SMARTTABLE

EEL 4914 Senior Design I

Project Documentation

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Table of Contents

Figure of Table

Lists of Table

1. Executive Summary

Humans have arguably been looking for ways to make life better and more comfortable since written history. With the arrival of modern technology, has only made this goal more accessible. With COVID-19 making an unprecedented arrival, the world has shifted into a new normal as society navigates a world where it is mandated to wear masks and stay socially distanced, much the opposite of the social norms from just one year ago. As the world adjusts to the new normal, unprecedented challenges have arisen as people find alternatives to communicate and work with others while maintaining a safe environment. Part of why communities have been able to transition to online or remote activities is through the advent of technology that make it accessible to the everyday person. With the invention of smart devices and the development of technology that is ever advancing, it has shaped the way people operate from day to day and has made us more connected than ever to loved ones, coworkers, and strangers. Aside from work purposes, technology has allowed people to entertain themselves remotely when previously they might have been in-person for their entertainment. This has come about with robust Wi-Fi, multiple streaming services, and wireless devices that could connect to others without giving a second thought. This era of home-based work and play was unthinkable before the 2000s, but with the pandemic looming over us, it has only hastened companies to offer services to supply the ever-increasing demand.

A smart device is considered to be an electronic device which is generally connected to other devices or networks through different wireless technologies such as Bluetooth, Zigbee, NFC, Wi-Fi, LiFi, 5G, etc. that can operate to some extent interactively and autonomously. Since the word “smart” has become synonymously used for different devices and products, this project needs further context and clarification. An example of the most common smart devices are smartphones, tablets, phablets, smartwatches, and smart glasses. For the context of this project the definition of “smart” as the interconnectivity between separate systems to make a larger system that incorporates all the different components. This project outlines the constituents of fabricating a smart table. This project is a smart table that will function as a multipurpose entertainment system with multiple modalities that the user would want at any given time, with all the controls within one device.

2. Project Description

This smart table will not only be used for decoration, but also to provide a multifactorial entertainment system that is able to be controlled from a single device/screen. This is composed of multiple devices embedded into a coffee table which would ideally be in the living room or family room of a single household. When plugged into a power source, the table will operate wirelessly and provide the user with an audio system, a USB type 3 charging station, and a projector that can be aimed at the living room wall or projector screen. The following Sections will discuss motivation / influence for the project, objectives, requirement specification and the quality of the system.

2.1. Objectives & Goals

The motives for the project are to demonstrate the knowledge that has been instilled at the University of Central Florida and successfully apply it. This is a great opportunity to work with a group to collaborate in order to create a useful device that will potentially be used by many people to their benefit. This type of group project is necessary and invaluable in that it can be applied to any future career path; any industry requires working with others, navigating thoughts and ideas, and putting different modalities together in order to make a great product. Aside from academic motivations, there is the aim to elevate the use of the side table in living spaces. From a practical point of view, side tables/coffee tables are mostly seen as an expensive piece of furniture that is appealing to the eye and people think brings the look of a room together. It can occasionally be used to display books and hold food and/or drinks when relaxing nearby, but for the most part it is only functional as something to be looked at. The Greeks were the first to invent a table/desk a furniture which was the steppingstone to what is seen now in present day.

With the table being such an integral component in almost every household, the idea to improve the functionality of this showpiece is slowly coming to the limelight as people switch to a more remote way of living from day to day. This table is a step forward into the modern world of internet as it integrates multiple components that build off existing feats of technology. It is a seamless extension of what exists in many homes, which are smart devices that are interconnected through Bluetooth, such as light bulbs, smart home hubs, thermostats and security cameras. By building a couple of hardware devices with electronic components, software interfaces and implanting them on a table gives more value to the table and it becomes even more efficient versus a monotonous household produce with one use.

The smart table is intended to improve the quality of life by providing comfort and setting the perfect social and academic environment in which all devices come together. The smart device could be both a study area and a theatrical zone due to the projector embedded into the table; which will allow people to project their smartphone, computer, or any device with Bluetooth settings that also syncs up audio to the built-in audio system. This provides functionality for younger audiences who want to create a theater at any point or put any lecture being streamed on a larger screen, as well as older audiences who might need magnification of videos or images and don't want to strain their eyes as much.

The objective for the smart table is to bring families, and friends together in this tough time by facilitating a remote, interactive entertainment system utilizing devices and features that humanity has come to expect and use in modern society. The goal is to provide a system that can go in anyone's home, office, or most indoor spaces. The objective is to provide an all-in-one self-contained projection system with the interconnectivity modern society has come to love and expect while providing a unique product that combines style as well as functionality as a shell for all the devices it will hold. This is also a statement to any builder or consumer that technology and electronics is universal and is only limited by imagination. Electronic devices are used in every corner of modern society, from communication devices, transportation, energy, software, medical devices, and most of these advances in these sectors were done by taking simpler devices and improving them in some capacity since there was a demand for it.

2.2. Requirements and Specifications:

The objectives will specify requirements of a fully wireless system, efficient, and light weight table. This table will be to provide an entertaining environment or a studied area while giving value to a standard coffee table. This table will be practical and universal in any household making a table internal relevant.

Hardware: The hardware will conclude all custom PCB which includes the power system, audio system, MCU, fingerprint reader, Bluetooth module, brightness/ LED driver, HDMI controller. Bluetooth, fingerprint, HDMI and the MCU will be implemented into a single unit for less of the clutter.

Software: The software consists of a control module for the various features. The user will have access to control the brightness of the projector screen as well as communication with the units via the wireless system and the embedded code for the fingerprint reader.

Control: The table will include a microcontroller that will act as a mediator unit to interface the communication system and the wanted setting or outputs such as controlling the volume level or brightness of the LED light within the projector.

Communication: Wireless communication system will handle the data inputs through Bluetooth that the user requests and any data that the software interface requires.

Power Supply: The power systems will be specific to each device implemented in the smart table and as efficient as possible. It will consist of a significant voltage source for which the needs of each custom PCB can then be addressed.

Fingerprint Reader: The Fingerprint reader will provide a level of security to access the user interface and a storage compartment.

Projector: The projector system will be containing a COB LED to transmit light, Fresnel Solar Lens to Collimate light from the LED, LED Driver

Layout of Table:

- ➢ A stander size for a coffee table

Table 1: Coffee Table Dimensions

Height	15 – 20 Inches
Length	36 – 50 Inches
Width	18 – 26 Inches

- ➢ Physical material will be primarily wood and aspects of plastic to structure attachments
- ➢ Perfectly leveled and it should not weight more than 30 lbs.

