Automated Testing Station for Sensing Applications

Design Document

Team Number sdmay23-41
Client/Adviser: Moneim Ismail
Team Members/Roles:
Thomas McCoy: Team Organizer/Software Developer
Garth Anderson: LED PCBs Developer
Malvin Lim: Gas Regulation PCB Developer
Matthew Rief: CAD Design Developer
Team Email: sdmay23-41@iastate.edu
Team Website: https://sdmay23-41.sd.ece.iastate.edu/

Revised: 12/2/2022

Executive Summary

Development Standards & Practices Used

IEEE: Code of Ethics and Software Engineering Standards

ASME: Boiler and Pressure Vessel Code

IPC-2221 Standard in Circuit Board Design

Summary of Requirements

Functional requirements:

1. The device must be able to collect I-V, which is the reflected light from the device under testing (DUT).
2. The device can shine LEDs with different wavelengths desired by the user from the top and bottom of the DUT.
3. The device could provide a different testing environment for DUT by changing the type of air in between sensors and the DUT.

Resource requirements:

1. PCBs
2. Servos
3. Probes for the DUT
4. Box that can hold a vacuum and block out light.
5. Gas regulators/valves & tanks

UI requirements:

1. Provide tables of processed data
2. Easy to navigate
3. Gives option to view raw data

Applicable Courses from Iowa State University Curriculum

EE 333 - Electronics Systems Designs.

New Skills/Knowledge acquired that was not taught in courses

LabView programming.

Table of Contents

1 Team

1.1 Team Members

Thomas McCoy

Garth Anderson

Malvin Lim

Matthew Rief

1.2 Required Skill Sets for Your Project

PCB design principles

CAD software

Gas regulation principles

Software design principles.

1.3 Skill Sets covered by the Team

Software design principles - Thomas McCoy

PCB design principles - Garth Anderson and Malvin Lim

CAD software - Matthew Rief

Gas regulation principles - Malvin Lim

1.4 Project Management Style Adopted by the team

Waterfall design approach

1.5 Initial Project Management Roles

Thomas McCoy - Team Organizer / Software Development

Garth Anderson - PCB Research & Design

Malvin Lim - PCB Research & Design

Matthew Rief - CAD Designs

2 Introduction

2.1 Problem Statement

Our client needs a more efficient and automated way to test different photosensitive devices and how they respond to different wavelengths of light through a medium of different gasses. Currently, when testing these devices' capabilities, the process is manual, making it arduous, expensive, and time-consuming. We will solve this problem by automating the testing process and collection/interpretation of data.

2.2 Intended Users and Uses

User 1: Perovskite solar cells researcher

1. Key characteristics - Research on solar cells currently available in the market and improve the efficiency of the solar cell.
2. Needs related to the project - A more efficient way of testing the solar cell or solar panel.
3. How they might use or benefit from the product you create - They could use this project to do a test on the solar panel without any knowledge of operating the automated testing device.

User 2: Photodetector manufacturer

1. Key characteristics - Produces mass quantities of precise photodetectors that must adhere to specifications
2. Needs related to the project - Photodetectors from each manufacturing run should be tested to ensure quality of the product is consistent and meets specifications.
3. How they might use or benefit from the product you create - It would allow for the manufacturing process to get faster feedback on the quality of their process if they can quickly test units, and make adjustments to the process if needed.

User 3: Students

1. Key characteristics - Students attending the university that are studying photosensitive devices.
2. Needs related to the project - Needs the machine to be intuitive and flexible for testing devices.
3. How they might use or benefit from the product you create - Students can experiment with different devices and learn about how testing these types of devices works.

2.3 Requirements & Constraints

Functional requirements:

1. The device must be able to collect I-V, which is the reflected light from the device under testing (DUT).
2. The device can shine LEDs with different wavelengths desired by the user from the top and bottom of the DUT.
3. The device could provide a different testing environment for DUT by changing the type of air in between sensors and the DUT.

Resource requirements:

1. PCBs

2. Servos
3. Probes for the DUT
4. Box that can hold a vacuum and block out light.
5. Gas regulators/valves & tanks

UI requirements:

1. Provide tables of processed data
2. Easy to navigate
3. Gives option to view raw data

2.4 Engineering Standards

IEEE: Code of Ethics and Software Engineering Standards

ASME: Boiler and Pressure Vessel Code

IPC-2221 Standard in Circuit Board Design

3 Project Plan

3.1 Project Management/Tracking Procedures

Which of agile, waterfall or waterfall+agile project management style are you adopting? Justify it with respect to the project goals.

Our group will adopt the waterfall methodology due to the time constraints of this project being two semesters. It makes more sense in our mind to start with a waterfall approach. The first semester will primarily be dedicated to the design and procurement of required parts (PCBs, servos, etc.), followed by our device's construction and eventual implementation in the second semester. This methodology also follows more in line with the expectations of the client/advisor so far in our biweekly meetings.

What will your group use to track progress throughout the course of this and the next semester. This could include Git, Github, Trello, Slack or any other tools helpful in project management.

Our group will use the Git framework and ISU ECpE Git Repository for project management. We will also keep the team website up-to-date with any relevant group information, along with meeting minutes. Regular assignments and updates to complete assignments for the upcoming weeks will be managed via discord.

3.2 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project.

Design:

- Determine which of the shelf PCB components will work
- Design custom PCBs for functionality we are unable to procure
- Keep updated diagrams of the projected design as we refine sub components
- Decide which servo motors and other mechanical components will be suitable
- Design rough interface for the device to communicate with a labview program

Procurement:

- Order custom PCBs of our designs from a manufacturer
- Suitable testing chamber that can house our device, hold a vacuum, and will block ambient light
- Gas flow regulators
- Optoelectronic testing devices such as LEDs, Solar cells, Photo Diodes, etc
- DUT probes

Construction:

- Assemble the electrical and mechanical sub components
- Check features match project requirements
- Write software interface to control the device

Implementation/Testing:

- Load software interface and other code for subcomponents as needed onto the device
- Test device output vs expected results
- Make adjustments as needed and keep testing integration

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

What are some key milestones in your proposed project? It may be helpful to develop these milestones for each task and subtask from 2.2. How do you measure progress on a given task? These metrics, preferably quantifiable, should be developed for each task. The milestones should be stated in terms of these metrics: Machine learning algorithm XYZ will classify with 80% accuracy; the pattern recognition logic on FPGA will recognize a pattern every 1 ms (at 1K patterns/sec throughput). ML accuracy target might go up to 90% from 80%.

In an agile development process, these milestones can be refined with successive iterations/sprints (perhaps a subset of your requirements applicable to those sprints).

Design Milestones:

- **Design circuit schematic and PCB which pass KiCad DRC**
- **Select a servo motor based on size of PCB**
- **Make final parts list with projected cost**
- **General plan for labview program**

Procurement Milestones:

- **Order PCB**
- **Obtain a box that meets the requirements for the device**
- **Obtain gas regulators, probes, and photosensitive device**

Construction Milestones:

- **Solder parts to PCB**
- **Attach PCB to motor**
- **Assemble PCB, motor, gas regulators and probes within the box**
- **Finalize software interface to output desired data**

Testing Milestones:

- **Software attached to device and outputs data as expected**
- **Calculate expected results and achieve 90% accuracy compared to device output**
- **Make any necessary hardware or software modifications**

