Autofocusing LED Projector

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

Dept. of Electrical Engineering and Computer
Science and The College of Optics and
Photonics, University of Central Florida,
Orlando, Florida, 32816-2450

Abstract — **Projectors are a common engineering product on the market today utilized in many industries, from academia to entertainment. The Autofocusing LED Projector is a senior design project aimed towards innovating common engineering designs of projectors. From incorporating unique technologies such as voice commands, LiDAR, and ground glass. While also improving on currently used projector technology such as LEDs, autofocusing, and low power consumption. This is a multidisciplinary project where software, electrical components, and optical components function cohesively to deliver an impactful engineering design. The future of projectors are hands-free, low power, high focusing speed, with high image fidelity.**

I. Introduction

The Autofocusing LED Projector is the future of projection technology, which has endless applications to all industries. Although projector technology has made various advances over the recent years, we believe there are many drawbacks that persist. This project will enable the design team to get hands-on experience with optical and electrical hardware engineering design. Furthermore, development of computer software engineering algorithms will expand our knowledge of the processes and implementations associated with design. It is our mission to improve on the limitations of current projector technology and expand the market beyond that of today.

The team has developed objectives for each goal that our senior design project plans to accomplish. Included are core goals which are what our project plans to showcase, advanced goals which elevate our system above the competition, and stretch goals which is what we aim to achieve in our limited time this year.

The core goals of the projector are to successfully create a projector that can render images and video with spatially uniform intensity. These images and movies will be generated by a smartphone or laptop connected to the liquid crystal display via an HDMI cable. Furthermore, an automated focusing system will act based on the information from a laser range finder. To achieve this, we aim to have a stepper motor connected to a translatable focusing lens for the projector. From the distance determined by the rangefinder, the stepper motor will then adjust the focusing lens position accordingly so that the rendered image is in focus.

Additionally, hands-free projector control via voice commands and power consumption less than industry standards are our final core goals. The voice commands will enable auto focusing, initialization and shutting down of the projector system. The execution of this will be enabled by a microphone with specific commands recognized by the Java speech grammar format specification.

The advanced goal for our project is to have stepper motor rotations on the projection lens gears. This will enable the adjustment of the focusing lens by the stepper motor so that the image is always in focus. Furthermore, video and audio input to the projector can be accomplished with a mobile device. Finally, our last advanced goal is fast turn on time of the projector. The stretch goals of our senior design project include fast focusing speed with high image accuracy; little to no distortion or aberration present in the final image. Additionally the final image size will auto adjust with various distances including automated brightness manipulation. Furthermore, the final stretch goal of our projector is to include a feature in which voice commands can be activated even when not projecting.

When setting up a projector, typically a contractor is needed and a lot of time and money is spent getting it just right. With the weight and focusing time cut down, the installation period and setup time will therefore drastically improve. As a result, the dimensions of the system will remain relatively compact while maintaining robustness.

Furthermore, the costs associated with this system will provide such an economic benefit. Thereby diversifying the market to allow for all types of consumers to enjoy this technology. We believe the design of the projector system will have a significant impact on the technology and market of our consumers.

II. System components

A. LiDAR

LiDAR, short for light detection and ranging, can be classified as a laser distance sensor. The simplest method that LiDAR uses is it measures the range of the given target using the time-of-flight method. This can be described as the transmitter on the LiDAR device emits laser light at the target object, the pulse of the laser is reflected by the target object, and the distance between them is calculated using the relationship between the constant speed of light in air and the time between sending and then receiving the given signal. LiDAR provides high measurement range and accuracy, fast update rate, can detect small objects, and can be used in the low light conditions, making it the prime candidate for our given use case. The desired device that meets the specifications is the TFmini-S LiDAR Module. The device operates on the OPT 3101 time-of-flight sensor, uses a VCSEL laser at a wavelength of 850 nanometers, a class 1 laser, ensuring consumer safety. It also uses a PIN photodiode to receive the reflected signal.

This device has an operating range of 0.1 meters to 12 meters, with an accuracy of +/- six centimeters from 0.1 meters to six meters, and +/- 1% from six meters to 12 meters. This device also has a distance resolution of 1 centimeter, a frame rate of 100 Hertz, and an ambient light immunity of 70 Klux. The device's electrical parameters are that it has a supply voltage of 5V, an average current less than or equal to 140 milliamps, power consumption less than or equal to 0.7 Watts, a peak current of 200 milliamps, and can use the UART or I2C as the communication interface.