- One microcontroller to all devices
- Controller through software application Connected through host MCU
    - ➢ Controller that controllers the brightness level of the light within the projector
    - ➢ Controlling volume levels
- Wall plug cord to a full wave bridge rectifier (AC to DC)
- Power Buck Converter reducing the volt and providing a stable DC volt
- Fuses will be implemented in case of current leakage or shortage
- A two-way speaker system for audio
- Speaker impedance of 4 and 8 ohm
- Class D audio amplifier with a low pass and high pass filters for a clear sound system
- Wireless communication to speakers will not only play the audio of what is being projected but also a phone or anything with Bluetooth capability.
- USB Type A 3.0 for charging devices
- LCD Screen will have a resolution of 1080 x 1920
- Projector Display area 68.04 x 120.96 mm
- HDMI (2.0, MIPI DSI display port) supporting 4k to 60 Hz connecting a computer to project its screen
- Fingerprint Reader Connected through host MCU
    - ➢ Allow a level of security for Home Pro accessibility
    - ➢ Access features such as opening a storage compartment
- Total cost wont excessed $ 800.00

2.3. Quality of House Analysis

In order to succeed in a project, the decision the team makes should be carefully picked. In the engineering industry, time for mistakes and budget play an important role in engineer's worst nightmares. Therefore, to avoid any failure in this project, Team 2 decided to use the Engineering Marketing Trade Off Matrix shown below to narrow the marketing and engineering requirements for the Smart Table project. The symbols used in Table 2 represent the degree of importance given to each requirement in order to facilitate the group decision making. Basically, the team focused on the priorities the project should consist of. Costumers need was chosen depending on the features the smart table include in order to determine the main points the team should focus on while designing the electronics of the project. In the HOQ table (Table 3), the highest points of focus were on the sound and projector quality, and the high performance of the project features since it depends on the efficiency of the electronics design. Bluetooth connection efficiency is other point the team focused on because a failure of wireless communication will lead to a project failure. The creativity, exterior feature (shape, color, etc...), and installation difficulties had a low focus since the team decided to first be certain that the performance quality and accuracy are all successfully achieved. Since electronics, these days are reliable, accurate, and most importantly cheap, the cost of the electronics was decided to have a lower attention but with a précised budget especially that no sponsorship has been involved in this project.

Table 2: Quality House Symbol

Symbol	Meaning
+	**Increase the requirement**
-	**Decrease the requirement**
++	**High correlation**
+++	**Super High Correlation**
--	**Low Correlation**
---	**Super Low Correlation**

Table 3: House of Quality Analysis

		Efficiency	**Quality**	**Install time**	**Weight**	**Cost**	**Dimension**
		+	+	-	-	-	-
Sound Quality	+		+++	-	--	-	--
Projector Quality	+		+++	-	--	-	--
Connection Efficiency	+	+++		-	--	-	--
High power	+	++	++	---	--	--	--
Install difficulty	+	+	+	+	+		
High Performance	+	+++	+++	-			
Creativity	+	++	++		---		
Exterior Features	-		++	---	---	---	-
Cost	-	-	-	-	---		---
Results		**>70%**	**>80%**	**2 weeks at most**	**35lb**	**<1000 400>**	**2X3 feet**

3. Standards, Constraints, and Safety

Used with care and reverence, electricity and electrical systems are safe and vastly improve the quality of life for human beings. Common sense as well as quality control measures are an integral component of the engineering design process. They allow the engineer to maximize the efficiency of their design while minimizing costs and risks to public and private health. The success of an engineering project is bounded by the standards of security as well as fiscal limitations. For example, quality benchmarks and cost assessments make it possible for life-critical systems such as pacemakers, airplanes, automobiles, MRI, and many other devices to exist and be reliable for use by both professionals and laymen. For the success of the Smart Table, it is necessary to implement measures for power safety, PCB, soldering, and coding standards. The methodologies discussed are not comprehensive but serve as an overview of the tools applied to address standards, constraints, and safety.

3.1. Soldering Standards

In this section The National Aeronautics and Space Administration (NASA) has a PDF guild line for soldering called “"NASA TECHNICAL STANDARD: SOLDERED ELECTRICAL CONNECTIONS”. This document informs the user several important preparations, environment, equipment, temperatures and techniques for soldering. Numerous diagrams are provided which representing the proper technique of soldering depending on the surface. Several hole technology and different types of surface mounts how to mount part onto a printed wired board (PWB). There are various types on mounting techniques such as Horizontal Mounting, Vertical Mounting, and Radial Lead Mounting. When mounting a component in a Horizontal position it will be parallel and in contact with the mounting surface. Slightly angular or a slight spacing when the parts are bonded are acceptable. In a Vertical Mounting more specifically in a plated through hole the end of the component must be at least 0.5mm and a maximum of 1.27mm above the PWB surface mount. However, in a non-plated-through-hole the end of the component must be mounted flush on the PWB surface, and the opposite leads should be bent at an angle. The Radial Lead Mounting has the same perimeters as the Vertical Mount.

Place the lead on the opposite sides to prevent any stress between the body and the solder termination by bending the lead slightly however, for leads on the same side must be bent no more than 95 degrees and less than 45 degrees. NASA describes a fillet as a smooth concave buildup of material between two surfaces, there must be a fillet of solder between the conductor and a terminal. Of course, there it also states that once a broken or damaged conductor pattern it is no longer usable and pressurized air should never be used to cool off soldered joints. This must happen in a cooled environment or a cooled room temperature. This is because cooling of the solder point too quickly could result in a fragile solder or a bad fillet connection. It is also important to avoid re-soldering because the quality of the connection may be comprised. Another important fact is that additional flux is almost always necessary if not required when resoldering. Reheating will not be sufficient to establish a proper connection between the component and the board and will not be of the same quality of a fresh solder. Placing a bit of flux before using the soldering iron will allow the solder to settle and flow gives a better fillet result.

After the soldering on the printed circuit board is complete it is important to inspect the board to make sure a good quality has been maintained. An inspections look can be insuring a fully working board will function properly without any complication. If any microprocessors or communications modules are above the pad and a visual inspection may not be possible, other means may be used such as Xray or fiberscope optics is another alternative. However, in this project a visual inspection will be enough, yet it is important to be aware of other methods.