3.4 Project Timeline/Schedule

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

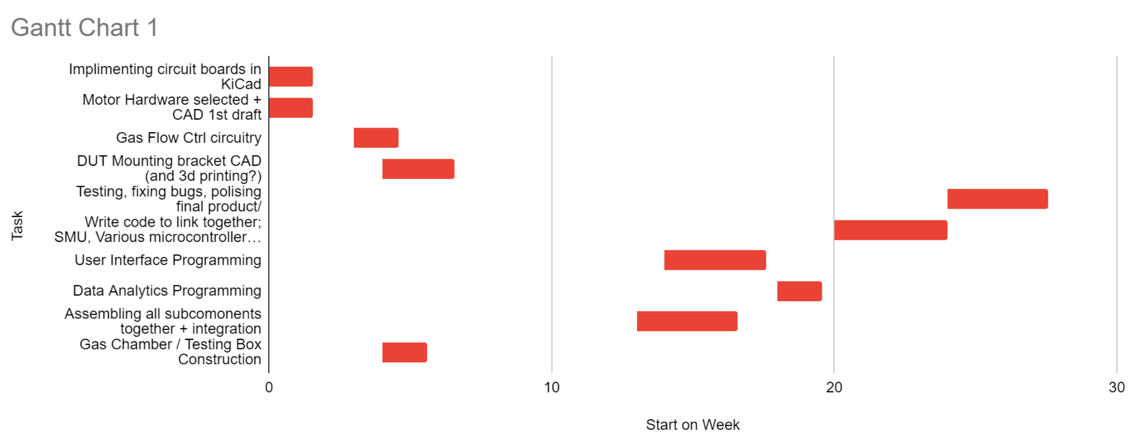
• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Project schedule/Gantt chart can be adapted to Agile or Waterfall development models. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.

	Task	Start date	End date
2	Implimenting circuit boards in KiCad	Oct-17	Oct 28
3	Motor Hardware selected + CAD 1st draft	Oct 17	Oct 28
4	Gas Flow Ctrl circuitry	Nov 7	Nov 18
5	DUT Mounting bracket CAD (and 3d printing?)	Nov 14	Dec 2
6	Testing, fixing bugs, polising final product/	Apr 3	Apr 28
7	Write code to link together; SMU, Various microcontrollers controlling the device, User Program running on desktop.	Mar 6	Apr 3
8	User Interface Programming	Jan 23	Feb 17
9	Data Analytics Programming	Feb 20	Mar 3
10	Assembling all subcomonents together + integration troubleshooting	Jan 16	Feb 10
11	Gas Chamber / Testing Box Construction	Nov 14	Nov 25



3.5 Risks And Risk Management/Mitigation

Consider for each task what risks exist (certain performance target may not be met; certain tool may not work as expected) and assign an educated guess of probability for that risk. For any risk factor with a probability exceeding 0.5, develop a risk mitigation plan. Can you eliminate that task and add another task or set of tasks that might cost more? Can you buy something off-the-shelf from the market to achieve that functionality? Can you try an alternative tool, technology, algorithm, or board?

Agile projects can associate risks and risk mitigation with each sprint.

There is a risk when making a circuit on a PCB, as any mistake could destroy the component on the circuit. The first risk is that when soldering components onto the PCB, we might make a mistake that might cause the PCB to not work as we want. So, we should order more of the PCB before we start soldering to prevent us from paying an unnecessary processing fee for the manufacturer to send us a new PCB. Then another risk is when we make a microcontroller for our circuit. Building a microcontroller for our project could save us some cost from buying a ready-made microcontroller. However, there is a risk in building the microcontroller as the component for making the microcontroller is fragile and hard to solder onto the PCB. Therefore, if we cannot find any way to build our microcontroller, we could get a ready-made microcontroller which is called Arduino Uno, that would cost around 25 dollars each.

3.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in the total number of person-hours required to perform the task.

1	Task	Start date	End date
2	Implimenting circuit boards in KiCad	Oct-17	Oct 28
3	Motor Hardware selected + CAD 1st draft	Oct 17	Oct 28
4	Gas Flow Ctrl circuitry	Nov 7	Nov 18
5	DUT Mounting bracket CAD (and 3d printing?)	Nov 14	Dec 2
6	Testing, fixing bugs, polising final product/	Apr 3	Apr 28
7	Write code to link together; SMU, Various microcontrollers controlling the device, User Program running on desktop.	Mar 6	Apr 3
8	User Interface Programming	Jan 23	Feb 17
9	Data Analytics Programming	Feb 20	Mar 3
10	Assembling all subcomonents together + integration troubleshooting	Jan 16	Feb 10
11	Gas Chamber / Testing Box Construction	Nov 14	Nov 25

In terms of weeks and working hours that is

Task	Start on week	Duration (weeks)	In terms of hours per member (5 project hrs/week)	Assuming average of 2 members dedicated per project
Implimenting circuit boards in KiCad	0	1.571428571	7.857142857	15.71428571
Motor Hardware selected + CAD 1st draft	0	1.571428571	7.857142857	15.71428571
Gas Flow Ctrl circuitry	3	1.571428571	7.857142857	15.71428571
DUT Mounting bracket CAD (and 3d printing?)	4	2.571428571	12.85714286	25.71428571
Testing, fixing bugs, polising final product/	24	3.571428571	17.85714286	35.71428571
Write code to link together; SMU, Various microcontrollers controlling the device, User Program running on desktop.	20	4	20	40
User Interface Programming	14	3.571428571	17.85714286	35.71428571
Data Analytics Programming	18	1.571428571	7.857142857	15.71428571
Assembling all subcomonents together + integration	13	3.571428571	17.85714286	35.71428571
Gas Chamber / Testing Box Construction	4	1.571428571	7.857142857	15.71428571

We had made estimates that on average our team members would be able to dedicate 5hrs of deliberate work to the project per week (1 hr per weekday). From there, members had decided which projects would likely be handled by who and made estimates when we would be able to start and comfortable deadlines for that project.

3.7 Other Resource Requirements

Identify the other resources aside from financial (such as parts and materials) required to complete the project.

Resource requirements:

1. **PCBs & components**
2. **Servos**
3. **Probes for the DUT**
4. **Box that can hold a vacuum and block out light.**
5. **Gas regulators/valves & tanks**

UI requirements:

1. **Provide tables of processed data**
2. **Easy to navigate**
3. **Gives an option to view raw data**

4 Design

4.1 Design Context

4.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

List relevant considerations related to your project in each of the following areas:

Area	Description	Examples
Public health, safety, and welfare	Our project could affect companies that sell products with solar cells and the customers of those companies, since our project can be used to test solar cells.	Our product may help producers test and create more efficient solar cell devices, which would be beneficial for public health by potentially reducing the use of other, less clean sources of power.
Global, cultural, and social	The communities that our project relates to the most are middle or upper class communities in developed nations, since these are the communities that have access to solar cell technologies. These communities may be looking for ways to use power more efficiently, which is reflected very well in our project since our project could be used to test the efficiency of solar cells.	A middle class family in Iowa may be looking for a way to use cleaner energy in their home. They decide to install solar panels, which have solar cells that were tested by our project. In this example, our project was beneficial for this community and reflected their value for clean energy use.
Environmental	Our project could have effects on the energy usage in communities that implement solar energy. This may change how environmental resources used for creating energy in that community are consumed.	Decreased use of nonrenewable energy sources as a result of increased use of solar energy.
Economic	Our product could affect the solar energy market. Our project could potentially provide a cheaper way for testing solar cells, which could have several cascading effects on the solar market and its consumers.	Cheaper solar cell testing could lead to cheaper manufacturing of solar energy cells. This could lead to decreased cost of solar energy cells, increased demand for solar energy cells, and increased job opportunities in the solar market.

4.1.2 Prior Work/Solutions

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

– If you are following previous work, cite that and discuss the **advantages/shortcomings**

– Note that while you are not expected to “compete” with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

Our Project's goal tackles similar objectives to some other products. An example would be this Solar Cell I-V Test System by Ossila

https://www.ossila.com/products/solar-cell-iv-test-system?_pos=1&_sid=1ad613d9c&_ss=r

Which accomplishes most of the goals of our project, but is lacking in a few key areas, the system provided by Ossila doesn't allow for gas/vacuum to be used, it is very expensive, and has non-configurable data interpretation. We hope to improve in this design by allowing more configuration of the test environment, different LED wavelengths, bottom-up / top-down lighting options, gas-flow / vacuum options, and a more configurable interface for the interpretation of data. Also since we are designing our own PCBs and testing environment, the price should be much less than the Ossila listed price.