B. Liquid Crystal Display (LCD)

To maintain the engineering design and specifications of our projector such as bright uniform light and image projection. The image source liquid crystal display technology that our senior design team has decided on is the 5.5” 2K Sharp LS055R1SX04 Screen for 3D HDMI-Compatible to MIPI to Printer Board. This LCD screen has a backlight attached to the back surface and thus our team plans to remove that backlight. The screen is 120mm in length and 70mm in width. The resolution of the screen is 1440x2560 pixels enabling a beautiful 2K display. The brightness is 450 cp/m^2, along with a contrast ratio of 1300 to 1. Given the resolution, brightness and contrast ratio we believe the projector will give a pleasant image with plentiful illumination capabilities. The viewing angle is eighty in all directions with a signal interface MIPI of two channels, four data lanes, fifty pins, and a connector for the driver. The MIPI is a yellow flex cable attached to the screen to connect to the LCD driver board.

C. LCD Driver Board

The other important component to the liquid crystal display screen is the printed circuit board driver as discussed previously. The driver board is HDMI-compatible with the 40 pin MIPI screen. This is a very important factor within our part selection process because we want to be able to easily connect a device from which the images can be projected from. The input micro USB power adaptor uses 5V. The audio will be connected via bluetooth to speakers. The board size is 60mm in length and 40mm in width further enabling the compact design of the projector. The LCD driver board and screen will remain connected at all times throughout the entire projector design and integration process.

D. Light Emitting Diode (LED)

The light source of our projector needs to be as bright as possible while consuming as little power as possible. The LED that our team has chosen is the chip on board (COB) LED. The design choice is perfect because the three rows of ten diodes will produce enough brightness where only one LED is needed. The price of the LED was only $7 keeping the costs of the light source to a minimum. This LED is energy star rated A++ with a lifespan of 10,000 hours. The dimensions are 40mm in length and 40mm in width. The wattage of the light source is 16W with a turn on voltage of 32V and a turn on current of 0.5A. The wavelength temperature of the LED is 6500K giving that natural white color needed for the light source of a projector.

E. Microcontroller

The microcontroller which we decided to use for the project is the ATMega2560. The microcontroller is a key component to the overall project, as it allowed us to program the various functions that were needed. This high-performance, low-power Microchip 8-bit AVR® RISC-based microcontroller operates between 4.5-5.5 volts and provides 256 KB of ISP flash memory, 8 KB of SRAM, 4 KB of EEPROM, and achieves a throughput of 16 MIPS at 16 MHz. This is more than enough memory and processing power for all of our needs. Additionally, the microcontroller has 86 general purpose I/O lines and 32 general purpose working registers, which is more than enough to connect all of our components. Additional features of the ATMega2560 include a real-time counter, six flexible timer/counters with compare modes, PWM, four USARTs, byte-oriented Two-Wire serial interface, 16-channel 10-bit A/D converter, and a JTAG interface for on-chip debugging. The software for the microcontroller was written and tested on the Arduino Mega R3 using the Arduino IDE.

F. Fan

In addition to the heat sink that we used for the LED, we also decided to add a fan as a precaution in order to provide extra cooling to the overall system. Due to the nature of the projector which needs to both output audio and listen for voice commands, it was very important that we chose a fan which was very quiet in order to keep any noise interference to a minimum. The fan that we decided on was the "Be Quiet! Pure Wings 2 120 mm Cooling Fan". This ultra-quiet fan is typically used for cooling desktop computers and consists of 9 airflow-optimized fan blades that are designed to reduce the noise level. This fan provides an airflow factor of 87 cubic feet per minute, while also only producing a noise level of 19.2 dB - less than that of a whisper, making it the perfect fan for our projector.

G. *Microphone*

As we moved forward with our design, we found both USB space and Arduino compatibility to be more important than we originally planned, and thus have decided to go with the secondary option listed in our design document, the Voice Recognition V3 Module Compatible Board for Arduino and its attached microphone. We were originally looking for an omnidirectional microphone to be able to pick up audio from any direction, but as the projector does make its own noise with the speakers, having a more pinpointed audio ended up working better in testing. In addition, by design it was simpler to implement into the pcb, and was easier to use with the development board to test the voice recognition software. Thus, it was selected to be integrated into our final design.

H. *Stepper Motor*

Now we will discuss the motor that will be moving the focusing lens, we have decided to use the 28byj-48 stepper motor. With a step angle of 5.625 degrees, this motor provides good accuracy, and is able to do half step driving, allowing for precise control of angular displacement and rotation.

