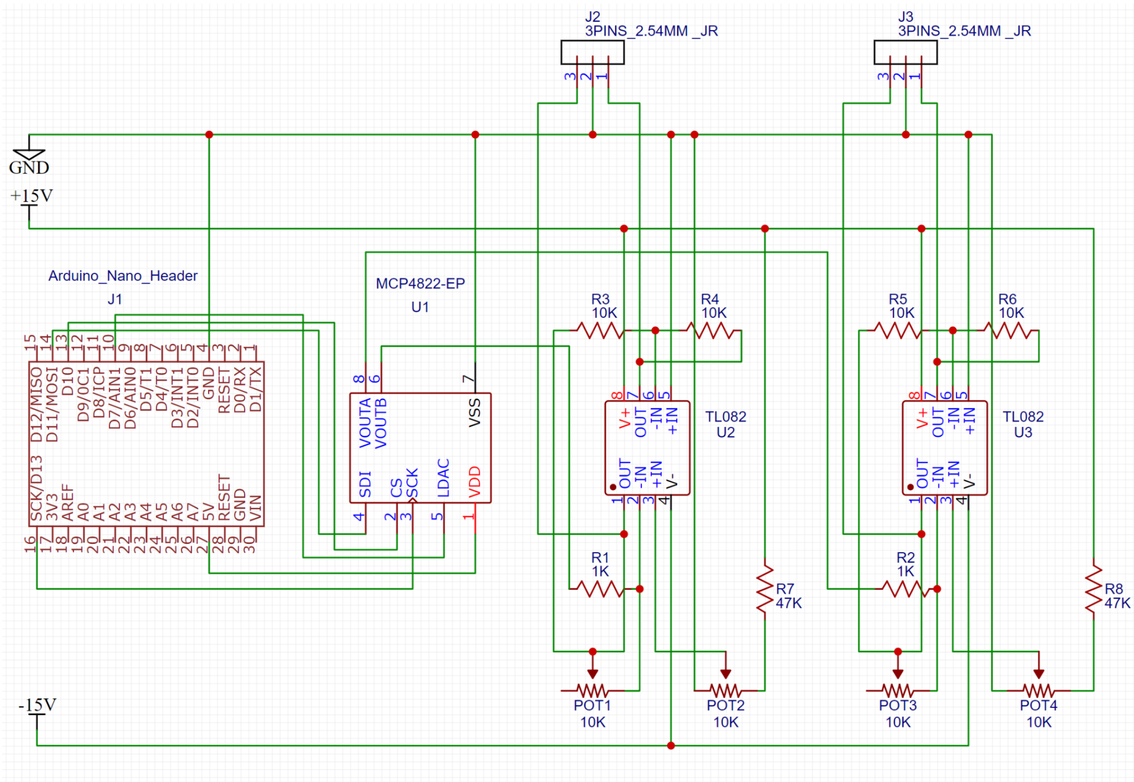
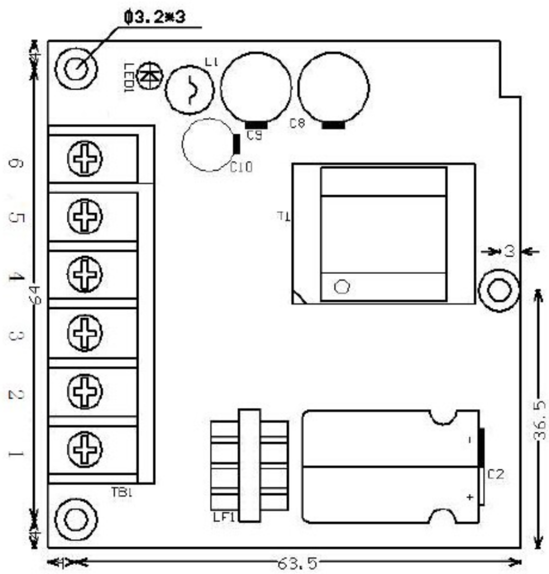


Figure 7: Product picture [3]

Figure 8: Terminal arrangement [3]



Terminal arrangement:

1. Input AC\L & access protected
2. Input AC\N
3. Output V+
4. Output G
5. Output V-

Notes:

lsr_systm_dc_acpwr

It is the DC input of the block. This block is powered by a +/-15V AC/DC switching power supply.

ardn_n_dc_dsig

It is the digital signal input of the block. An Arduino provides a 5V DC voltage to the MCP4822 and outputs a digital signal to the DAC block.

dc_lsr_systm_asig

It is the output of the block. The DAC block will convert a digital signal to an analog signal and output the analog signal to the motor driver.

Pin connection between the Arduino and the MCP4822:

Arduino CLK (pin D13) -> DAC SCK (pin 3)

Arduino MOSI (pin D11) -> DAC SDI (pin 4)

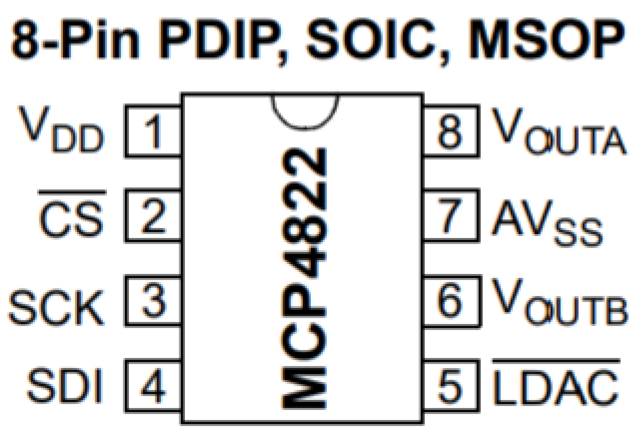
Arduino CS (pin D10) -> DAC CS (pin2)

Arduino pin D7 -> DAC LATCH (pin 5)

Arduino 5V -> DAC VDD (pin 1)

Arduino GND -> DAC VSS (pin 7)

Figure 9: Footprint of an MCP4822 [1]



4.1.3 General Validation

The DAC (Digital to Analog Converter) block is powered by an Arduino and a +/- 15V AC/DC switching power supply [3]. The maximum and minimum input voltage of an MCP4822 is 5.5V and 2.7V, respectively [1]. The Arduino will power a 5V DC voltage, which satisfies the operating voltage of the MCP4822. The MCP4822 chip is connected to the Arduino via SPI and supports an additional LATCH pin which offers synchronous updates of the two channels on the motor driver.

Since the motor driver has two channels, X and Y, each channel requires a bipolar signal to function properly. Therefore, the DAC block also contains two op-amps. The two op-amps correspond to the X and Y channels on the motor driver, and two TL082 [2] are chosen for the operational amplifier. The circuit of the operational amplifiers has four 10K ohms potentiometers

instead of fixed resistors, which makes the gain and offset generated by the DAC block adjustable. Both op-amps are with two 10K ohms potentiometers, one potentiometer is used for the gain (it scales the image) and the other for the offset (it moves the image).
A TL082 amplifier needs two opposite supply voltages, Vcc+ and Vcc- [2]. The maximum and minimum input voltage of Vcc+ is +5V and -15V, respectively. And The maximum and minimum input voltage of Vcc- is -5V and -15V, respectively. By viewing the datasheet of the AC/DC switching power supply [3], the power supply will provide a +15V and a -15 V voltages, which satisfies the Vcc+ and Vcc- required by the TL082.

4.1.4 Interface Validation
The tables below show the properties of the three interfaces of the block. The tables include the values of the interfaces and why the block meets the values.

Table 5: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

lsr_systm_dc_acpwr : Input

Ipeak: 1A at +15V and 0.5A at -15V	The maximum peak current that the op-amp can accept during normal operation.	KHD 15-15 AC power supply webpage, product description: Rated Current: 1A at +15V and 0.5A at -15V.
Iripple: 0.1-1A at +15V and 0.1-0.5A at-15V	The acceptable current range for the op-amp to operate normally.	KHD 15-15 AC power supply webpage, product description: Current Range: 0.1-1A at +15V and 0.1- 0.5A at -15V.
Vmax: +/- 15V.	TL08xx datasheet, page 11: the maximum supply voltages for Vcc+ and Vcc- are +15V and -15V, respectively.	KHD 15-15 AC power supply webpage, product description: Output Voltage: +15V for CH1 and -15V for CH2, which satisfies the required maximum voltage.

Vmin: +/- 5V.	TL08xx datasheet, page 11: the maximum supply voltages for Vcc+ and Vcc- are +5V and -5V, respectively.	KHD 15-15 AC power supply webpage, product description: Output Accuracy: +/- 1%, which means the power supply will provide a voltage higher than the minimum required voltage.

ardn_n_dc_dsig : Input

Other: Active high	The Pin D13 on the Arduino is active high.	Introduction to the Arduino Board, Digital Pins, LED: 13. When the pin is HIGH value, the pin is on, when the pin is LOW, it's off.
Other: The input digital signal is converted into an analog signal under the work of the DAC, and the output signal enters the motor driver so that the motor driver drives the motor.	The input digital signal is generated by an Arduino, and it's converted into an analog signal under the work of the DAC. Then, the DAC block outputs the analog signal to the motor driver so that the motor driver drives the motor.	It is tested by the physical circuit.
Other: The voltage of the input digital signal is excepted to be below 300mV.	The maximum input voltage of an MCP4822 SCK pin is 300mV, and an Arduino should provide a digital signal below 300mV.	MCP4822 datasheet, page 2: All inputs and outputs: AVss -0.3v to VDD +0.3V.

dc_lsr_systm_asig : Output

Other: Has a single active high 5V signal to turn the laser off and on.	DIYmall Laser Transmitter Module for Arduino, Product Description, Operating voltage. The operating voltage of the laser is 5V.	The Arduino can provide 5V to supply other components.
Vrange: 0 to +/- 10V.	The DAC block has outputs for the x-axis and y-axis respectively. Each terminal has three terminals:	The Vrange is tested by the physical circuit.

	output V+, output V-, and a ground line. The working output range is between 0 and +/- 10V.	
Vmax: 10V.	This is a minimum requirement based on the output of the amplifier circuit.	The Vmax is tested by the physical circuit.

4.1.5 Verification Plan

Step 1: Power the DAC block with a 15V and a 5V input voltage, make sure the block can work under the Vmax and Vmin.

Step 2: Connect the DAC block to the AC/DC switching power supply's +15V and -15V terminals, measure Ipeak and Iripple under the +15V and -15V voltage supply, respectfully.

Step 3: Use an oscilloscope to measure the Pin D13 on an Arduino Nano. Make sure that the Pin D13 is active-high and the output voltage from Pin D13 is below 300mA.

Step 4: Use an oscilloscope to measure the digital signal generated by Pin D13 on an Arduino Nano, make sure the maximum voltage of the digital signal that Pin D13 generates is 5V.

Step 5: Connect the laser source with the VDD pin of the MCP4822, so that the laser source can get a 5V voltage provided by an Arduino Nano.

Step 6: Use an oscilloscope to measure the analog signal generated by the DAC block, make sure the voltage range of the output signal is from 0V to +/- 10V, and the maximum voltage is 10V.

4.1.6 References and File Links

[1] "12-bit DAC with internal Vref and SPI interface." [Online]. Available: https://ww1.microchip.com/downloads/en/devicedoc/21953a.pdf. [Accessed: 17-Jan-2022].

[2] "TL082 wide bandwidth dual JFET input operational ... - ti.com." [Online]. Available: https://www.ti.com/lit/ds/symlink/tl082-n.pdf?ts=1590189682545. [Accessed: 17-Jan-2022].

[3] "5.2US $: 100 240VAC input voltage dual output +15V 15V PSU universal switching power supply 15W: Dual output: Switch powerswitching power supply - aliexpress," *aliexpress.com*. [Online]. Available: https://www.aliexpress.com/item/32777180206.html. [Accessed: 04-Jan-2022].

[4] T. A. Team, “Nano: Arduino documentation,” *Arduino Documentation | Arduino Documentation*. [Online]. Available: https://docs.arduino.cc/hardware/nano. [Accessed: 21-Jan-2022].

[5]“Board,” *Arduino*. [Online]. Available: https://www.arduino.cc/en/reference/board . [Accessed: 21-Jan-2022].

[6] “DIYmall Laser Transmitter Module for Arduino”, Amazon. [Online]. Available: https://www.amazon.com/Laser-Transmitter-Module-Arduino-10pcs/dp/B07FQ6696X/ref=pd_lutyp_ci_mcx_mr_typ_d_1/134-6058017-5388160?pd_rd_w=hXffy&pf_rd_p=f6afbe6e-f56a-4b64-9493-07a01722d421&pf_rd_r=9MGBG2H8N860FYKC4MDH&pd_rd_r=c3f7feec-cdd3-4a17-a4fc-8e8da411d53b&pd_rd_wg=1Es4P&pd_rd_i=B07FQ6696X&psc=1. [Accessed: 21-Jan-2022].

[7] “Item.taobao.com.” [Online]. Available: https://item.taobao.com/item.htm?spm=a230r.1.14.1.6a2f7ce5gb1bBy&id=643132380880&ns=1&abbucket=11#detail . [Accessed: 17-Jan-2022].

4.1.7 Revision Table

Date	Name	Description
1/30/2022	Yuhao Su	- Adjusted the interface validation.
1/21/2022	Yuhao Su	- Adjusted the interface validation. - Adjusted the Verification Plan. - Added more references.
1/20/2022	Yuhao Su	- Adjusted the interface validation.
1/17/2022	Yuhao Su	- Adjusted the document. - Added the schematic and PCB design of the block
1/5/2022	Yuhao Su	- Made the interface validation and verification steps.
1/4/2022	Yuhao Su	- Adjusted the description. - Made the design and validation.
1/2/2022	Yuhao Su	- Made the description. - Created the document and copy the template from the course website.

4.2.Laser System

4.2.1 Description

The Laser System block includes an AC/DC switching power supply, a motor driver, a galvanometer, and a laser source. The inputs of this block are a 120V AC voltage and an analog signal. An Arduino will generate digital signals based on the code and send the digital signals to a DAC (digital-analog converter) block. The converted digital signal will go into the input of the motor driver. Then the motor driver will drive the motors of the galvanometer to adjust the two mirrors as expected. This block also contains a laser transmitter module, and the DAC block has a 5V active high signal to turn the laser on and off.

4.2.2 Design

Figure 10 below shows the black box diagram of the Laser System block. Figures 10, 11, 12, and 13 show the picture of the products included in the block. Figure 7 shows the terminal arrangement of the AC/DC switching power supply. Figure 14 shows the physical connection of the Laser System block.

Figure 10: Black box diagram of Laser System

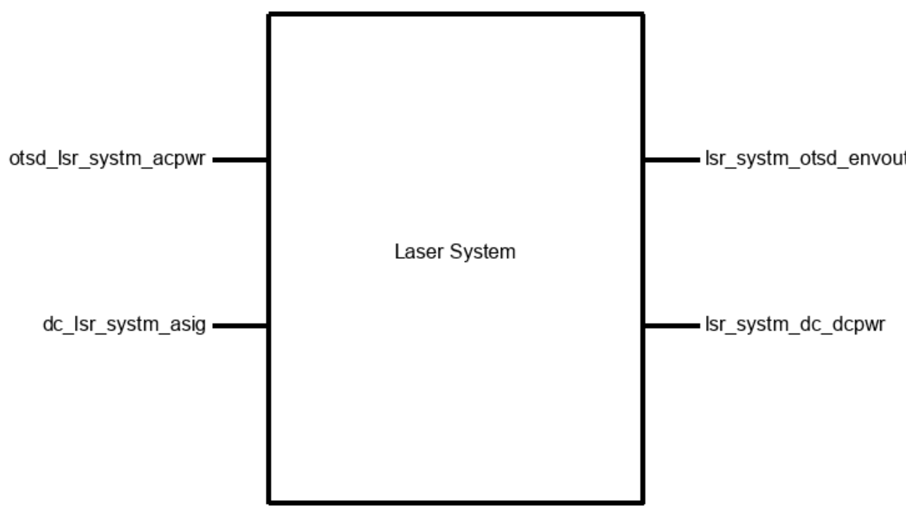


Figure 11: Motor driver

Figure 12: Galvanometer

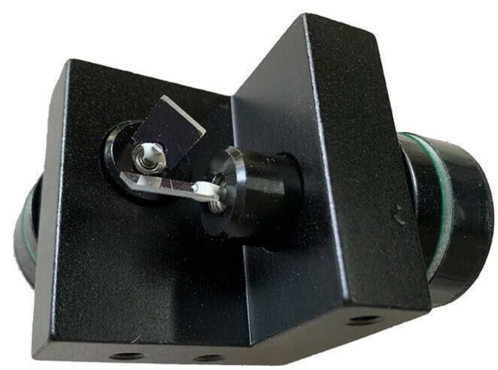
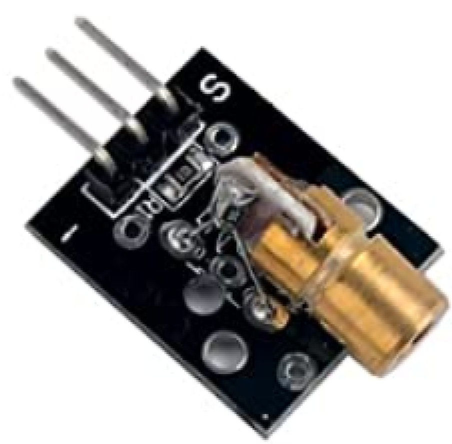


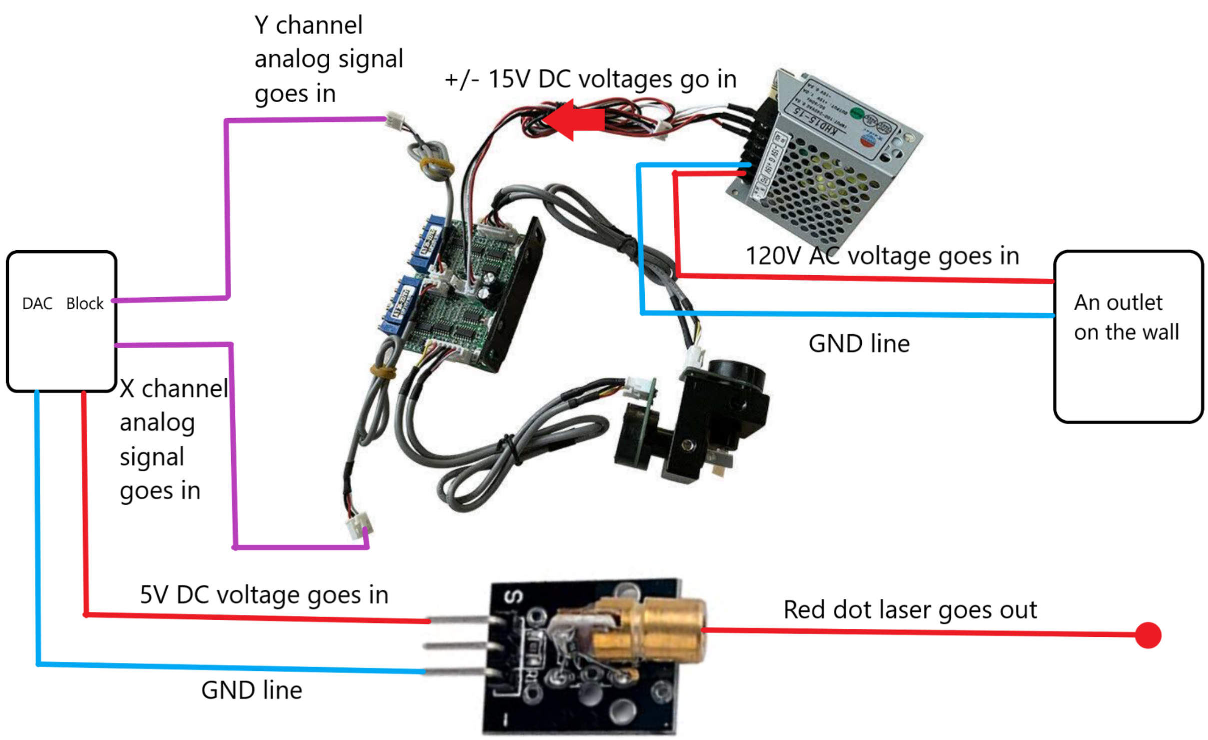
Figure 13: Laser source



Terminal arrangement:

1. Input AC\L & access protected
2. Input AC\N
3. Output V+
4. Output G
5. Output V-

Figure 14: Laser System connection diagram



Notes:

otsd_lsr_systm_acpwr

It is the AC input of the block. It will provide a 120V AC voltage and a 15A current to the AC/DC switching power supply included in the block.

dc_lsr_systm_asig

It is another input of the block. The DAC block will convert a digital signal to an analog signal and output the analog signal to the motor driver included in the Laser System block.

lsr_systm_otsd_envout

The block will emit a 5mW and 650nm red dot laser to the mirrors of the galvanometer.

lsr_systm_dc_dcpwr

The AC/DC switching power supply will convert a 120V AC voltage to a +15V and -15V DC voltage.

4.2.3 General Validation

The Laser System block includes an AC/DC switching power supply, a motor driver, a galvanometer (which has two mirrors), and a laser source. The AC/DC switching power supply will convert a 120V AC voltage provided by an outlet on the wall to a +15V and a -15V DC voltages. The output voltage from the power supply will power the DAC block, motor driver, and galvanometer.

The motor diver will receive the analog signals from the DAC block, and the signals go into the X and Y channel on the driver separately. The motor driver will drive the x-axis and y-axis motors on the galvanometer based on the analog signals it receives to rotate the mirrors on the motors.

The system also includes a laser source, and It will emit a 650nm red laser. The DAC block will provide a 5V DC voltage to turn on and off the laser source. The laser will be set to emit to the mirrors directly, and the mirrors vibrate at high speed and reflect the laser light to create an image on the wall.

As we are not able to design the motor driver, galvanometer, and laser source block by ourselves, we have to use the specific modules we talked about above. We only can give an alternative solution to the 15V AC/DC switching power supply. If the 15V power supply can not work as our expectation, we are going use a 15V–1A and a 15V-0.5A AC wall adapter to power the motor driver.

4.2.4 Interface Validation

The tables below show the properties of the four interfaces of the block. The tables include the values of the interfaces and why the block meets the values.