3.2. Lead Soldering Safety

Choose the type of lead can be extremely important and determines the temperature in which it melts. In this project a PB63sn37 solder was used and this is comprised up of 63% lead and 37 percent tin. In the application a soldering iron is used and set to 750 degrees Fahrenheit of course this is a potential health hazard if no precautions are taken and because lead is a neurotoxin this can be the cause of several chronic health issues. The potential effect includes but are not limited to memory, concentration, muscle/joint pain, digestive issues, and the soldering iron can cause savior burns if not handled properly. However, when handling a soldering iron, it is important to be extremely careful while only using it for short periods of time and returning it back to the cradle. Most of this building will be done by hand soldering this will include the protype and the parts will be attached onto a beadboard through soldering wired onto the pins. This will also include any last-minute soldering or repairs such as misalignment or other issues.

As stated in the intro this section is to inform the reasoning behind the selected lead chosen for this project and the potential health hazards. There is also the decision of picking the appropriate solder and as such there are certain factors to be considered and analyzed before coming to a final conclusion. The first thing to consider is safety and health in any development or product; not only for the manufacturer but the consumer as well. However, a lead solder poses very little threat to humans it would take an extreme about of lead solder to be harmful. Typically, RoHS compliance is one of the considerations made when choosing a particular solder. RoHS stands for the Restriction of Hazardous Substances Directive and it restricts the use of certain hazardous substances in electrical and electronic equipment. RoHS is primarily the one who restrains type of lead and is the case for almost all electrical engineering application. In other words, RoHS restricts certain chemicals or elements in order to meet foreign export necessities and other health standards. For this project RoHS is not a major issue because the produce is not being exported internationally and it is not going to be sold at all in any extent. However, if this changes at any point in time, the type of solder will be changed accordingly. But for the present need a 63% lead base solder will be adequate. This type of solder is appealing for many applications and is easily accessible, cheap, and susceptible to temperature fluctuations. Non lead base solders require more finesse while tending to become finicky when there is a change in temperature and needs a finer adjustment, so it flows onto the pad. A non-lead base also has a grainy disposition and does not look as smooth or refined as a lead base solder.

3.3. C Language Standards

Speaking professionally there are not C programming or coding standards as of right now. However, there are learner looks and different styles. In order to get some content of some standards Nasa provides a document specifying their standards for C ++ coding. As a coder even though there are no official rules the idea is to be organized, easy to read, easy to understand, maintainable, and efficiency. The general principles for readability and maintainability are as followed

- Organize classes vis encapsulating and hiding techniques while as providing text
- Readability by the use blank lines and indentation
- When using header files provide comments
- Adding comments in implemented files for the maintainer
- Readable and meaningful names

As stated, above names are important and should be meaningful and readable. The names should fit together naturally, the relationship is clear, derivable, and reasonable to anyone. When given the opinion of using upper case abbreviation an alternative is to use initial upper case followed by all lowercase letters and make sure to capitalize the first letter of each word. For class library names the coder wants to avoid any names that will clash by using name spacing and when there are many uses of namespaces components, it is preferable to use a 'using' clause to avoid clutter in the code. When choosing a function name, it is important to make the meaning clear in what it does preferably a verb and writing in mixed cases starting with upper case. For argument names the argument can have the same name as its type when passing a class and because it can become cumbersome the names should be succinct. Variables should begin with a lowercase letter, with the first letter of each word in the name capitalized and should only add a comment when the variable is not clear in meaning. An internal variable needs to be stated at the level which its being used or needed. for example, if a variable is used throughout a procedure it needs to be stated at the top of the procedure, and if its only used in a computation block it can be declared at the top of the block. An internal variable also contains a comment if the name is not clear then it can also contain a unit. In a for loop, the internal variable can be inside. If the variable is needed after a for loop it will be declared above the for loop not inside. A pointer variable is placed with the variable name and not with the type. However, for a null pointer just use "NULL". Reference variables contain a "&" with the variable name rather than with the type which is also true for class overloaded operators. For structure names the use of classes is highly recommended to structs. However, if all data is public a struct can be used and when naming a C function, the names should be lower case and there should not be many C functions in C or C++ programing. Last but not least the coder should void using global variables but use namespaces.

Having standards for formatting can make a code easier to read and the general standards for formatting is as followed:

- To organize statements in paragraphs and separate logically related statements, blank lines are used
- Breaking a statement into various statements can make a code cleaner and easier to use.
- To provide structure in the code indent.

When formatting, a cleaner look is to, declare one variable per line and braces should not be used for all the block but a brace is necessary in an if/if else statement. Parentheses are needed around a condition and never forget to put a space between keywords and parentheses. Indentations, spacing and tabs are a key factor for formatting. In indenting to optimize readability and maintainability use three spaces. However, if that is not an opinion use logical spacing and if several variables are declared line up the variables. Blanks lines are used to create paragraphs or comments making the code more readable. All arguments should be lined up but if an argument is too long and will not fit and the argument may be line up with the method name instead. When using switches, they should have a default case and the default case should be last which does not need a break but is nice for consistency. It is okay if a case statement fails and it goes on to the next statement as long as a comment is provided. In a for loop or while loop, indent the first statement using braces and for a single statement braces are optional. Break statements are used to exit an inner loop in a for loop, do while loops, or switch statements at a logical breaking point. Finally return statements are allowed in a function and are much more efficient rather than declaring a local variable and returning it.

Although there are many ways of coding and no official rules when writing a program these are some tips and tricks to help organize your work and also make it readable not only for the user but others as well. Another reason is for decoding because when righting a long program it is hard to keep track of everything the user has done and when decoding it is important to know every aspect of the coding whether it be an if statement or variable and even a pointer/ array.

3.4. Power standards and safety

The main goal of maintaining power safety standards in electrical equipment is to prevent injury, fire, and electrical shock. These standards are maintained nationally and internationally. Products meeting this standard and requirements are embossed with the identifying safety mark form the associated standards organization to indicate compliance within a specific economic region. For the American and Canadian economic region, the governing agency that gives its seal is the CSA mark. The international principle governing bodies for said standards are the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). A product meeting an IEC standard such as IEC 60950 or the newer 62368-1 standard may be identified with the standard's number as well as in some cases the identifying economic region in which the standards is maintained, for example EN 62368-1, the EN represents the European Norm.

3.5. PCB design standards

A group must come together and agree on what is acceptable and feasible and the principle governing body for PCB design standards is no different. The ICP or the institute of printed circuit boards came about through six PCB fabrication companies in 1957 and in alter years adopted the IPC standards tree.