One of the key advantages of the 28byj-48 stepper motor is its ability to provide excellent torque at low speeds. Furthermore, the 28byj-48 stepper motor operates with low power consumption, making it energy-efficient and cost-effective. Its compact size and lightweight design also make it versatile, enabling us to integrate onto our project without adding unnecessary bulk or weight. Additionally, this motor boasts a unipolar design, simplifying the control circuitry required to drive it. This feature reduces complexity and enables easier implementation.

I. *Battery*

The power supply we used for our projector are rechargeable lithium ion battery packs. The main reason we chose to use lithium ion batteries was because it was the most cost effective and practical option for our projector while also allowing the projector to be portable. To ensure a reliable power supply we made sure to purchase both batteries from amazon as their power supplies are certified by the Underwriters Laboratories 1642,a standard that discusses the use and performance of Rechargeable and non-rechargeable Lithium-Ion batteries. One battery, manufactured by Abenic, has an output voltage of 12 volts, a current limit of 2 amps and a rated capacity of 6800 mAh. The other battery, manufactured by Sparkole, has an output voltage of 12 volts, a current limit of 3 amps and a rated capacity of 5200 mAh. Our goal is the two batteries will be able to power the projector long enough for the user to enjoy a short film.

J. *Voltage Regulator*

In our projector we used 3 different types of voltage regulators to step up, step down and regulate the 12 volts from our power supply. The 3 different regulators we used are a buck boost converter module, Linear low dropout regulator and a buck switching regulator. The buck boost converter module is an adjustable voltage regulator board that can take an input of 5 to 35 volts and output 0.5 to 30 volts, with a max current output of 3 amps. We are using this module to supply power to the light source in our projector, the LED. The module will be configured as a voltage booster to step up the 12 volt input from the battery and supply 30 volts to the LED. The linear low dropout regulator (LDO) we used was the LF120ABDT-TR from STMicroelectronics. This LDO is a fixed regulator that can take an input of 2.5 to 16 volts and output 12 volts and 0.5 amps. The LDO will be used to supply power to the fan. For the switching regulators we used TPS562208DDCR by Texas Instruments. The regulator can take an input of 4.5 to 17 volts and output 0.8 to 7 volts, with a max current rating of 2 amps. We used these regulators in two switching regulator circuits (will be discussed further in the design section) to power the majority of our components including the LiDAR, stepper motor, speaker, LCD, microcontroller and microphone.

K. *3D Printed Gears*

The gear system created is the optomechanical design of the project. Our desire was to create a gear system that could move the focus of the projection lens as the stepper motor moves. To enable the use of a gear system, the projection lens had to be modified to accommodate our design, this modification will allow us to fit our gears onto the lens as we desire, where the drive gear will connect to the motor shaft of the stepper motor, and the driven gear will be attached to the outer rim of the projection lens which adjusts the focus. The gears are to be attached using a press fit, which means to design the piece so it is a tight fit. The number of teeth on each gear can also assist with how fine of resolution we get, our design has 8 teeth on the drive gear and 30 teeth on the driven gear. The following image is a Solidworks model of our gear design.

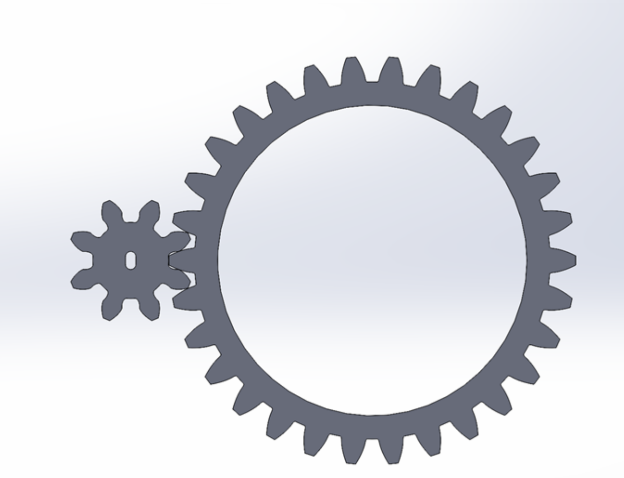


Fig 1. Example Gear System Schematic in SolidWorks

III. Hardware System Concept

The hardware project block diagram enables a nice visualization of our hardware engineering design. At the heart of the design is a microcontroller receiving power from a power supply. Furthermore, the detector along with the microphone will provide additional input into the microphone for autofocusing capabilities.