4.1.3 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

    1. **Our project contains several distinct components each that utilize distinct engineering principles. Examples include the development of specialized PCBs to control LEDs for our light emitting component, the development of a gas regulation device in order to control gas flow or vacuum, and a specialized interface that connects components and extrapolates data, that implements software development principles.**

2. **Our project requires the development and implementation of newly designed PCBs and hardware specific software. With the goal of creating a much more cost effective device that combines the functionality of what would otherwise be thousands of dollars in components.**

4.2 Design Exploration

4.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc. Describe why these decisions are important to project success.

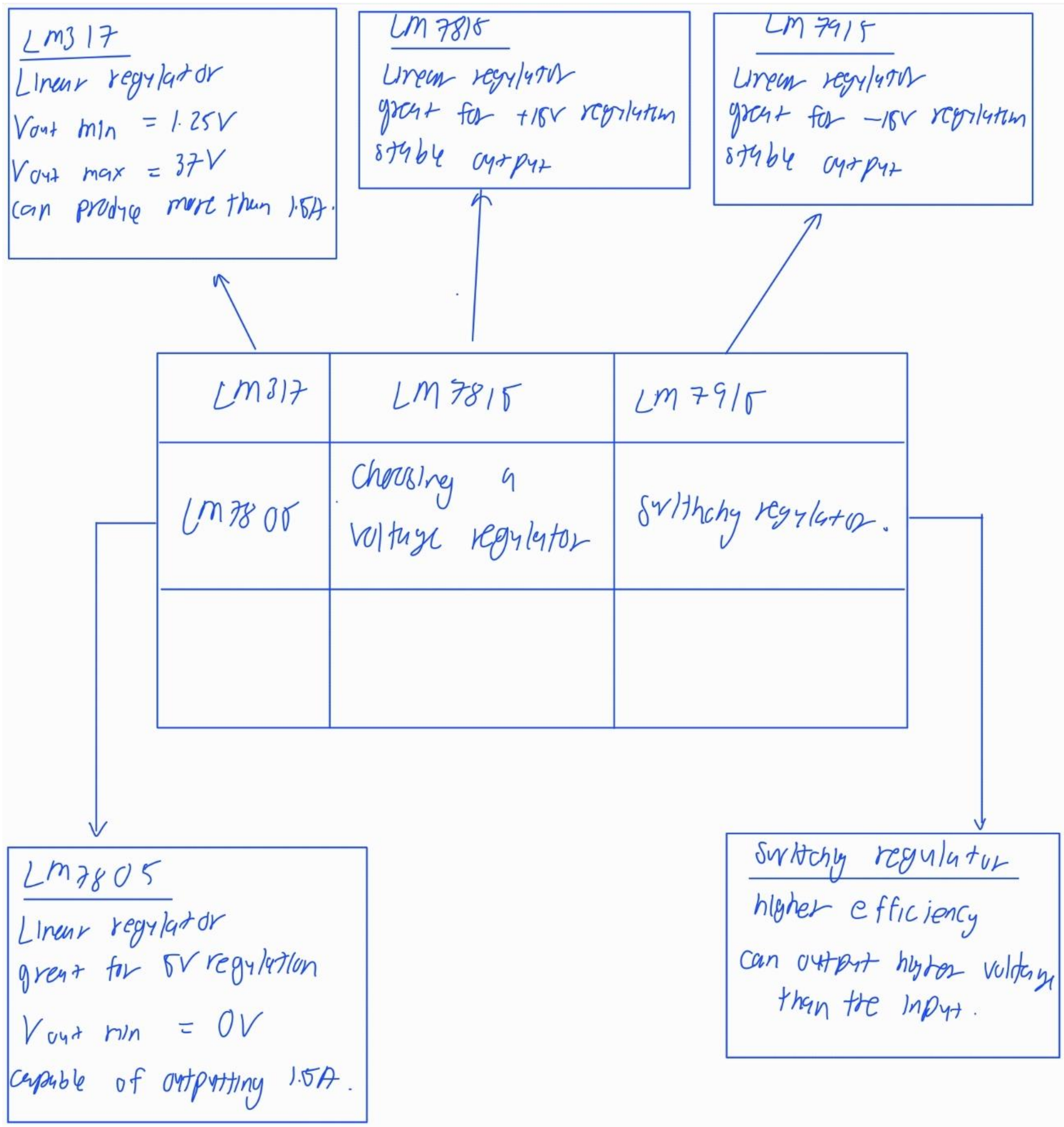
1. **For this project, we required a motor that could rotate between 0 to 40 degrees so that the LEDs or the photosensor could be placed right under the device under testing (DUI). We decided to get a motor from Digikey, an electronic component supplier. We choose to get our servo motor from them because they have a lower price and sample code for programming our Microcontroller to control the servo motor.**

2. **Next, we must decide how to mount our PCB onto the servo. There are a few ways we could mount our PCB onto the servo, and the first way is to use the mount that comes with the servo motor. The manufacturer provided some mounting parts with the servo motor, and we can use them. However, this requires drilling holes in the PCB and screwing the PCB onto the mount. This would give us a risk of making a mistake and breaking the PCB board. On the other hand, we could use glue to stick the PCB onto the servo, which can greatly reduce the chance of breaking our PCB.**

3. **Then, in our project, a gas regulator could input gas into the device to regulate the testing environment. Three voltage regulators are required in this part of the project, which are +15V, -15V, and adjustable 0 to 5V regulators. After going through the components of the following regulators, our project's advisor suggested that we use LM7915 rather than LM7815 voltage regulator for the -15V regulator. We initially thought we could use four diodes to invert the voltage to negative. However, this could lead to power loss, requiring more components to use LM7815 for a -15V regulator.**

4.2.2 Ideation

For at least one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). Describe at least five options that you considered.



4.2.3 Decision-Making and Trade-Off

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish you include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

	Cost	Usability	Availability	Total score
Weight	3	5	4	
Digikey Servo	4	4	3	44
ANNIMOS Servo (Amazon)	2	3	4	37

From the table above, there are two different potential servo motors we are going to use for your project. However, after using a weighted decision matrix, we have decided to use Digikey servo as the total score is higher. The first thing we would consider is the cost of the servo motor. Using a suitable servo motor with low cost could save some of the cost to produce this project. The servo we found on Amazon has a higher price than Digikey as the cost for a servo in Amazon is 15 dollars, and the servo in Digikey has servo motors ranging from 5 to 10 dollars. Then, the most important thing we considered was the usability of the servo motor. Both are very similar in usability, but Digikey provided code for us to program the servo. Lastly, the availability of the servo. From what we can see from the website of Digikey, the quantity of servo is limited, and there might be a small risk of selling out by the time we decide to order one.

4.3 Proposed Design

4.3.1 Overview

Provide a high-level description of your current design. This description should be understandable to non-engineers (i.e., the general public). Describe key components or sub-systems and how they contribute to the overall design. You may wish to include a basic block diagram, infographic, or other visual to help communicate the overall design.

Our Automated Testing Station is composed of a few subsystems. Our device includes the LED PCBs, the gas regulation system, the DUT(device under testing) probe system, and the software interface that interprets the data and controls

certain components. The LED PCBs are composed of two identical PCBs mounted to servos. The PCBs have three different LEDs of different wavelengths that can be pulsed and a photosensor. The servo allows the PCBs to be rotated by the servos to allow the different LEDs to be used for testing. The gas regulation system controls the gas flow rate into the testing environment and also allows for a vacuum within the testing environment. This system contributes to the ability to test different devices in the presence of different gasses. The DUT probe system allows for collecting raw data from the DUT, which the software interface can then interpret. Lastly, the software interface communicates with each component, allowing for control of certain features. It also collects data from the DUT and interprets and graphs that data.