The IPC standards are set in place to ensure the proper standard to hold manufacturers to in order to construct safe, reliable, and high performing PCB boards. This is done through paying close attention to details of the manufacturing and dedication towards maintaining the quality throughout the manufacturing process. These standards have been agreed upon and implemented to ensure that the production companies not only meet the expectations of the customer but also maintain a level of reliability and safety. The IPC also helps support standards for the industry in five different ways:

Maintaining End product Quality and Reliability: The IPC standards when implemented correctly will ensure that when a company is producing a product it will meet the generally accepted standards for quality every time.

Maintaining Consistency: Maintaining consistency is arguably one of the hardest tasks for the IPC governing body, however it is essential so that no matter who is manufacturing and designing the product the quality and production will remain the same.

Better Communication: The internationally accepted IPC standard also regulates the langue used to with and without for commonality and easy of design no matter where the product is being manufactured or who is designing the product.

Maintains the Reputation: The IPC standards are internationally recognized in the electronics community and as such is a trusted standard for which companies strive to achieve.

Cost Reduction: When the IPC standards have been implemented correctly and, in every process, there will be a significantly decreased need for quality inspection for every single produced item which will intern reduce costs.

Class 1 (General Electronic Products): This class of product are considered to be the most lenient and are stated as everyday products such as a flashlight.

Class 2 (Dedicated Service Electronics products): This class of electronics must maintain prolonged functionality under continual use, some examples are air conditioning and home appliances.

Class 3 (High-Reliability Electronic Product): The class of electronics is conserved the most stringent class and must maintain peak performance under any conditions, examples of this are a pacemaker, or military reader which are dependent on stringent reliability.

3.6. Laser Safety Standards

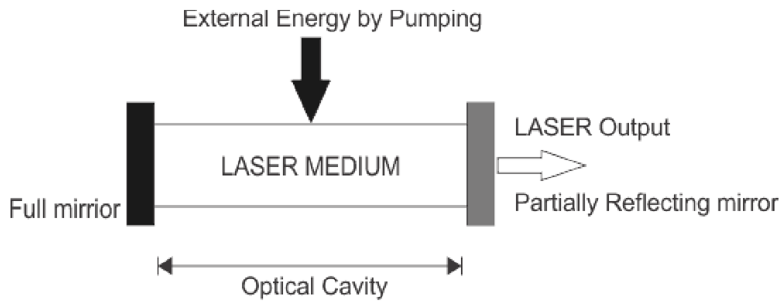

Figure 1: Components of Laser

The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Light can be produced by atomic processes which generate laser light. A laser consists of an optical cavity, a pumping system, and an appropriate lasing medium.

Optical Cavity

The optical cavity contains the media to be excited with mirrors to redirect the produced photons back along the same general path.

Pumping System

The pumping system uses photons from another source as a xenon gas flash tube (optical pumping) to transfer energy to the media, electrical discharge within the pure gas or gas mixture media (collision pumping), or relies upon the binding energy released in chemical reactions to raise the media to the metastable or lasing state.

Laser Medium

The laser medium can be a solid (state), gas, dye (in liquid), or semiconductor. Lasers are commonly designated by the type of lasing material:

- Solid state lasers
- Gas lasers
- Excimer lasers
- Dye lasers
- Semiconductor lasers

Wavelength Output

The wavelength output from a laser depends upon the medium being excited. Most of the laser types and their wavelength output defined by the medium being excited can be found on the internet.

3.6.1. Laser Hazard Classifications

Lasers and laser systems are assigned one of four broad Classes (I to IV) depending on the potential for causing biological damage.

- **Class I:** cannot emit laser radiation at known hazard levels (typically continuous wave: cw 0.4 µW at visible wavelengths). Users of Class I laser products are generally exempt from radiation hazard controls during operation and maintenance (but not necessarily during service).

- **Class I.A.:** a special designation that is based upon a 1000-second exposure and applies only to lasers that are "not intended for viewing" such as a supermarket laser scanner. The upper power limit of Class I.A. is 4.0 mW. The emission from a Class I.A. laser is defined such that the emission does not exceed the Class I limit for an emission duration of 1000 seconds.
- **Class II:** low-power visible lasers that emit above Class I levels but at a radiant power not above 1 mW. The concept is that the human aversion reaction to bright light will protect a person. Only limited controls are specified.
- **Class IIIA:** intermediate power lasers (cw: 1-5 mW). Only hazardous for intrabeam viewing. Some limited controls are usually recommended.
- **Class IIIB:** moderate power lasers (cw: 5-500 mW, pulsed: 10 J/cm2 or the diffuse reflection limit, whichever is lower). In general Class IIIB lasers will not be a fire hazard, nor are they generally capable of producing a hazardous diffuse reflection. Specific controls are recommended.
- **Class IV:** High power lasers (cw: 500 mW, pulsed: 10 J/cm2 or the diffuse reflection limit) are hazardous to view under any condition (directly or diffusely scattered) and are a potential fire hazard and a skin hazard. Significant controls are required of Class IV laser facilities.

How to Determine the Class of Lasers During Inspection

The classification of a laser or laser product is, in some instances, a rather detailed process. It can involve determination of the AEL, measurement of the laser emission, measurement/determination of the emission pulse characteristics (if applicable), evaluation of various performance requirements (protective housing, interlocks, etc.) as specified by the FLPPS and/or ANSI standards.

It should be stressed that classification is a required specification provided by the laser manufacturer and the label that specifies the class is found in only one location on the laser product. The class of the laser will be specified only on the lower left-hand corner (position three) of the warning logotype label.

The logotype is the rectangular label that has the laser "sunburst" symbol and the warning statement of CAUTION (Class II and some Class IIIA) or DANGER (some Class IIIA, all Class IIIB and Class IV). This label will also have the type of laser designated (HeNe, Argon, CO2, etc.) and the power or energy output specified (1 mW CW/MAX, 100 mJ pulsed, etc.).

Class I lasers have no required labeling indicating the Class I status. Although the FLPPS requires no classification labeling of Class I lasers it does require detailed compliance with numerous other performance requirements (i.e., protective housing, identification and compliance labeling, interlocking, etc.)

Laser Exposure Limits

At present either the FDA criteria for medical lasers or the following ANSI standards can be useful in evaluating laser safety.

FDA Long-Term Exposure Limits. The FDA/CDRH Federal Laser Product Performance Standard (FLPPS) assumes a linearly additive biological effect for exposures to visible light between 10 and 10^4 seconds (2.8 hours). The standard accepts that a cumulative radiant energy exposure of 3.85 millijoules (mJ) will not cause a biological effect. Hence a 10-second total accumulated exposure corresponds to an average power entering a 7-mm aperture of 385 microwatts (μW). For an exposure of 10^4 seconds, the average power would be 0.385 μW. In the FLPPS, the power level of 0.385 μW is referred to as the Class I Accessible Emission Limit (AEL) for a visible CW laser.