Table 6: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

otsd_lsr_systm_acpwr : Input

Inominal: 15A.	In the U.S., a typical outlet is rated at 15 amps, 120 volts.	"What Is the Standard Voltage and Amps for an Outlet?", paragraph 2. The input current of this block should be 15A to ensure that the power supply can work normally. Most outlets in U.S. households are standard 15 amp sockets.
Ipeak: 20A	In the U.S., some outlets may be rated for 20 amps. A 20 amp outlet can be identified if the neutral slot is a horizontal "T" shape.	"What Is the Standard Voltage and Amps for an Outlet?", paragraph 2. Twenty amperes is not the normal operating current required by the power supply, but 20 amperes does not exceed the maximum input current limit. In the process of using this block, the input current of 20 amperes will not be maintained, but the input current of 20 amperes will be tested.
Vnominal: 120V AC voltage.	In the U.S., a typical outlet is rated at 15 amps, 120 volts.	The outlet allows electrical equipment to be connected to the grid, and the grid provides alternating current to the socket. The power socket represents a part of the wire loop. Power sockets in North America provide 120V voltage.

lsr_systm_otsd_envout : Output

Other: At 2 feet: Laser dot is no larger than 1cm	Since the two mirrors on the galvanometer are tiny, the laser dot can be too larger.	By measuring the size of the mirrors, the length of the mirrors is approximate 1cm. Therefore, the diameter of the laser dot is no larger than 1cm.
Other: At 2 feet: laser can sweep between +-6 inches horizontal	This is a minimum requirement based on the Laser System block.	The sweeping horizontal length has been tested physically.
Other: At 2 feet: laser can sweep between +-6 inches vertical	This is a minimum requirement based on the Laser System block.	The sweeping vertical length has been tested physically.

lsr_systm_dc_dcpwr : Output

Ipeak: 1A at +15V and 0.5A at -15V.	The maximum peak current that the op-amp can accept during normal operation.	KHD 15-15 AC power supply webpage, product description: Rated Current: 1A at +15V and 0.5A at -15V.
Iripple: 0.1-1A at +15V and 0.1-0.5A at-15V.	The acceptable current range for the op-amp to operate normally.	KHD 15-15 AC power supply webpage, product description: Current Range: 0.1-1A at +15V and 0.1- 0.5A at -15V.
Vmax: Vmax: +/- 15V.	TL08xx datasheet, page 11: the maximum supply voltages for Vcc+ and Vcc- are +15V and -15V, respectively.	KHD 15-15 AC power supply webpage, product description: Output Voltage: +15V for CH1 and -15V for CH2, which satisfies the required maximum voltage.
Vmin: Vmin: +/- 5V.	TL08xx datasheet, page 11: the maximum supply voltages for Vcc+ and Vcc- are +5V and -5V, respectively.	KHD 15-15 AC power supply webpage, product description: Output Accuracy: +/- 1%, which means the power supply will provide a voltage higher than the minimum required voltage.

dc_lsr_systm_asig : Input

Other: Has a single active high 5V signal to turn the laser off and on	DIYmall Laser Transmitter Module for Arduino, Product Description, Operating voltage. The operating voltage of the laser is 5V.	The Arduino can provide 5V to supply other components.
Vmax: 10V	This is a minimum requirement based on the output of the amplifier circuit.	The Vmax is tested by the physical circuit.
Vrange: 0 to +/- 10V	The DAC block has outputs for the x-axis and y-axis, respectively. Each terminal has output V+, output V-, and a ground line. The operating output range is between 0 and +/- 10V.	The Vrange is tested by the physical circuit.

4.2.5 Verification Plan

Step 1: Connect the power supply plug with an outlet on the wall that provides a 120V voltage and a 15A current.

Step 2: Measure the output voltage provided by terminals 3 and 5 of the AC/DC switching power supply, make sure the measured voltages are +15V and -15V, respectively. Then, measure the current peak and current ripple. Ensure the measured current peaks are 1A and 0.5A on terminals 3 and 5, respectively. Ensure the measured current ripples are 0.1-1A and 0.1-0.5A on terminals 3 and 5, respectively.

Step 3: Use an oscilloscope to measure the analog signal generated by the DAC block, make sure the voltage range of the output signal is from 0V to +/- 10V, and the maximum voltage is 10V. Measure the terminal which will power the laser source in the DAC block can provide a 5V DC voltage.

Step 4: Put the laser source 2 feet away from the wall, turn on the switch of the Laser system block. When a laser dot is shown on the wall, measure the diameter of the laser dot and make sure it is no larger than 1cm.

Step 5: Turn on the switch of the DAC block. Set the laser sweep vertically on the wall and measure the sweep length. Then, set the laser sweep horizontally on the wall and measure the sweep length. Make sure both sweep lengths are within +/- 6 inches.

4.2.6 References and File Links

[1]J. James, "What is the standard voltage and Amps for an outlet?", *Survival Freedom*, 30-Dec-2021. [Online]. Available: https://survivalfreedom.com/what-is-the-standard-voltage-and-amps-for-an-outlet/. [Accessed: 01-Feb-2022].

[2] "TL082 wide bandwidth dual JFET input operational ... - ti.com." [Online]. Available: https://www.ti.com/lit/ds/symlink/tl082-n.pdf?ts=1590189682545. [Accessed: 31-Jan-2022].

[3] "5.2US $: 100 240VAC input voltage dual output +15V 15V PSU universal switching power supply 15W: Dual output: Switch powerswitching power supply - aliexpress," *aliexpress.com*. [Online]. Available: https://www.aliexpress.com/item/32777180206.html. [Accessed: 31-Jan-2022].

[4] "DIYmall Laser Transmitter Module for Arduino", Amazon. [Online]. Available: https://www.amazon.com/Laser-Transmitter-Module-Arduino-10pcs/dp/B07FQ6696X/ref=pd_lutyp_ci_mcx_mr_typ_d_1/134-6058017-5388160?pd_rd_w=hXffy&pf_rd_p=f6afbe6e-f56a-4b64-9493-07a01722d421&pf_rd_r=9MGBG2H8N860FYKC4MDH&pd_rd_r=c3f7feec-cdd3-4a17-a4fc-8e8da411d53b&pd_rd_wg=1Es4P&pd_rd_i=B07FQ6696X&psc=1. [Accessed: 31-Jan-2022].

4.2.7 Revision Table

Date	Name	Description
2/15/2022	Yuhao Su	- Added alternative solution to the 15V power supply. - Corrected wording and grammar mistakes.
1/31/2022	Yuhao Su	- Added sections of design, general validation, interface validation, verification plan, and reference.
1/30/2022	Yuhao Su	- Draft created. - Added description.

4.3.Users' Interface

4.3.1 Block Overview

The Users' interface block champion is Alex Greiner. This block provides a medium for the user to interact with and instruct the system. Through the user interface block, the user will be able to set several system parameters, including:

- System ontime duration
- Image displayed
- Control method
  - Image upload
  - Drawing

These control options are integrated into an Android app, allowing for inuitive and seamless user setup. From the Android device, the user inputted data is sent via bluetooth protocol to an Arduino. The device will also serve as a graphical user interface (GUI), where the user will see system information such as:

- On time remaining
- Light level
- System temperature

This block is purely a user interface block in the form of an Android application. All hardware associated with communication, such as a bluetooth module, the Arduino hardware/software, and the image storage method, is not included in this block. However, hardware elements may be used to demonstrate correct system functionality.

4.3.2 Block Design

Figure 15: Block Black Box Diagram

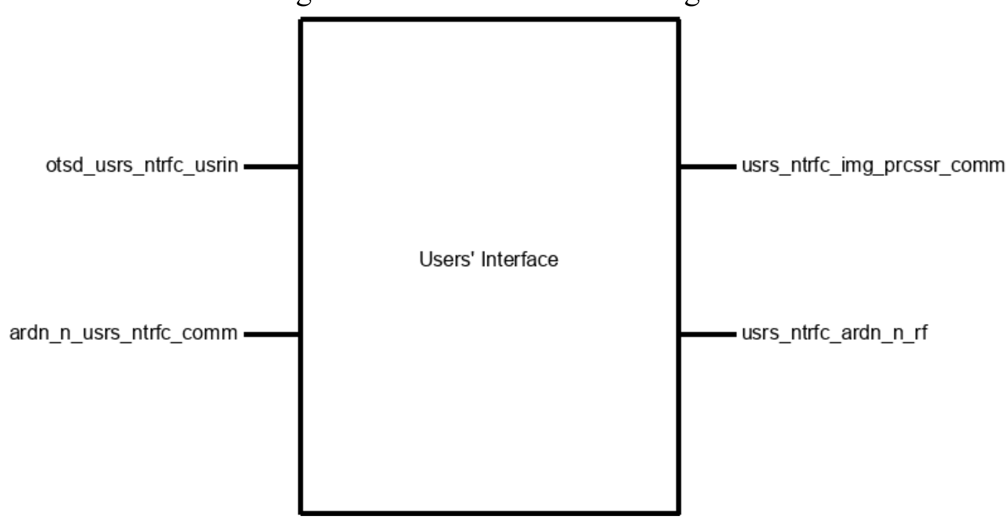


Figure 15 shows the black box diagram for the Users' Interface block. The block receives and image to display from the user and system parameters from an Arduino sent via bluetooth communication protocol. The block outputs a .jpeg file to the image processor block and sends user defined system parameters, such as laser on time duration, to the Arduino using the same bluetooth protocol used to receive data.

Figure 16: GUI Layout

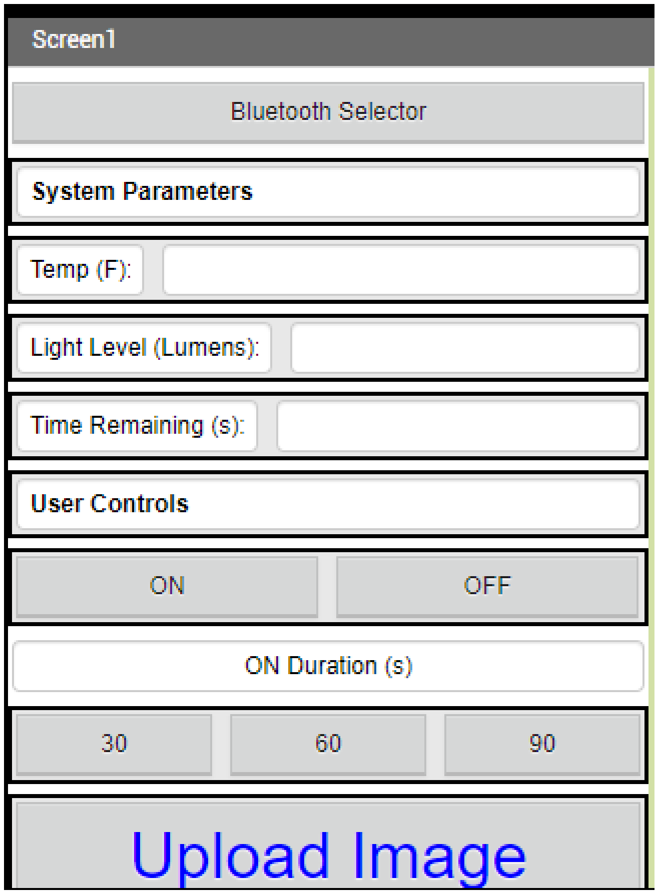


Figure 16 shows the basic layout for the GUI. Before the GUI will interface with the rest of the system, bluetooth communication must be established, so the bluetooth selector is conveniently located at the top of the screen. The GUI then lists out the system parameters that may be of interest to the user. The GUI then lists out user control options, with the primary control option, the user uploaded image, being in a larger and different colored font at the bottom.

Figure 17: Upload Image GUI Screen

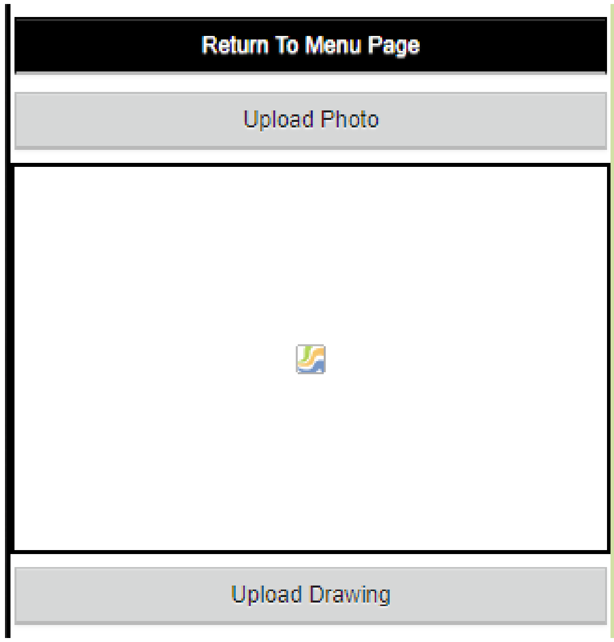


Figure 17 shows the page that the user is brought to after selecting “Upload Image.” Here, there is an option to upload a photo from the users’ camera roll, draw an image and upload said image, or return back to the main menu.

Pseudocode Android App:

```
Set up bluetooth communication
    Display “connected” if connected
    Display “Disconnected” if not connected
If “TurnOff” send 0
If “TurnOn” send 1
If “Sec30” send 2
If “Sec60” send 3
If “Sec90” send 4
If “imageUpload”
    Open camera roll to upload image
If “drawPicture”
    Open blank drawing canvas for drawing
    Wait until user submits drawing
    Upload image to SD card
Initialize received data list
    Receive field data in order:
        Temp
        Light
        On time
```

4.3.3 Block General Validation

The Users' interface block fits the needs of the system by creating an interface for the system to communicate with the user, and for the user to instruct the system in an intuitive way. This block nearly completes three system requirements:

1. The system will have auto turn off durations
2. The system should have an upload image option
3. The system should be intuitive.

By programming an Android app, there is a barrier of understanding, as this is a system that nobody in our group has tried to implement prior. Thus, the block will take a greater amount of engineering time to effectively integrate, as there may be unforeseen issues with the intended implementation. Being the primary path for the user to interact with the system, the block will be frequently sending and receiving data. Communicating over bluetooth protocol, the block has a very small footprint. To inhibit the system from wasting energy from the user leaving the system on idley, this block integrates an auto timeout feature.

Using an Android application for the GUI provides a familiar interface for most users. However, the block could have been integrated into a python script. This would reduce the amount of hardware needed, by removing the bluetooth communication and SD card storage required for the user to upload an image through a phone application, but it would require additional user setup to access the GUI. Furthermore, it would require the user to have access to a system that can execute a python script.

4.3.4 Block Interface Validation

Table 7: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
otsd_usrs_ntrfc_usrin : Input		

Type: User uploaded drawing	In initial planning, there was a desire for the user to be able to control the laser in multiple ways. This is one of the unique ways for the user to control the image, through drawing on the GUI and uploading the image to the system.	The GUI contains a drawing menu, in which the image is then stored on the phone and sent via bluetooth to the system through the usrs_ntrfc_img_prcssr_comm interface once the user specifies the drawing is complete.
Type: User set system parameter	The user can control the laser being on and how long the laser will be on for. This meets the design impact assessment need of not wasting energy while the system is idle.	The GUI allows the user to turn the laser ON/OFF and has three auto timeout durations, 30, 60, and 90 seconds. These selections are sent via bluetooth protocol through the usrs_ntrfc_ardn_n_rf interface.
Type: User uploaded image	The GUI has an option for uploading an image from the users' camera roll to the system.	The GUI contains an image upload option menu, which is sent via bluetooth to the system through the usrs_ntrfc_img_prcssr_comm interface once the user selects the photo.

usrs_ntrfc_img_prcssr_comm : Output

Datarate: minimum 500 bytes per second	500 bytes per second allows for a 300pix by 300pix image to be uploaded in approximately 180 seconds. The bluetooth module also has a data transfer limitation of 700 bytes/sec.	This block does not contain the bluetooth module that will be required for this message to be sent, but rather communicates with the external block through bluetooth protocol.
Messages: Maximum size 350pix by 350pix (approximately 75 KB)	A 300pix by 300pix resolution photo has greater resolution than the system's hardware capabilities, without the bluetooth protocol taking too	The GUI allows for greater image size uploads, but the processed image is compressed down to the maximum resolution.

	long to send the image.	
Messages: .png file	The .txt file contains color code mapping for each pixel, which can be interpreted by the other system blocks.	The GUI sends the image information to a .txt file through bluetooth communication.

ardn_n_usrs_ntrfc_comm : Input

Datarate: Maximum 15 char array per second	The system needs 5 chars for temp, 5 chars for light, 2 char for ontime, and 3 char for sectioning information.	A char contains 1 byte and the bluetooth protocol can communicate at 500 bytes/second [2]. Thus, 15 chars per second is achievable.
Messages: array of char of format "temp|light|ontime"	A standardized array of char format creates an intuitive way to translate information between blocks.	A char contains 1 byte and the bluetooth protocol can communicate at 500 bytes/second. Thus, the message can be sent within a second.
Protocol: bluetooth protocol between Arduino and Android	Bluetooth can transmit data at least 500 bytes/second, which meets the above parameters for this interface	An Android phone has a builtin bluetooth communication module which can be utilized to communicate with an external bluetooth module.

usrs_ntrfc_ardn_n_rf : Output

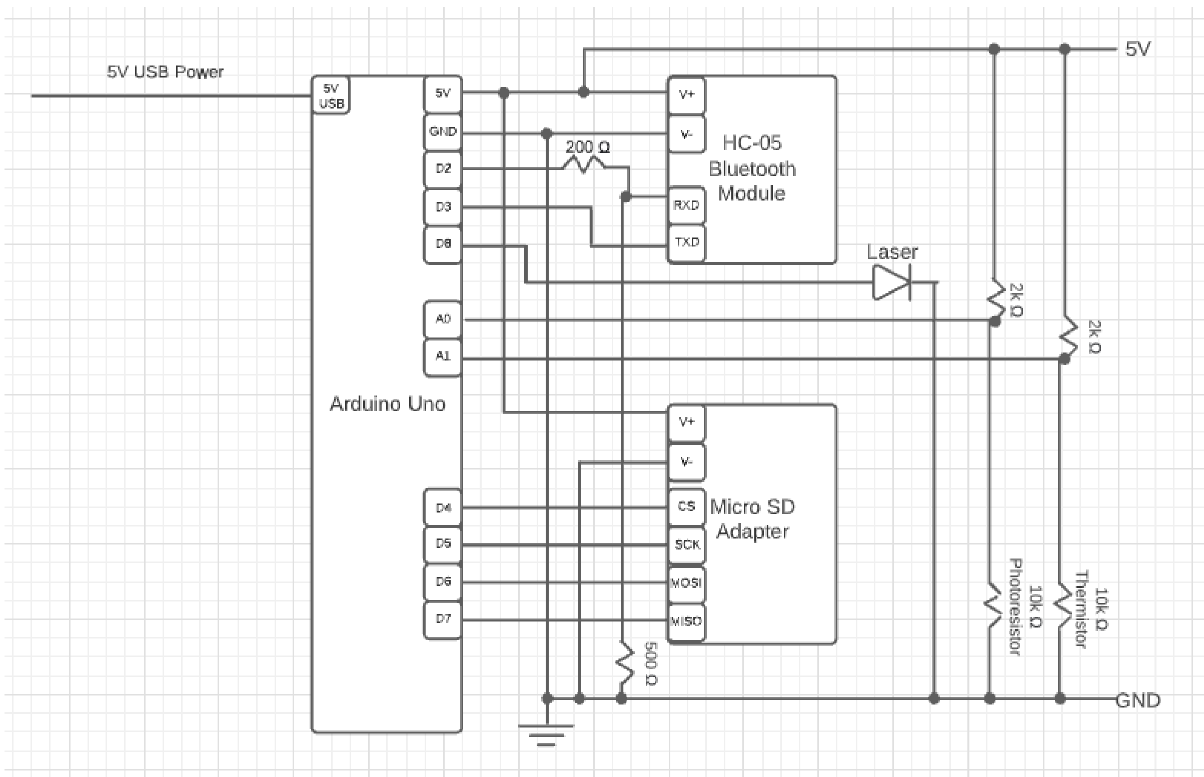
Datarate: 1 char per second	A single char provides enough options for user control of the system.	The information is sent via bluetooth communication protocol, which can support a minimum of 500 bytes/second. A char is 1 byte.
Messages: single char type indicating user control option	A single char provides enough options for user control of the system. Currently, there are 5	The GUI can send a char via bluetooth protocol.

	user control options. Chars can be easily interpreted by an Arduino block.	
Protocol: bluetooth protocol between Arduino and Android	The android has a built in bluetooth module and the protocol serves enough bytes per second for the application.	The android has a built in bluetooth module.

4.3.5 Block Testing Process

Figure 18 shows the electrical schematic used for testing.

Figure 18: Block Electrical Schematic



General Setup

1. Wire the experimental setup as shown in Figure 18
2. Insert a micro SD card into the micro SD adapter

3. Flash the arduino code attached in section 6.2 to the Arduino Uno
4. Pair the Android app with the Arduino via bluetooth

Verifying otsd_usrs_ntrfc_usrin

1. On the Android app, select “upload image”
2. Upload desired image
3. Unplug the micro SD card from the micro SD adapter
4. Plug the micro SD card into a file viewer, such as a computer
5. Confirm the image was processed into the SD card
6. On the Android app, draw a design in the upload image menu
7. Upload drawing
8. Repeat steps 3-5
9. On the Android app, select 90 second on time duration
10. Select ON
11. Confirm the LED turns on for 90 seconds

Verifying usrs_ntrfc_img_prcssr_comm

1. On the Android app, upload the desired image
2. Begin timing
3. Once the application indicates the image is uploaded, stop timing
4. Unplug the micro SD card from the micro SD adapter
5. Plug the micro SD card into a file viewer, such as a compute
6. Confirm the desired image is 300pix by 300pix TXT file stored on the SD card
7. View the file size of the TXT file.
8. Take the file size, divide by the number of seconds the file took to upload the image
9. Confirm that the communication protocol was greater than or equal to 500 bytes per second

Verifying usrs_ntrfc_ardn_n_rf

1. On the Android app, select 90 second on time duration
2. Select ON
3. On the Arudino serial monitor, verify a single CHAR is being transmitted for steps 1 and 2 within a second of the GUI button being pressed
4. Confirm the LED turns on for 90 seconds

Verifying ardn_n_usrs_ntrfc_comm

1. On the Android, verify that the system is displaying temperature, light, and on time data, and is being updated every second
2. On the Arduino serial monitor, verify that the data is of the form “temp|light|ontime” and is 16 chars long.

4.3.6 References and File Links

4.3.6.1 References

[1] "Image Size, File Size, and Image Resolution Explained," *BoldBrush*. [Online]. Available: https://support.boldbrush.com/faso-images-other/difference-between-image-size-and-resolution. [Accessed: 21-Jan-2022].

[2] J. G. Sponås, "Things you should know about bluetooth range," *Welcome to our blogs*. [Online]. Available: https://blog.nordicsemi.com/getconnected/things-you-should-know-about-bluetooth-range. [Accessed: 21-Jan-2022].

