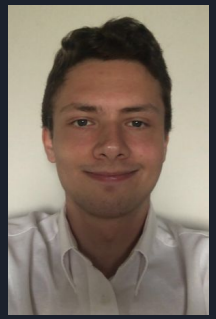
Autofocusing LED Projector

Alexander Neal, Corey Katchen, Daniel Enix, Gabriel Recinos, Tyler Yorke

Senior Design Team

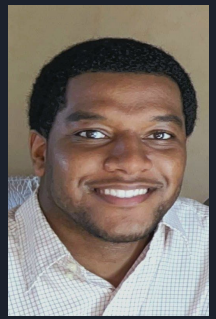


Corey Katchen

Computer Engineering

Alexander Neal

Computer Engineering

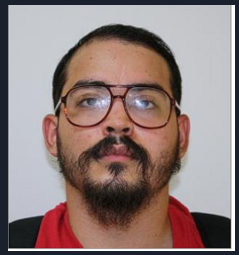


Tyler Yorke

Electrical Engineering

Daniel Enix

Photonic Science and Engineering



Gabriel Recinos

Photonic Science and Engineering

Motivation

Autofocusing projectors are currently available for consumers, although as they gain functionalities they quickly become more expensive, which creates an opportunity in the market for our project.

Therefore, our senior design team has decided to develop a projector that is low-powered with the possibility of voice command control. Furthermore, a range finder will be utilized to detect distance with a LED as our primary illumination source.

Keeping the weight of the projector down will enhance the user-friendly experience and enable portability for multi-use functionality. We intend for our projector to be applicable in many different settings, such as businesses, universities, and homes.

Goals and Objectives

Core:

- Spatially uniform illumination intensity from LED
- Distance measurement from an IR laser rangefinder
- Hands-free projector control via voice commands
- Power consumption less than industry standards

Advanced:

- Stepper motor rotations on projection lens gears
- Video and audio input from mobile device
- Fast turn on time of projector

Stretch:

- Fast focusing speed with high accuracy
- Auto adjust image size
- Automated brightness manipulation
- Voice commands active even when not projecting

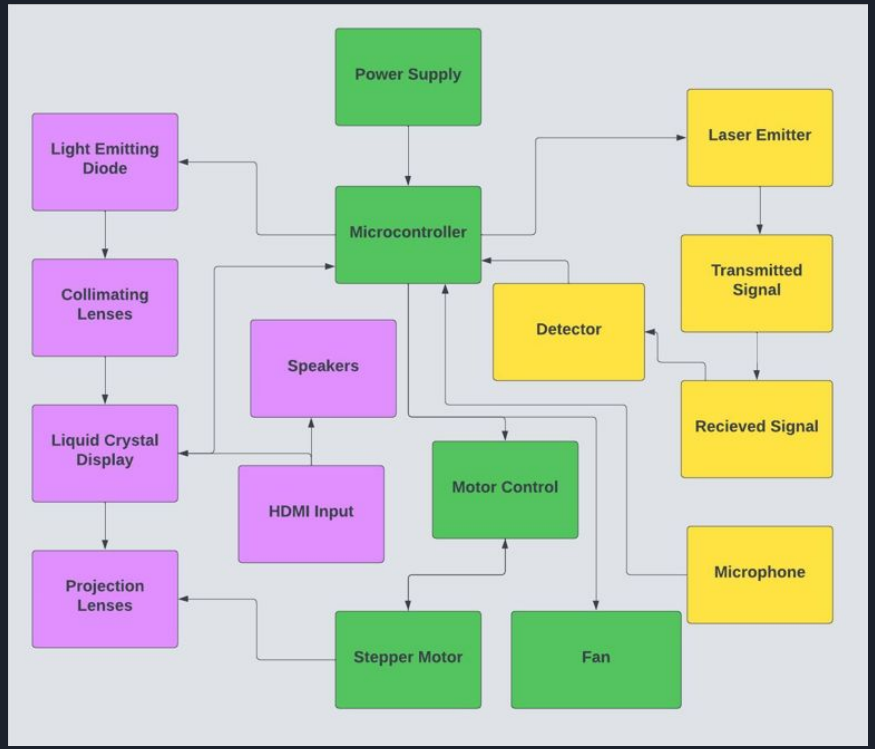
Engineering Requirements and Specifications

Component(s)	Requirement	Specification	Unit(s)
LED	Uniform Image Brightness	5,000	LM
Ground Glass	Light Collimation	100 x 100	mm
LCD Screen	Image Resolution	1440 x 2560	pixels
Final Image	Size	50 x 50	cm
Projection Lens	Autofocus	360 turns	degree

Engineering Requirements and Specifications (Continued)

Component(s)	Requirement	Specification	Unit(s)
Rangefinder	Detection Range	5	m
Stepper Motor	Focusing Speed	<10	s
Projector	Power Consumption	<50	W
Microphone	Voice Commands	2	unitless
Batteries	Lifespan	60	minutes