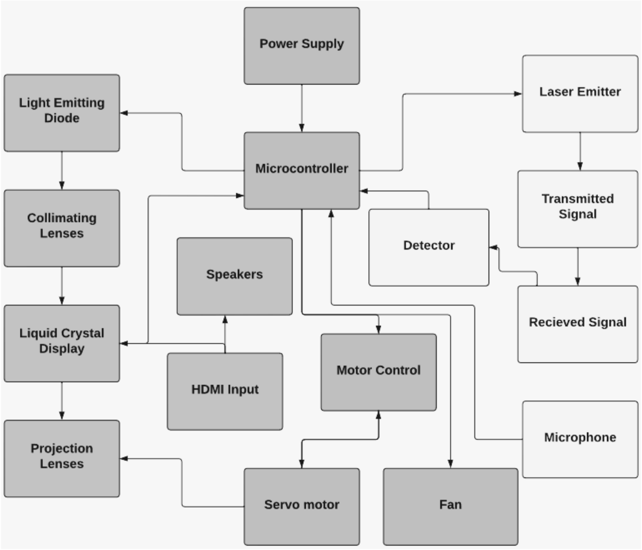


Fig 2. Project Block Diagram

The optical path of the projector show begins at the light source LED then a collimating lens followed by the LCD screen along with the projection lens. The LCD screen will receive video input from the LCD driver board via HDMI-cable and the speakers will receive audio input via bluetooth connection. The LiDAR will enable the autofocusing by the use of a laser emitter, transmitted signal, then a received signal by the detector sent to the microcontroller to control the servo motor which adjusts the focusing of the projection lens. Finally, the fan will cool down the projector to prevent excess heating.

IV. Software System Concept

The software design for the Autofocusing LED Projector consists of two main systems: the autofocusing system and the voice recognition system. The autofocusing system will be responsible for receiving the reading of the LiDAR module and then using that reading in order to focus the projector accurately. This will be achieved by using the stepper motor which is attached to the focus knob of the projection lens via 3D printed gears . The voice recognition system is responsible for listening to the voice commands “turn off” and “focus”. This is done using the microphone mentioned in the “components”’ section along with the PocketSphinx library for Arduino. The following figure shows a flowchart consisting of these two systems.

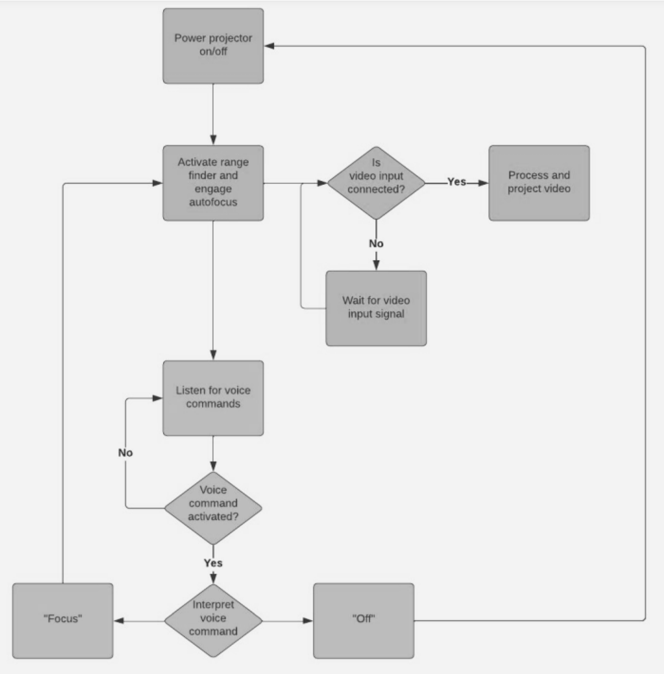


Fig 3. Software Flowchart

As you can see in the software design figure, the autofocusing system is shown towards the top and the voice recognition system is shown towards the bottom.

The flowchart starts with powering the projector on and off.

Once the projector is turned on it moves to the autofocusing system. The first step in this process is to activate the LiDAR rangefinder module in order to find the distance to the screening area. Next, we use this distance in order to engage the stepper motor, which will adjust the focus knob of the projection lens accurately in order to produce a focused image. After the lens is focused accurately, we then check for a source for the image or video. If the source is provided, the image or video is projected to the screening area.