4.3.6.2 File Links

Project Document:
https://drive.google.com/file/d/113xmfM35EppXj2N73ktT27BfAyQP3VUI/view?usp=sharing

Arduino Code:
https://drive.google.com/file/d/183WsfOokKfqRc2mUB5v_3G8xJd6JJJMT/view?usp=sharing

4.3.7 Revision Table

Date	Revision
1/21/2022	- Revised artifacts based on current project scope. Revised interface definitions based on current project scope. Updated verification method based on revised interface definitions. - Added references and file links per Ingrid Scheel's feedback
1/18/2022	- Added data limitation rational to the data transfer interfaces per Liuqiao Song's feedback.
1/16/2022	- Specified the purpose of the block in the block overview, changed the block box diagram to match the block diagram portal

	tool, added interface definitions per Ingrid Scheel's feedback.
1/16/2022	- Added block artifact descriptions based on Miles Drake's feedback.
1/7/2022	- First Draft

4.4.Image Processor

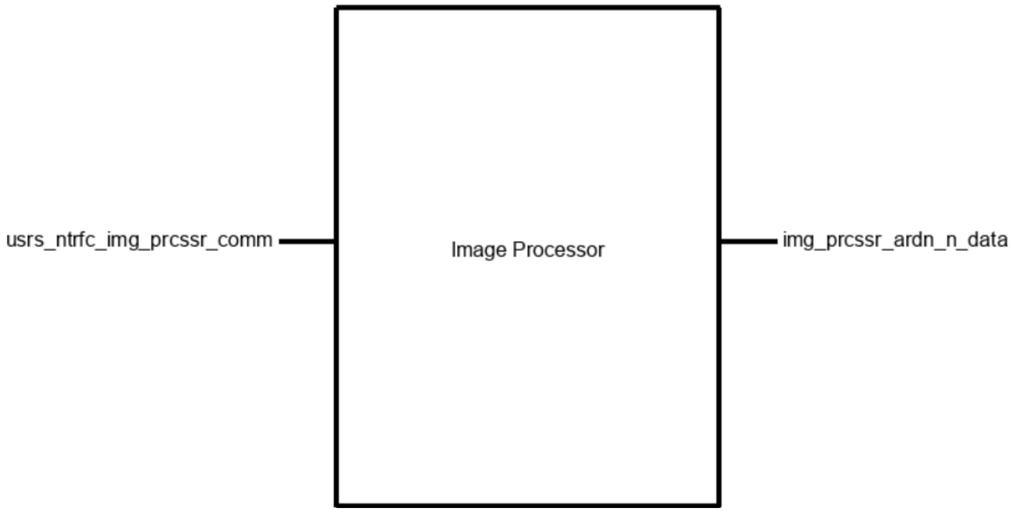
4.4.1 Description

The image processor block will interact with the user interface and the Arduino block. The user interface block is a graphical user interface (GUI) on an Android app. The Arduino block is the code to control the gyrometers, which determine the output image location through laser projection. The purpose of the image processor block is to take the user upload image from the GUI and process the image into prepared data. Prepared data is of the form of a 2D bit mapping. This array of bits indicates to the Arduino block where to instruct the gyrometers to display the laser image. The image processor block will take in a .jpeg file in a preloaded file location on a micro SD card and take the weighted color average of sections of the photo to determine where the image is most prominent. This block enhances the user functionality of the system by displaying the user uploaded control methods.

This block is strictly code that will be flashed onto an Arduino. This block will be a function within the Arduino, while the main Arduino script is a secondary block. Any schematics or hardware elements depicted or referenced are for testing purposes only and are not to be included in the final block integration.

4.4.2 Design

Figure 19: Block Black Box Diagram



The pseudocode implementation below begins by creating an empty 20 x 20 array of bits that serves as the image locations to be interpreted by the Arduino block. It then sets the beginning image location row and column to 0. The outer loop is set to 400, as there are 400 individual bits that are needed to be stored in the resulting image locations array. The code then makes an empty 5 column, 225 row array. The columns are used to store the row, column, and RGB values for a given pixel. The row is set to 225, as each image location output is associated with a 15 pixel by 15 pixel block in the JPEG file, or 225 pixels. Each of these color values are stored for their associated locations, incrementing row after each iteration. If row reaches 15, the end of the block's row is met, so row is reset to 0, and column is incremented. After the data block is stored, the weight RGB value is calculated. If the average color value is less than 150, a logic HIGH bit is written to the associated output array location. After each block is processed, the memory used for the block is freed.

Pseudocode

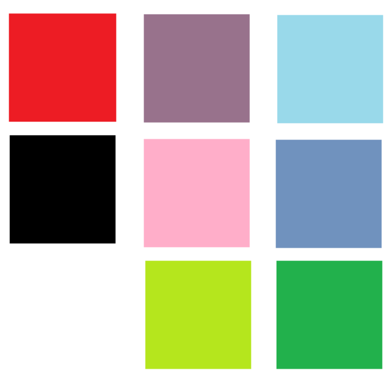
```
Create an empty 20 x 20 array of bits // Resulting array to build
Set bit_array_row = 0
Set bit_array_column = 0
Loop 400 times // This is the (300 pixel * 300 pixel image divided by 225 pixel (15x15) section)
    Create a 5 column, 225 row array // Column to store "row, column, red, green, blue"
    Set pic_row = 0
    Set pic_column = 0
    Set Row = 0
    Loop 225 times
        Read the red value, green value, and blue value of the pixel at (row,
        column) from SD card
        Store pic_row, pic_column, red, green, blue into row
        Increment row
        Increment pic_row
        If pic_row is >= 15 //If out of array bounds
            Set pic_row = 0 // Set row to 0
            Increment pic_column // Next column
    Add all red, green, blue values together
```

```
Divide RGB values by (225 * 3)
If (average RGB < 150)
        Set bit_array at location row, column = 1 //Output HIGH value at location
Increment bit_array_row
If (bit_array_row >= 20) // If out of output array bounds
        Set bit_array_row = 0
        Increment bit_array_column
Delete color array memory allocation // Clear temporary storage to reallocate SRAM
```

4.4.3 General Validation

This block provides a method for the user uploaded image to be processed into instructions that the machine can understand. By integrating this block into an Arduino, we are using hardware that the entire group is familiar with and can debug given unforeseen circumstances. Arduinos are widely available, relatively cheap, and mass produced. The Arduino Uno has 2kB of SRAM, of which the pseudo code implementation in section 2 requires 1,115 bytes to calculate each 15 pixel by 15 pixel color value. This is known as there are 225 colors to be stored, of which each color has a red, green, and blue 8-bit value [1], with an associated row and column byte. While this is over half of the available SRAM for the entire microprocessor [2], the memory only needs to be allocated within the function call, of which it only produces a 50 byte result (20x20 array of bits). See Figure 20 and Table 1 for the expected output behavior of this block. As seen from the figure and table, a darker color, associated with a lower average RGB value, will write a HIGH bit in the associated output row and column.

Figure 20: 3x3 Test Image



1	1	0
1	0	1
0	0	1

While this integration of taking the weighted color average of sections provides a more "painting" objective to the display, the color gradient of the image can be calculated to show more of an image outline. The con to doing this is the increased data memory needed to store each pixel to calculate the color gradient, of which the uno is already limited in. If this alternative were to be integrated, an Arduino with more SRAM, such as the Arduino mega, would need to be used. Another alternative to the image processing method would be to send the image to a server and use an image processing script.

4.4.4 Interface Validation

Table 8: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
otsd_img_prcssr_usrin: Input		
Timing: 2 seconds minimum time between user upload images	The database takes takes approximately 1.5 seconds to return a resulting word. Any faster uploads results in combined string outputs.	The image processor block diasabled the user scan button after it has been clicked and re-enables the button after 2 seconds.
Type: User uploaded image	The block accesses the user's camera and scans the camera view.	As the GUI is integrated in an android, the system already has a built in camera to scan from.
Messages: Android camera	The block accesses the user's camera and scans the camera view.	As the GUI is integrated in an android, the system already has a built in camera to scan from.
img_prcssr_ardn_n_data : Output		
Datarate: Maximum 19 byte word (19 characters) every 2 seconds	19 characters is the largest resulting word from the data base	The bluetooth module has a default baud rate of 9600, which is more than capable of transmitting 19 bytes every 2 seconds.
Messages: User uploaded image	A data base result creates a fun interactive way for the user to	The data base is a google list of over 400 resulting words.

database resulting text	control the system.	
Messages: Maximum word size of 19 characters	The largest word size the data base can return is 19 characters.	The bluetooth module has a default baud rate of 9600, which is more than capable of transmitting 19 characters.
Protocol: Bluetooth protocol from GUI (Tx) to Arduino (Rx)	Bluetooth provides sufficient data transfer speed and is intuitive to most users.	The bluetooth module has a default baud rate of 9600.

4.4.5 Verification Plan

General Setup Procedures

1. Flash the Arduino with the code provided in section 6.2
2. Install and run the Android application provided in section 6.2

Verifying usrs_ntrfc_img_prcssr_comm

1. Upload an image through the user interface
2. Verify the image sent into the sd card in 7 seconds or less
3. Verify the image is 300 pixels by 300 pixels
4. Verify the image is of .jpg type

Verifying img_prcssr_ardn_n_data

1. Upload a test image with known color constants for each 15 pixel by 15 pixel section
2. Move the micro SD card from the Android into the Arduino SD card reader
3. View the Arduino serial monitor to see the printed 20 bit by 20 bit processed image result
4. Verify the serial monitor is displaying 20x20 bits
5. Verify at least 10 bits are as expected based on the known color constants of the uploaded image

4.4.6 References and File Links

4.4.6.1 References

[1] “8 bit versus 16 bit color mode,” *Martin Podt*. [Online]. Available: https://www.martinpodt.com/Tutorials/8-bit-versus-16-bit#:~:text=Well%2C%20a%20JPEG%20is%20an,contain%20about%2016.8%20million%20colors. [Accessed: 18-Feb-2022].

[2] R. Teja, “Electronics hub - latest free electronics projects and ...,” *Different Types of Memory on Arduino | SRAM, EEPROM, Flash*, 30-Jan-2021. [Online]. Available: https://www.electronicshub.org/types-of-memory-on-arduino/. [Accessed: 19-Feb-2022].

[3] “Image Size, File Size, and Image Resolution Explained,” *BoldBrush*. [Online]. Available: https://support.boldbrush.com/faso-images-other/difference-between-image-size-and-resolution. [Accessed: 21-Jan-2022].

[4] “SD card module with Arduino: How to read/write data,” *Arduino Project Hub*. [Online]. Available:https://create.arduino.cc/projecthub/electropeak/sd-card-module-with-arduino-how-to-read-write-data-37f390. [Accessed: 18-Feb-2022].

4.4.6.2 File Links

Project Document:
https://drive.google.com/file/d/113xmfM35EppXj2N73ktT27BfAyQP3VUI/view?usp=sharing

Arduino Code:
https://drive.google.com/file/d/1QCxLL3tv7LM_IgwLCmQ0uddhHTg8h4eD/view?usp=sharing

Android Application:
https://drive.google.com/file/d/1tRl-ztzhPyVEOU8BZCysvOusaTPwUKmF/view?usp=sharing

4.4.7 Revision Table

Date	Name	Revision
3/11/2022	Alex Greiner	- Updated validation document to match current block design
2/18/2022	Alex Greiner	- Added file links to project documents and arduino code. Revised the alternative solution to image processing in section 6.
2/18/2022	Alex Greiner	- Based on Chih-Hao Kung’s feedback: ● Added pseudocode description, clarified interface definitions ● Added background information to section 1 ● Added a general testing setup
2/15/2022	Alex Greiner	- Based on Jordan Hendricks’ feedback: ● Added comments to pseudo code to emphasize why the looping variables are the size they are. ● Added an example color conversion to section 3.
2/10/2022	Alex Greiner	- Added testing electrical schematic to the verification section.

2/4/2022	Alex Greiner	- First Draft

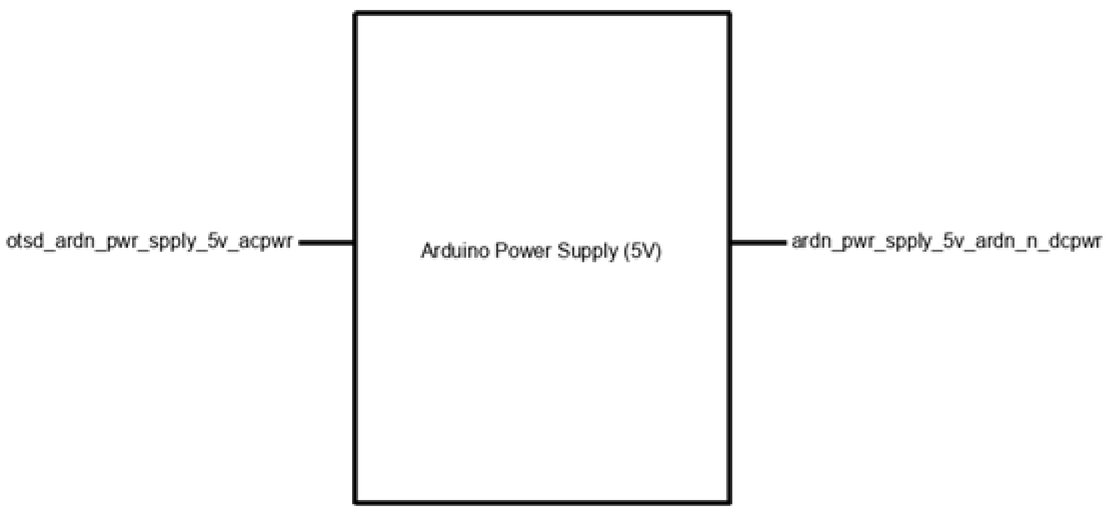
4.5.Arduino Power Supply (5V)

4.5.1. Description

This block will provide a 5V DC voltage to the Arduino Uno. Input to the block will be 120V AC and output will be 5V DC. This 5V DC output will be used to run the Arduino system, which acts as the brains of the system.

4.5.2. Design

Figure 21: Arduino Power Supply (5V) Black Box Diagram



This Block consists of normal plug-in type power from a wall outlet (120VAC). The voltage from the outlet enters an AC-DC 120V isolated switching power supply board. This piggy backs off the voltage coming in the system from the wall outlet and converts the 120VAC to 5VDC to power the Arduino while allowing the laser system power supply to still receive the voltage it needs to operate. The laser system uses a 120V AC system for power. We did not want to plug in two different cords to run the system, so the decision was made to convert from 120V AC to 5V DC for the rest of the system. Due to safety concerns for the users and the large cost of the galvanometers for the laser system, it was decided to use a commercially built power supply for the conversion from 120V AC to 5V DC. Below is a sketch of how the wiring would be applied (Figure 23).

Figure 22: Schematic of the switch power supply

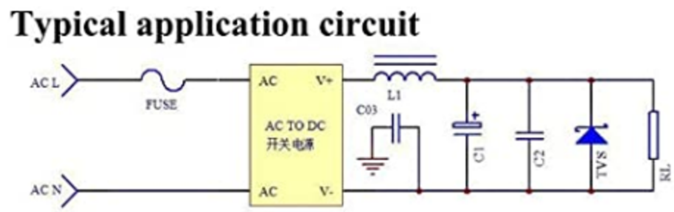


Figure 1 - Isolated switching power supply

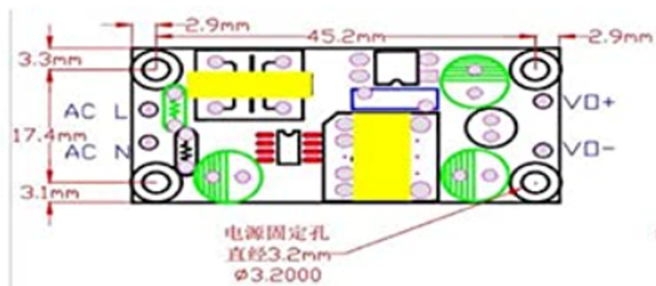


Figure 2 - Schematic for switching power supply

Figure 23: Wiring the system

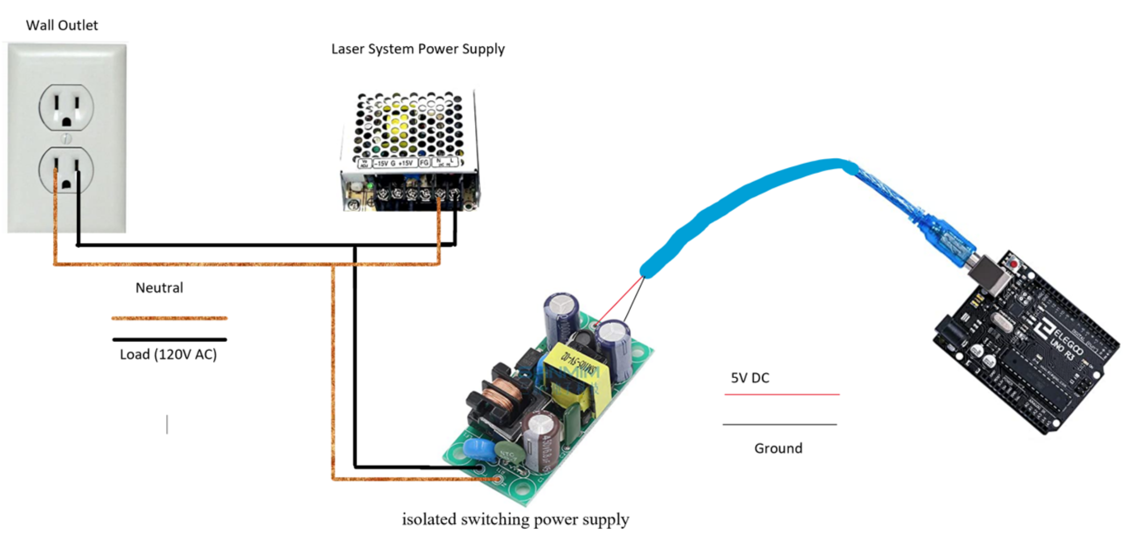


Figure 3 - Wiring

4.5.3. General Validation

The design for this block was chosen out of specific need for a voltage source that had the correct current output necessary to run the Arduino. In addition, this would not be a momentary situation. The power supply for the Arduino is essentially the oxygen that gets delivered to power the brains of the operation. Without the Arduino, the rest of the system is basically a paper weight. Thus, this application was crucial in maintaining long term operation of the system as a whole without fear of failure.

4.5.4. Interface Validation

Table 9: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

otsd_ardn_pwr_spply_5v_acpwr : Input

Vmax: 120.1V AC	This value was the max found when measuring a wall outlet voltage.	The max voltage input for the power supply 264V AC. There is no reason to test this number as the standard where the unit is produced is 120V AC, therefore it exceeds.
Vnominal: 120V AC	The 115V AC input for the system would not be conducive to powering the Arduino safely, therefore this is needed to mitigate risks.	115V AC is required for the power supply to the motor drivers and the motors. Therefore, wall outlet power was necessary for this application.
Vmin: 119.5V AC	This value was the min found when measuring a wall outlet voltage.	The max voltage input for the power supply 85V AC. There is no reason to test this number as the standard where the unit is produced is 120V AC, therefore it exceeds.

ardn_pwr_spply_5v_ardn_n_dcpwr : Output

Inominal: 1A	The data sheet for the power supply lists the rated output current at 1A.	Since the Arduino generally pulls about 50mA, current from the switching power supply exceeds what is necessary.
Vmax: 5.25V DC	The max voltage delivered from the switching power supply is 5V DC. While the data sheet did not mention a +- range, this was the max measured.	The Arduino requires a recommended range of 5V DC to 12V DC to operate. Outside this range could be detrimental to the unit or the unit's output. With a stable power supply a constant 5V DC can be provided to the Arduino, therefore it meets expectations.
Vmin: 4.4V DC	The max voltage delivered from the switching power supply is 5V DC. While the data sheet did not mention a +- range, this was the min measured.	The Arduino requires a recommended range of 5V DC to 12V DC to operate. Outside this range could be detrimental to the unit or the unit's output. With a stable power supply a constant 5V DC can be provided to the Arduino, therefore it meets expectations.

4.5.5. Verification Plan

1. Obtain a voltage from the wall outlet we intend to test with, to ensure we have the proper voltage going into the switching power supply.

2. Ensure the unit does not release magic smoke when connected to the wall outlet.

3. Measure the output voltage and current from the unit under load to ensure that limits are not being exceeded or undercut.

4. Plug the output of the switching power supply into the Arduino, and again look/smell for any burning or smoking components.

5. If all is good, let Arduino run for a minute or two to ensure safe operation.

4.5.6. References

[1] "GP," *Amazon*, 2011. [Online]. Available: https://www.amazon.com/gp/product/B07V5XP92F/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&th=1. [Accessed: 08-Jan-2022].

[2] "2pcs Leonardo R3 Pro Micro ATmega32U4 Development Board with USB Cable," *HiLetgo 2pcs Leonardo R3 Pro Micro ATmega32U4 Development Board With USB Cable-Shenzhen HiLetgo Tech*. [Online]. Available: http://www.hiletgo.com/2pcs-Leonardo-R3-Pro-Micro-ATmega32U4-Development-Board-With-USB-Cable-PG3452841. [Accessed: 08-Jan-2022].

4.5.7. Revision Table

Revision Number	Date	Description
R1	1/5/2022	- Modified black box diagram.
R2	1/6/2022	- Adjusted interface validation section.
R3	1/7/2022	- Added more references, updated interface validation
R4	1/20/2022	- Deleted the word stable from the initial description and general validation
R5	1/20/2022	- Clarified the design confusion about where the laser system power supply comes into play
R6	1/20/2022	- Adjusted interface properties for input and output of unit.

R7	1/20/2022	- Revised Verification step 3 plan to be more clear.
R8	1/20/2022	- Revised verification step 5 to be more clear

4.6.Arduino Mega

4.6.1. Description

The Arduino will take data from external sensors (temp, light, distance finder) and adjust the system accordingly. It will transmit data to the android app, namely system information. In addition, data from the Arduino will be displayed in the android app (system temp, ambient light levels). The code for this section, will monitor levels for each peripheral, for example, if the surrounding ambient light is very dark, the laser output level will be reduced. If the surrounding light is very bright, the laser will need to be on a higher power setting to help visibility during system operation.

4.6.2. Design

Figure 24: Black box diagram

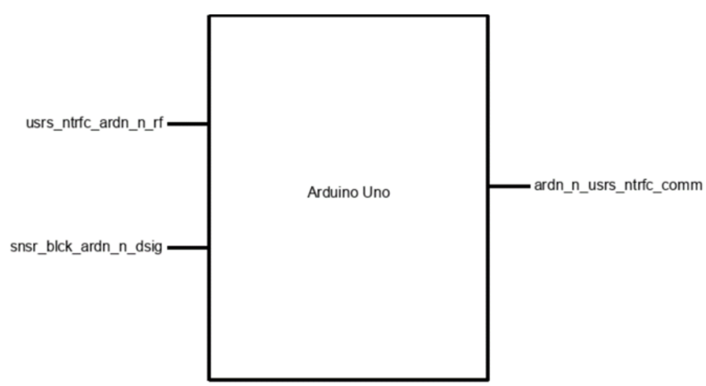


Figure 1 - Black Box Diagram

Figure 25: Overall Schematic

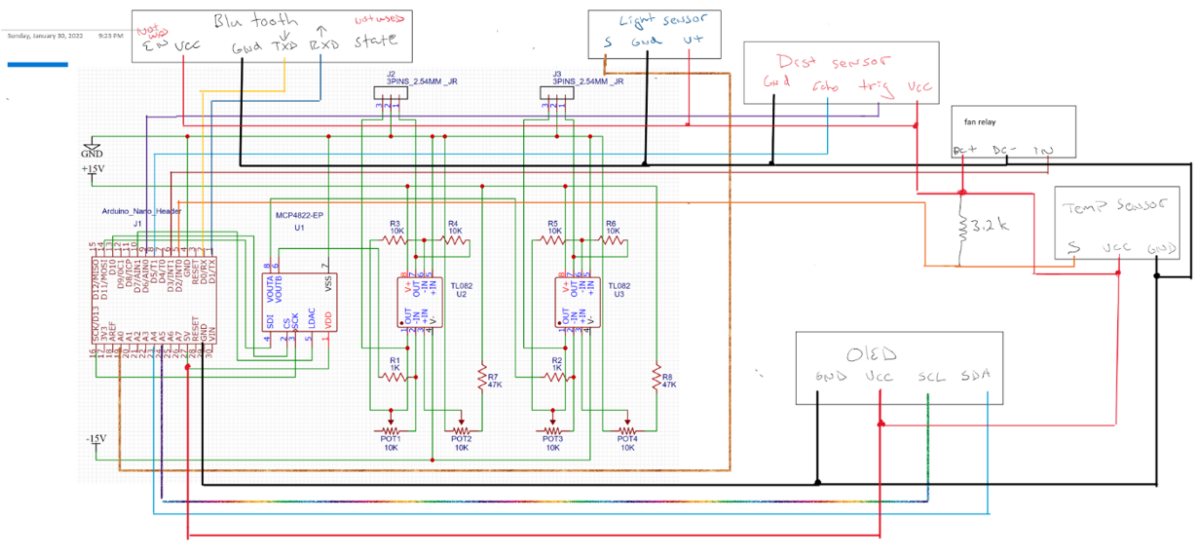


Figure 2 - Overall Schematic

The Arduino Uno receives environmental data from several peripheral sensors. These sensors include the ambient light values, the ambient temperature, and the distance found from the distance sensors on start up of the system. In the code the Arduino computes the values received from the environment and either displays the data, or takes action based on the value.