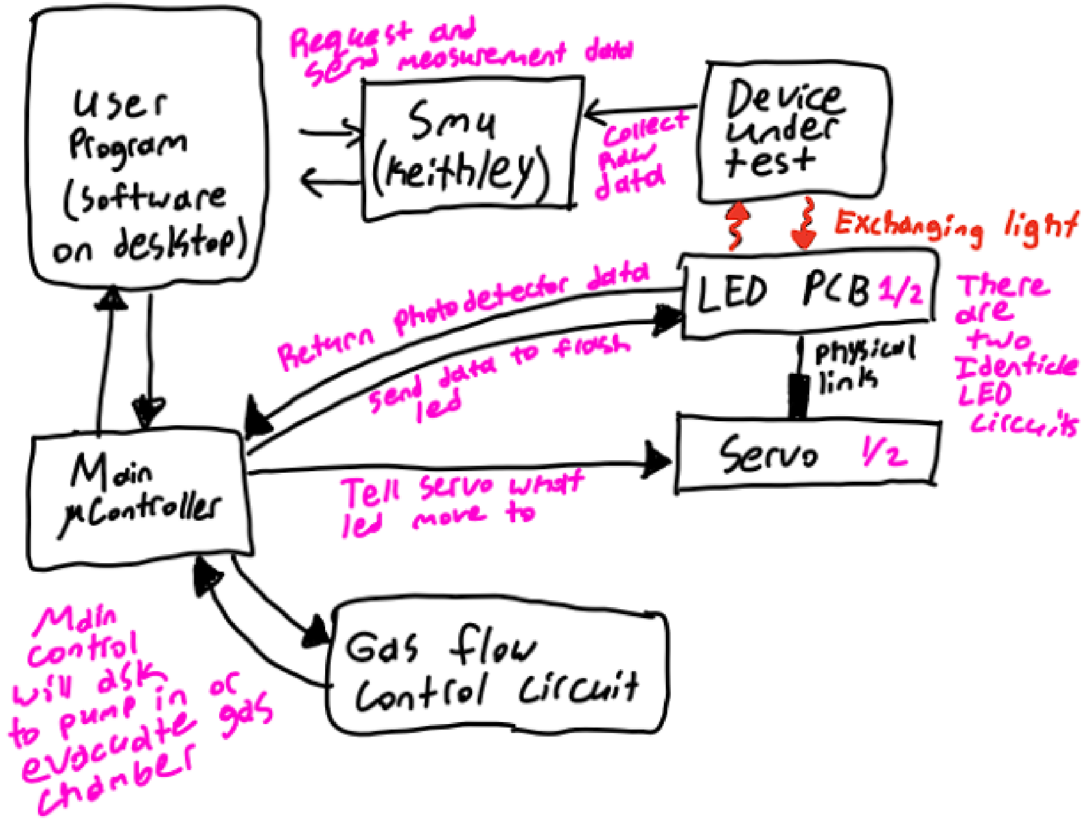
4.3.2 Detailed Design and Visual(s)

Provide a detailed, technical description of your design, aided by visualizations. This description should be understandable to peer engineers. In other words, it should be clearly written and sufficiently detail such that another senior design team can look through it and implement it.

The description should include a high-level overview written for peer engineers. This should list all sub-systems or components, their role in the whole system, and how they will be integrated or interconnected. A visual should accompany this description. Typically, a detailed block diagram will suffice, but other visual forms can be acceptable.

The description should also include more specific descriptions of sub-systems and components (e.g., their internal operations). Once again, a good rule of thumb is: could another engineer with similar expertise build the component/sub-system based on your description? Use visualizations to support your descriptions. Different visual types may be relevant to different types of projects, components, or subsystems. You may include, but are not limited to: block diagrams, circuit diagrams, sketches/pictures of physical components and their operation, wireframes, etc.

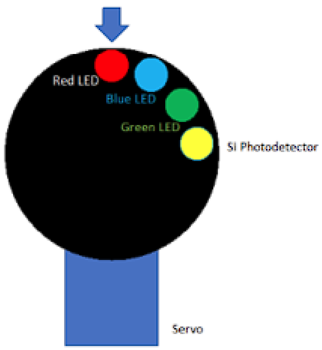
Systems level design

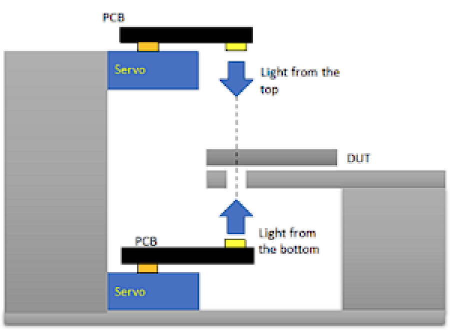


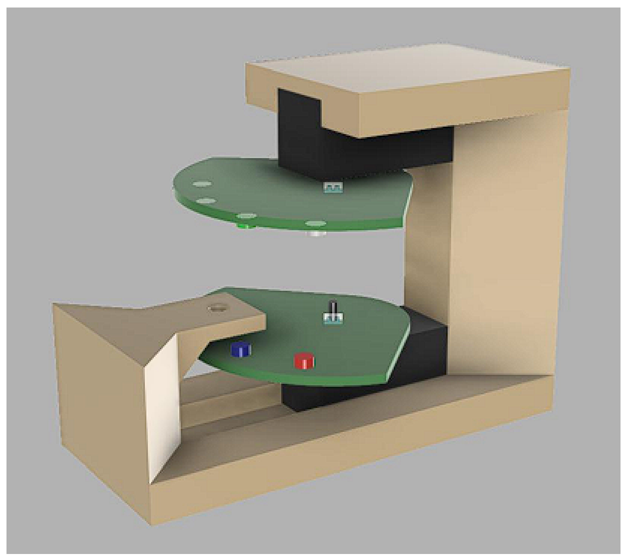
Above is a systems level diagram of our proposed solution. The user will load the device under test (DUT) into the machine and seal it up. From there they will begin interacting with the user interface software running on a desktop computer. The program will be a lab view interface that allows the user to graph and analyze data as well as control the machine to take measurements. When instructed to make a measurement by the user, the desktop software will communicate with a main microcontroller that will send directions to subcomponents to begin making measurements. To make a measurement the gas control circuit will be instructed to either vacuum out the testing chamber or fill the chamber with air or another provided gas (note the machine will sit inside an airtight chamber). From there it will instruct one of the two servos (top or bottom) to move the proper LED or Photodetector into position under/over the DUT. It will then instruct the LED PCB to flash the LED to stimulate the DUT with light. At this point the user interface will also need to talk to a source measurement unit (SMU) that will periodically take electrical current vs voltage measurements of the DUT, which will be solar cells for most types of test. For a specific type of test the DUT will be an LED or some other

device that will generate light itself, the intensity of which can be measured by a photodetector on one of the PCB boards. The main controller will then send data from the photodetector back to the program. Finally the program will automatically perform analysis and graph relevant information for the user.

Physical design







Above are initial design concepts for the physical assembly of the core of the machine. As you can see the two PCBs will be mounted above and below the DUT which will be sitting on a stage in the middle of the device. The main structure will be 3-d printed, and will include mounting holes to secure the servomotors. The LED flasher PCB will sit on top of these servos. (Not Pictured) This core assembly will be placed inside of an airtight, blacked out chamber that will also house PCB's for the the gas control circuitry and main servo controller. Additionally there will be many wires connecting for power and communication between the various components. As well as wires leading through airtight junctions of the chamber for connecting the SMU multimeter leads to the DUT, and connecting the main microcontroller back to the desktop running the user interface.