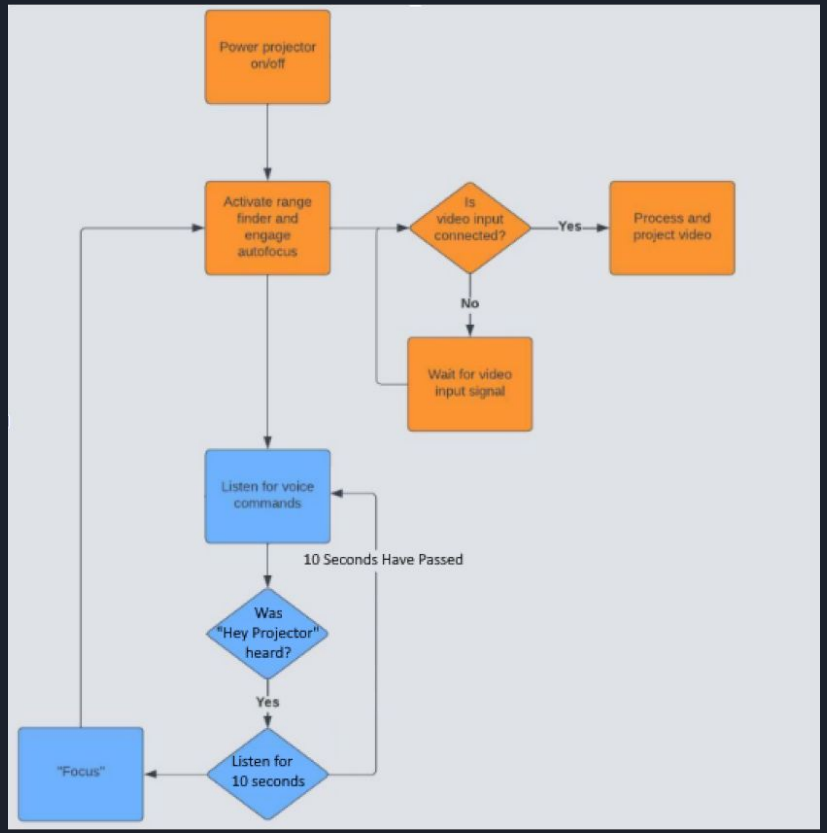
Hardware Block Diagram



Key

- Tyler Yorke
- Daniel Enix
- Gabriel Recinos

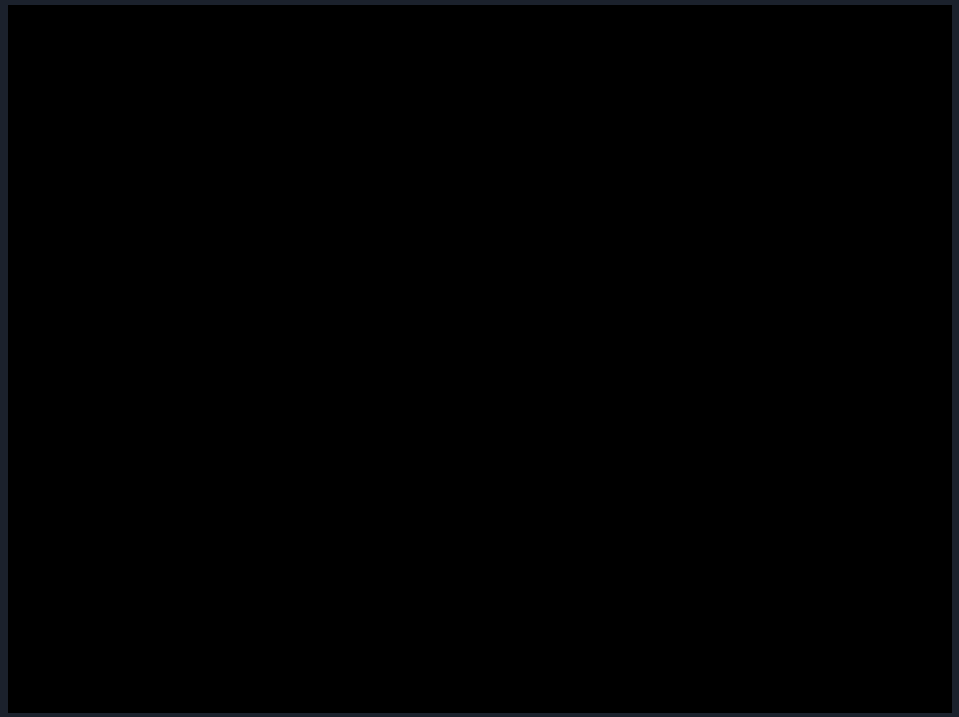
Software Flowchart



Corey Katchen

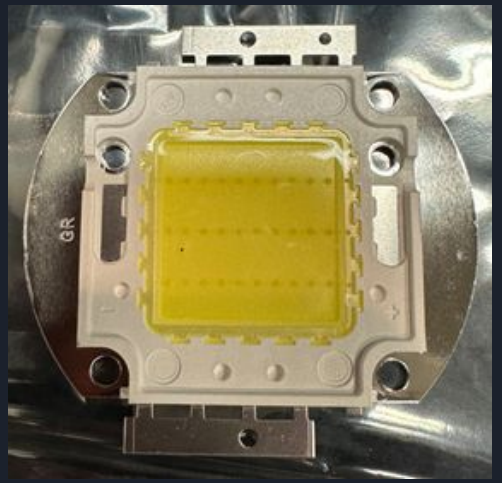
Alexander Neal

Visual Representation of Autofocusing



Illumination Source

Light Sources	Quality Advantage	Power	Costs
Lamp	Vibrant	Watts	~ $25
Fiber Optic	Color gamut	Watts	~ $500
Laser	Finest light	milliWatts	~$50
LED ✅	Brightness	Watts	~ $10



COB LED Specifications:

- Power
  - 30 Watts
- Brightness
  - 27000 LM
- Dimensions
  - 40mm x 40mm x 2mm

Light Collimation

	Condenser Lens	Ground Glass ✅
Focal Length	50 mm	N/A
Thickness	30 mm	1.5 mm
Transmission	~ 95 %	~ 85 %
Costs	$105	$50

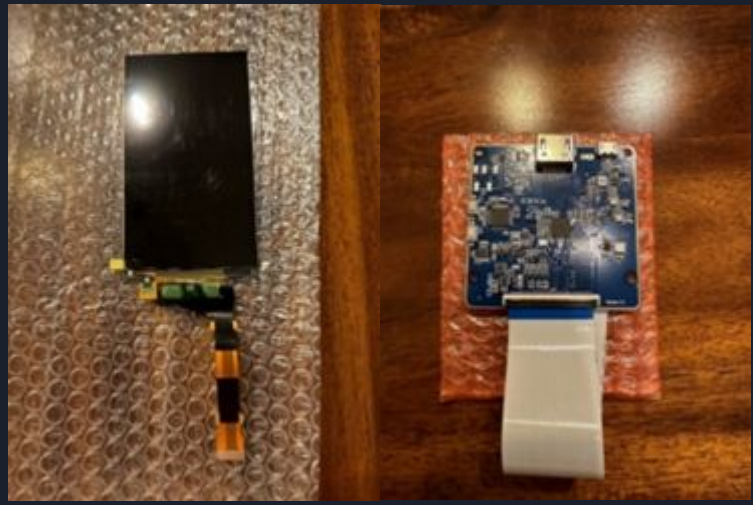
Specifications:

- Uncoated
- Dimensions
  - 100mm x 100mm

Image Source and Driver Board

	LCD Screen
Screen Height	120mm
Screen Width	70mm
Image Height	45mm
Image Width	70mm

	LCD Driver Board
Turn on Voltage	5V
Video Input	HDMI Cable
Power Input	USB Micro C



Projection Lens

Projection lens removed from old unused projector.