For the light sensor the values are displayed both on a mounted OLED screen and are sent via Bluetooth to the android application. Based on the light value found, the laser will be adjusted for brightness. For example, at 100% light, the laser will be 100% brightness. As the light value falls the laser brightness falls until reaching a value of 25% brightness in the darkest conditions.

For the distance finder sensor, an initial value of distance will be found upon start up of the system. If the distance is ever to be found less than this threshold (+/- 10% in case the surface is cloth), the laser will be shut down to ensure safety.

For the temperature sensor, if the ambient temperature is found to be above 24 degrees Celsius, an AC powered fan turns on to pull heat out of the system and help maintain a temperature that will not damage the system.

4.6.3. General Validation

The laser brightness was designed to change brightness based on ambient light because when there is little ambient light, the laser does not need to be at 100% brightness. The distance finder was designed to calculate an initial distance to the surface that will be projected on, and use this distance as a measuring device from that point to see if there is any change in the distance from measurement to measurement. If there is a change in this distance beyond the acceptable threshold, the laser will be shut off for safety as it is assumed that a living entity has entered the projection area. An AC fan was used for the job of dissipating heat from the system as the fan speed and capabilities far exceeded the initial 5V DC fans that were planned for. The drivers for the galvanometers were found to produce more heat than expected, and thus a stronger fan and better ventilation in the enclosure would be needed, however this added an extra relay to be necessary so the Arduino could turn the relay on to power the AC fan.

4.6.4. Interface Validation

Table 10: Interface Property Validation Interfaces.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?
usrs_ntrfc_ardn_n_rf : Input		
Datarate: Maximum 1 char per second	This value represents the maximum allowed data rate for communication between the android app and system Bluetooth	With a single value sent from the android application, it is sufficient to trigger a function in the Arduino code and produce an effect.
Messages: single char type indicating user control option	By sending a 1 from the android application the user can turn on a 2nd laser in the system, sending a 0 would turn off the 2nd laser	When the user changes the value in the application, the laser will either turn on, or turn off depending on the value sent.
Protocol: bluetooth protocol between Arduino and Android	Connection between the two units is essential and must be completed prior to sending any data between the two systems.	The android application will search for nearby bluetooth devices, once the devices are found the user can select the appropriate unit and begin to monitor data or send data.

ardn_n_usrs_ntrfc_comm : Output

Datarate: maximum 15 char array per second	This value is the limit as to what can be sent back to the android application in terms of data	Here we can send data back to the android application in terms of variables which contain numerical data for display
Messages: array of char of format "temp|light|"	The code must have some separation between the variables being sent back to be displayed on the android application.	For this project we use the ‘ | ‘ symbol to differentiate between the values being sent back to the application. So, the android app. knows that when it sees this symbol the next available data will be X value and place it in Y spot for display
Protocol: bluetooth protocol between Arduino and Android	The Bluetooth data is sent in both directions for this block. Here we will send data back to the application on the android device.	Temperature in F and C will be sent and light value will be sent in LUX and light %. These values can be corroborated by the hard mounted OLED screen which will also display the sensed data.

snsr_blck_ardn_n_dsig : Input

Other: AC Fan turns on at 24 degrees Celsius or 75 degrees F.	Our system will produce some heat from operation. The purpose of this section would be to dissipate some heat and keep temperatures at a manageable limit.	A heat source can be applied to the temperature sensor and show that the fan will turn on above the threshold and turn off below said threshold
Other: Display temperature in Celsius and F.	The data will be displayed on the mounted OLED screen and the android application	As the data seen on the mounted OLED screen and the data seen in the android app do not display conflicting data, the system is seen to exceed limits

Other: A heat source will be used to apply simulated heat around the temperature probe, as the fan turns on when the threshold is reached, the temperature sensor will show a decrease of 4 degrees F in ambient temp over a minutes time.	With a heat source applied we can see the temperature with and without the use of the AC fan.	As the temperature is lowered with the use fan, and is seen to keep the temperature at acceptable limits, this meets expectations
Other: Display Light in Lux and percent total	The value for the light sensor will be displayed on the mounted OLED screen and the Android application	Both, the mounted OLED display and the Android application coincide in terms of numbers so we can conclude that this meet the property

4.6.5. Verification Plan

1. Turn the system on

2. Record data

    a. Light value
    b. Distance
    c. Temperature

3. For the light value

    a. Shine a flashlight on the light sensor

        i. The light value should increase

        ii. The laser brightness should increase

    b. Turn flashlight off

        i. The light value should decrease

        ii. The laser brightness should decrease

4. For the Distance finder

a. The system will have a threshold obtained from start up

i. Interrupt the distance signal

1). The laser should turn off

ii. Remove interruption from distance signal

1). The laser should turn back on with the current brightness signaled by the sensor.

5. For the temperature sensor

a. Record ambient temperature for a baseline.
b. From a distance of 12 inches a blow dryer will be turned on.

i. The power to the fan will be turned off at this time

c. The heat will be applied for 1 minutes time to achieve a max value.
d. Now the power to the fan will be applied, also for a minute time limit.

i. At the end of this time, the value shown will be >= 4 degrees Fahrenheit lower.

ii. With the heat source removed

1). The sensor should return to ambient temperature within 30 seconds time

4.6.6. References and File Links

[1] "Amazon.com: GDSTIME EC Cooling Fan 60mm x 60mm x 25mm AC 110V 115V 120V 220V 240V Dual Ball Bearings : Electronics," *www.amazon.com*. https://www.amazon.com/gp/product/B07H8V6YS6/ref=ppx_yo_dt_b_asin_title_o07_s00?ie=UTF8&th=1 (accessed Feb. 05, 2022).

[2] "Amazon.com: DIYmalls DS18B20 Digital Temperature Sensor Module with 3pin XH2.54 to Dupont Cable Female for Arduino UNO R3 (Pack of 2) : Electronics," *www.amazon.com*. https://www.amazon.com/gp/product/B0925D91RY/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1 (accessed Feb. 05, 2022).

[3] "Amazon.com: Smraza 5pcs Ultrasonic Module HC-SR04 Distance Sensor with 2pcs Mounting Bracket for Arduino R3 MEGA Mega2560 Duemilanove Nano Robot XBee ZigBee : Industrial & Scientific," *www.amazon.com*.

https://www.amazon.com/gp/product/B01JG09DCK/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1 (accessed Feb. 05, 2022).

[4] "Amazon.com: HC-05 Arduino Wireless Bluetooth Receiver RF Transceiver Module Serial Port Transmitter Module : Electronics," *www.amazon.com*. https://www.amazon.com/gp/product/B01MQKX7VP/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1 (accessed Feb. 05, 2022).

[5] "DIYmall Laser Transmitter Module forArduino (Pack of 10pcs) - - Amazon.com," *www.amazon.com*. https://www.amazon.com/gp/product/B07FQ6696X/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1 (accessed Feb. 05, 2022).

[6] "Comidox 4Pcs TEMT6000 Light Sensor Module Analog Light Intensity Module Visible Light Sensor for Arduino: Amazon.com: Tools & Home Improvement," *www.amazon.com*. https://www.amazon.com/gp/product/B07JB5TQ93/ref=ppx_yo_dt_b_asin_title_o07_s00?ie=UTF8&psc=1 (accessed Feb. 05, 2022).

4.6.7. Revision Table

Revision Number	Date	Description
R0	12/9/2021	- Don Heer: Initial Document Creation.
R1	2/18/2022	- Updated initial description per Liuqiao Song's suggestion
R2	2/18/2022	- Updated initial description per Sean-Michael Riesterer's suggestion
R3	2/18/2022	- Updated reference list
R4	2/18/2022	- Deleted erroneous text

4.7.OLED Display

4.7.1 Block Overview

An OLED display along with the distance sensor is implemented in our system to illustrate the distance that the laser is being emitted at. The OLED display and the distance sensor will operate simultaneously by working with one another so that the user knows how far the laser is being projected. For the verification process, a buzzer will be implemented and it will be activated when an object is out of the range that has been set. Furthermore, I had the range set to 7cm to 30cm. This is an important concept because the safety of the users and the people around the laser painter remains the top priority. We don't want to damage any retinas and cause permanent blindness. We want to make certain that the laser painter can be enjoyed by others without getting harmed in any way.

4.7.2 Block Design

Design Details:

Figure 26: Represents the black box diagram of the OLED Display block

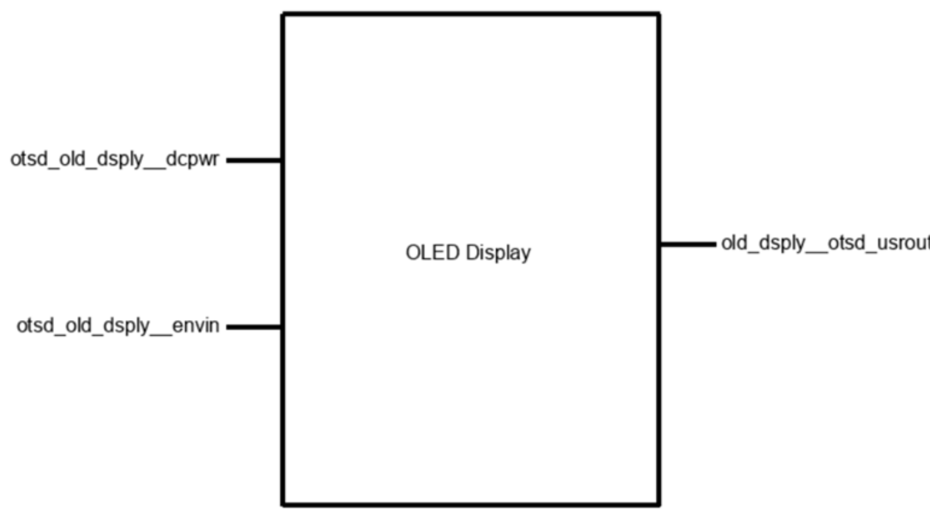
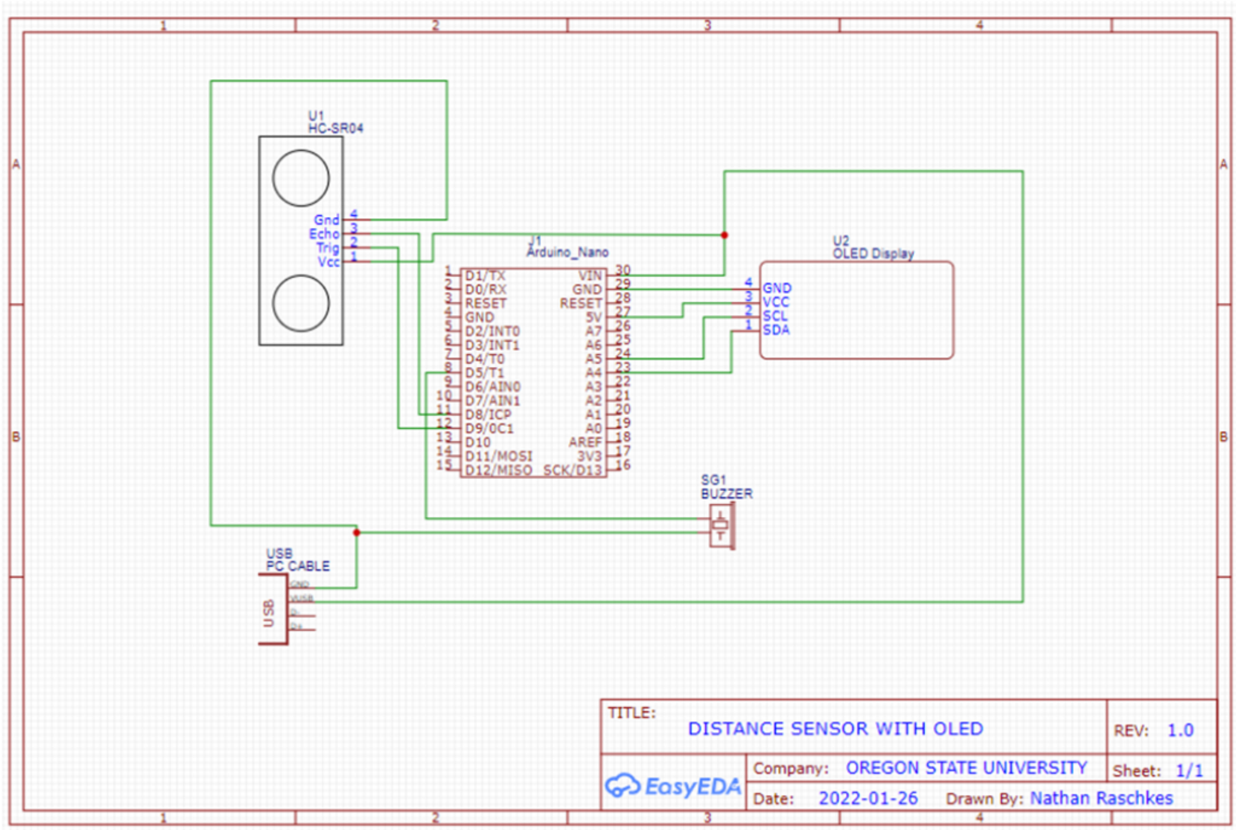


Figure 27: Represents the OLED Display schematic



4.7.3 Block General Validation

The design validation of the OLED display could affect the design impact statement by potentially impacting the safety of others and the public if this block isn't set up properly. An issue that arises with lasers is the known capabilities of causing blindness. A typical laser pointer can produce a range of one to five milliwatts of power which can damage the retina in our eyes after merely ten seconds of exposure. A laser can burn through paper at 3,500 milliwatts and can be purchased online for two hundred dollars (Can a laser pointer blind you?).

Unfortunately, that means those who acquire these unregulated lasers that have the capability of producing higher power would need to be exposed to the laser beams for less than ten seconds to sustain permanent damage. It is vital when the laser painter is being assembled that the intensity of the brightness won't damage the eyes of the viewers while ensuring that it is bright enough that it can be seen and enjoyed. Likewise, in order to mitigate this particular risk, we all want to make certain that the selected laser is safe, regulated and approved by the FDA because having reputable brands that are well known and that are reliable will help protect and build trust to the public. The FDA has been regulating lasers and the powers that are being emitted. It's worth pointing out that there are unregulated lasers that are being sold into the marketplace that have the ability to generate higher levels of power than what is set by the FDA. Furthermore, the distance sensor will help ensure that all users and observers will be operating at a safe proximity due to the OLED screen displaying the distance range of the laser beam. This feature will help keep everyone safe by showcasing how far the laser beam is being projected at so they know how far or close that the laser is being emitted. Lastly, providing safety goggles to those who are watching and using the laser painter will help reduce the risks of any eye injuries (Can a laser pointer blind you?).

Ensuring that the OLED display block is installed properly will save a lot of money. If the laser being emitted catches an object on fire that would create a lot of headaches which would mean more money would have to be spent just to replace any damaged commodities. Likewise, if someone is within the range of the laser painter while it's being projected, the cost would be astronomical just to cover the damages for any injuries. With the time constraint given, we can't afford to lose any more time because all of these circuitry parts work in synchrony with one another. Likewise, it will take time to be able to fix the issue which might involve rebuilding the entire system depending on how significant the problem is.

A five volts DC power source through the USB cable from the computer will be utilized to generate enough power to ensure that the OLED Display and the entire circuit is fully operationally. The objects that will be utilized to conduct this verification will be the wall, floor and the table. The objects will be used to verify that the distance sensor and the OLED Display are fully operational and that they are working properly. Those specific object inputs will be gradually getting closer to the distance sensor which will then have the OLED Display have the distance of the object from the distance sensor displayed on the screen in centimeters and inches. Likewise, the objects will also be moved away from the distance sensor to show that it can read the distance going near and away from the distance sensor. Additionally, the objects will be placed out of specified range for this experiment as well. The range has been set at 7cm to 30 cm. Once the objects are out of that range, a buzzer will activate to notify the user that the objects are not within the range.

Source: Ceenta, "Can a laser pointer blind you?," *Charlotte Eye Ear Nose & Throat Associates*, 28- Oct-2020. [Online]. Available: https://www.ceenta.com/news-blog/can-a-laser-pointer-blind-you. [Accessed: 25-Jan-2022].

4.7.4 Block Interface Validation

Design OLED Display Overview

The demonstration is intended to show the capabilities of employing an ultrasonic sensor to measure and retain the laser within a range from the target. Likewise, it will also show the capabilities of the OLED display. The distance sensor has a detection range of 2cm to 400cm with a resolution of 3mm and it requires a target with 0.5 square meters with no more than a 15 degree angle. Furthermore, the sensor emits a 40 kHz signal which travels at the speed of sound, 340 m/s. The sound wave needs to travel forward and back to complete the distance measurement and is accounted for in the code. Additionally, the imagine unit requires a sweet spot to operate which is approximately 7cm to 30 cm. Lastly, the software is written to activate a buzzer when out of this range. The OLED will display the distance in centimeters and inches as well.

Table 11: Example Interface Property Validation for One Input Interface.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

Input: otsd_old_dsply_dcpwr

Input power: 5V DC Power Source	This value was chosen because I’m using a fan that requires 5 volts to power the OLED Display. A USB cable via the computer will supply 5 volts to generate enough power to activate the OLED Display and power the entire circuit.	Vmin: 4.6V Vmax: 5.1V Inominal: 4-8mA Ipeak: 5-10mA

Input: otsd_old_dsply_envin

Input: Test objects (Wall, table and floor)	These objects were chosen as test inputs because they are commonly found in most room scenarios and they are large enough to be in the range that the distance sensor can detect.	The distance sensor has a detection range of 2cm to 400cm with a resolution of 3mm and it requires a target with 0.5 square meters with no more than a 15 degree angle. The sensor emits a 40 kHz signal which travels at the speed of sound, 340 m/s. The sound wave needs to travel forward and back to complete the distance measurement and is accounted for in the code.

Output: old_dsply_otsd_usrout

Output: Distance values	I have decided to set the range to 7cm to 30 cm because I wanted a range that's broader to show that the objects (wall, floor and table) can be detected in a variety of distances. The imagine unit requires a sweet spot to operate which is approximately at 7cm to 30 cm.	The OLED Display block will illustrate: -The numeric values of the distance in centimeters and inches - Show that objects (wall, table and floor) are within the given range of 7cm to 30 cm -Have the buzzer activate when the objects (wall, table and floor) are out of range that has been set (7cm -30 cm)

4.7.5 Block Testing Process

1. 5V DC Power Source (otsd_old_dsply_dcpwr) via the computer on the USB cable will power the entire circuit. Likewise, the 5V DC Power Source (otsd_old_dsply_dcpwr) will supply enough power so that OLED Display is able to activate.

2. Test input objects such as the wall, table and floor (otsd_old_dsply_envin**)** will be used to verify that the distance sensor and the OLED Display are fully operational and that they are working properly. The objects (wall, table and floor) will be gradually getting closer to the distance sensor which will then have the OLED Display showcasing the distance of the object from the distance sensor by having it displayed on the screen in centimeters and in inches as well (old_dsply_otsd_usrout). The object will be moved away from the distance sensor to show that it can read the distance going near and away from the distance sensor. Likewise, the object will be placed out of specified range for this experiment as well. The range has been set at 7cm to 30 cm. Once the object is out of that range, a buzzer will activate to notify the user that the object is not within the range.

3. Lastly, I will be measuring the minimum and maximum voltage for the DC power source that is being supplied which will generate a reading around 4.6-5.1 volts. Additionally, the nominal current will be around 4-8mA and the peak current will be approximately at 5-10mA.

4.7.6 References and File Links

4.7.6.1 References (IEEE)

[1] “Distance Sensor and OLED,” *Arduino Project Hub*. [Online]. Available: https://create.arduino.cc/projecthub/javier-munoz-saez/distance-sensor-and-oled-ad9e35. [Accessed: 28-Jan-2022].