4.3.3 Functionality

Describe how your design is intended to operate in its user and/or real-world context. What would a user do? How would the device/system/etc. respond? This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

The device we are building is called an Automated Testing Station, and the main purpose of this device is to get the data and information required when testing a solar panel. The operation of the device would be very simple. The user will place the device under testing (DUI) in a bracket and use a computer to control the testing environment. To control the testing environment, the user can choose the light frequency and the type of gas going into the testing device. By choosing that, the user can understand how the DUI would react in different environments. After choosing the light frequency, the motor responsible for the light frequency will rotate to the angle so that the chosen LED will be placed directly above and under the DUI. Then, after the type of gas is selected by the user, the device will input the gas into the device while the flow rate of the gas device will appear on the LED screen that will be on the device. Then, sensors placed onto the PCB will collect data and send data to the Microcontroller, which will then show complete data in the computer.

4.3.4 Areas of Concern and Development

How well does/will the current design satisfy requirements and meet user needs?

The current design met the user's needs as the device would collect and show the data required by the user.

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

The primary concern that we have for our device is we do not know if the device can work synchronously or not, as PCBs for light frequency and gas type are in two different PCBs.

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

We plan to have them connect via cables to the pin available on the Microcontroller.

4.4 Technology Considerations

Describe the distinct technologies you are using in your design. Highlight the strengths, weakness, and trade-offs made in technology available. Discuss possible solutions and design alternatives.

Our Design will link several key technologies for measurement and further data analysis. On the hardware side, we will be making the bulk of our electrical measurements using highly accurate source-measurement units (SMU) such as the Keithley 2400 that has been provided to us. The benefit of using such a device is the precise measurements the system can take compared to other measurement devices. The tradeoff being such units can cost thousands of dollars to purchase, so our design solution is predicated on the user already having access to an SMU (although nearly every college and electrical lab likely does have this available). Additionally, our design solution requires actuators to move certain components into or out of position for measurement. To do this, we have paired an Atmega-238PB microcontroller (the same controller used on the Arduino Uno) with common RC servo motors. The servo motors are a great choice as opposed to regular DC motors and Stepper motors, as they allow precise, repeatable positioning of the attached disk. The negative is that controlling them is a little more challenging, which is why we need a microcontroller. Thankfully, the Atmega has great support from pre-existing code libraries provided by the Arduino community. Besides controlling the servos, the microcontroller will have to communicate with the user interface program hosted on a computer over an interface such as serial communication standards like UART.

The final piece of our electrical system will be the gas flow controller. We need a system to ensure that we can control the atmosphere of our testing station, ranging from regular air to vacuum, to CO2, and more. This will allow us to test semiconductor materials-based sensors under different operation conditions, a key requirement of our design goals. Besides the electrical hardware, we still need support structures to hold all the components together. We have decided on using 3-D printed parts for this part as it will allow us to rapidly prototype different parts.

Additionally, it will allow for easy replacement should a custom part break. On the software side, we will be creating an interface with LabView. This allows for the efficient development of data interpretation and graphing, along with existing libraries for easy connection to device components. The downside to LabView is that since it's a graphical language, it might lack certain configurability options. A possible solution to this would be to develop the interface with C++ or some related language, but this would require a much more complicated coding solution as the libraries available via LabView would not be available.

4.5 Design Analysis

Discuss what you have done so far, i.e., what have you built, implemented, or tested? Did your proposed design from 4.3 work? Why or why not? Based on what has worked or not worked (e.g., what you have or haven't been able to build, what functioned as expected or not), what plans do you have for future design and implementation work? For example, are there implications for the overall feasibility of your design or have you just experienced build issues?

So far, we have created electrical schematics, and a PCB design for the LED PCBs mounted on motors. We have begun designing electrical schematics for the gas control valve portion of the device. We have created a BOM for the project. We have begun CAD designs for the supporting structures of the device. We have begun working on the software for the device as well. Some aspects that we have yet to start working on include adding a silicon cell to the LED PCBs for light detection, programming the processors to flash the LEDs and rotate the motors, programming the gas control valve portion of the device, and designing a 3D printed structure for mounting the PCBs. We will also have to add the software to the device once it is ready. One feasibility issue we might encounter involves the LEDs and whether they will provide enough light to achieve the desired results. The LEDs must be as close as possible to the DUT, which may cause some build issues. Even if the LEDs are as close as possible to the DUT, we are still determining whether they will be strong enough to produce the desired results.

5 Testing

5.1 Unit Testing

What units are being tested? How? Tools?

Our device is used for testing photosensitive devices. It will utilize different colored LEDs to test the capabilities of optoelectronic devices under different gas conditions. We will be using a Keithley 2400 to collect data from our device to be analyzed by a computer.

5.2 Interface Testing

What are the interfaces in your design? Discuss how the composition of two or more units (interfaces) are being tested. Tools?

Our design combines several hardware and software interfaces. It will have 2 to 3 separate hardware interfaces which each have their own microcontroller and communicate with each other via I2C (or another method if our plans change). The data collected by our device will be output to a computer to be analyzed and displayed on a digital interface that we design. Additionally we will be using an SMU to make measurements that will need to be connected to the host computer through a wired "GPIB" interface.

5.3 Integration Testing

What are the critical integration paths in your design? Justification for criticality may come from your requirements. How will they be tested? Tools?

As previously mentioned there are several subsystems that are being developed concurrently. Integrating these systems is one of the key challenges to making our design work. The most critical of these system integrations will be getting the Software user interface to communicate with the PCB board that handles LED flashing & servo movement. Secondly will be integrating the Software interface with the Keithley SMU. If the software can interface with these other two components we can achieve nearly all core functionality our client needs. I.E. testing solar cell electrical response. Other features such as integrating the control of gas flow are core requirements for the final product but are not needed to begin systems level testing and making real measurements. Integration testing will be done by testing basic functionality. For example, on the software side we can develop basic commands such as "Move servo to Red LED" , "Make SMU voltage measurement", "Make LED pulse at x Hz". When running these commands we should obviously see some sort of corresponding response from the hardware.

5.4 System Testing

Describe system level testing strategy. What set of unit tests, interface tests, and integration tests suffice for system level testing? This should be closely tied to the requirements. Tools?

In order to do system testing, we have to review each individual component, and compare the results to expected values, this would be done via the unit tests. For testing the interface, we would feed data with known results into the interface, and see if the outcome matches the expected results. If every component functions correctly we know that the entire system is functioning as expected.

5.5 Regression Testing

How are you ensuring that any new additions do not break the old functionality? What implemented critical features do you need to ensure they do not break? Is it driven by requirements? Tools?

We will implement a series of interface/unit tests to be run using a 'testing' DUT that will remain consistent throughout the testing process. Whenever we add a new component, if the tests fail, we'll know that the component we added broke old functionality and therefore needs to be changed

5.6 Acceptance Testing

How will you demonstrate that the design requirements, both functional and non-functional are being met? How would you involve your client in the acceptance testing?

There are several functional design requirements that we could test for the device that we have built. First, We can test the LED and servo on the PCB, which will be placed above and under the DUI. Before placing the PCB into the device we are building, we could test the device by selecting the light frequency that we want from the computer, seeing how many angles the servo rotates, and checking if the LED we have chosen is blinking. Since there

will be two servos and 2 LEDs, we need to ensure that both will rotate to the same angles and that both LEDs will blink simultaneously.Then, we can test the mass flow controller. The mass flow controller will have an input of plus and minus 15V, which will power up the gas device. Then, there will be a zero to 5V regulator, which adjusts the flow rate of the gas. We could test the device by looking at the LED on the PCB board. In designing the PCB for the device, we placed some LED on the PCB so that we could know that all of the circuits on the PCB were working. If a circuit is not working, the LED will not work.

5.7 Results

What are the results of your testing? How do they ensure compliance with the requirements? Include figures and tables to explain your testing process better. A summary narrative concluding that your design is as intended is useful.

We cannot do any testing on the device as no physical device has been built. However, from the circuit we have designed, we can know if the circuit will work or not by doing the tests we mentioned above. The diagram below shows an LED connected to the circuit, which will light up if the circuit is working.