ANSI Z 136.1, Long-Term Exposure Limits

The ANSI Z 136.1 (1993) standard is a "user" standard and therefore provides maximum permissible exposure (MPE) limits. These were derived by normalizing the power (or pulse energy) data derived from biological research studies relative to a defined limiting aperture. For example, in the visible and near-infrared spectra, the limiting aperture is based upon the diameter of a fully dilated pupil of the human eye, 7 mm. The area of a 7-mm pupil is 0.385 cm2. Hence, the irradiance limit for long-term ocular exposure is computed by dividing the AEL value of 0.385 μW by the area of the limiting aperture of 0.385 cm^2. This yields the worst-case MPE value of 1.0 μW/cm2 for long-term exposure in the wavelength range of 0.400 to 0.550 mm.

The ANSI Z 136 and FDA/CDRH allowable-exposure limits for CW lasers (Class I limits) are essentially identical for wavelengths between 0.400 and 0.550 μm. The ANSI limits are, however, more relaxed for wavelengths between 0.550 and 1.40 μm. ANSI recognizes a decreased biological hazard in the red and infrared regions that is not recognized by the CDRH.

The ANSI Z 136 MPE level for a very long-term exposure by a helium-neon laser is, in fact, seventeen times greater than the CDRH standard. In the 1976 revision, ANSI Z 136 introduced the correction factor CB which has a value of 17.5 at the 0.633-μm HeNe laser wavelength, and, thus, permitted a radiant exposure of 185 mJ/cm^2 accumulated exposure for times from T1 = 453 seconds to 104 seconds, and about 18 w/cm2 (7 w in a 7-mm limiting aperture) for continuous operation of exposure durations exceeding 104 seconds.

ANSI Z 136.1, Repetitively Pulsed Exposures

The ANSI Z 136 standard requires a decrease in the maximum permissible exposure (MPE) for scanned or repetitive-pulse radiation as compared to continuous-wave radiation for pulse repetition frequencies (PRF) in the general range of 1000-15000 Hz. Because of pulse additivity, scanned or repetitively pulsed radiation with repetition rates less than 15 KHz have lower retinal damage threshold levels than CW radiation of comparable power.

The ANSI Z 136 Standard includes a reduction factor of the threshold for each of the single pulses based on biological data that are not yet well explained by any theory. The FDA/CDRH standard does not recognize this repetitive-pulse correction factor. However, some experts envision the possibility of a repetitively pulsed laser which is Class I by the FDA/CDRH standard could be rated Class II or even Class IIIB by the ANSI Z 136 standard.

The ANSI standard requires that multiple-pulse (scanning) lasers operating from 1 to 15,000 Hz have a correction to the single pulse MPE. The correction factor is determined by taking the fourth root of the total number of pulses (N) in a pulse train. Then, the correction factor is calculated such that the MPE radiant exposure or integrated radiance of an individual pulse within the train is reduced by a factor N-¼.

ANSI Z 136.1, Maximum Permissible Exposure Limits

- A summary of Maximum Permissible Exposure (MPE) limits for direct ocular exposures for some of the more common lasers is presented in Table III:6-6. For further information on MPE values, refer to the ANSI Z 136.1 "Safe Use of Lasers" Standard.
- The MPE value for different lasers operating for different overall exposure times. The times chosen were:
- 0.25 second: The human aversion time for bright-light stimuli (the blink reflex). Thus, this becomes the "first line of defense" for unexpected exposure to some lasers and is the basis of the Class II concept.
- 10 seconds: The time period chosen by the ANSI Z 136.1 committees represents the optimum "worst-case" time period for ocular exposures to infrared (principally near-infrared) laser sources. It was argued that natural eye motions dominate for periods longer than 10 seconds.
- 600 seconds: The time period chosen by the ANSI Z 136.1 committees represents a typical worst-case period for viewing visible diffuse reflections during tasks such as alignment.
- 30,000 seconds: The time period that represents a full 1-day (8-hour) occupational exposure. This results from computing the number of seconds in 8 hours; e.g.: 8 hours × 60 minutes/hour × 60 seconds/minute = 28,800 seconds. Rounded off, it becomes 30,000 seconds.
- The "safety" exposure limits (MPE's) in Table III:6-6 are expressed in irradiance terms (W/cm2) that would be measured at the cornea. Note that they vary by wavelength and exposure time.

4. Similar Projects and Background Research

This section is to inform the user of various approaches to a smart table and the challenges that were achieved through careful planning and budgeting constrains as well as new and creative ways of applying the hardware and software and numerous selections of components have been implemented. It will also include products that are similar or same in function and appearance to a smart table. This includes their protocols / different technologies embedded in the smart tables and finally considerations of numerous devices. Researching similar projects/projects is critical to an organization's productivity and competitiveness. From wireless communications to robotics, and sustainable energy, it will helps fill gaps in knowledge and develop new products while improving organizational efficiency and growth.

Our team has also come together and collaborated to research previous projects and products that are similar in one fashion or another to our smart table project. We have found two projects that can be discussed that can be considered related to our project in one fashion or another.

- Smart table with LED matrix screen – This basis and idea behind this project was to create a smart table with a user interface to be able to display content like letters, words, and even simple pictures n to an LED matrix. This group came together to design most aspects of this project. The team who design and assembled this project have to physically build their project similarly to ours and have very similar constraints our team will be facing. They also worked together to feed the information processed into the LED matrix to be displayed into a human seeable fashion. This is similar to our project because we have come together to design an HDMI system to properly pip[e the information to an LCD screen for the projection system.
- Coffee table with RGB LED – This project, like the smart table LED matrix project, has a very impressive implantation and execution. This project is very similar to our in several ways. The first way it is similar the size and construction of the project. Our team has come together and collaborated to design and implement a coffee size table. In that respect our design constraints are very similar. The team designed their project to be able to display images onto an LED matrix that have been piped from a user's computer. This again relates to our team's goals because like they have implemented, we plan to have images and video piped though HDMI from a user's computer to an LCD screen for processing.

4.1. Amplifiers for Speaker

Most electronics system requires at least one stage of amplification. Amplifiers are devices that are used to increase the amplitude of the input signal there for this section will discuss the different type of amplifier and their applications and of course there are much more type of amplifiers which are not covered here.