After the initial autofocusing setup, the software will then continue to listen to the voice commands to refocus or turn off. If the “focus” command is activated we go back to the autofocus system in order to refocus the image source. If the “turn off” command is activated, then we move back to the starting on and off block.

V. HARDWARE DESIGN

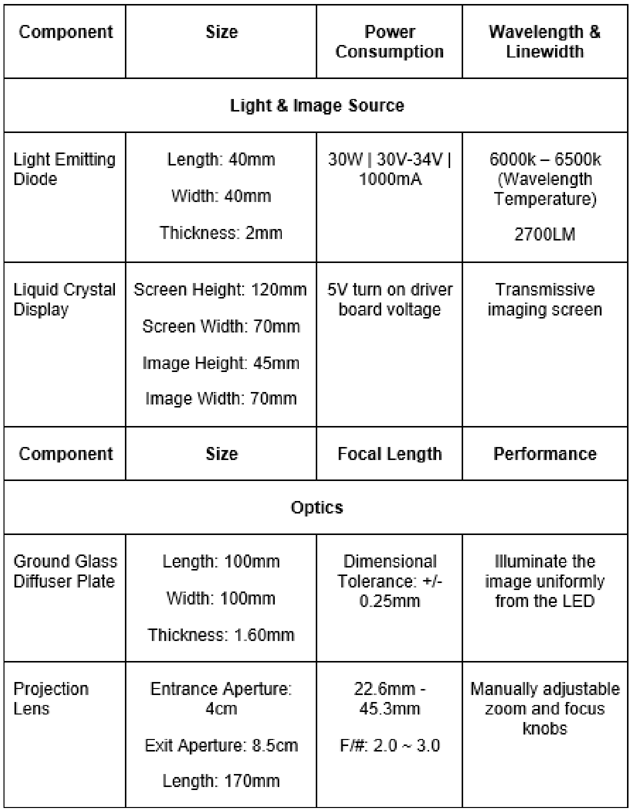
A. Image Projection Design

The design of the optical path or projected image is arguably the most important when designing a projector. First a light source is needed for the illumination component of our projector. We have thus selected a chip on board LED which can illuminate up to 27,000LM. The LED consumes 16W, drawing 32V and 0.5A. The wavelength temperature of the LED is 6500K. In order to ensure the LED does not dissipate excess heat it will be placed onto an aluminum heatsink. The dissipated heat from the LED was measured with a thermal heat gun. The LED dissipated 215°F without the aluminum heatsink and only 70°F with the aluminum heatsink. Therefore the LED mounted onto the aluminum heatsink improves our engineering design greatly by reducing the heat of our light source by roughly 3x!

Directly following the light source will be the ground glass diffuser plate which will serve as our collimating lens. The ground glass has no focal length so the optic can be placed directly in front of the LED to capture as much light as possible. The dimensions of the ground glass are 100mm by 100mm which will be sufficiently large enough.

Directly behind the ground glass will be the LCD screen so that the pixels are illuminated as much as possible. The ground glass will spread the light uniformly across the image source so that the final image will have equal brightness from the center to the edges. The physical image on the LCD screen is 45mm in height and 70mm in width. The screen itself is completely transmissible.

The final image projection design component is the projection lens which will be placed directly behind the image source LCD screen. The length of the lens is 17cm with an entrance aperture of 4cm and an exit aperture of 8.5cm. Furthermore, the lens contains adjustable zoom and focus knobs for high quality imaging and various distances. The zoom range is 22.6mm to 45.3mm and the f-number of the projection lens is 2.0 to 3.0. Shown in the following table are the optical path design specifications which will serve as a simplified overview.



Component	**Size**	**Power Consumption**	**Wavelength & Linewidth**
Light & Image Source			
Light Emitting Diode	Length: 40mm Width: 40mm Thickness: 2mm	30W | 30V-34V | 1000mA	6000k – 6500k (Wavelength Temperature) 2700LM
Liquid Crystal Display	Screen Height: 120mm Screen Width: 70mm Image Height: 45mm Image Width: 70mm	5V turn on driver board voltage	Transmissive imaging screen
Component	**Size**	**Focal Length**	**Performance**
Optics			
Ground Glass Diffuser Plate	Length: 100mm Width: 100mm Thickness: 1.60mm	Dimensional Tolerance: +/- 0.25mm	Illuminate the image uniformly from the LED
Projection Lens	Entrance Aperture: 4cm Exit Aperture: 8.5cm Length: 170mm	22.6mm - 45.3mm F/#: 2.0 ~ 3.0	Manually adjustable zoom and focus knobs