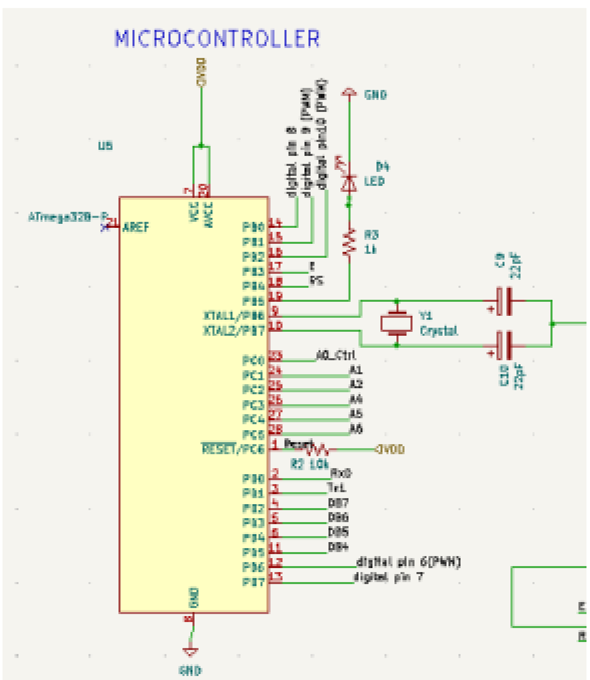


Figure 1: Circuit for MCU for Mass Flow Controller.

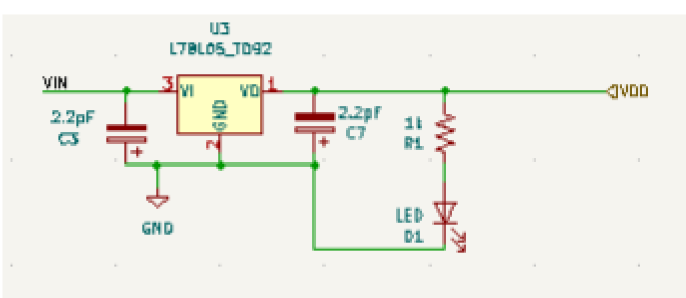


Figure 2: Circuit for 5V regulator for Mass Flow Controller.

6 Implementation

Describe any (preliminary) implementation plan for the next semester for your proposed design in 3.3. If your project has inseparable activities between design and implementation, you can list them either in the Design section or this section.

In the next semester, we plan to make changes to our existing PCBs and gas control valve to make them fully functional according to our project goals. Next, we plan to implement our software and a form of communication between the separate hardware components of our device. Finally, we will produce a 3D printed structure and vacuum sealed container in order to construct our final product. From there, we will do testing with our device and look for areas of improvement.

7 Professional Responsibility

This discussion is with respect to the paper titled " Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Pick one of IEEE, ACM, or SE code of ethics. Add a column to Table 1 from the paper corresponding to the society-specific code of ethics selected above. State how it addresses each of the areas of seven professional responsibilities in the table. Briefly describe each entry added to the table in your own words. How does the IEEE, ACM, or SE code of ethics differ from the NSPE version for each area?

Area of responsibility	**Definition**	**NSPE Canon**	**IEEE**
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.	IEEE members agree "to maintain and improve technical competence and to undertake tasks for others only if qualified or after a full disclosure of important limitations"
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	Members agree to uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities.

Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.	IEEE members pledge to seek and accept honest feedback of technical work from others, as well as to treat others with respect while seeking this communication
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.	Members agree "to hold paramount the safety, health, and welfare of the public..."
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.	The IEEE ethics outline avoiding damage to others property in addition to acting in accordance with the highest ethical and legal standards.
Sustainability	Protect environment and natural resources locally and globally.		In addition to protecting the public the IEEE ethics outline disclosing factors that might damage the environment
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	Ieee members agree to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems.

7.2 Project Specific Professional Responsibility Areas

For each of the professional responsibility areas in Table 1, discuss whether it applies in your project's professional context. Why yes or why not? How well is your team performing (High, Medium, Low, N/A) in each of the seven areas of professional responsibility, again in the context of your project. Justify.

Work Competence: This responsibility applies to our project's context because it is necessary that we perform high quality work in order to achieve our project goals on time. Our group is demonstrating a high level of work competence by establishing individual tasks for each member and communicating frequently in order to make sure that each member is completing quality work in a timely manner.

Financial Responsibility: This responsibility applies to our project's context because we need to buy many parts for our design. The very low cost of our design compared to existing products is important to our group. We are diligent in our efforts to keep our project costs low by ordering the cheapest parts that we can find and using existing components for prototype designs that we have leftover from previous labs.

Communication Honesty: Communication honesty applies to our project's context because it is crucial that we communicate with one another effectively in order to bring the several different parts of our project together into a final product. We are performing at a high level in this category by meeting frequently with one another and our advisor to discuss our progress and future plans for our project.

Health, safety, well-being: This responsibility applies to our project's context because it is important that our final product is safe for consumer use. We are performing at a high level in this area by following engineering standards for electrical safety and making sure that our PCBs are safe and functional. We are also utilizing the datasheets for the components that we are using in order to make sure that we are using the components correctly and safely.

Property Ownership: Property ownership is relevant to our project because we are implementing many different components in our device which are produced by other companies. We are respecting property ownership by following the datasheet guidelines for these components and citing those references in our design documents.

Sustainability: Our project does not produce any kind of waste or use large amounts of exotic materials that would cause damage to the environment. The information it provides scientists should in fact help the development of more energy efficient electronics.

Social Responsibility: Social responsibility is important in the context of our project because our project aims to provide a cheaper alternative to testing photosensitive devices. Existing methods can be very expensive and we hope that our device will provide an effective and reasonably priced solution.

7.3 Most Applicable Professional Responsibility Area

The most applicable professional responsibility area that we need for this project is the first responsibility in the table, which is Work Competence. We always aim to complete our projects on time with the best quality and practice the best integrity. Doing so will benefit

us in the long run as the success of our project will gain us a good reputation in our field of study in the future, and we will gain useful skills that will be beneficial when we need to apply them in the future.

8 Closing Material

8.1 Discussion

Discuss the main results of your project – for a product, discuss if the requirements are met, for experiments oriented project – what are the results of the experiment, if you were validating a hypothesis – did it work?

By the end of the semester, we managed to get the PCBs for LED and Gas devices. The output we got is promising, but we will modify the design for the coming semester to make the outcome near perfect. Also, we get to design the housing for the project, and the design has been done in AutoCAD and will be printed using a 3D printer.

From the previous design documents, we have mentioned three functional requirements for this project. For now, we get the LED to shine on different wavelengths. Also, we got to power up the gas device with positive and negative 15V, and we added a potentiometer to change the gas flow rate. We will be putting all of the PCBs and the case of the project in the next semester so that we can start testing the product's functionality.

We have met all the resource requirements except that we still need to get the project case ready, as it requires time to get a perfect size that will satisfy the client's needs. Also, we have yet to start with the UI requirement as we have yet to put all the parts together in this project. After getting all of the parts set up, we will start working on the software of this project.

8.2 Conclusion

Summarize the work you have done so far. Briefly reiterate your goals. Then, reiterate the best plan of action (or solution) to achieving your goals. What constrained you from achieving these goals (if something did)? What could be done differently in a future design/implementation iteration to achieve these goals?