There are many different types of amplifier and when generally talking about amps there are three basic types Voltage amplifier, Current amplifier, and Power amplifier. Depending on the application will depend type of amplifier however for the audio application a power amplifier is applied for speaker or any type of amplification for sound. For loudspeaker Power amplifiers are used to amplify the audio frequency from 20 Hz to 100 kHz. Because speakers generally have an impedance between 4Ω to 8Ω a power amplifier is needed to drive the loudspeaker load. In theory an amplifier can be ideal and are characterized as linear, signal gain, and efficient however, there are always tradeoffs. Which depends on the circuit configuration of the amplifier and method operation. This is referred to has Amplifier Classes and is a representation of the amount of output signal within the amplifier circuit over one cycle of operation when inputting a sinusoidal signal. The classification ranges from a linear operation with a low efficiency to a non-linear operation but with a higher efficiency and of course there is also in between. One common set of classes are controlled conduction angle amplifiers and are known as class A, B, AB, and C. This common set is defined by the cycle in which the amp is turned off and on and determines the conduction state over a time period of the output waveform. If a complete sinusoidal cycle is achieved, then the amp conducted 100% of the time and a provides a 360-degree conduction angle. The other set of classes are defined as the "switching" amplifiers this consists of class D, E, F, G, S, and T which use pulse width modulation (PWM) to control the switches the signal between on/off which drives the output into the transistors saturation.

4.1.1. Class A, B, AB Amplifier

Class A amplifier is the easiest and has the most basic topology out of all the classes which incorporates only one output switch transistor such as a FET, Bipolar, IGBT, etc. within the design of the amplifier. With only a single output transistor biased around the Q-point of the load line never reaches its saturation/cut off state therefore the transistor always remains ON allowing it to conduct a 360-degree output waveform. This can provide a better high frequency (high gain) and feedback loop stability (low signal distortion). However, because the transistor never turns Off the amp never stop conducting and is constantly carrying a current there is a high amount of power loss. Power lose equivalates to emitting heat and a low efficiency rate and could possibly require a heat sink. Another issue is the distortion and unwanted noise therefore the components must be carefully selected. Overall, the Class A has a low efficiency of 30% and is best suited for low signal or low power purposes.

A Class B amplifier uses two active transistors for its topology which take turns during the positive and negative half cycle of a sinusoidal input which creates a push-pull arrangement. With the push-pull the signal gets amplified from the both the positive and negative each transistor amplifies half of the output, then it combines both to complete linear output waveform. This makes the class B amp extremely efficient and has a low heat dissipation because there is no DC base bias current as its quiescent current is zero and the dc power is extremely small making it more efficient then Class A amplifier. However, it is not without limitations because this relies on two transistors, a voltage of 0.7 volts is needed to start conducing and once one is finished the other requires the same voltage almost instantly. As a results distortion is presented this is also known as (zero-crossing distortion) and makes it unsuitable for precision amplifier applications.

Class AB was designed to overcome the issues of both Class A & Class B the heat dissipation and zero-crossing distortion. Similar to Class B topology, Class AB utilizes two transistors or active devices are allowed to conduct simultaneously so each transistor is biased differently therefor they do not full turn OFF during an unstable moment. Each transistor conducts a small portion of the input of half of the waveform and by using this method is eliminates the distortion crossover. Because of the design of the push-pull transistors this amplifier does not conduct a full cycle but more than a half cycle. The efficiency of the Class AB remains more than the efficiency of typical Class A amplifier however, it is less than the Class B amplifier system. In conclusion this a great compromise between A and B and has become very popular for audio power amplifier design.

4.1.2. Class C & D Amplifiers

Class C amplifier has the greatest efficiency but the worst linearity out of class A, B, and AB. The amplifier is biased so that the output current is zero for than half of the sinusoidal signal cycle with the transistor or device in other words the conduction angle is around 90 degrees. This is a tuned amplifier that works on two different operating modes, tuned or untuned and this introduces distortion across the output. When the tuned load is presented the circuit clamps the output bias equaling the supply voltage and this is called the clamper operation. During the clamper, the signal gets properly shape and the center frequency becomes less distorted.

The Class D amplifier was first proposed in 1958 and have become very popular in recent years. Class D is a switching amplifier meaning it uses Pulse Width Modulation or (PWM) and with this type conduction is not a factor because the variable pulse width changes the direct input signal. With a D class system, a linear gain is not accepted, and the input signal is converted into a pulse stream then applied to the amplifier system. there are a few disadvantages to this class one being that during the initial connection and final shutdown of power in the transistor the class d power amp, the potential close the ground will fluctuate and increases the noise. There is also no special switch for the class D and if the installed power transistor does not match well with other devices, the quality of the produce may not pass it could also present a dead band. However, some advantages are that the minimum value of the load impedance connected to it can be very low and the battery conversion rate can be constant regardless if there is a change in the load impedance. The battery usage rate can reach more than 90 percent and meets the requirements of environmental protection and the amp can directly implement functions such as group control, remote control, and monitoring without adding any devices. Theresa los no relative change of high frequency, intermediate frequency and low frequency which makes the sound very clear making it perfect for this project.

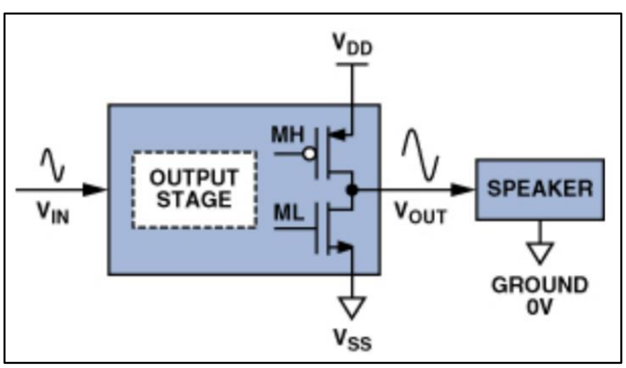

Figure 2: Class D Amplifier Configuration

4.1.3. Components for audio speaker

The type D amplifier contains four basic components which make up a switching type class amp. The first is the wave form that need to be generated and this can be any kind of wave from a triangle or a square wave. The sinusoidal wave is necessary in order to compare the incoming audio frequency from the media player. So, a type of timer is going to be needed to generate any type of sinusoidal wave a list of timers is listed below:

Table 4: Comparing Timers

Name	**Description**
MCP7940M-I/P	IC RTC CLK/CALENDAR I2C 8DIP
SE555P	PRECISION TIMER, PDIP8
NE555P	NE555 SINGLE PRECISION TIMER
TLC555IP	IC OSC SINGLE TIMER 2.1MHZ 8-DIP