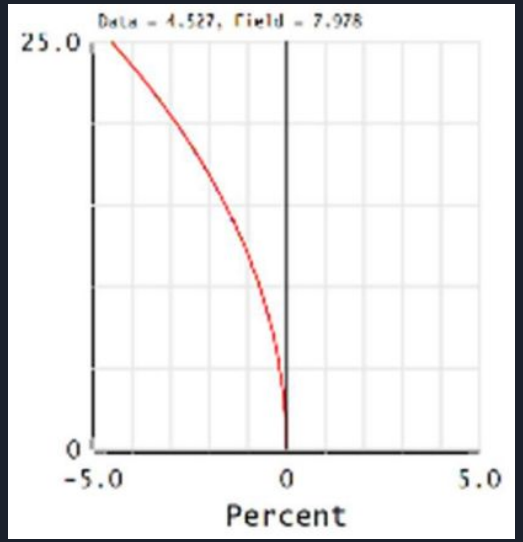
Adjustable zoom and focus knobs shown.

Achromatic doublet lens is implemented as the exit aperture.

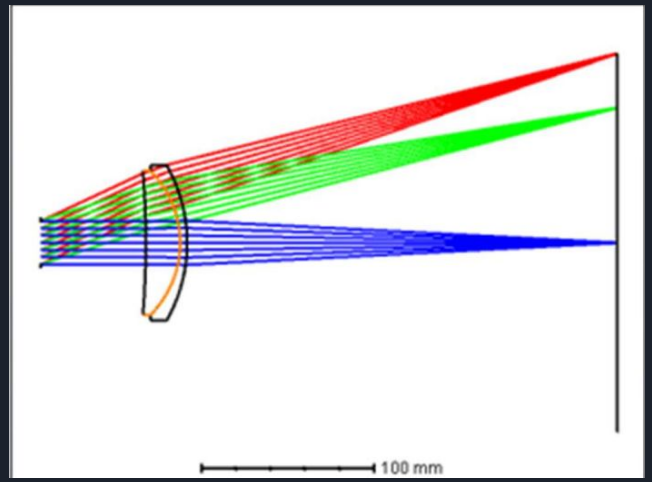
Specifications:

- Aperture size
  - Entrance: 4cm
  - Exit: 8.5cm
- Focal Length
  - 22.6mm - 45.3mm
- Length
  - 170mm

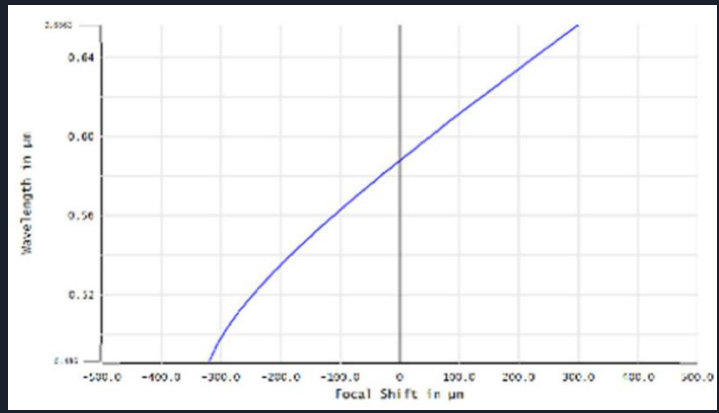
Projection Lens Zemax Simulation



Distortion Curve

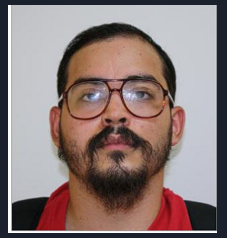


Ray Trace Diagram

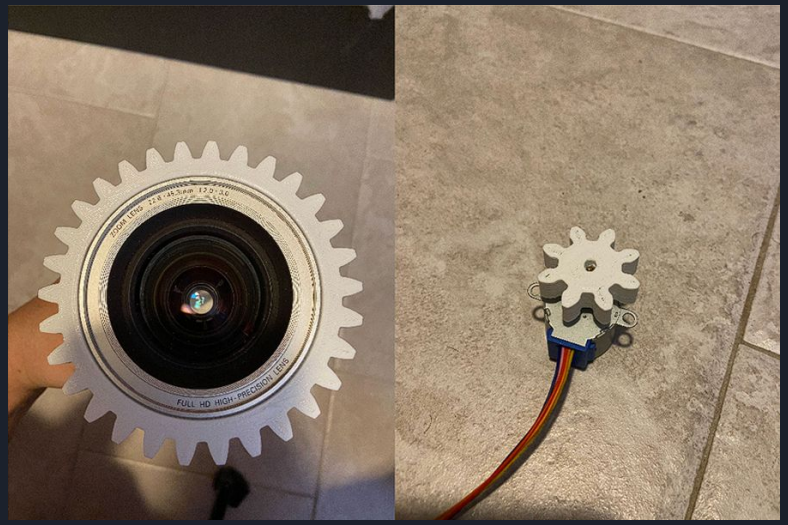


Focal Shift (Aberration) Curve

Mechanical setup for autofocusing

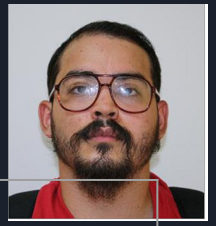


Projection lens modification



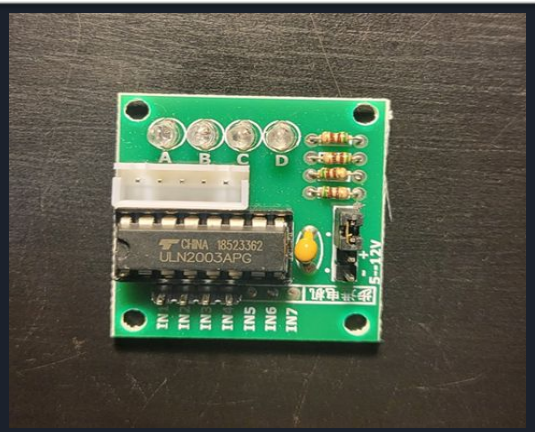
Gear system integrated onto motor and projection lens