4.7.6.2 File Links

Table 12: Represents the Bill of Materials

ID	Description	Designator	QTY	Manufacturer P/N	Manufacturer	Price	Data Sheet
1	Ultrasonic Sensor	U1	1	HC-SR04	Adafruit	$3.99	https://media.digikey.com/pdf/Data%20Sheets/Adafruit%20PDFs/3942_Web.pdf
2	128 x 64 OLED	U2	1	SSD1306	Hitgo	$7.99	https://www.digikey.com/htmldatasheets/production/2047793/0/0/1/ssd1306.html
3	Arduino Nano	J1	1	Nano	Arduino	$21.00	https://www.arduino.cc/en/uploads/Main/ArduinoNanoManual23.pdf
4	Buzzer	SG1	1	CMI-1295IC-0585T	CUI Devices	$0.85	https://www.cuidevices.com/product/resource/cmi-1295ic-0585t.pdf
5	PC Micro USB Cable	P1	1	USB A to Micro	Belkin	$3.99	https://www.belkin.com/us/cables/charging/boost-charge-usb-a-to-micro-usb-cable/p/p-cab005/

CODE:

//Code is based upon open source and was obtain from:
https://create.arduino.cc/projecthub/javier-munoz-saez/distance-sensor-and-oled-ad9e35

//Code is designed to provide the distance using an ultrasonic sensor and activate a buzzer when the max distance is exceeded or when it is below the minimum.

```
#include <SPI.h>  //Arduino specific library for OLED

#include <Wire.h> //Arduino specific library for OLED

#include <Adafruit_GFX.h> //Arduino specific library for OLED

#include <Adafruit_SSD1306.h> //Arduino specific library for OLED

#define trigPin 9  //defining trigger pin

#define echoPin 8 //defining echo pin

#define Buzzer 5  //defining Buzzer pin

#define OLED_RESET 4 //reset display

Adafruit_SSD1306 display(OLED_RESET);

void setup() {

Serial.begin (9600); //communication speed

pinMode(trigPin, OUTPUT); //trig pin is output

pinMode(echoPin, INPUT); //echo pin is input

pinMode(Buzzer, OUTPUT);  //buzzer is output

display.begin(SSD1306_SWITCHCAPVCC, 0x3C); //initialize with the I2C addr 0x3C (128x64)

display.clearDisplay(); //clear display

}

void loop() {
```

```
float duration; //time variable

float distance_cm; //disance variable in centimeters

float distance_in;  // distance variable in inches

const int DISTANCE_THRESHOLD = 30; // integer for the max distance required for the image module

const int DISTANCE_CLOSE = 7; // integer for the min distance required for the image module

digitalWrite(trigPin, LOW); //PULSE ___|---|___  //ultrasonic pulse setup

delayMicroseconds(2); //time delay

digitalWrite(trigPin, HIGH); //activate the trig pin

delayMicroseconds(10); //time delay

digitalWrite(trigPin, LOW); //deactivate the trig pin

duration = pulseIn(echoPin, HIGH); //ultrasonic sensor activated

distance_cm = (duration/2) / 32; // distance in centimeters calculation

distance_in = (duration/2) / 80; //distance in inches calculation

if (distance_cm > DISTANCE_THRESHOLD || distance_cm <DISTANCE_CLOSE) //boolean expression to envoke buzzer when outside bounds for the image module

digitalWrite (Buzzer, HIGH); //buzzer on

else

digitalWrite (Buzzer, LOW); //buzzer off

 display.setCursor(5,0); //oled text location

display.setTextSize(1); //text size

display.setTextColor(WHITE); //text color

display.println(F("ECE442 Dist. Meter")); //display first line of text and flash on/off

display.display(); //print text
```

```
display.setCursor(1,10); //oled text location

display.setTextSize(2); // text size

display.setTextColor(WHITE); // text color

display.println(distance_cm); //display distance for Centimeters

display.setCursor(80,10); // oled text location

display.setTextSize(2); //text size

display.println("cm"); //display cm

display.setCursor(10,25); //oled text location

display.setTextSize(1); //text size

display.setTextColor(WHITE); //text color

display.println(distance_in); //display distance for inches

display.setCursor(50,25); //text location

display.setTextSize(1); //text size

display.println("in"); //display inches

display.display();

delay(500); //time delay

display.clearDisplay(); //clear display

Serial.println(distance_cm); //display measured distance in cm

Serial.println(distance_in); //display measured distance in inches

}
```

4.7.7 Revision Table

Revision Number (Revisions conducted by: Nathan Raschkes)	Date	Description
R1	1/24/2022	- Adjusted the block overview section.
R2	1/31/2022	- Modified the interface validation section.
R3	2/12/2022	- (Addressing Aaron Chung's feedbacks) -Added a third interface to the black box diagram -Added to the interface definition section -Having my name included in the revision table to claim responsibility for doing the revisions
R4	2/12/2022	-Added in code under the file section 6.2 -Altered the black box diagram -Modified the block testing process section -Adjusted the voltage min and max on the portal for the OLED Display block and

		made changes to the interfaces for the OLED Display block on the portal
R5	2/12/2022	(Addressing John Zontos' feedbacks) -Made images larger in the block design section so it's easier to read -Added a hanging indentation for the source cited in the block general validation section -Modified the interface validation section -Added more to the description section in the revision table

4.8.Sensor Block

4.8.1 Block Overview

A fan is implemented in our system to assist in regulating the temperature. The objective is to ensure that the system doesn't overheat or become too hot. When the system reaches a specific temperature, the fan will be activated by cooling the system. Likewise, when the fan has been turned on, another feature that will be applied to the system is the ability to govern the speed of the fan. The sensor block will be executing this feature based off of the temperature readings in Celsius. Once 28 degrees Celsius has been achieved, the fan will be activated and the speed of the fan will be displayed. Furthermore, we don't want the system to utilize the fan when it isn't necessary and to consume too much power. It's vital that the fan isn't blowing at a speed that's too rapid because it would create a lot of noise and blow a lot of dust. The speed that has been established will make certain that a lot of dust won't get blown because I implemented a fan that isn't too powerful so that once the fan speed reaches 100%, it won't generate a lot of dust. Additionally, it's crucial that the fan doesn't operate at a speed that is too slow because if the system is overheated, it won't be cooled down fast enough which could potentially affect the quality and performance of the system. Another primary objective is to ensure energy efficiency. Controlling the speed of the fan and having the ability to trigger the fan both play important roles in making certain that the energy efficiency is maintained.

4.8.2 Block Design

Design Details:

Figure 38: Represents the black box diagram of the sensor block

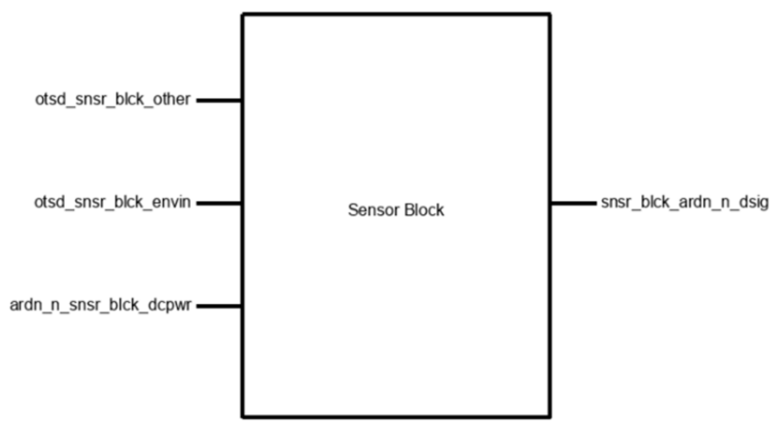
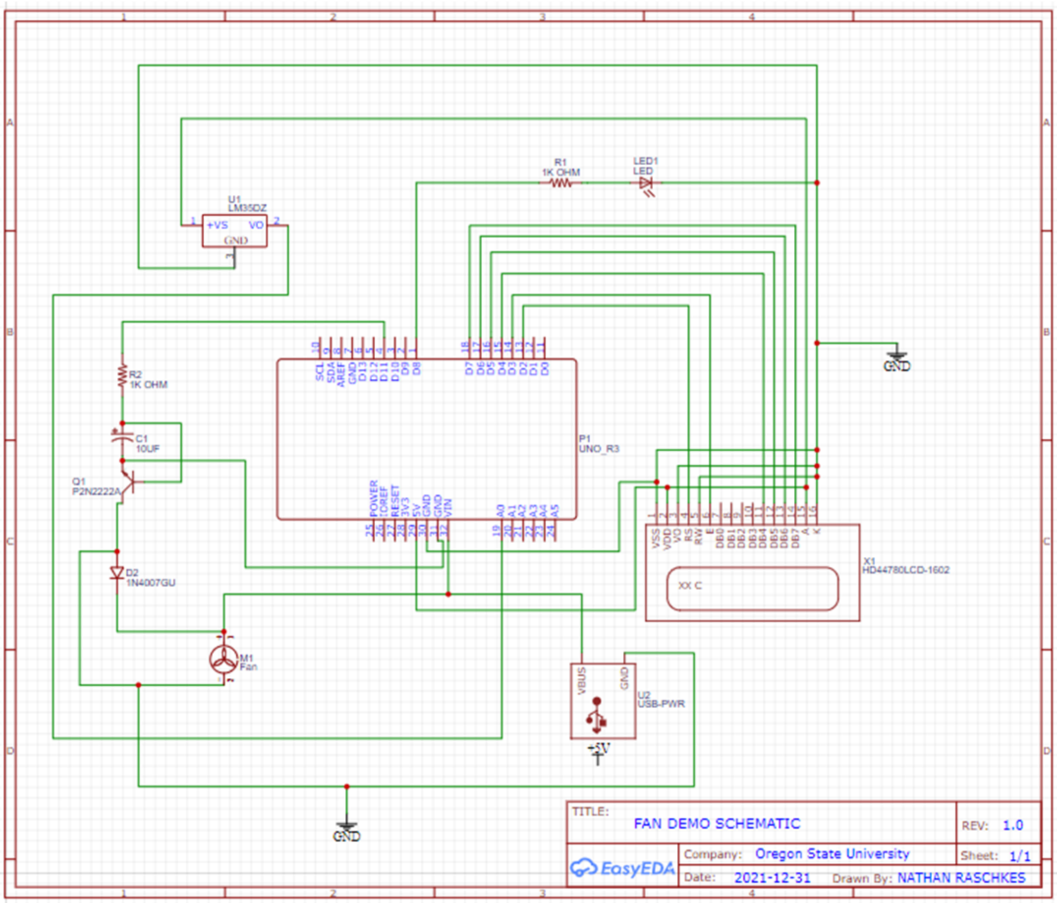


Figure 29: Represents the fan schematic



4.8.3 Block General Validation

The design validation of the fan might affect the design impact statement by potentially impacting the economic aspects which would affect the performance and quality of the laser painter. If the system were to overheat, it could produce a lot of unnecessary background noises; blow a lot of dust in the background which could be distracting. If the system is too hot, it might not be able to function properly by making the display shakier and it could also generate a lower quality image due to the amount of power being utilized.

Ensuring that the sensor block is installed properly will save a lot of money. If the system overheats by causing a component or several circuitry parts to break that would create a lot of headaches which would mean more money would have to be spent just to purchase replacement parts. There's currently a shortage going on involving the circuit components, which would make obtaining the necessary parts a lot more difficult. Some parts are even on backorder for months. With the time constraint given, we can't afford to lose time because all of these circuit parts work in synchrony with one another. Likewise, it will take time to be able to fix the issue which might involve rebuilding the entire system depending on how significant the problem is.

Furthermore, having a damaged circuit component could potentially make the entire system not function at all which would mean that it won't be operational for people to utilize. Since each component affects one another, that also means that each block interacts with other blocks. If a part were to get destroyed because it was overheated, it will be a domino effect which will impact the quality and function of the laser painter.

This design validation will work because there will be multiple tests conducted. I will be utilizing a soldering iron as one input and a hair dryer for the other input. Both will be used as a heat source so that the LM35 temperature sensor will detect the heat which will then activate the fan at 28 degrees Celsius and cause the LED to glow at 38 degrees Celsius. The speed of the fan will start at 0% at 28 degrees Celsius and max out at 100% speed when 38 degrees Celsius has been reached. Parenthetically, this would lead to the outputs of showcasing the live temperature readings, the live speed of the fan and the illumination of the LED. Additionally, using a hand to feel the heat being given off and a temperature gun will also verify that heat is being applied to the system. The LM35 temperature sensor will also produce temperature readings showcasing that the temperature is increasing as well. The input for air can be seen as the system draws in the air and the blades of the fan will move in a circular fashion. You can also take a piece of toilet paper and put it near the fan which will result in the toilet paper getting sucked in closer to the fan which will illustrate that the air is being taken in. I'll also be measuring the minimum and maximum voltage for the DC power source that is being supplied which will be approximately 5.1 volts. Additionally, the nominal current will produce around 70-80mA. The peak current will also be documented by being at approximately 100mA.

4.8.4 Block Interface Validation

Design Fan Overview

Temperature Control (Fan), Control Circuit Overview

This particular circuit utilizes an Arduino UNO R3 microcontroller and it's designed, to regulate and cool the laser, with the usage of a 5 volt DC fan and to activate only, when a prescribed temperature of 28 ºC is reached. The temperature is continuously monitored with the usage of an LM35 temperature sensor. The LM35 temperature sensor has a linear scale factor of 10mV/Celsius and a range of measurement from -55 ºC to 150 ºC. The laser is a red dot 650nm diode, with a power consumption of 5mW and an operational temperature range of -10ºC to 40ºC.

The Arduino also varies the speed of the fan, in relation to the LM35 temperature sensor reading, with full speed (100%) set at 38 ºC. The LED will be activated when the temperature exceeds 38°C indicating the laser is operating near its max temperature limit.

The LCD will display the temperature in Celsius (°C) and the fan speed as a percentage (%).

The 2N2222 transistor is the fan switch and the 1N4007 diode serves as reverse current protection to the fan.

Table 13: Example Interface Property Validation for One Input Interface.

Interface Property	Why is this interface this value?	Why do you know that your design details for this block above meet or exceed each property?

Input: otsd_snsr_blck_other

Input: Heat	The heat generated by the hair dryer and soldering iron is transferred to the LM35 temperature sensor. According to the datasheet, the LM35 temperature sensor can operate from a range of 4 volts to 30 volts. In my validation process, I will be supplying 5 volts DC power source because I'll have a small fan that requires 5 volts.	The heat generated by the heat source (hair dryer and soldering iron) will be detected by the LM35 temperature sensor. I will be using a hair dryer and a soldering iron as a heat source to increase the temperature so that the LM35 temperature sensor will detect the temperature so that it can activate the LED and by displaying the temperature and the speed of the fan. The heat input can be validated with the temperature sensor detecting the increase in the temperature in Celsius. Likewise, using your hand to feel the heat being given off is another method. Lastly, a temperature gun will also be used to validate that heat is being applied.

Source:
https://www.ti.com/lit/ds/symlink/lm35.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-wwe&ts=1640904235471&ref_url=https%253A%252F%252Fwww.ti.com%252Fgeneral%252Fdocs%252Fsuppproductinfo.tsp%253FdistId%253D10%2526gotoUrl%253Dhttps%253A%252F%252Fwww.ti.com%252Flit%252Fgpn%252Flm35

Input: Ardn_n_snsr_blck_dcpwr

Input power: 5V DC Power Source	This value was chosen because I'm using a fan that requires 5 volts to power the fan. A USB cable via the computer will supply 5 volts to generate enough power to activate the fan and power the entire circuit.	Vmin: 5.13V Vmax: 5.15V Inominal: Around 70-80mA Ipeak: Around 100mA The current varies depending on the amount of heat being applied which affects the temperature and when the fan is activated.

Input: otsd_snsr_blck_envin

Input: Fan Air Intake	The temperature in the given room will affect whether the fan is activated or not. This value was chosen because room temperature is 20 degrees Celsius and a solder iron will be used because it can easily provide a heat much greater than the room temperature. The maximum temperature is 40 degrees Celsius for the laser. Just to ensure safety, 38 degrees was chosen as a safety precaution by providing an extra safety cushion.	-The cooling fan will draw in room air. The fan will activate once it reaches the specified temperature. -The blades on the fan will move by spinning in a circular motion. - A piece of toilet paper could be put near the fan to prove that the fan is working, which will result in the paper getting sucked closer to the fan.

Output: snsr_blck_ardn_n_dsig

Output: LCD Display (Temperature and Speed)	The maximum operating temperature of the laser is 40ºC and a safety factor was chosen to be just below at 38ºC. The fan will begin from 0% to 100% to indicate the speed of the fan. When it is 28 degrees Celsius, the fan will begin from 0% and when it reaches 38 degrees, the fan will be at 100% in terms of the speed.	The LM35 temperature sensor will output on the LCD display: -LCD laser temperature in Celsius. -LCD fan speed in %. Other forms of verifications for the output: -LED will turn on when 38 degrees Celsius has been achieved. -The system will cool down. -The fan via forced convection will have the air in the room flow because the air goes in and then goes out (fan air exhaust).

4.8.5 Block Testing Process

1. 5V DC Power Source via the computer on the USB cable will power the entire circuit and the 5 volt fan. The 5V DC Power Source will supply enough power so that fan is able to activate.

2. Heat from the hair dryer and the soldering iron (otsd_snsr_blck_other) will activate the fan. The hair dryer and the soldering iron will cause the temperature to increase on the LM35 temperature sensor. Using your hand, along with a temperature gun will also verify that heat is being applied. The temperature sensor will illustrate the LCD Display (snsr_blck_ardn_n_dsig) by showcasing the live temperature in Celsius and the speed of the fan in a percentage format. The LED will be activated when the temperature sensor detects 38 degrees Celsius. Fan air intake (otsd_snsr_blck_envin) will begin since the fan has been turned on. The cooling down process will commence. The fan via forced convection will have the air flown across in the room. The blades on the fan will display that the air is being drawn. Furthermore, a piece of toilet paper will be put near the fan which will result in the toilet paper getting sucked in closer to the fan which will illustrate that the air is being taken in. Lastly, I will be measuring the

minimum and maximum voltage for the DC power source that is being supplied which will generate a reading around 5.1 volts. Additionally, the nominal current will be around 70-80 mA and the peak current will be approximately 100mA.

4.8.6 References and File Links

4.8.6.1 References (IEEE)

[1] Admin, S. says: A. N. says: D. says: 6303620092 says: M. V. says: A. Says: N. S. M. says: K. says: N. C. says: G. says: L. says: P. Says: A. says: A. J. says: N. K. S. Says: R. says: B. Says: M. A. says: E. Says: S. A. I. S. A. R. A. T. H. R. says: C. says: D. P. says: S. R. says: tuferu2021 says: P. says: and I. K. E. N. N. A. says: “Temperature based fan speed control & Monitoring with Arduino,” How To Electronics, 17-May-2020. [Online]. Available: https://how2electronics.com/temperature-fan-speed-control-arduino/. [Accessed: 05-Jan-2022].

[2] C. S. Staff, D. H. says: and C. S. S. says: “Temperature based fan speed controller using Arduino and LM35,” Circuit Schools, 30-Mar-2021. [Online]. Available: https://www.circuitschools.com/temperature-based-fan-speed-controller-using-arduino-and-lm35/. [Accessed: 05-Jan-2022].

[3] Saiswetha, “Temperature based fan speed control & monitoring using Arduino,” Electronics For You, 16-Aug-2021. [Online]. Available: https://www.electronicsforu.com/electronics-projects/fan-speed-control-monitoring-arduino/amp. [Accessed: 05-Jan-2022].

4.8.6.2 File Links

Table 14: Represents the Bill of Materials

ID	Description	Designator	Quantity	Manufacturer P/N	Manufacturer	Price	Data Sheet
1	Capacitor	C1	1	10uF	Kemet	$0.25	https://content.kemet.com/datasheets/KEM_A4004_ESK.pdf
2	1N4007GU	D2	1	1N4007GU	Diodes Inc	$0.35	https://www.diodes.com/assets/Datasheets/ds28002.pdf
3	LED	LED1	1	XLUR11D	Sun LED	$0.50	https://www.sunledusa.com/products/spec/XLUR11D.pdf
4	Fan	M1	1	3368	Pi Fan	$3.50	https://www.adafruit.com/product/3368#technical-details
5	Arduino UNO	P1	1	Uno R3	Arduino	$26.00	http://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf
6	NPN Transistor	Q1	1	P2N2222A	On Semi	$3.75	https://media.digikey.com/pdf/Data%20Sheets/ON%20Semiconductor%20PDFs/P2N2222A%20Rev3.pdf
7	1K OHM	R1,R2	2	4-1879619-9	TE Connect.	$1.25	https://www.mouser.com/datasheet/2/418/7/ENG_CD_1879619_BA-2077784.pdf
8	Temp Sensor	U1	1	LM35DZ	TI	$3.15	https://www.ti.com/lit/ds/symlink/lm35.pdf
9	USB-PWR Cable	U2	1	Home Made	Student	0	
10	LCD Display	X1	1	HD44780LCD-1602	Hitachi	$5.99	https://www.sparkfun.com/datasheets/LCD/HD44780.pdf

CODE:

```
include <LiquidCrystal.h>

LiquidCrystal lcd(2,3,4,5,6,7);

int tempPin = A0; //Output pin regarding LM35 temperature sensor

int fan = 11; //Fan pin

int led = 8; // Pin of the LED

int temp;

int tempMin = 28; // the temperature to start the fan 5%

int tempMax = 38; // the maximum temperature when fan is at 100%

int fanSpeed;

int fanLCD;

void setup() {

pinMode(fan, OUTPUT);

pinMode(led, OUTPUT);

pinMode(tempPin, INPUT);

lcd.begin(16,2);

Serial.begin(9600);

}

void loop()

{

temp = readTemp(); // Acquire the temperature

Serial.print( temp );

if(temp <= tempMin) // if temp is lower or equal to minimum temp
```

```
{

fanSpeed <= 11; // fan is not spinning

analogWrite(fan, fanSpeed);

fanLCD=0;

digitalWrite(fan, LOW);

}

if((temp >= tempMin) && (temp <= tempMax)) // if temperature is higher than minimum temp

{

fanSpeed = temp;//map(temp, tempMin, tempMax, 5, 100); // the actual speed of fan//map(temp,
tempMin, tempMax, 32, 255);

fanSpeed=3.5*fanSpeed;

fanLCD = map(temp, tempMin, tempMax, 5, 100); // speed of fan to display on LCD100

analogWrite(fan, fanSpeed); // spin the fan at the fanSpeed speed

}

if(temp > tempMax) // if temp is higher than tempMax

{

digitalWrite(led, HIGH); // turn on led

}

else // else turn off led

{

digitalWrite(led, LOW);

}


lcd.print("TEMPERATURE: ");
```

```
lcd.print(temp); // display the temperature

lcd.print("C ");

lcd.setCursor(0,1); // move cursor to next line

lcd.print("FAN SPEED: ");

lcd.print(fanLCD); // display the fan speed

lcd.print("%");

delay(200);

lcd.clear();

}

int readTemp() { // get the temperature and convert it to Celsius

temp = analogRead(tempPin);

return temp * 0.4;

}
```

4.8.7 Revision Table

Revision Number	Date	Description
R1	1/5/2022	- Modified black box diagram.
R2	1/6/2022	- Adjusted interface validation section.

R3	1/15/2022	(Addressed Camden Robustelli's suggestions) -Clarified the speed fan and dust in the block overview. -Adjusted interface definitions. -Added information about the fan. -Added code to the document -Fixed revision table numbering.
R4	1/15/2022	(Addressed Sean Booth's suggestions) -Modified the black box diagram -Made schematic diagram image larger. -Made the interface definition into a link. -Fixed interface definition formatting. -Adjusted block validation interface definition section. -Adjusted the block testing process section.