When choosing the type of timer, the most important thing to keep is that the human hearing frequency range is between 20 to 20,000 Hz however, the human hear is most sensitive in the 2000 – 5000 Hz frequency range. The first thing to look at is the maximum frequency in which each timer operates at the MCP7040 runs at 400 KHz, SE55P at 100 KHz , NE55P at 100 KHz, and finally TLC 555IP at 2.1 MHz. The next important spec to look at is the voltage supply, when design its sometimes earlier to picky a voltage that's already being used thus another no other voltage need to be provided by the power supply. For this timer the voltage should be able to work at 5V. The 5 Pin or the Cont (control comparator threshold) must be 2/3 VDD and allows the bypass capacitor connection and the trigger level need to be at 1/3 of the power supply. Price is not an issue in this cast as these four timers are cheap therefore quality is more important here.

The next component as mentioned in the timer is a comparator this is to control the volume of the incoming frequency of the media player. For this component was not compared with other types of comparators for the soul fact of already having a LM393 which was already provided in one of the labs at UCF and it meets the requirements for this application. The comparator power supply ranges from 2 to 36 volts and the necessary volts is 12 which is calculated. This also provides the perfect wiggle room just in case the calculation is off, and the input frequency needs to be pulled higher.

One the input frequency is pulled high the next thing that is to feed the frequency to a MOSFET Driver however the signal needs to be inverted first as it acts like the control indicating the driver when to pull up or down. Inverters listed down below and there are only to parameters that are truly important which is the price and the power that needs to range from 3 to 12 volts.

Table 5: Comparing Inverters

Name	Description
NTE74HC04	IC-HI SPEED CMOS INVERTER
CD74HCT04E	IC INVERTER 6CH 6-INP 14DIP
SN74HC04N	IC INVERTER 6CH 6-INP 14DIP

The MOSFET and MOSFET Driver are interconnected and must be chosen together as the driver will be turning on and off the MOSFETs. The MOSFETS driver is a type of power amplifier that accepts a low power input from an IC or in this case the output of the inverter and then the driver produces a high current drive for the gate of a high power MOSFETS. The MOSFET therefore have to be able to withstand high voltages and current while keep cool under the multiple switching from on to off. Instead of a normal power amplifier, the N type MOSFETs will act as a replacement. The table down below shows some of the MOSFETS that were compared and considered for the audio system.

Table 6: Comparing MOSFETS

Name	Description
IRLZ44NPBF	MOSFET N-CH 55V 47A TO-220AB
FQP30N06L	MOSFET N-CH 60V 32A TO-220
IRF3708PBF	MOSFET N-CH 30V 62A TO-220AB

The part shown and discussed are some of the parts/components that we considered for a basic class D amplifier but necessary. In this section parts were considered and bought based on research and theory however, more components may be added of taken away or replaced as the actual building of the audio system is built and tested. The design of the audio system is discussed greater detail and explains every part and aspect of the built-in section 5.1.2 labeled Design of Audio Speaker.

4.2. Power Technology

This section will discuss various methods of providing power to the systems or the overall project. It is important to research different methods and figure out the positive and negative of each technique when design the PCB or motherboard. Because this project will contain various system it is important to supply them with a steady DC source with no spikes in the current. This section will include the following:

- Transformers
- Rectifiers
- Buck Converter
- Linear Regulator

4.2.1. Transformers and Comparing components

This section will describe how a transformer works and its applications. Transformers are used for alternating AC supplies because it generates at a convenient voltage into much higher voltages. In other word a transformer is a passive electrical device that transfers electrical circuit to another or multiple circuits. They are commonly used for increasing a low AC voltage at high current or decreasing high AC voltage at low current in electric power applications and coupling the stage of signal processing circuits. It is also used to distribute power around the country using a national grid of pylons and cables over very long distances. The purpose of transforming the voltage to higher level is that higher distribution voltages implies lower currents for the same power and therefore lower I^2 R losses along the network grid of cable. Then the higher Ac transmission voltages and currents will be reduced to a lower/safer and usable voltages where it can be applied in electrical equipment in our houses and workplaces.

A voltage transformer is a basic simple static/electro-magnetic passive device that works on the principle of Faraday's Law of induction by converting electrical energy from one value to another. The transformer links two or more circuits using an oscillating magnetic circuit and is provided by the transformer itself this also operates on a principal call "electromagnetic induction" in the form of Mutual Induction. Mutual Induction is the way coils of wires magnetically induce a voltage onto another coil which is near it. The transformer has the capability of either increasing or decreasing the voltage and current levels of their supply and this is without affecting the frequency or the power being transferred from one winding to another through the magnetic circuit. A single-phase voltage transformer consists of two electrical coils of wire which are called "Primary Winding which is usually the side with the bigger voltage and other is called the "Secondary Winding. The primary takes in the power and the secondary will deliver power. The two-coil wired are not directly in contact however they are wrapped together around a common closed magnetic iron called the "core". The coil is made up of individual laminations connected and this prevents losses in the core. The Primary winding and the Secondary winding are isolated but are magnetically linked through the core which allows electrical power to be transferred from one coil to another. The electrical current goes through the primary winding first then a magnetic field is created which induces a voltage onto the secondary winding.

In a transfer there is no direct electrical connection between the two coils winding and because of this it can it also be called an "Isolation transformer". In stand uses the primary winding of is connected to the voltage input supply then converts/transforms the power into a magnetic field and the second winding is to convert the alternating magnetic field to electrical power. In this single-phase transformer can either increase or decrease the voltage on the primary winding. "Step-up transformer” refers to increasing the voltage and “Step-down transformer” refers to decreasing the voltage.

After understanding the research shown above and concluding the power system will be powered by the wall outlet. Because the wall outlet contains a 120 volts AC power supply which is too much power for the entire system and would cause the hole system to blow in plugged in and not to mention AC current which needs to be changed to DC. The first thing to do is to reduce the voltage before change the it from AC to DC therefore a step-down transformer will be needed to apply the right about of to every system. In the table down below will be show some transformers and a small description explains the choosing process.