Rangefinder

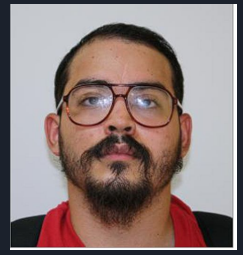


Transmitter	850 nm VCSEL
Receiver	PIN photodiode
Detection range/ resoultion 0.	0.1 to 12 meters/ 1 centimeter
Power consumption	=<0.7 Watts

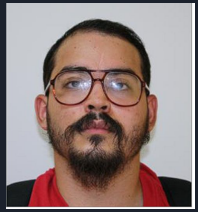
Stepper motor

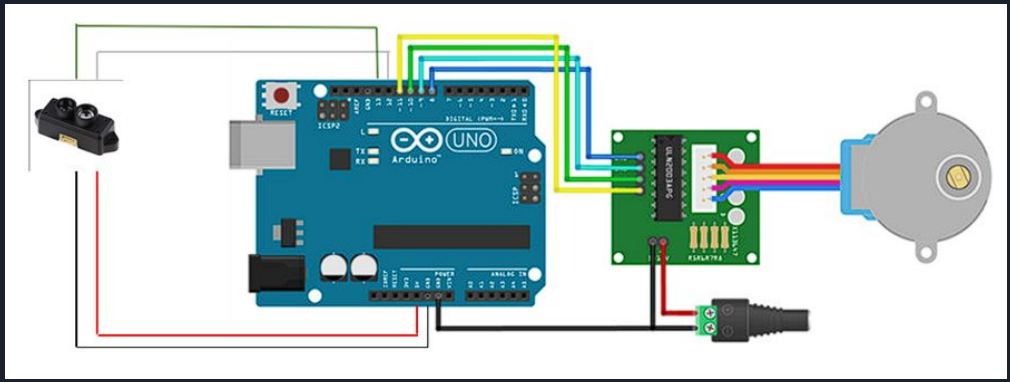


Gear ratio	64:1
Voltage	5 V
Step angle	5.625’/64
Torque	11.4 in-oz



Autofocusing design



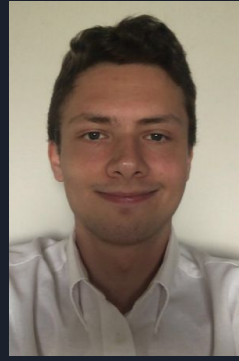


Rangefinder > Stepper motor > Gear system= change in focus

Lookup table will be used to determine appropriate adjustment of focusing lens

Rangefinder distance	# of steps
1 meter	5 steps counterclockwise

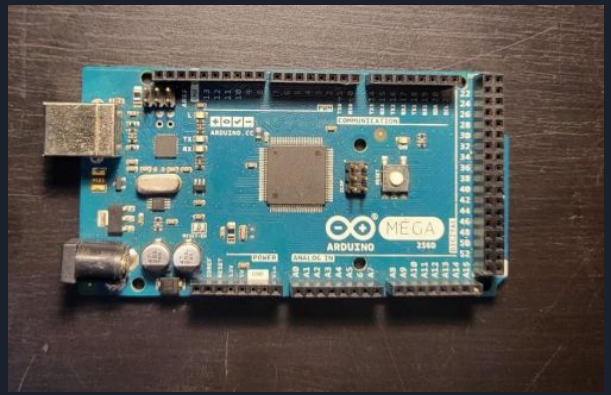
Development Board



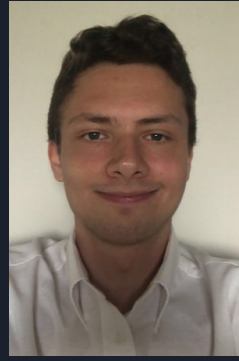
The development board that we are using during the testing and prototyping phase is the Arduino Mega R3

This development board has 54 digital input/output pins which more than meets our needs

More than enough memory/processing power for our needs



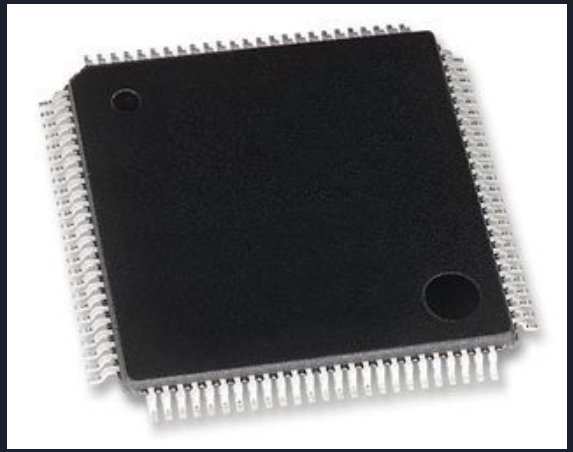
Microcontroller



For our final design, we plan to use the ATMega2560 microcontroller

The microcontroller will be placed on the PCB allowing us to control various components

Since this is the same microcontroller that is used for the Arduino Mega R3, it should be easy to use the software created during the development phase



Power Supply (Batteries)

ABENIC Rechargeable Lithium Battery Pack:

Output Voltage : 12 Volts

Current Limit: 2 Amps

Rated Capacity: 6800 mAh

Weight: 7 ounces

SPARKOLE Battery Pack Rechargeable:

Output Voltage : 12 Volts

Current Limit: 3 Amps

Rated Capacity: 5200 mAh

Weight: 12.5 ounces

Voltage Regulators (Fixed Output)

Linear & Low-Dropout (LDO) Regulators

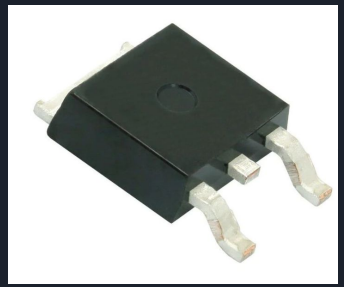
LF120ABDT-TR:

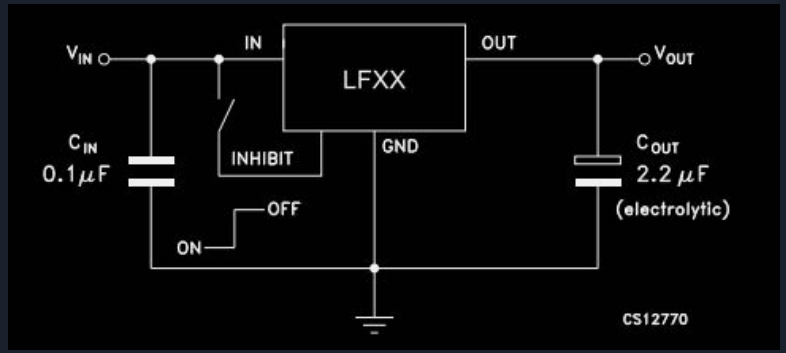
Function: Regulate

Vin: 2.5 - 16 volts

Vout: 12 volts

Iout: 0.5 Amps





Voltage Regulators (Fixed Output)

Switching Regulator Circuit

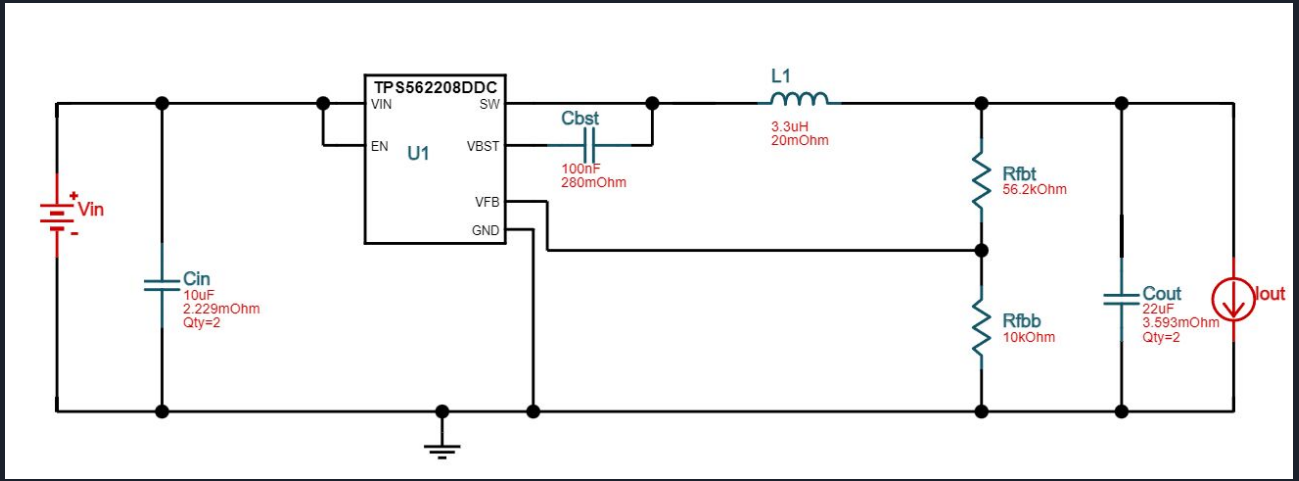
Function: Step Down

Regulator: TPS562208DDCR

Vin: 5 - 15 volts

Vout: 5 volts

Iout: 2 Amps



Voltage Regulators (Adjustable)