Table 1. Optical Path Design Specifications

B. Autofocusing Design

The autofocusing subsystem is made of the following components: LiDAR module, motor driver, stepper motor, and gear system. Our goal with this design is to correlate distances measured from the rangefinder to the number of steps required to achieve the best focus. We plan to do this by calibrating the motors to determine what is the optimal focus position on the focus knob given a certain distance. The process will begin with the LiDAR component, while this component has a detection range of 12 meters, we have decided to only go out to a range of 5 meters, this is because the performance of the rangefinder in terms of detection accuracy worsens, going from +/- 5 centimeters to +/- 1% variance in measurement, so to ensure more accurate results, five meters will be our maximum range.

Once the distance has been measured, that will serve as the input for the stepper motor/motor driver to move a certain distance in either the clockwise or counter-clockwise direction. The following image is the wiring diagram for the setup of the rangefinder and stepper motor combination.

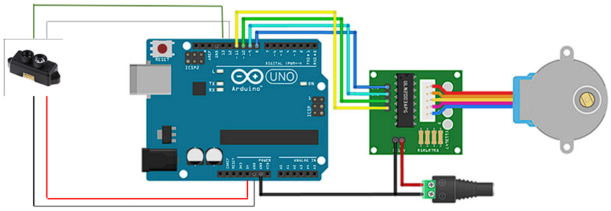


Fig 4. Rangefinder and Stepper Motor Pin Configuration

Lastly, the gear system will enable the movement of the focus of the projection lens to result in an actual change of the focus. The following figure shows the gears attached to the focus knob of the projection lens (left) and the drive shaft of the stepper motor (right).

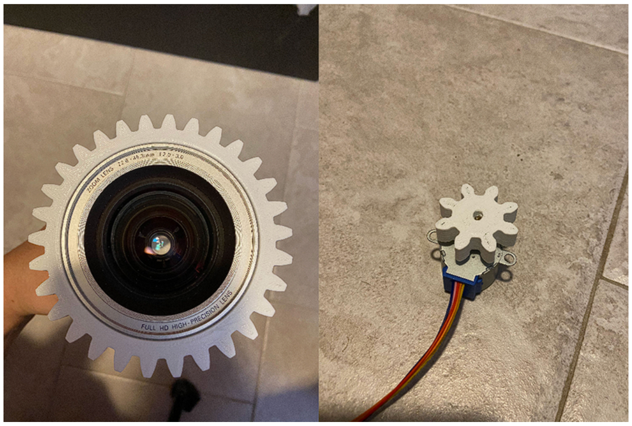


Fig 5. Gear System

C. System Circuit Design

To design the system circuit you first must understand the power flow. To do so we will need all the voltage and current ratings of each component. The voltage requirements for the devices in our projector can be separated into two categories, 12 volt input device and 5 volt input device. The 5 volt input devices include the LCD, microphone, stepper motor, LiDAR, speaker and ATMEGA 2560 microcontroller. While for the 12 volt devices we only have two, the fan and the boost module (which will step up the 12 volt input to 30 volts which will power the LED). Regarding the current, what's important is making sure we don't draw more current than the batteries can supply. The two batteries total output current is 5 amps and the approximate current draw of all the components in our system is 3.7 amps which is well below our max rating.

In order to ensure the components are supplied with the proper voltage for them to operate ideally we need to use a voltage regulator to do so. As stated before the will be connected to the boost module so we will need regulators for the 5 volt devices and the fan. For the fan, even with the supply voltages possible deviations from 12 volts there will be such a minimal difference between the fan’s rated voltage and the supply input we can use a LDO (LF120ABDT-TR) despite its lower efficiency. The LDO will be connected to parallel capacitors on the input and output of the LDO to prevent any oscillations and further stabilize the voltage.

For the 5 volt devices, because of the difference between the supply and the devices rated voltages we will use a switching regulator circuit based around the TPS562208DDCR shown in figure 6. The circuit is designed to take the 12 volt input from the battery and output 5 volts and 2 amps with an efficiency of 93 percent. We will use two of these circuits to connect to each battery to power all of the 5 volt devices. The switching regulator circuit connected to the Abenic battery will power the stepper motor, LiDAR, Microphone and ATMEGA 2560. While the other regulator circuit connected to the Sparkole battery will power the LCD and the speaker.