R5	1/17/2022	(Addressed Jordan Porter's suggestions) -Included how the block could be validated -Added more information for the interface definition for the heat input -Modified black box diagram -Added to the DC Power input for the interface section

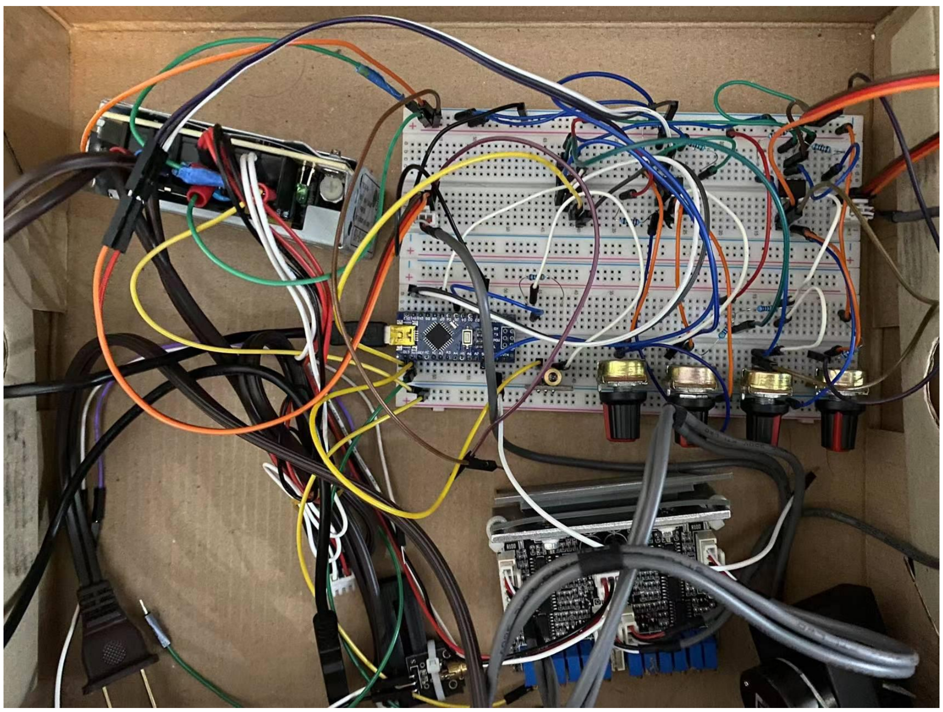
R6	1/18/2022	Addressed Ingrid Scheel's suggestions) -Added in the black box diagram from the portal tool template -Added in the interfaces with the right naming conventions -Added in more detail regarding how the sensor block is conducting the speed of the fan rather than the system -Added more information to the general block validation section -Added in temperature control for the interface validation section -Adjusted interface validation section regarding the heat input -Modified the output for the interface validation section -Adjusted and added to the verification plan section

Section 5: System Verification Evidence

5.1.Universal Project Constraints

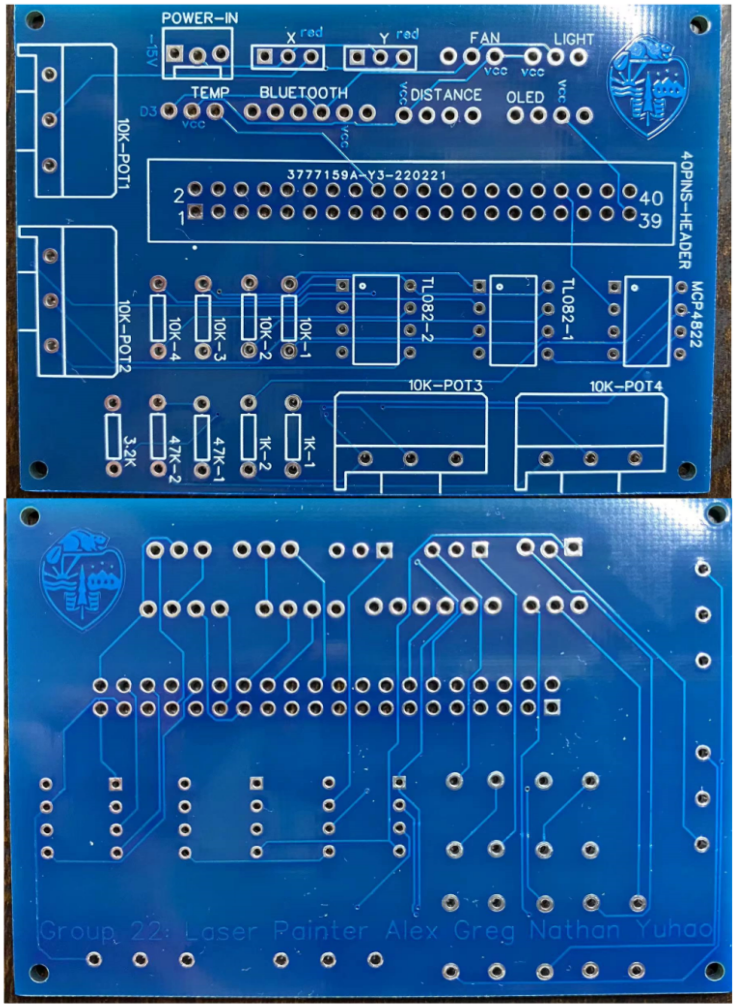
5.1.1 The system may not include a breadboard
When we were testing laser systems, a breadboard was without a doubt the best option. However, including a breadboard in the final product of the project is not what we need. After we made sure the laser system worked as we expected, we designed the PCB based on the breadboard circuit. Of course, the breadboard was **replaced** by a PCB board in the final project. Information on the PCB board is contained in 5.1.2.

Figure 30: Picture of the physical circuit with using a breadboard



5.1.2 The final system must contain both of the following: a student designed PCB and a custom Android/PC/Cloud application.
Based on the design of the physical circuit board shown in 5.1.1, we designed our custom PCB, and it is shown below. The dimension of the PCB is 56.134mm * 78.74mm, and the thickness of it is 1.6mm. The PCB has two layers, the base material FR-4. The FR-4 materials have wide range operating temperature($50^{\circ}C$ to $115^{\circ}C$), offer decent mechanical properties to maintain board structure integrity, and cost friendly when compared to other materials. The glass transition temperature is 130 to 140 celsius. The PCB cotanins the soldering header for the Arduino Mega, DAC block, Laser System, and the sensor block. It contains 4 out of 8 blocks of the project.

Figure 31: Picture of the designed PCB



The Android app serves as the user interface for the system. In the app, the user can connect to the system via bluetooth, select the laser timeout duration, turn the laser on/off, and scan images to display the database resulting word from the laser. Furthermore, system parameters, such as system temperature and ontime, are displayed.

Figure 32: Android app data and laser control menu

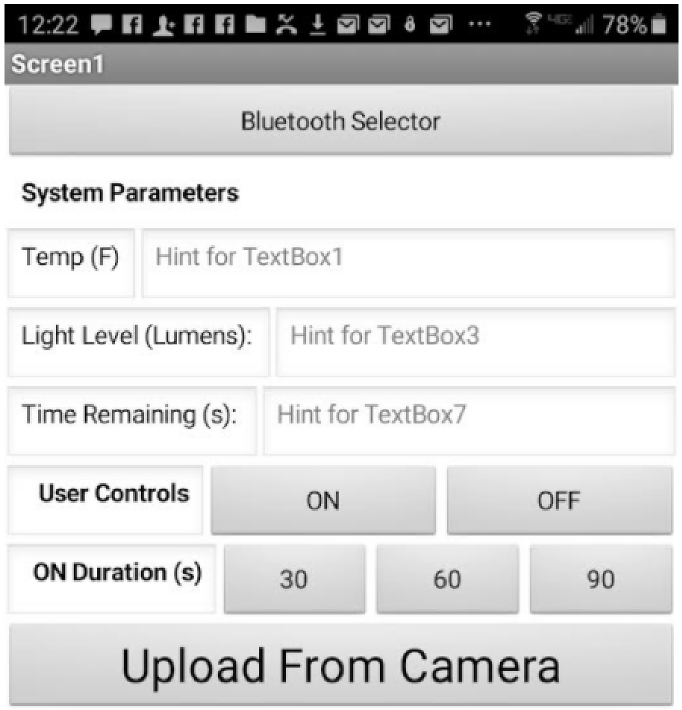
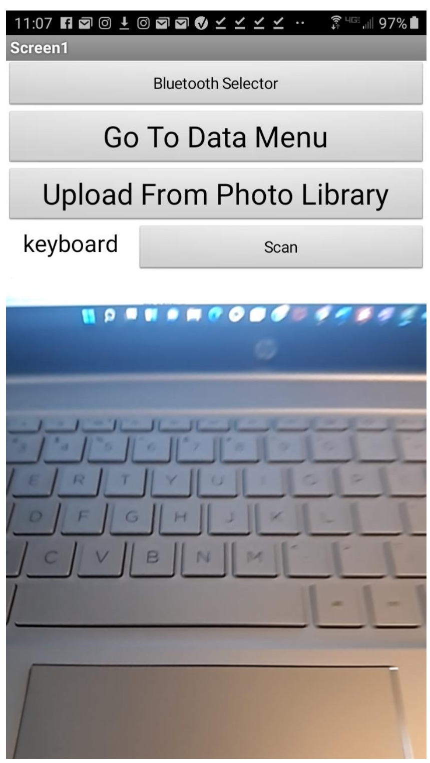
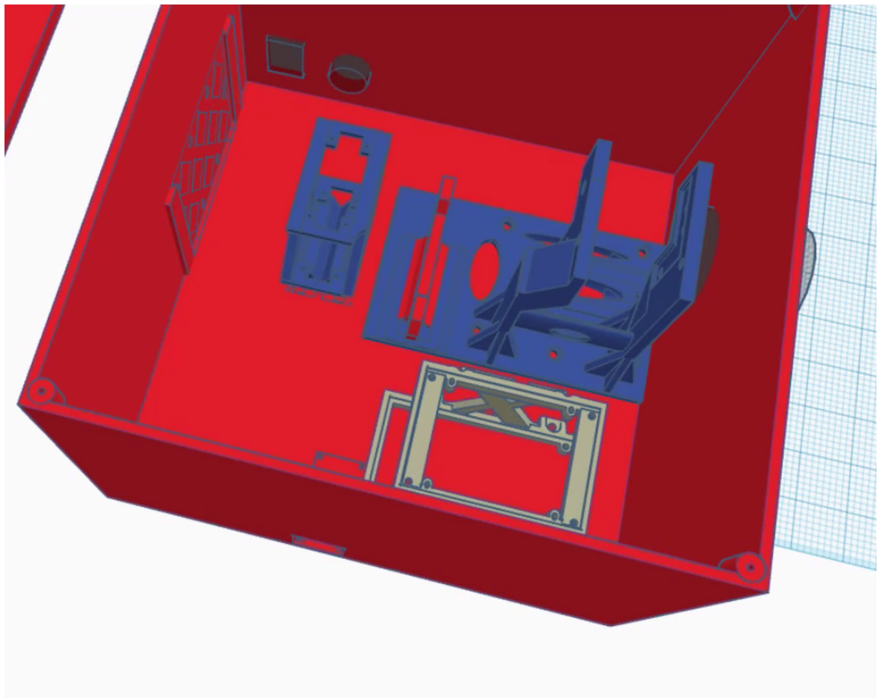


Figure 33: Android app image upload menu



5.1.3 If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor.

Figure 34: 3D Printed enclosure layout with mounting locations



5.1.4 If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors.

See figure 34 with the two connector ports on the top left and one port on the bottom of the enclosure.

5.1.5 All power supplies in the system must be at least 65% efficient. All power supplies in the system must be at least 65% efficient.

The DAC block (4.1.DAC) uses a power supply with 84% efficiency [1].

The 5V Arduino Power Supply (4.5.Arduino Power Supply (5V)) uses a power supply with 80% efficiency [2].

Together, these blocks combine for a total system efficiency of 67%, as the blocks are integrated in series.

5.1.6 The system may be no more than 50% built from purchased 'modules.'

Project block	Statement
Users' Interface Champion: Alex Greiner	The users' interface contains an Android phone APP, the APP was entirely built from self produced code. While a packaged developer tool was used to assist in making the code, this does not constitute a prebuilt module in the final system.
Image Processor Champion: Alex Greiner	This block is a module that was integrated into the app. Thus, the data base the image result is pulled from is prebuilt, but the app layout and user interface options are self produced. Therefore, this block is approximately 50% prebuilt.
OLED Display Champion: Nathan Raschkes	The OLED Display block contains circuitry components such as a 1K Ohm resistor, capacitor, NPN transistor and a 1N4007GU (diode). Likewise, an LED, Arduino Uno, temperature sensor and LCD display were also used to verify this specific block. This illustrates that the block didn't come pre-made through purchases online and that 50% of the parts weren't bought through the internet.
Laser System Champion: Yuhao Su	The Laser System block includes an AC/DC switching power supply, a motor driver, a galvanometer, and a laser source. All of the modules are purchased as needed. However, the wiring of the modules, adjusting the position of the mirrors on the galvanometer and the emitted laser dot, the design of the way the galvanometer are mounted, and the laser source are finished by the responsible champion. Therefore, at least 50% of the block is done without purchase.
Arduino Power Supply (5V) Champion: Greg Stapley	For this section we have just a few parts. 1. Converter (purchased) 2. 120 V wire (scavenged from old tools) 3. 120 V plug (scavenged from broken tools) 4. Power switch (scavenged from broken roomba) 5. USB adaptor (scavenged from a broken USB cord) 6. Mounting system for the enclosure (designed and printed by me) Therefore less than 50% of the block is store purchased.
Arduino Mega Champion: Greg Stapley	For this block the hardware is a complete pre-built microcontroller. The code integrates a prebuilt galvanometer controller, which was modified for our system requirements. Thus, the code is self-made. The total block is 20% prebuilt hardware and 80% self-built software.

Sensor Block Champion: Nathan Raschkes	The sensor block involves a buzzer, Arduino Nano, ultrasonic sensor and a 128x64 OLED. All of these components are parts that I already own and that I had extra copies of in my home, hence, this showcases that this particular block didn't come pre-made through purchases online and that 50% of the parts weren't bought via the internet.
DAC Champion: Yuhao Su	The DAC (Digital to Analog Converter) block contains some purchased chips and electric components. The design of the circuit and wiring of all the devices are done by the responsible champion. 90% of this block is not pre purchased.

5.2.Auto Turn off

5.2.1Requirement

The system lets users define timeout durations of 30, 60, and 90 seconds.

5.2.2.Testing Processes

1. Turn on the power switch for the system
2. Open the GUI
3. Connect the GUI to the system's bluetooth using the bluetooth selector button in the GUI
4. Select one of the three auto timeout durations (30, 60, or 90 seconds) through the GUI.
5. On the GUI, select "on" to project an image with the system.
6. Leave the system idle for the selected duration.

5.2.3.Testing Evidence

Requirement verification link:
https://drive.google.com/file/d/1_9-zM-N2hlHXzL__BXTIIghnpPaWWsuU/view?usp=sharing

5.3.Upload Image

5.3.1.Requirement

The system lets the user control the system via a user scanned image from the user interface.

5.3.2.Testing Processes

1. Turn on the power switch for the system
2. Open the GUI
3. Connect the GUI to the system's bluetooth using the bluetooth selector button in the GUI
4. Select the "Upload From Camera" option
5. If prompted, allow the GUI to use the access the Android camera
6. Point the camera to view the desired scan image
7. Press the "Scan" button on the GUI

8. Select “Go To Data Menu”
9. Select “on” to project an image with the system

5.3.3.Testing Evidence

Requirement verification link:

https://drive.google.com/file/d/14ZEGbFJ-xuwxt-uDdcTe56UqEva-YfU1/view?usp=sharing

5.4.User Control Option

5.4.1Requirement

The system lets the user control the system using control knobs to adjust the X and Y location of the image.

5.4.2.Testing Processes

6. Use the laser painter to display an image
7. Turn the x-axis potentiometer clockwise
    a. Verify the image translated to the left
8. Turn the y-axis potentiometer counterclockwise
    a. Verify the image translated to the right
9. Turn the y-axis potentiometer clockwise
    a. Verify the image translated up
10. Turn the y-axis potentiometer counterclockwise
    a. Verify the image translated downwards

5.4.3.Testing Evidence

Requirement verification link:

https://drive.google.com/file/d/1vsVyXq-rh0qleBObLGOhxnzDcurIiULx/view?usp=sharing

5.5.Overheat Protection

5.5.1Requirement

The system will turn on an intake and an exhaust fan if the internal components are greater than or equal to 75 +/- 5 degrees fahrenheit.

5.5.2.Testing Processes

1. Use the laser system to display an image
2. Use a temperature measurer to measure the temperature at the thermistor location
3. Verify that the intake and exhaust fans turn on when the temperature gun reads 75 +/- 5 degrees fahrenheit or greater.

5.5.3.Testing Evidence

Requirement verification link:

https://drive.google.com/file/d/1Bw7CmGcAk9x_EqZBeRZZxnT8lclcyuUG/view?usp=sharing

5.6.Not Blind People

5.6.1.Requirement

A receptor will run parallel to the laser beam and the laser will turn off if an object crosses the laser system's path.

5.6.2.Testing Process

1. Power on the laser system.
2. Turn the laser on with the GUI.
3. Move an object between the laser system and the surface the laser is projecting onto.
4. Verify the laser turned off when a surface passed the projecting surface.

5.6.3.Testing Evidence

https://drive.google.com/file/d/1Ng1-vjS4CBcC38fxj0d5FcbybQn2iEP2/view?usp=sharing

5.7. Display a word

5.7.1Requirement

The system will display an identifiable and readable word.

5.7.2.Testing Processes

1. Turn on the power of the system
2. Using the GUI, connect to the system bluetooth
3. On the GUI, select "Upload From Camera"
4. On the GUI, select "scan"
5. On the GUI, select "Go To Data Menu"
6. Ensure the distance sensor is not obstructed measured from the start up distance
7. On the GUI, select "ON"
8. Verify the word is identifiable and readable as determined by the course evaluator.

5.7.3.Testing Evidence

Requirement verification link:

https://drive.google.com/file/d/1mVk7rtLg72z4PWercqZz3OVl1pdG9_Tx/view?usp=sharing

5.8.Portable

5.8.1Requirement

The system is within the following parameters:

- The system is less than 30 pounds
- The system is less than 1.5 cubic feet
- All connectors are removable

5.8.2.Testing Processes

1. Use a scale to weigh the laser system excluding all external cables
2. User a measuring tape to measure the length, width, and height of the laser system in feet
    a. Multiply the length, width, and height to get the total cubic feet of the laser system
3. Verify that the power cable can be removed from the laser system

5.8.3.Testing Evidence

Figure 35: Laser Painter power connector

Figure 36: Laser Painter system weight (2.094Kg)

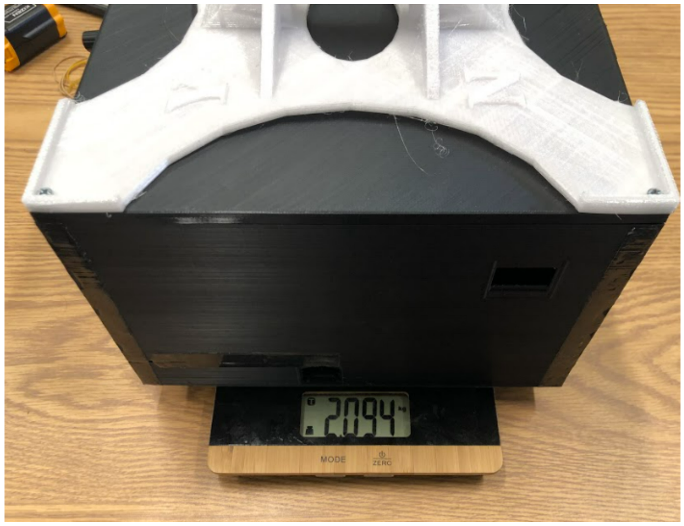


Figure 37: Laser Painter system depth (10 inches)

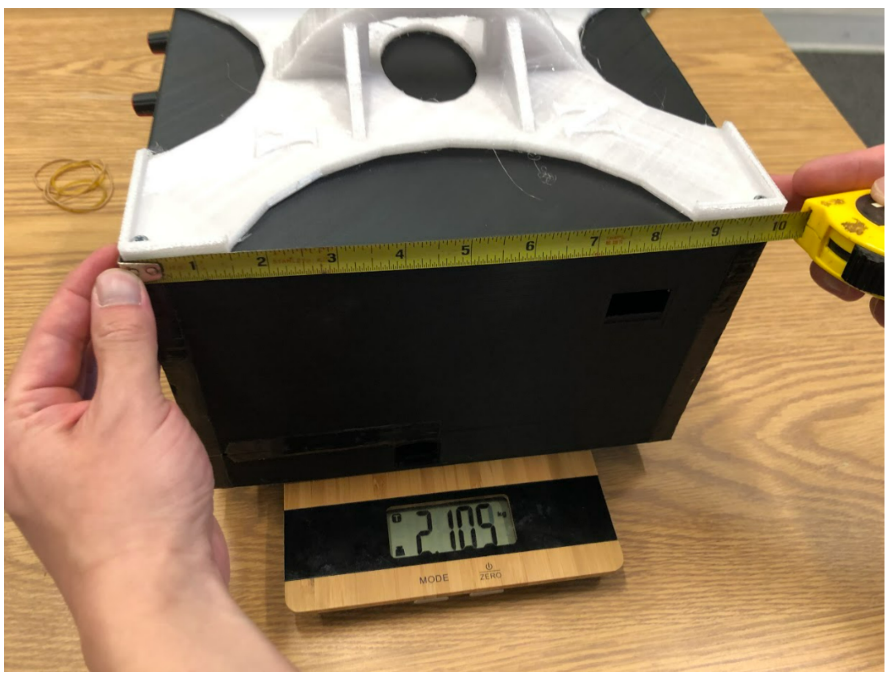


Figure 38: Laser Painter system height (7.5 inches to handle)

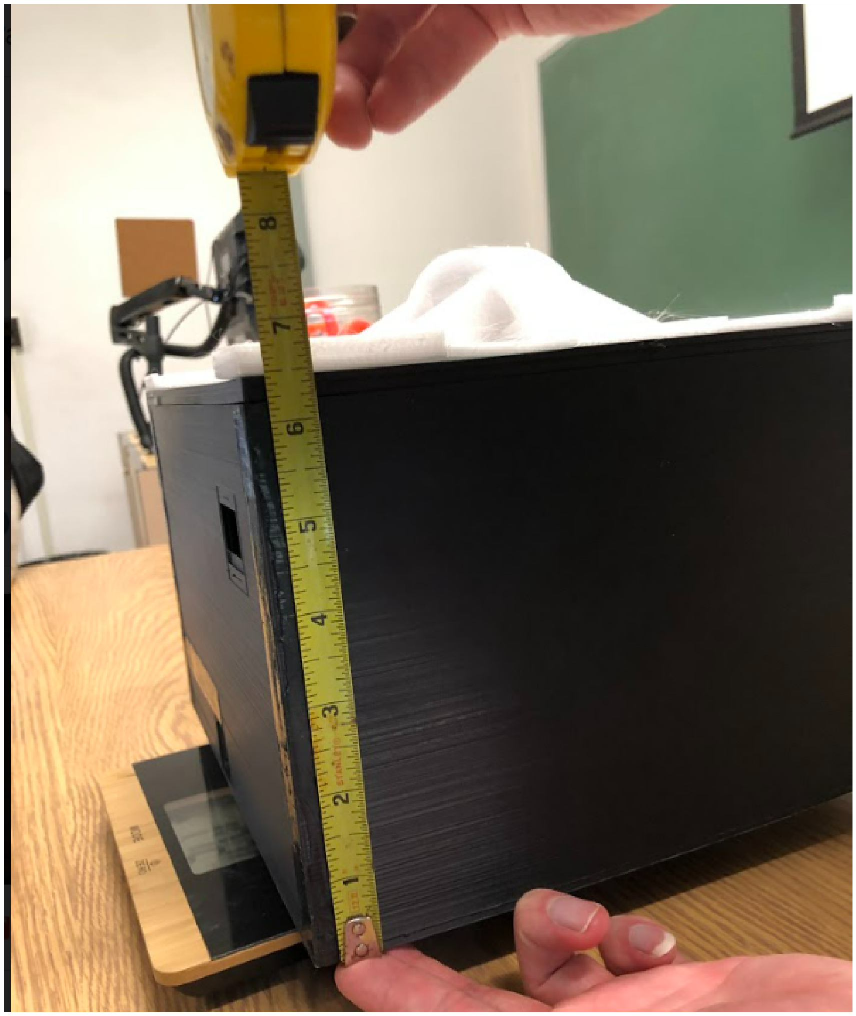
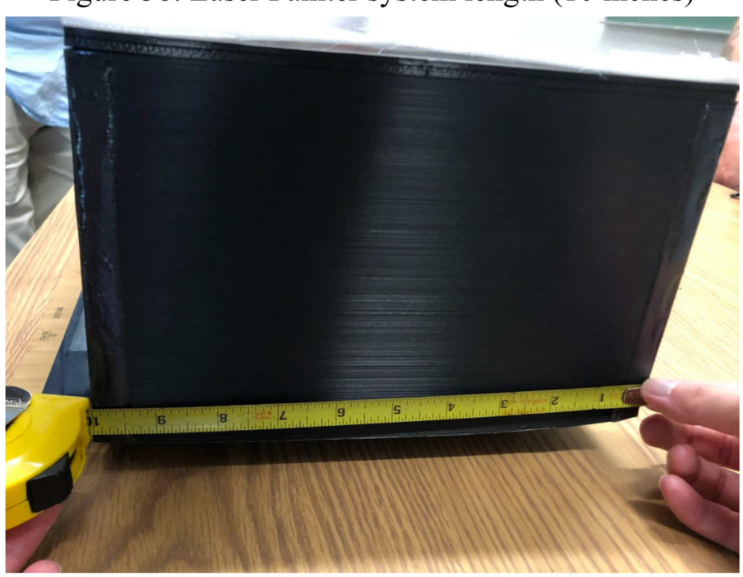


Figure 38: Laser Painter system length (10 inches)



5.9.System Data

5.9.1Requirement

An OLED display will show the following system parameters:

- The display distance in centimeters +/- 10 centimeter
- Internal temperature in fahrenheit +/- 5 degrees
- Total system run time since start up (+/- 2 seconds) for at least 100 seconds

5.9.2.Testing Processes

1. Use the laser painter to display an image
2. Use a tape measure to measure the distance between the laser system and the display surface.
3. Use a temperature meter to measure the temperature at the internal thermistor
4. Uses a lux meter to measure the light level at the photoresistor.
5. Verify the measurements from steps 2-4 are within the specified range displayed on the OLED

5.9.3.Testing Evidence

Requirement verification link:
https://drive.google.com/file/d/1Qfle8LlxwGv_jY3nyCFmr-A-la7gy1RX/view?usp=sharing

5.10.References and File Links

[1] "5.2US $: 100 240VAC input voltage dual output +15V 15V PSU universal switching power supply 15W: Dual output: Switch powerswitching power supply - aliexpress," *aliexpress.com*. [Online]. Available: https://www.aliexpress.com/item/32777180206.html. [Accessed: 06-Mar-2022].