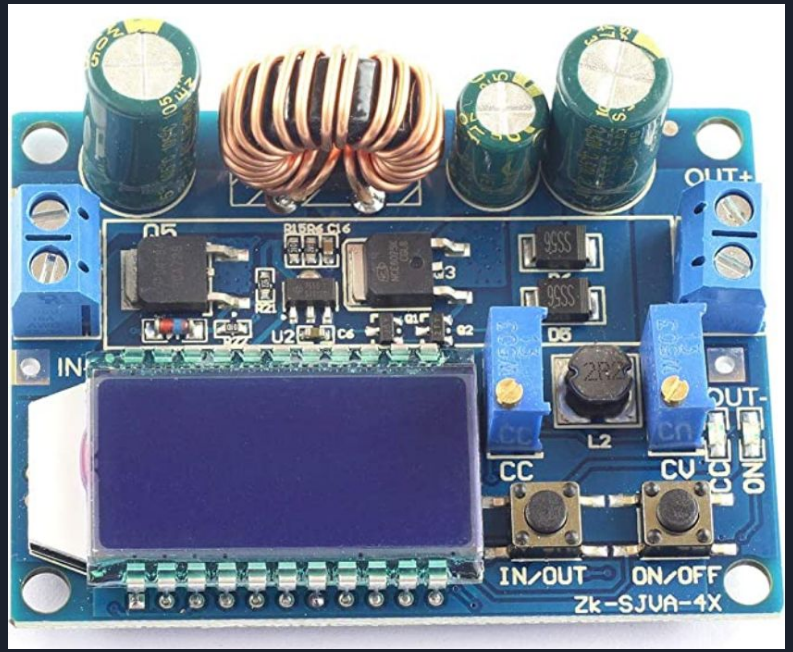
DC Buck Boost Converter Module

Characteristics

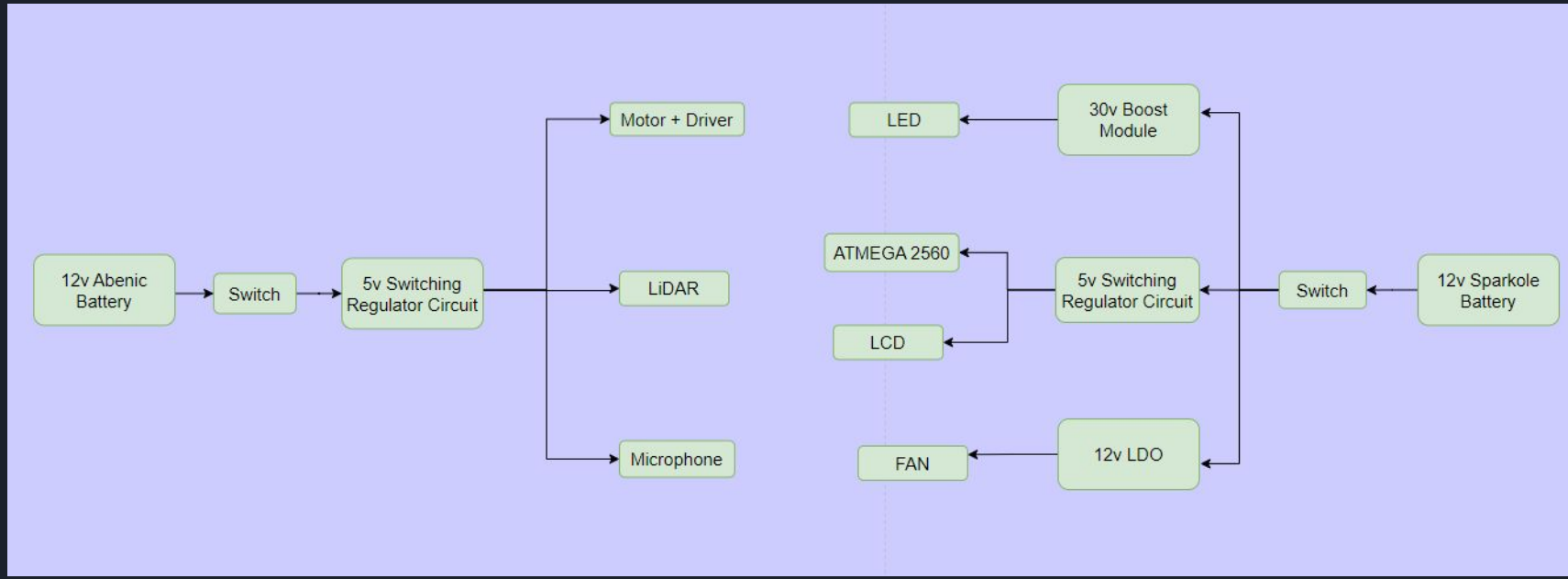
- Vin: 5 - 35 volts
- Vout: 0.5 - 30 volts
- Iout: 3 Amps

Projector (LED)

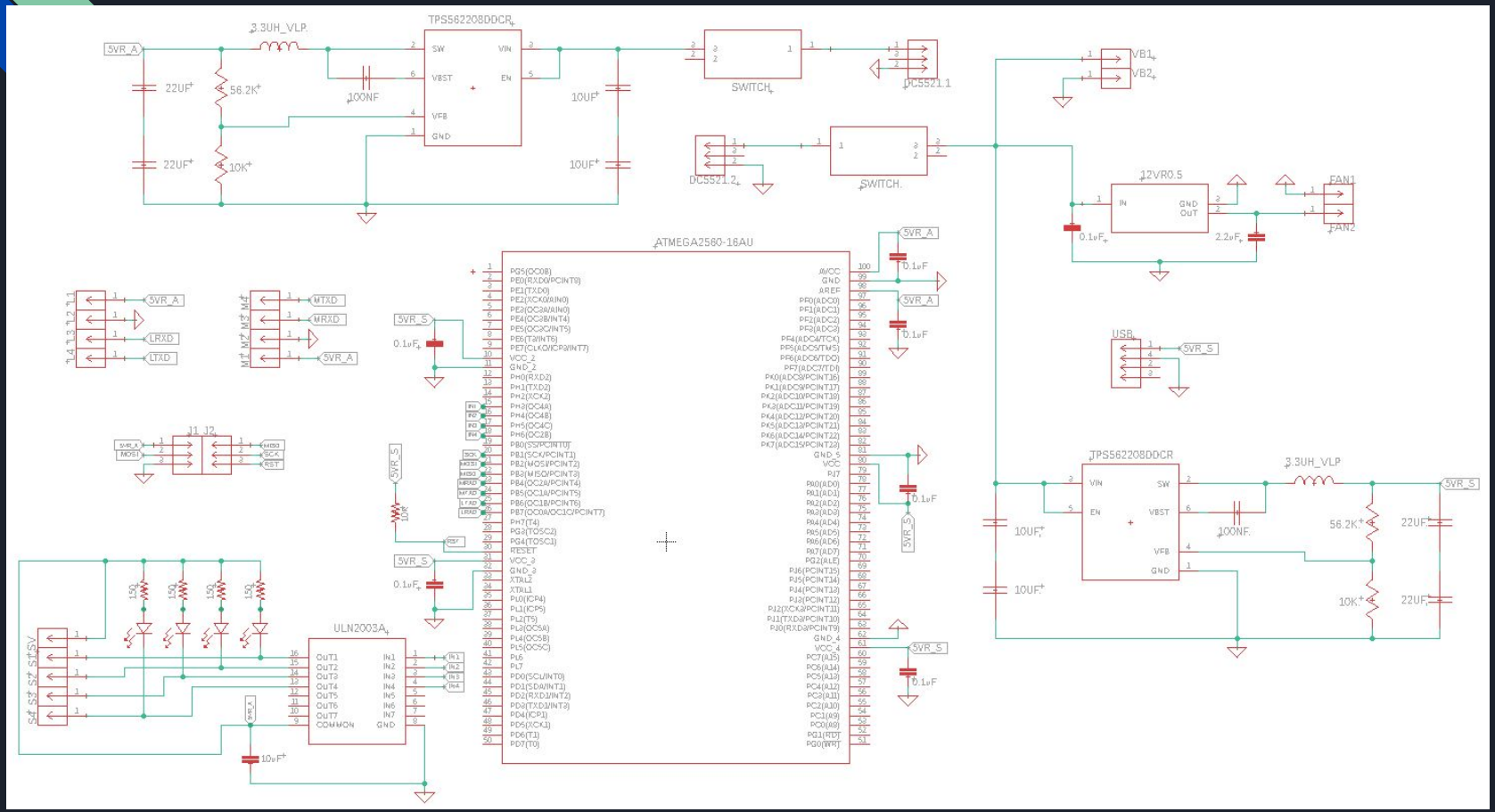
- Vin: 12 volts
- Vout: 30 volts
- Iout: 0.5 Amps