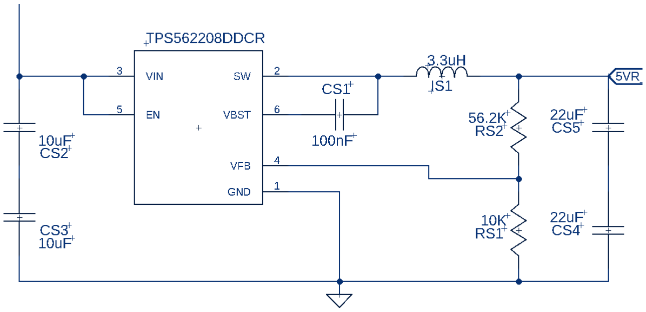
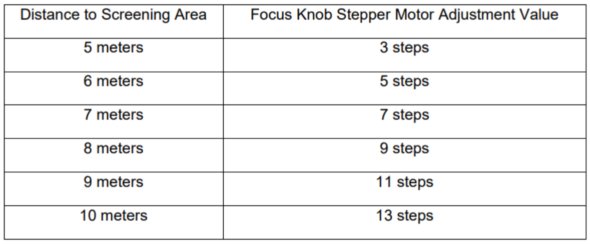


Fig 6. Switching Regulator Circuit

VI. Software Design

A. Autofocusing Software

The overall goal of the autofocusing software is to receive the range from the projector to the screen area using the LiDAR module, and then use that range to determine how the stepper motor should be used to adjust the projection lens. In order to correlate the projector’s distance to the screening area with the adjustment amount of the stepper motor we decided to use a lookup table. An example of what the lookup table will look like is shown in the following table.



Distance to Screening Area	Focus Knob Stepper Motor Adjustment Value
5 meters	3 steps
6 meters	5 steps
7 meters	7 steps
8 meters	9 steps
9 meters	11 steps
10 meters	13 steps

Table 2. Example Lookup Table

The lookup table is a simple 2D array consisting of sets of two values. The first value represents the distance of the projector to the screening area and the second value represents the amount of steps the stepper motor needs to move in order to accurately focus the projector. Using this array, we are able to use the distance found by the LiDAR module in order to adjust the stepper motor accurately.

The largest challenge with this approach was setting a "home" position for the stepper motor so that the adjustment amount would consistently be the same. In order to overcome this obstacle we have implemented logic into the software such that each time the projector focuses, the amount of steps is saved in order to reverse the focus knob back to the starting position before focusing again. Using this approach, we are able to accurately focus the projector within a preset range of distances.

The most time consuming part of this approach consisted of testing the projector at numerous distances in order to fill up the lookup table with accurate values. To achieve this, a number of test programs were used to find the number of steps from the starting position needed in order to focus the projector accurately. Once the needed values were calculated, we moved onto integrating this system with the voice recognition system.

B. Voice Recognition Software

Our voice recognition software is based on the open-source speech recognition system CMUSphinx. CMUSphinx uses the Mel-frequency cepstrum representation of the power spectrum of a sound to identify and process the sounds being picked up [2]. Essentially, it breaks down a sound signal to be easier to compare to the sounds defined in CMUSphinx's configuration files, which also means that stable noises can be identified and subtracted to better interpret sounds that are not coming from the ambient environment. We then take those new sounds and compare them to our "cmudict-en-us.dict" configuration file, and match phonemes to determine if/what words are being spoken. Phonemes are distinct units of sounds, a word like "Focus" is made of the phonemes "F OW K AH S".

The issue with this is that words can have many different ways of being spoken, and a specific phoneme combination can often make up more than one word or words. Another correct pronunciation for "Focus" is "F OW K IH S", but that phoneme combination would also map to the words "Foe Kiss", so much of the testing and refining of the system was adding and defining the phoneme combinations to the "cmudict-en-us.dict" file, and specifying what words to listen to (only "Hey, Projector, Focus, Turn" and "Off") in the "grammar.gram" file.

Despite these challenges, CMUSphinx was still the best possible technology we could've chosen for this project. While industry giants like Google and Bing have much better speech-to-text recognition, they also require an internet connection and are not free, open-source software. Using an A.I and/or machine learning would've increased recognition, but that comes with the downside of much more time invested on the human side and more computational power/energy on the machine side. If there were certain features locked behind voice commands, or if we had many commands, then that would have been time/energy worth investing, but as it stands we only have two real commands, "Focus" and "Turn Off", that can both be achieved without voice recognition. The power button can turn the projector off, and every time the projector turns on it autofocuses. Voice commands were added to improve the projector, not define it.