[2] "GP," *Amazon*, 2011. [Online]. Available: https://www.amazon.com/gp/product/B076K8HT8Z/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&th=1. [Accessed: 06-Mar-2022].

5.11.Revision Table

Date	Name	Description
4/21/2022	Alex Greiner	- Added final system verification videos/photos
4/17/2022	Alex Greiner	- Added system requirement tests

3/27/2022	Yuhao Su	- Modified formating
3/6/2022	Alex Greiner	- Added verification videos for 5.2 and 5.3
3/6/2022	Nathan Raschkes	- Added to section 4 for the sensor and OLED blocks. Furthermore, added to section 5.1.6.
3/6/2022	Yuhao Su	- Added 5.1.1 and parts of 5.1.2 and 5.1.6.
3/6/2022	Alex Greiner	- Added testing requirements and verification methods for requirements 5.2 and 5.3

6.1 Future Recommendations

6.1.1. Technical recommendations

1. The Arduino code in 6.3 includes several functions to draw complex figures and moving photos, such as a robot and moving text. Our project was limited to only displaying a word due to the program memory on the Arduino nano. We recommend upgrading to a microcontroller with more than 32kB of program memory. The Arduino Mega has 256kB of program memory [1], but you should make sure that it has the proper clock pins to drive the DAC block.
2. The OLED display and the Android application take approximately 0.25 seconds to process in the Arduino nano. Thus, the system does not display an image during this processing time. The result is that the image flashes and is of poor resolution. To fix this, you may be able to call the image "display" function *Drawing::drawString(str,-w/2, 0);* within the OLED and bluetooth functions in the Arduino. Or, several microcontrollers can be used for each function. These microcontrollers would all need a communication method, such as bluetooth, to send data to the other functions.
3. Add an on/off switch or button to the enclosure to turn the laser on and off. Having the only method to turn the laser on/off through an Android application using a wireless bluetooth module creates a weak point in the entire design in regards to functionality. If the bluetooth module loses connection, or the user does not have an Android, the system is not functional. The physical on/off switch can be wired into a digital input on the Arduino, and use the same function to turn on the laser as the Android application uses.
4. The sensors are jumpered to the PCB in our design because the PCB is small and the through holes of the sensors on the enclosure are far from the location of the PCB (*see Figure 43: Case Layout*). To fix this, you might want to design a bigger PCB so that it has enough space to solder the sensors on the PCB directly. Then, design the through holes on the enclosure based on the placement of the sensors on the PCB and attach the PCB on the inside of the enclosure via the sensor through holes. This will help to save space inside of the enclosure and allow more airflow through the enclosure for better interior cooling.

6.1.2. Global impact recommendations

1. Photosensitive epilepsy is most common within the 5Hz to 50Hz range [2].Currently, the project is set to show the image 5 times every quarter second, or 20Hz. Thus, the project displays an image at the most common photosensitive epilepsy range. To fix this, it may be necessary to integrate several microntrontrollers. This should increase the program's execution rate of the laser display. Choose a microcontroller that can execute this portion of the program at a rate greater than 50Hz.

2. Lasers contain small traces of hazardous materials such as lead and toxic semiconductors[3]. In order to be more environmentally friendly, a good approach is to recycle the components in places that are known to reuse electronic parts.

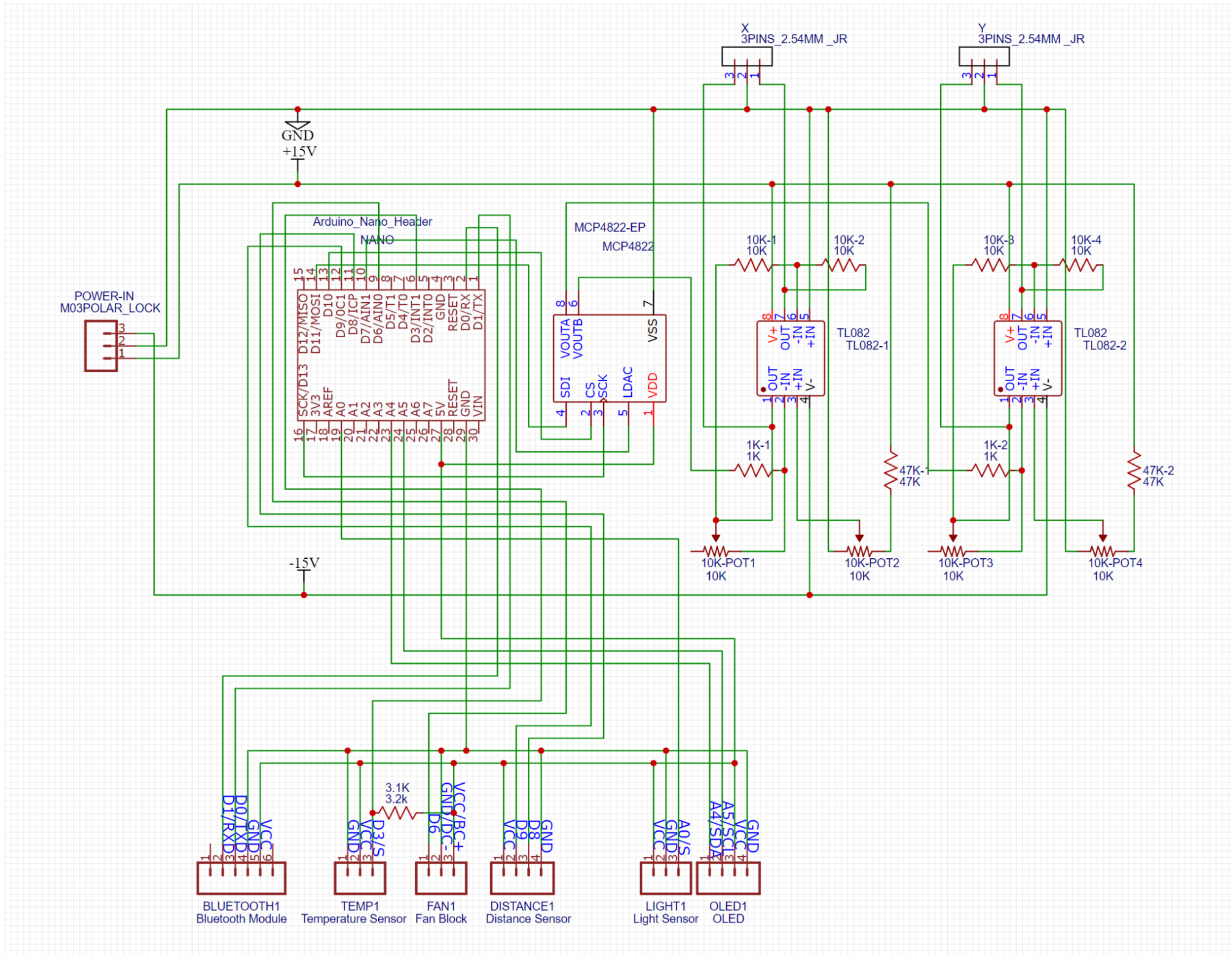
6.1.3. Teamwork recommendations

1. Operating in a hybrid model allows for flexibility and regardless of the distance, the entire team can work remotely on the technical documents and design the necessary schematics which will be needed for the construction phase. This work model worked well because we had people who were commuting from far away. By doing so, this permits the ability to focus on the building of the project in person [4].
2. Having a timeline helps to keep things organized by ensuring that everything gets completed on time. Furthermore, it will make certain that you're on track and that you aren't falling behind. See section 1.4 for our team's timeline for the 2021/2022 capstone courses.
3. Establishing a group chat on a platform that everyone uses frequently and that they're all familiar with will be essential by providing a means of communication and any updates on the progress of the project. When a problem arises, you're able to contact your entire team very quickly and they'll be able to respond in a timely manner. See section 1.2 for our team's communication and protocols for more information.
4. Identifying each team members' strengths and weaknesses. This would permit the ability to complete the project faster by assigning the roles that each team member is good at. If someone isn't good at coding and doesn't enjoy it, logically speaking, it would make sense to give the role to someone on the team that is great at coding.

6.2 Project Artifact Summary with Links

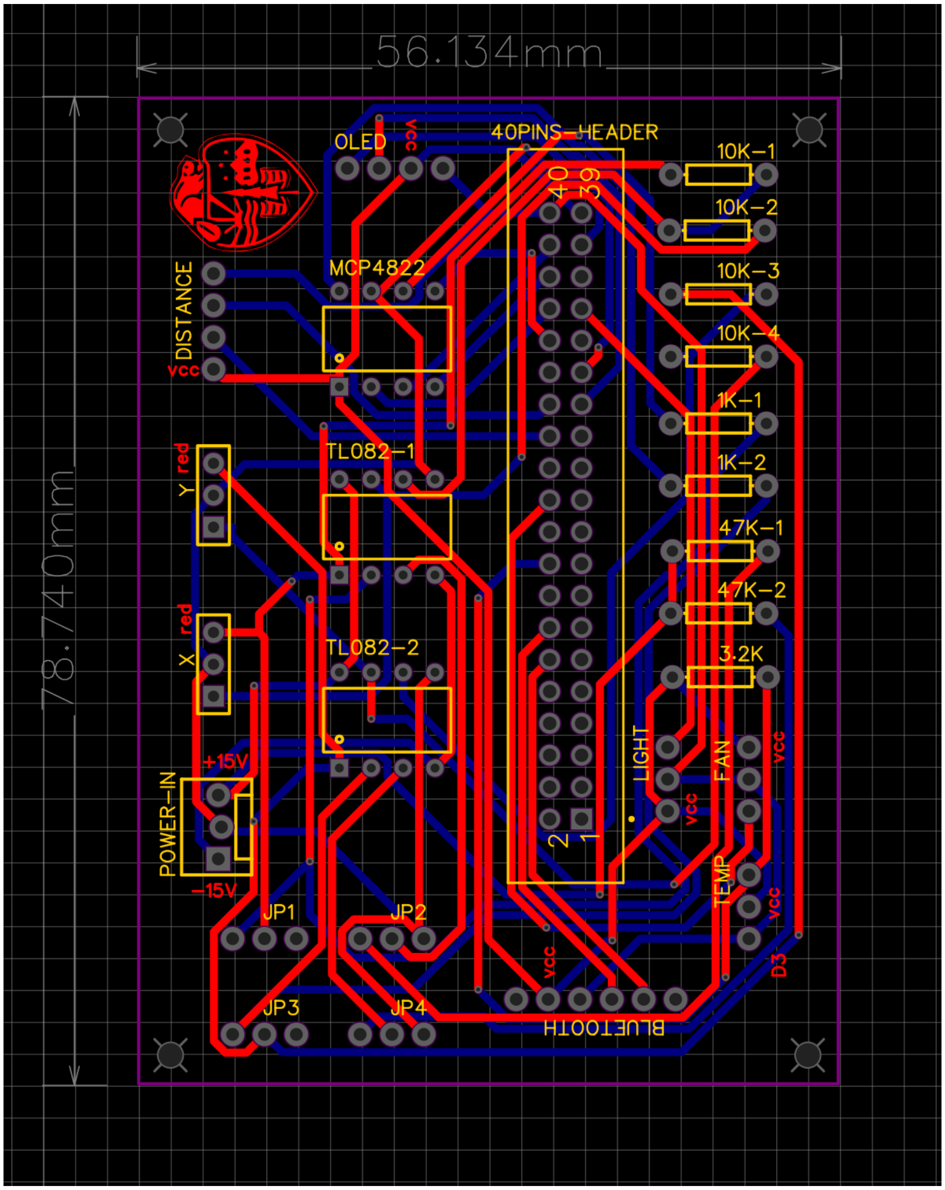
6.2.1. Schematic of the DAC and Sensor blocks

Figure 39: Schematic of DAC and Sensor



6.2.2. PCB layout (File Link)

Figure 40: PCB design



6.2.3. 3D Enclosure Layout ([File Link]())
All the measurements seen in Figure 41-49 are in inches.