Power Flowchart



Schematic Design Diagram



PCB Design Layout

VB1 - 2: Boost Module

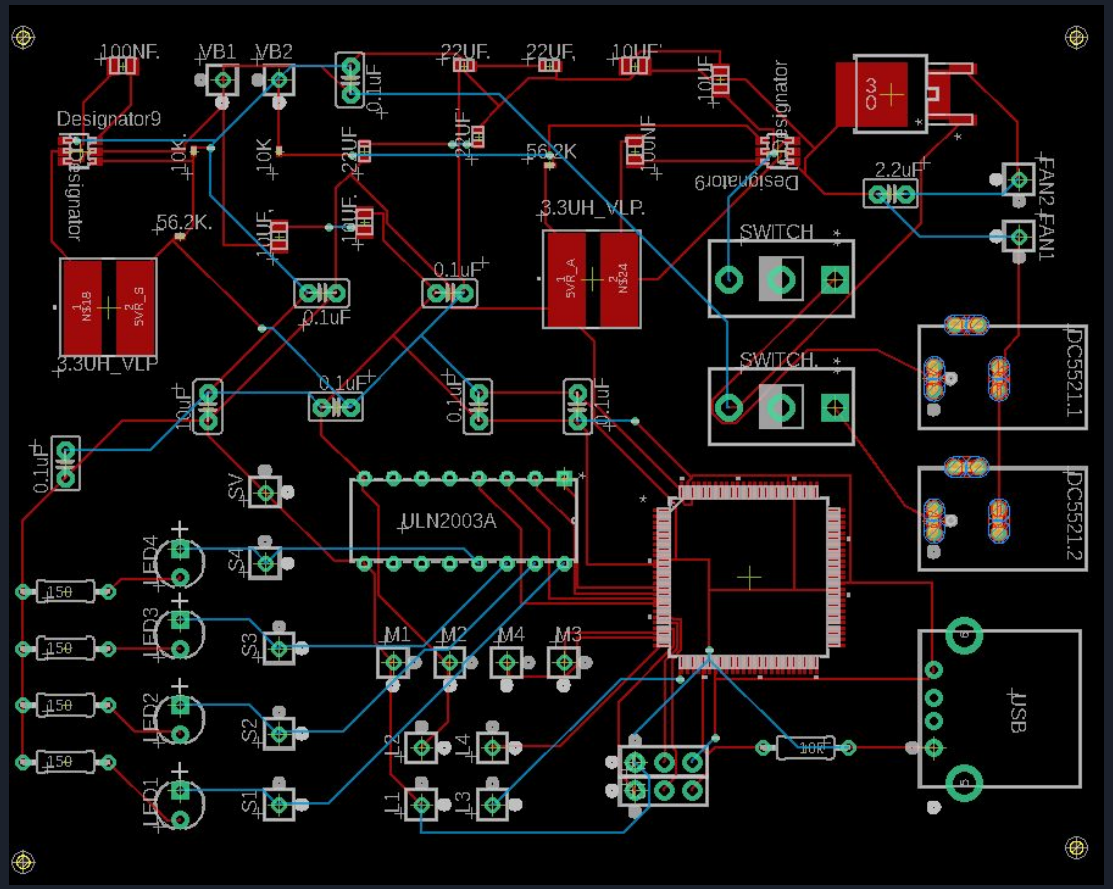
M1-4: Microphone

S1-6: Motor

L1-4: LiDAR

— Top Layer

— Bottom Layer



Battery Barrel jack

USB A Port for LCD and Speaker

Voice Commands

The projector is capable of interpreting the following commands:

- Hey Projector!
- Focus

By default, the projector is listening for the “Hey Projector!” command. Once it is heard, the projector will listen for the “Focus” command for the next 10 seconds.

If said within 10 seconds of the “Hey Projector” command, the “Focus” command pings the rangefinder to calculate the distance to the wall or other flat surface, and then adjusts the focus accordingly using the stepper motor.

Example in the Serial Monitor of Focus being heard within 10 seconds of “Hey Projector”, and after 10 seconds have passed, by measuring the milliseconds when “Hey Projector” is called (t1) compared to when “Focus” is called (t2)

```
VR Index        Group   RecordNum       Signature
6               NONE    6               NONE

Focus entered within 10 seconds, t1 is
6039 and t2 is 7777VR Index     Group   RecordNum       Signature
1               NONE    1               NONE

VR Index        Group   RecordNum       Signature
6               NONE    6               NONE

Focus entered after 10 seconds, t1 is
11884 and t2 is 22136VR Index   Group   RecordNum       Signature
1               NONE    1               NONE
```

Voice Command Technology

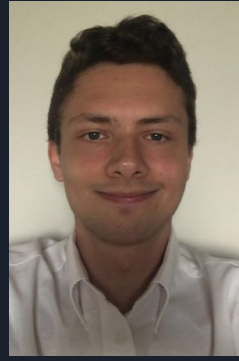
Voice recognition is achieved through the Voice Recognition V3 Module Compatible Board for Arduino (pictured below). By recording an audio input, it is capable of storing up to 80 commands, but only has 7 available for quick access.