On that train of thought, we also had to make sure that the voice commands weren't accidentally triggering. If a character in a movie said "turn off" and then your projector powered down, that would be a negative feature that detracts from the project instead of improving upon it. To mitigate this risk, we added the extra step of having to say "Hey Projector" up to 10 seconds before the system would take in another command. Now, with our properly defined phonemes we were not receiving false positives, and by adding the "Hey Projector" step, a phrase rarely heard in movies or videos, we practically eliminated the chance of the correct phoneme combinations for a voice command to come from an unintended source. "Turn Off" and "Focus" are relatively common words, but preceding them with a "Hey Projector" is incredibly unlikely to happen by accident.

For the exact code of how the system works, on startup it defines the AcousticModelPath, DictionaryPath, and GrammarPath to the appropriate configuration files to determine what sounds the phonemes are defined by, what phonemes the words are defined by, and what words the system is listening for respectively. It then starts a new thread, SpeechRecognition, and when the end of a new sound signal is reached, it compares that sound as speechRecognitionResult to the LiveSpeechRecognizer (defined by the earlier Paths) to determine the word/phrase being said. That value is used to determine what happens in the makeDecision function, whether it be flipping heyProjectorSaid to true for ten seconds, calling the autofocusing function described in the previous section, or powering down the projector system.

Interestingly, as the SpeechRecognition thread is always running, it doesn't stop when processing a new sound; instead of the SpeechRecognition thread stopping, the value of "ignoreSpeechRecognitionResults" flips to "True" until the sound is processed, during which time the system is still picking up audio, but not interpreting new sound signals. User privacy isn't an issue, as while "the system is always listening" sounds invasive, the system does not have the capabilities to store or send the data anywhere. Since most of the values (what the phonemes sound like, what phonemes make up each word, etc) are defined in the configuration files, they can be quite long ("cmudict-en-us.dict" is essentially an entire dictionary), but the actual logic of the code is only around ~250 lines, which is very good for our system's desire to be low-power and have fast computation.

VII. Conclusion

In conclusion, by identifying and implementing the best possible components and technologies for our budget, we have succeeded in delivering a cost-effective and user-friendly projector that can automatically adjust a projected image to the optimal focus for that distance, and can even do so through verbal commands. This was achieved through effective collaboration between team members of different strengths and skill sets.

This project represents the innovations that are still possible in the world of portable projection, with potential applications in the world of education, entertainment, and business. Through our team's expertise in their respective fields of optical engineering, electrical engineering, software engineering, and a bit of mechanical engineering, we have met our initial product requirements and specifications, and are proud of our final product.

Acknowledgement

The authors wish to acknowledge the assistance and support of Dr.s Samuel Richie, Lei Wei, Chung Yong Chan, and Aravinda Kar; University of Central Florida.

References

[1] Team, The Arduino. "Mega 2560 REV3." *Arduino Documentation*, docs.arduino.cc/hardware/mega-2560. Accessed 7 July 2023.

[2] The Verification of Voice Recognition Using Cmusphinx and DTW. Retrieved 6 July 2023, World Wide Web ijcat.com/archieve/volume9/issue2/ijcatr09021007.pdf.

[3] Be Quiet!, Info@bequiet.com. "P Bequiet.Com." *Be Quiet! Pure Wings 2*, www.bequiet.com/en/casefans/pure-wings-2/783. Accessed 7 July 2023.

[4] Marsh, Jacob. "Lithium-Ion vs. Lead Acid Batteries: How Do They Compare?: Energysage." *EnergySage Blog*, 13 Dec. 2022, news.energysage.com/lithium-ion-vs-lead-acid-batteries/.

[5] "Customized Projection Lens: Design & Manufacturing Assembly." *Shanghai Optics*, 13 Feb. 2023, www.shanghai-optics.com/assembly/projection-lenses/.

[6] "Free Gear Generator - Design & Create Spur Gears." *Evolvent Design*, evolventdesign.com/pages/spur-gear-generator. Accessed 7 July 2023.

[7] "LED Chip Types: Dip Led vs SMD Led vs Cob Led." *123 LED Lighting*, 20 Apr. 2021, 123ledlighting.sg/led-chip-types/.

[8] Dejan. "How a Stepper Motor Works." *How To Mechatronics*, 17 Feb. 2022, howtomechatronics.com/how-it-works/electrical-engineering/stepper-motor/.