Figure 41: Case Design_1

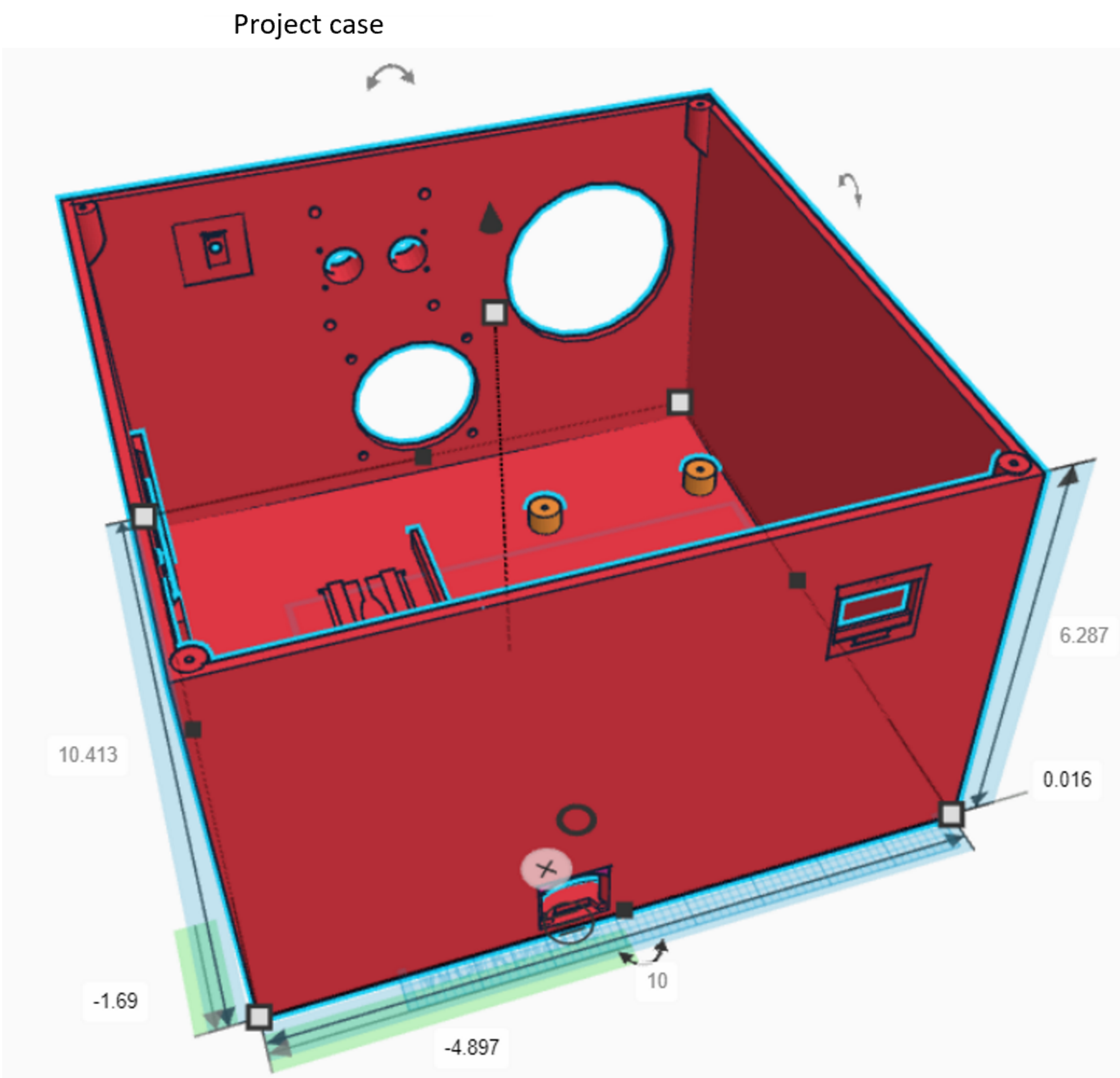


Figure 42: Case Design_2

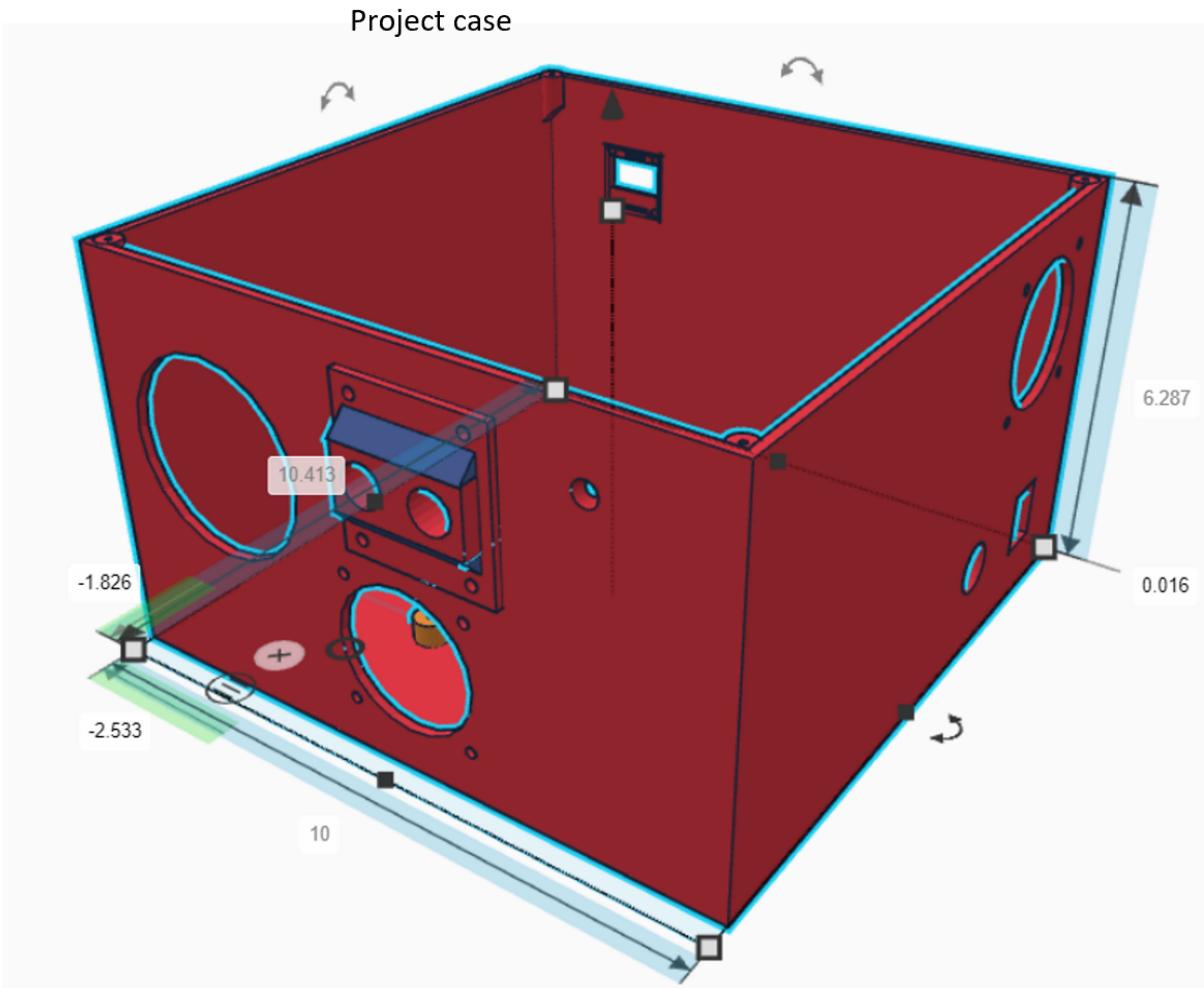


Figure 43: Case Layout

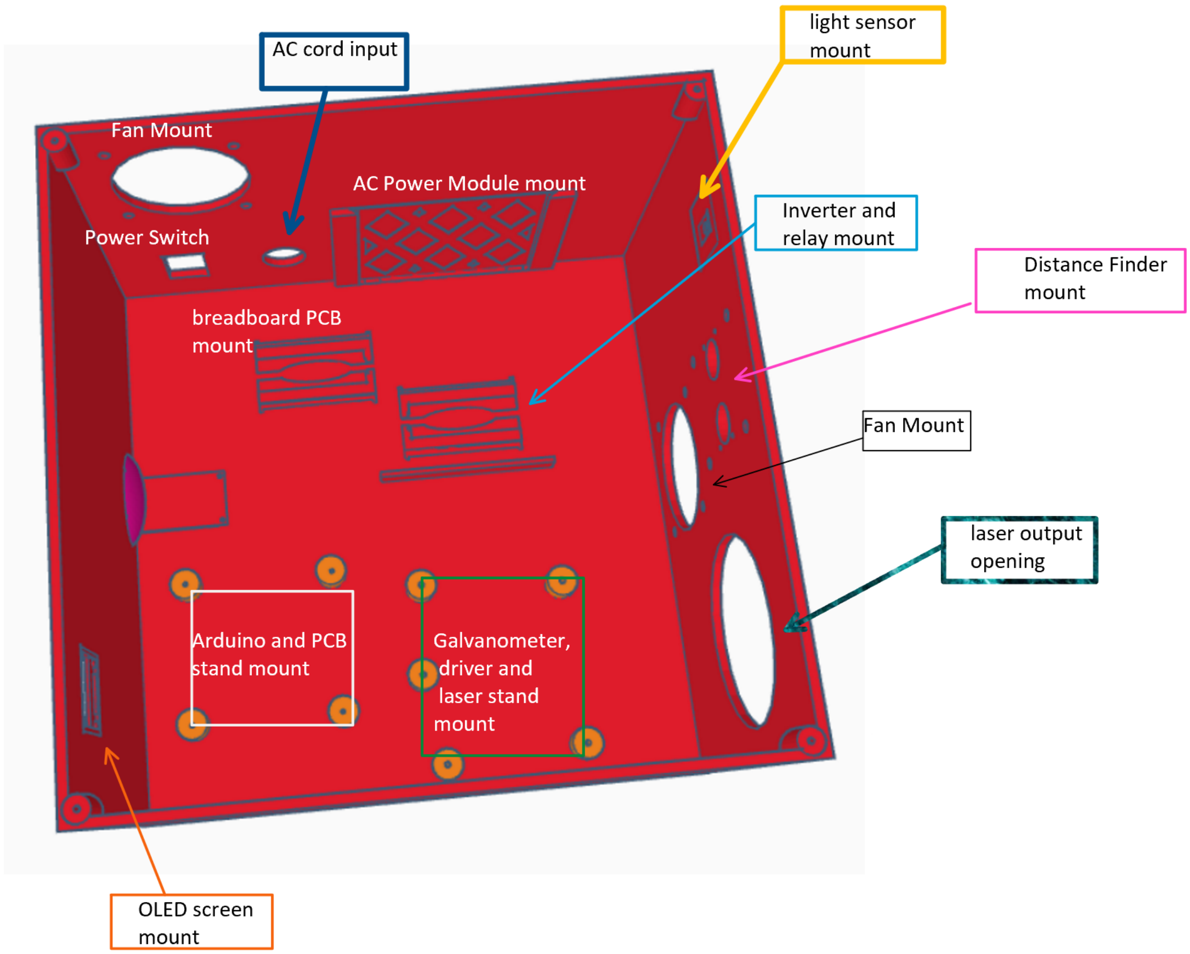


Figure 44: Breadboard PCB mount

Breadboard PCB mount

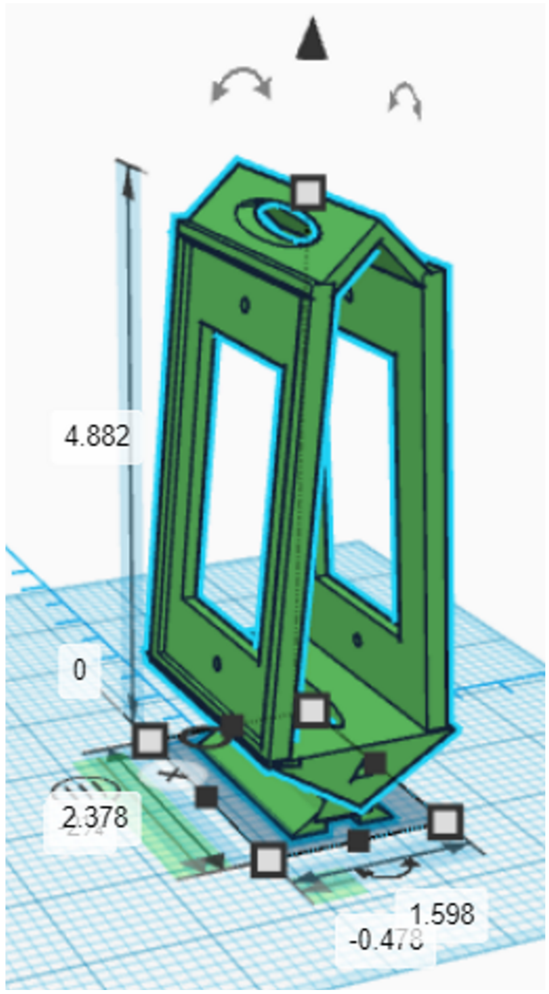


Figure 44: Inverter and relay mount

Inverter and relay mount

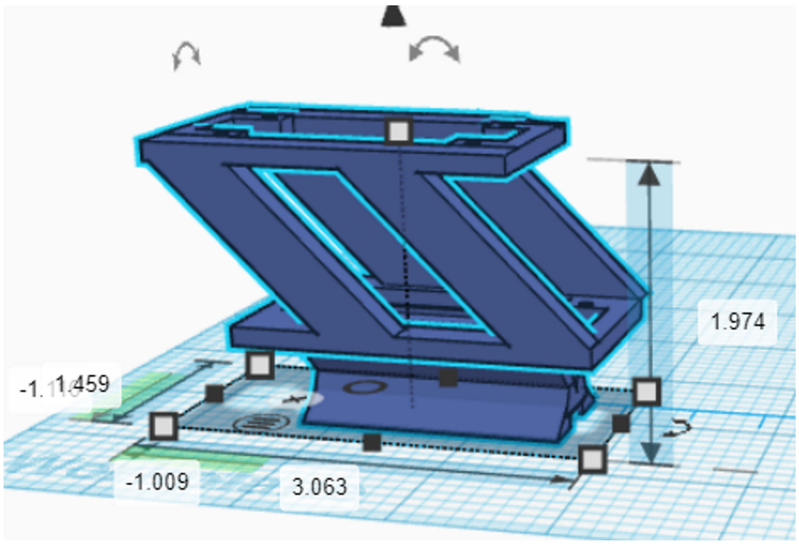


Figure 45: Laser Module mount

Laser Mount

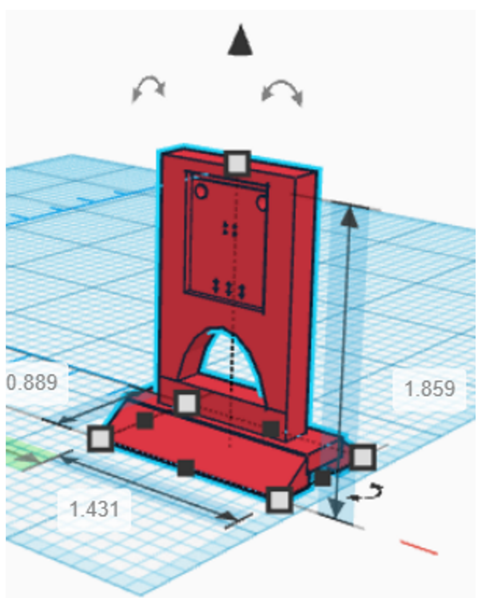


Figure 46: Galvo, laser and Driver mount

Galvo, laser and Driver mount stand

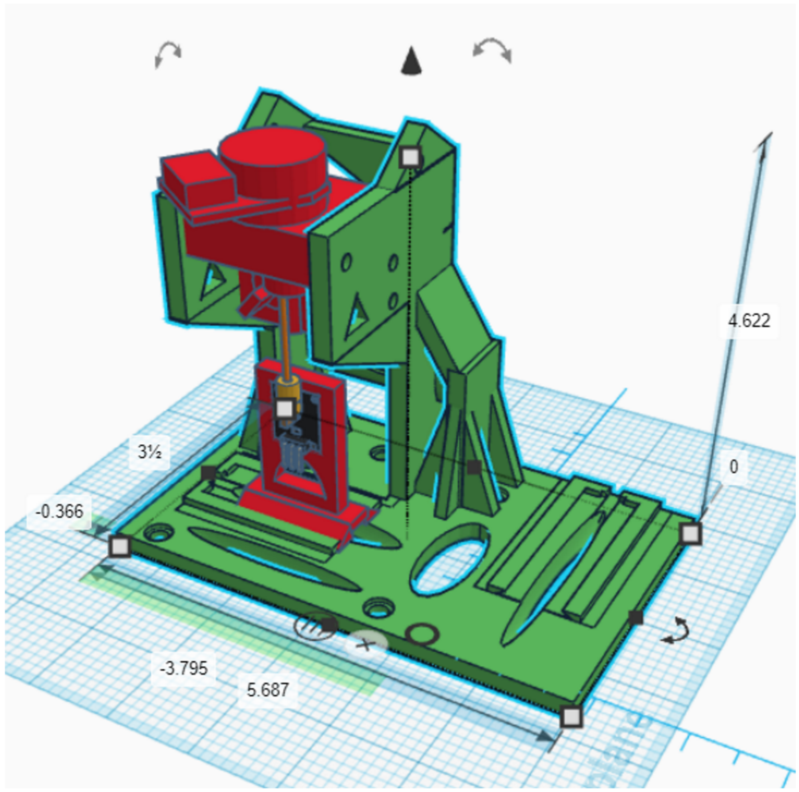


Figure 47: Galvo, laser and Driver mount

Power supply mount

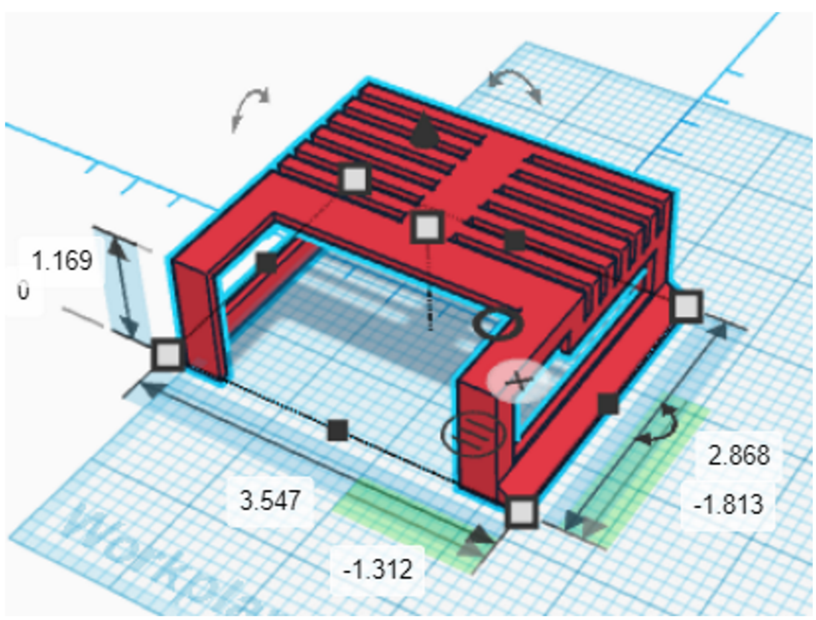


Figure 48: Mega and PCB mount stand

Mega and PCB mount stand

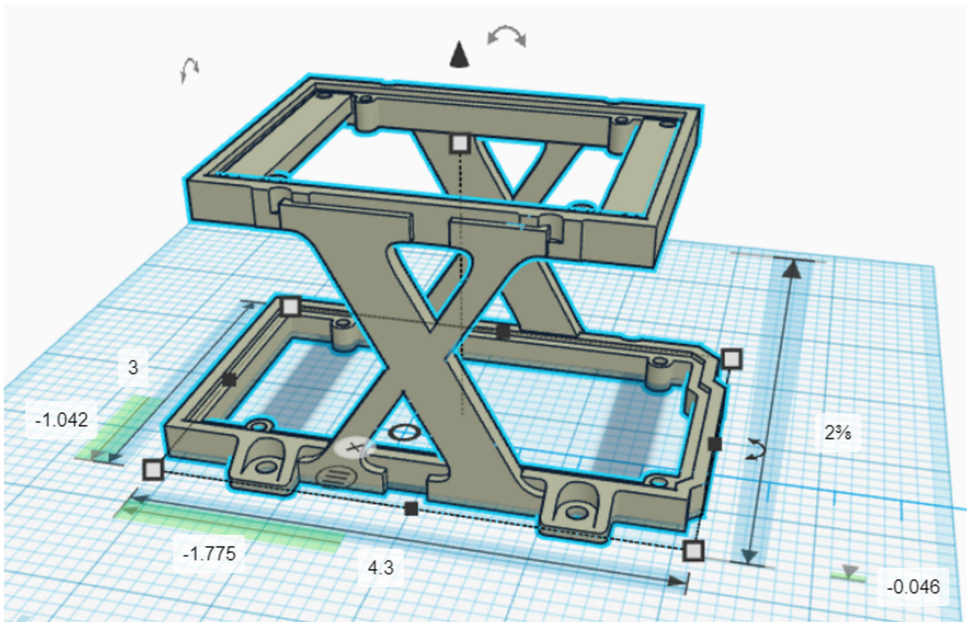


Figure 49: Handle attachment

Handle

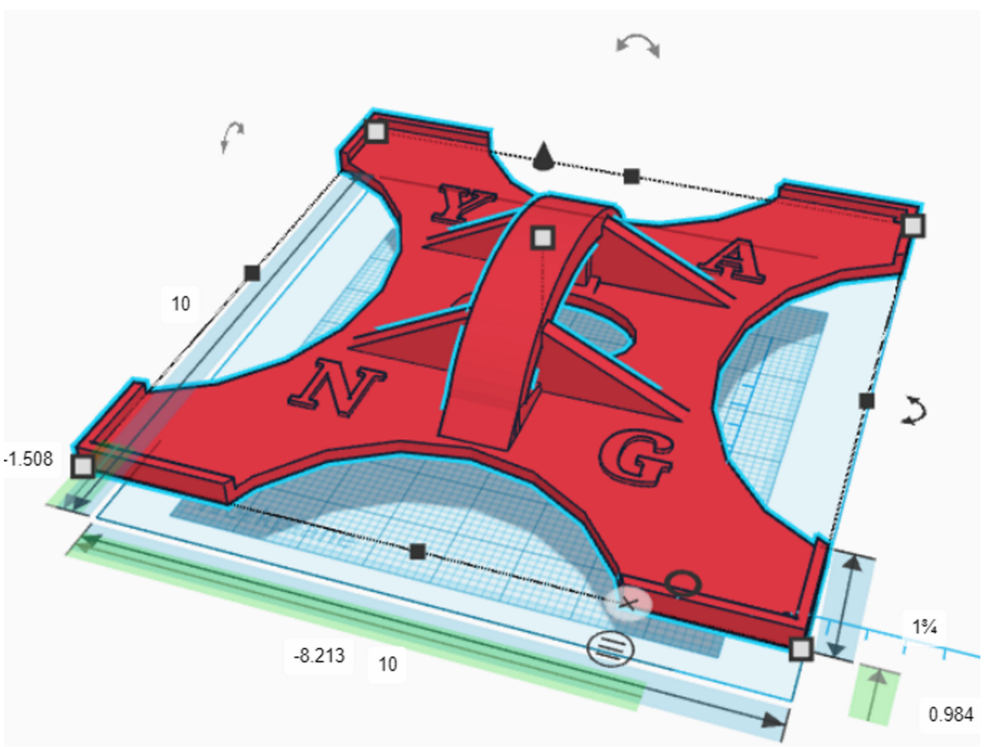
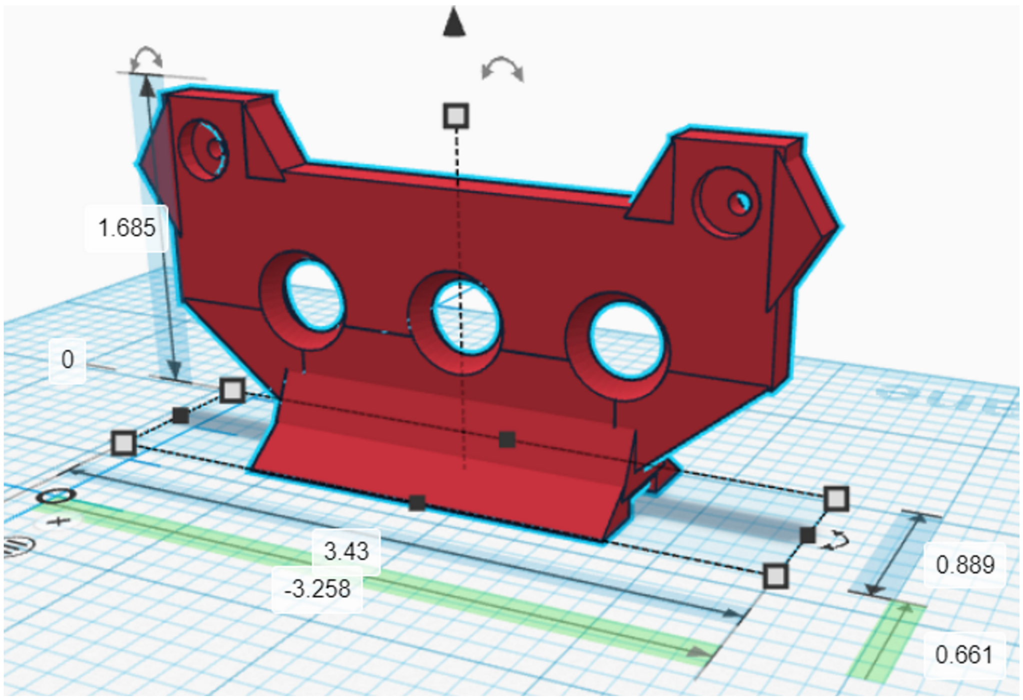


Figure 50: Galvo Driver Mount

Galvo Driver mount stand



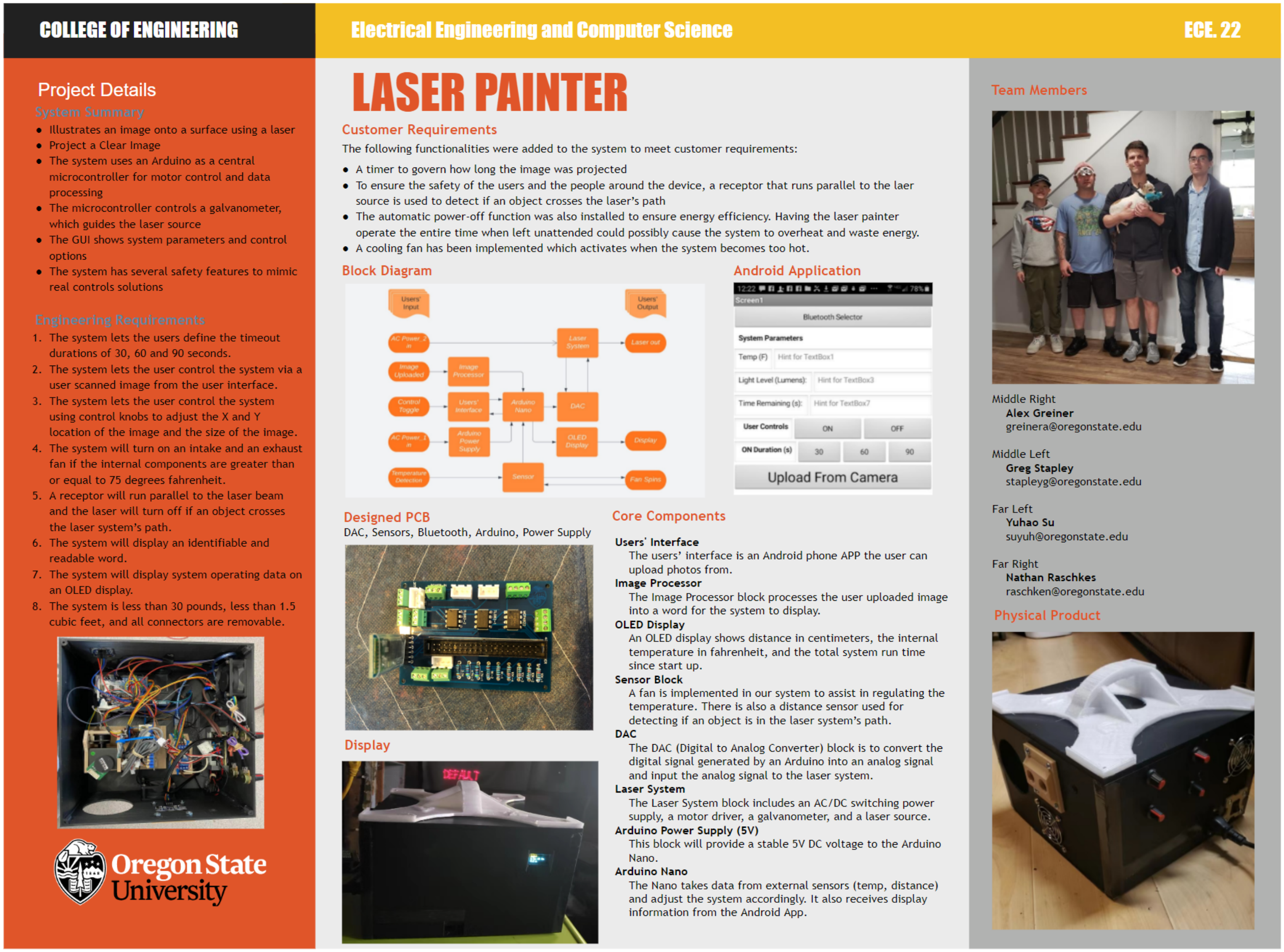
6.2.4. Code

[Arduino Code Link]

[Android Application Link]

6.3 Presentation Material (Poster Link)

Figure 51: Laser Painter (Group 22) Expo Poster



6.4 References

[1] R. Teja, “Electronics hub - latest free electronics projects and ...,” *Different Types of Memory on Arduino | SRAM, EEPROM, Flash*, 30-Jan-2021. [Online]. Available: https://www.electronicshub.org/types-of-memory-on-arduino/. [Accessed: 19-Feb-2022].

[2] G. F. A. Harding and P. F. Harding, “Photosensitive epilepsy and image safety,” Applied Ergonomics, vol. 41, no. 4, pp. 504–508, Jul. 2010. [Accessed: 28-April-2022].

[3] “Laser pointer,” *How Products Are Made*. [Online]. Available: http://www.madehow.com/Volume-7/Laser-Pointer.html. [Accessed: 28-April-2022].

[4] V. Garment, “6 benefits of implementing a hybrid working model in your organization,” Parallels Remote Application Server Blog - Application virtualization, mobility and VDI, 01-Jun-2021. [Online]. Available: https://www.parallels.com/blogs/ras/hybrid-working-model/. [Accessed: 28-Apr-2022].

6.5 Revision Table

Date	Name	Description
4/28/2022	Team	-Added in section 2.2 - Section 6 created - Added technical recommendations, global impact recommendations, teamwork recommendations, project artifact summary with links and presentation materials.