As we only have 2 (Hey Projector and Focus) this is not an issue for our project, and we used the remaining 5 slots to record “Hey Projector” and “Focus” additional times to increase recognition accuracy.

Voice Recognition V3 Module Compatible Board for Arduino

VR Index	Stored
0	Hey Projector
1	Focus
2	Hey Projector
3	Focus
4	Hey Projector
5	Focus
6	Hey Projector

Financing

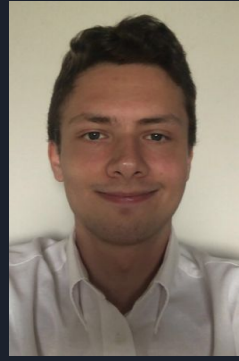


As our team does not have any sponsors, the financing for this project is entirely dependent on the team

As a result, we have decided to all contribute towards the purchases of the various parts and components needed for the project

Since the financing for this project is not sponsored, we have to be sure to stay within a strict budget

Budget



Without a sponsor, the team is entirely responsible for the costs of the project

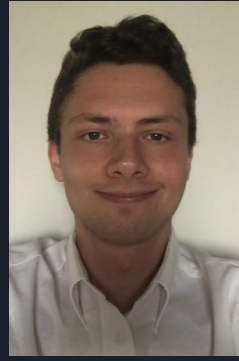
As a result, we have decided to set a strict budget with the goal being to keep the total cost of the projector under $500

In an effort to keep the total expenses as low as possible, we took advantage of the various parts and components that team members already had

See the table in the following slides which outlines the various parts and components along with the corresponding cost

Parts with a cost ‘N/A’ listed for the cost were already possessed by the team

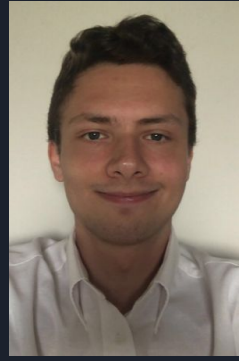
Budget - Optical Components



Material	Unit Cost	Quantity	Total Cost
Chip on Board Light Emitting Diode	$8.51	1	$8.51
Ground Glass Diffuser	$56.50	1	$56.50
Liquid Crystal Display	$56.55	1	$56.55
Projection Lens	N/A	1	N/A
Micro LiDAR module	$40.00	1	$40.00

Total: $161.56

Budget - Electrical Components

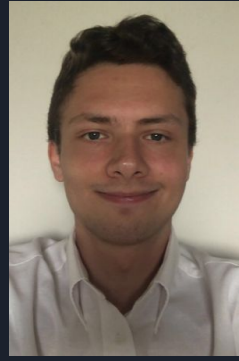


Material	Unit Cost	Quantity	Total Cost
28BYJ-48 Stepper motor	$5.00	2	$10.00
12-volt Lithium Ion Battery	$40.00	2	$80.00
ULN2003 motor driver	$5.00	2	$10.00
DZS Elec DC-DC Buck Boost Converter Module	$12.00	1	$12.00

Total: $112.00

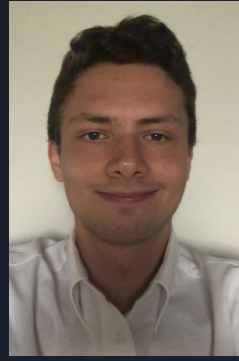
Budget - General Components

Material	Unit Cost	Quantity	Total Cost
Pure Wings 2 Cooling Fan	$11.66	1	$11.66
Arduino Mega R3 Development Board	N/A	1	N/A
Cheers.US K3 Omnidirectional Microphone	$10.99	1	$10.99
Voice Recognition V3 Module Compatible Board for Arduino	$18.53	1	$18.53
Amazon Basics A100 USB Powered Computer Speakers	$13.69	1	$13.69



Total: $54.87

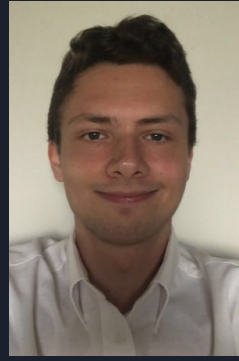
Budget - Building Materials



Material	Unit Cost	Quantity	Total Cost
Wood	$4.07	6	$24.42
Epoxy Glue	$8.48	1	$8.48
Thermal Paste	$7.98	1	$7.98

Total: $40.88

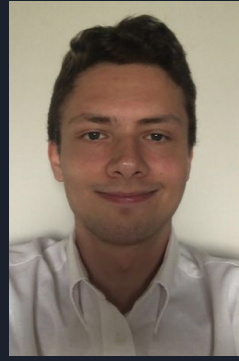
Budget - Miscellaneous



Material	Unit Cost	Quantity	Total Cost
HDMI Cable	$15.93	1	$15.93
Aluminum Heat Sink	$15.43	1	$15.43
USB 2.0 A Male Dual USB Female Jack Y Splitter Hub Power Cord	$6.88	1	$6.88

Total: $38.24

Budget - Total Cost



The final cost of all of the components and materials comes to a total $407.55

With our original goal of a budget of $500 we are still well under budget in the case that we run into issues and need to purchase additional components

Work Distribution

- Corey

Worked on the software design using the Arduino development board with the LiDAR module and stepper motors. Collaborated with Gabriel to complete the initial autofocusing system. Created and updated the team's website.

- Alex

Studied the specifications of how voice recognition works, from the hardware of the microphone/speaker to the software in CMUSphinx. Generally took on the miscellaneous tasks that weren't attributed to any one person in the software/hardware flowcharts (such as editing and uploading this video).

- Tyler

Designed the printed circuit board used to power all the devices within the projector. Worked with each team member to understand the power requirements and microcontroller connections for each device, and created the system circuit design based off that information.

- Daniel

Designed and created the optical path, leading to the selection, testing, and integration of the light source, collimating lens, image source, and projection lens. 3D printed specific parts such as the optical mounts.

- Gabriel

Created the initial approach for the autofocusing system to use a rangefinder and stepper motors. Collaborated with Corey to complete the initial autofocusing system, and with Daniel to modify the projection lens to accommodate the design.