We have four main goals for completing our project, which are to create a gas control valve, create PCBs for the LEDs mounted on motors, produce a 3D printed structure for the device, and implement software to output the desired data. Our plan of action for achieving these goals has been to assign one task to each group member. We have each made progress on our respective tasks, including schematics and prototypes for our PCBs and gas control valve, and CAD designs for our 3D printed structure. So far, the main constraint to our progression has been finding and ordering all the components that we need and waiting for our PCBs to be delivered. Making an effort to order components and

PCBs as early as possible will help us in the future. Overall, we are confident that we are on track to complete our project.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

ATmega328P 8-Bit AVR Microcontroller with 32K Bytes In-System Programmable Flash DATASHEET, https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf

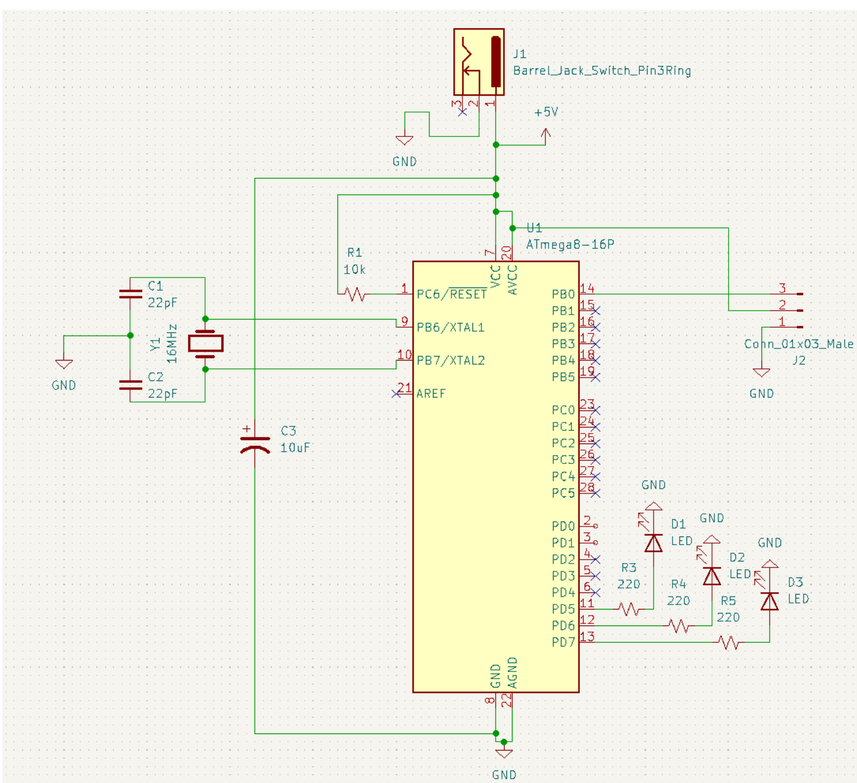
"Writing Your First LabVIEW Program." www.youtube.com, www.youtube.com/watch?v=ZHNlKyYzrPE&list=PLB968815D7BB78F9C.

8.4 Appendices

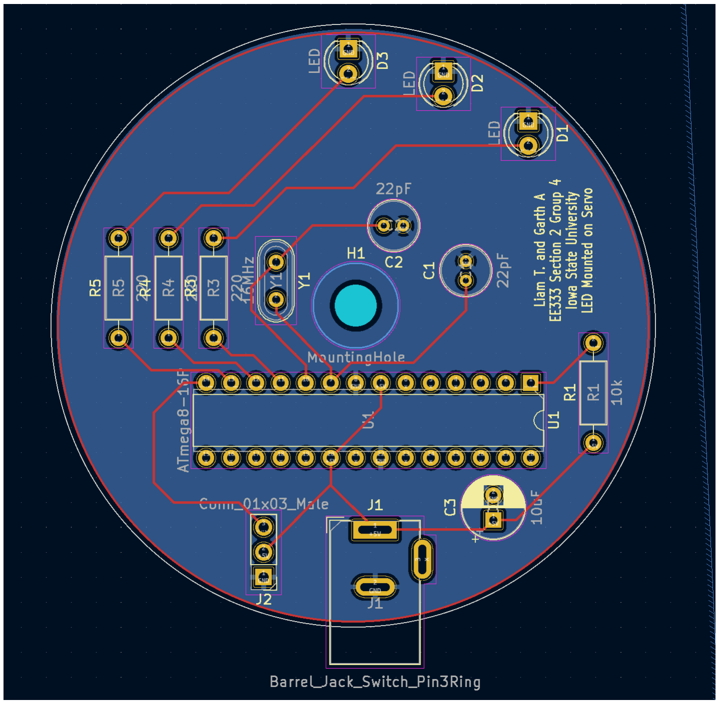
Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.

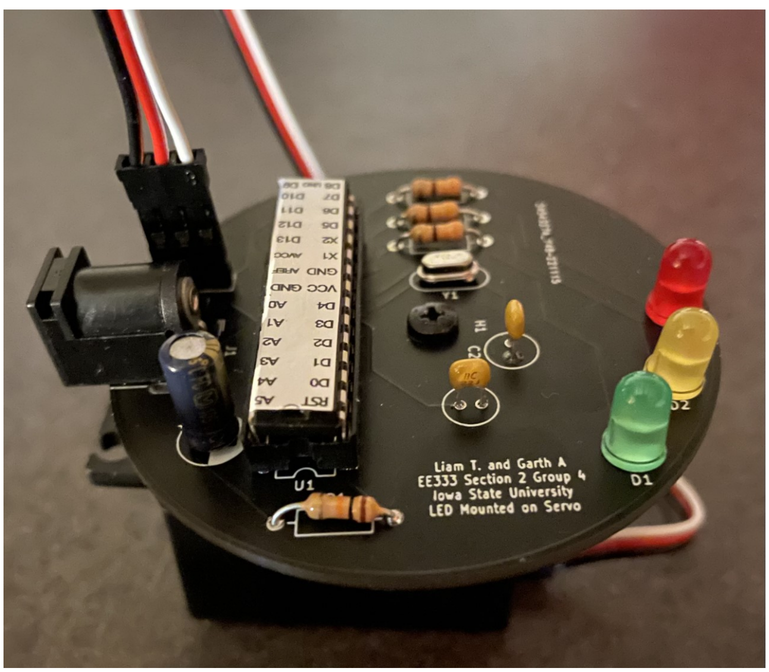
Schematic for LEDs mounted on motor:



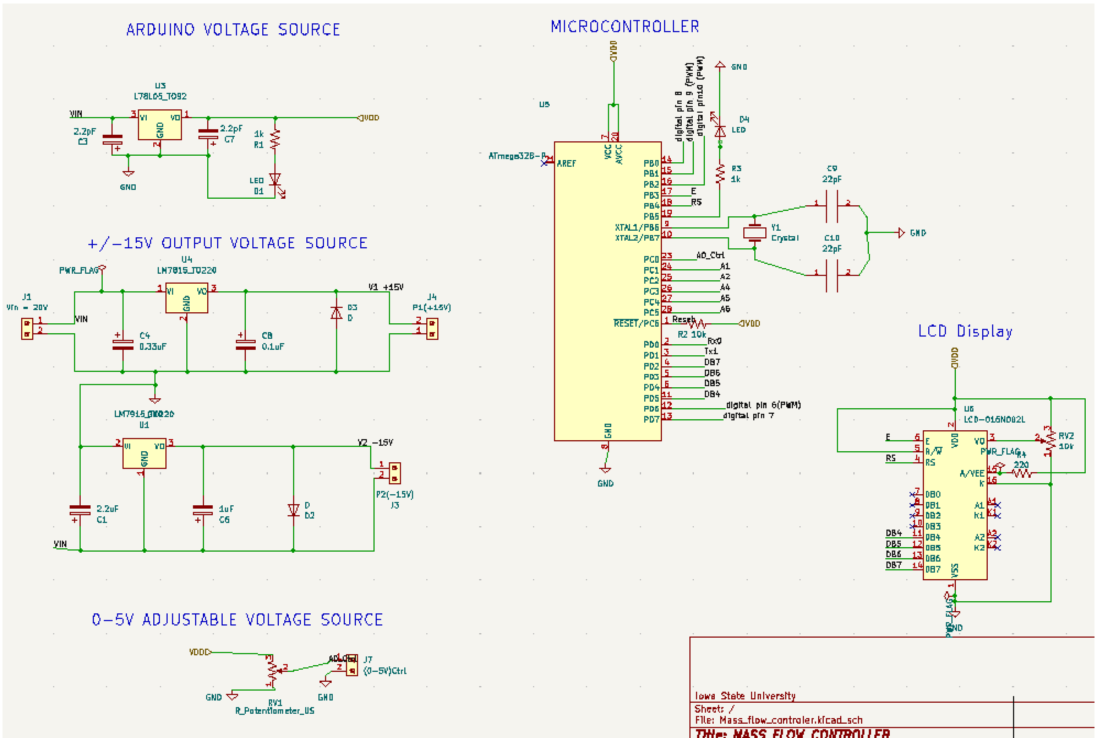
PCB design for LEDs mounted on motor:



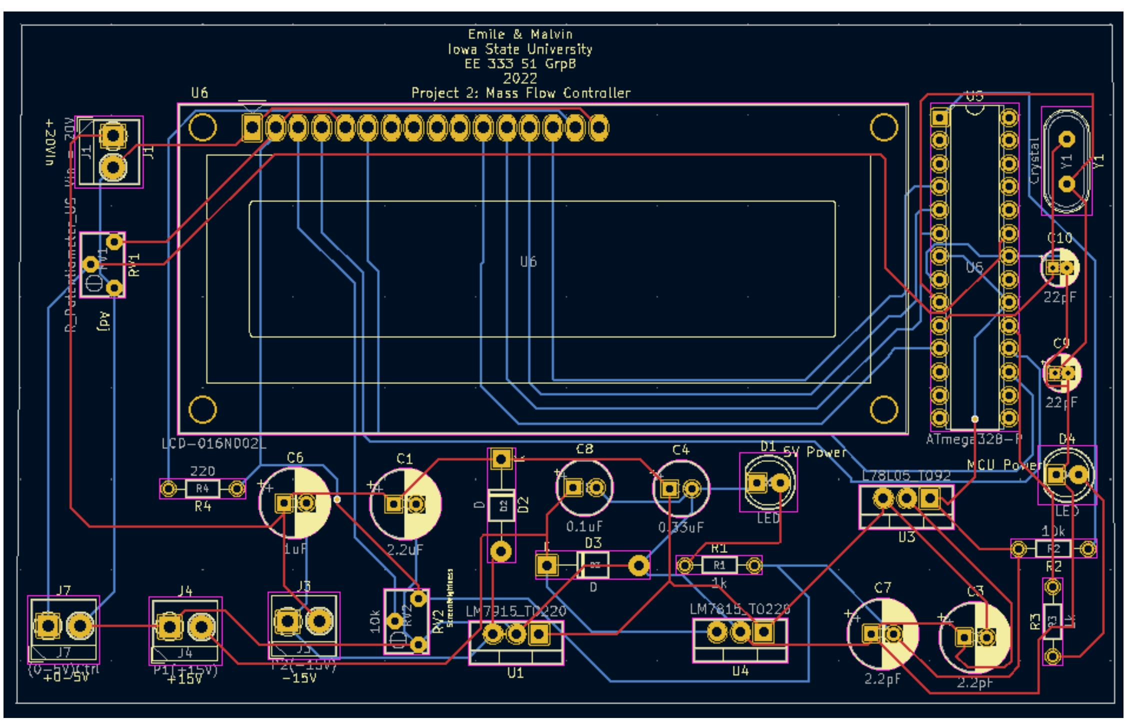
Prototype for LEDs mounted on motor:



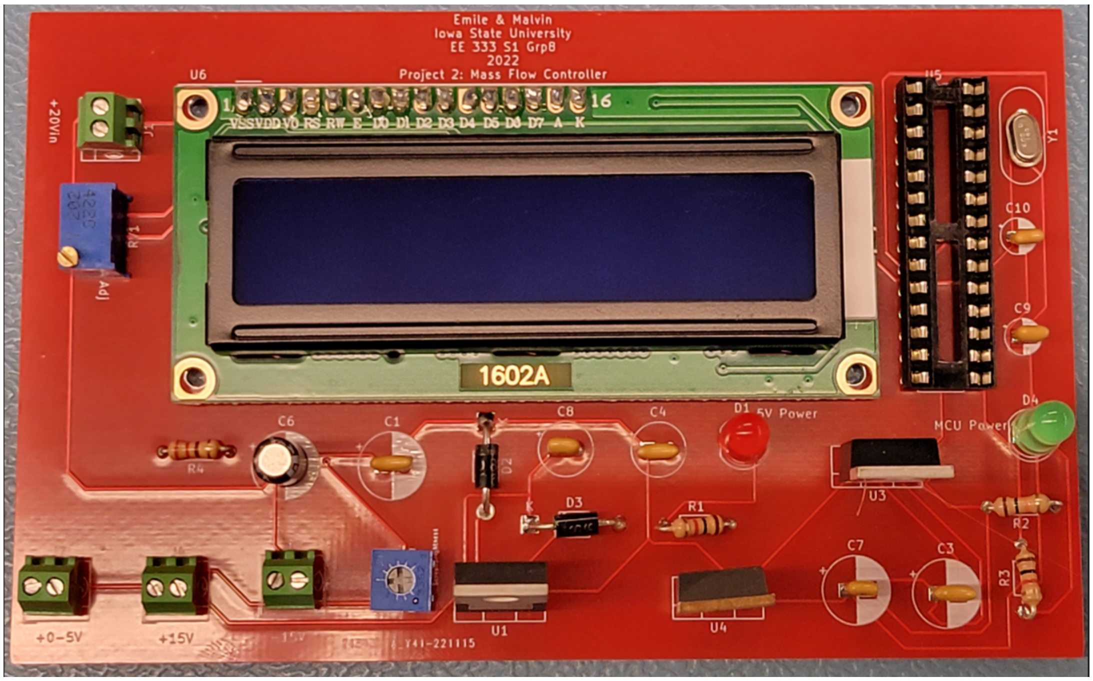
Schematic for Mass Flow Controller



PCB design for Mass Flow Controller



Prototype for Mass Flow Controller



8.4.1 Team Contract

Team Name __________sdmay23-41________________

Team Members:
1) __Thomas McCoy________________ 2) ___Malvin Lim__________________
3) __Garth Anderson________________ 4) ___Matthew Rief_________________

Team Procedures

1. **Day, time, and location (face-to-face or virtual) for regular team meetings:** Face-to-face meetings Thursdays during and after 491 lectures. Meetings with client/advisor on Wednesday every two weeks.
2. **Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):** Combination of email and discord messaging.
3. **Decision-making policy (e.g., consensus, majority vote):** Come to a group consensus, where consensus cannot be reached, group majority vote.
4. **Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):**

Meeting minutes will be recapped via discord messaging and will be provided by one of the attending group members after the meeting.

Participation Expectations

1. **Expected individual attendance, punctuality, and participation at all team meetings:**
   Group members are expected to be in attendance at all meetings. If a group member is unable to attend a meeting they need to inform the group. Group members are expected to be punctual.
2. **Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:**
   Every group member is to negotiate with other group members, what work they are able to complete, and are expected to complete that work. If a group member is not able to complete their responsibilities, they need to inform the group that they need assistance before the agreed deadline.
3. **Expected level of communication with other team members:**
   Team members are expected to communicate regularly with the group and client/advisor. The minimum amount of communication would be at least once a day.
4. **Expected level of commitment to team decisions and tasks:**
   Each team member is expected to commit at least the amount of time/work they would normally commit to a 3 or 4 credit hour course.

Leadership

1. **Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):**
   Group members generally will share roles and responsibilities throughout the semester(s)
   Thomas McCoy - team organizer
   Malvin Lim - client interaction