Table 7: Comparing Transformers

Name	Description	Manufacturer	Price
241-8-36	PWR XFMR LAMINATED 100VA CHAS MT	Signal Transformer	$ 23.25
166G30	PWR XFMR LAMINATED 15VA CHAS MT	Hammond Manufacturing	$ 21.25
186E28	XFRMR LAMINATED 56VA CHAS MOUNT	Hammond Manufacturing	$ 17.88
166N24	PWR XFMR LAMINATED 96VA CHAS MT	Hammond Manufacturing	$ 34.00

The table above is some of the transformers looked at after doing research. Although when looking to purchase a transformer various transformer were looked at only four are listed here and are considered to the best for this project. the standards for choosing a transformer is the amount of voltage needed throughout the entire system, how many devices need to be powered and finally price. As of this moment the voltage of every device and the amount of current each of them needs is not known however the project shouldn’t require more than 50 volts. therefore, the lists taking is into account the various secondary voltages are provided with high currents to ensure every device will function as expected. The 241836 is rated to have the secondary voltage at 36V at 2.8 A current and the 166G30 at 30 volts at 500mA current. The 186E28 has an output voltage of 28 volts at 2A current and the 166N24 outputs 24 volts at 4A current. The final selection of transformer component is shown in section 5.1.6.

4.2.2. Rectifiers and Components

A rectifier is a device that converts an oscillating two directional alternating current or (AC) into a single directional direct current or (DC). Now rectifiers can come in many different forms, from a vacuum tube diode, crystal radio receivers to a modern silicon-based designs. However, for this application a simpler more common design will be sufficient. This section will compare three types of rectifiers Full Wave and Full Wave Bridge rectifier.

The Full Wave as stated earlier the job of a rectifier is to convert AC power source to a DC source and the purpose of this rectifier is to improve the Half Wave rectifier. The topology of the full wave is to provide a steady and smooth DC supply voltage. The advantages of the full wave are that the average DC output is two times higher over the half wave and has much less rippling as well producing a smoother output. A full wave rectifier consist of two diodes and this configuration results in each diode conducting when the anode terminal is positive with respect to the transformer center point meaning both half of the sin wave is produced. This makes the output of the full wave rectifier 100% efficiency.

A full wave bridge rectifier also produces the same efficiency as a full wave rectifier however this type of signal phase rectifier uses four diodes which are connected in a close loop hence the name “bridge” configuration. This has benefits one being that it does not require a special centre tapped transformer and as a result the size and cost is reduced significantly. The four diodes are arranged in series and two of those diodes conduct during each of the half cycles. When the positive half cycle diodes 1 & 2 conduct in series then 3 & 4 are in reverse bias and the current flows through the load. The figure below shows this configuration.

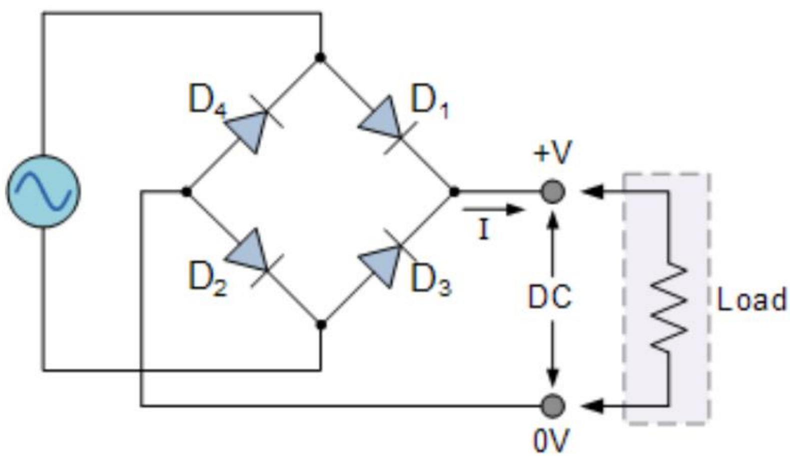

Figure 3: Full Wave Bridge Rectifier

The main advantage of the full wave bridge rectifier is that the AC ripple is smaller for a given load and the amount of ripple voltage that is superimposed on top of the DC supply voltage by the diodes can be practically eliminated by adding pie filter to the output terminals. The pie filter is a lowpass filter that contains two smoothing capacitors of the small value and a choke to introduce a high impedance path to the alternating ripple component.

Even though four individual power diodes can be used to create the full wave bridge rectifier, premade rectifier components are also an opinion. They are also available in a range of different voltages and current size making the process of soldering the component to a PCB much easier and convenient. And finally using a smoothing capacitor is extremely beneficial and is recommended to produce a steady DC supply. The full wave rectifier produces a greater DC value with less superimposed ripple while the output waveform is twice that of the frequency of the input supply frequency. This is where the capacitor come in to play not only improving the average DC output but the AC variation of the rectified output.

The component for the rectifier is at straight forward as full bridge rectifier is the best choice for converting AC to DC with the maximum efficiency. The only thing that really matters is the specification the components such as the voltage peak reverse, current average rectified (Io), forward voltage (VF) and finally the reverse leakage current at the Vr. The important thing is to that the rectifier can held the incoming voltage and the output voltage and current as well. The different rectifiers that were compared are shown in the table down below. The chosen rectifier is shown in section 5.1.6 in more detail.

Table 8: Comparing Rectifiers

Name	Description	Manufacturer	Price
LVB2560-M3/45	BRIDGE RECT 1P 600V 25A GSIB-5S	Vishay Semiconductor Diodes Division	$ 4.69
GBU1004-G	BRIDGE RECT 1PHASE 400V 10A GBU	Comchip Technology	$ 0.92
GBJ2506-F	BRIDGE RECT 1PHASE 600V 25A GBJ	Diodes Incorporated	$ 1.32
GBPC606-E4/51	BRIDGE RECT 1PHASE 600V 3A GBPC6	Vishay Semiconductor Diodes Division	$ 2.07

4.2.3. Buck Converter

The team has determined the necessity of using buck converters in the project. This section will discuss what a Buck converter is, the basic operation, as well as the proper implementation of said devices. However first it is necessary to briefly go through operational configurations and what a switching regulator is.

Switching regulators have become widely popular and have also become a more feasible solution to many designers for various applications. The topology that makes up a switching regulator allows designers and engineers a significantly higher efficiency device as while also providing a much wider range when powering devices. The tradeoff for said efficiency and wide range of use is there are more components leading to larger real estate usage when in production equating to higher costs as well as higher engineering constraints and more noise in the system. This project will most likely require the use of multiple types of switching regulators to power our various devices and as such this section will briefly discuss the operation mechanisms for switching regulators as well as some commonly accepted and used switching regulators also commonly referred to as switching converters.

There are many variants and uses for switching regulators, this section will however briefly dive into the most widely used standard forms, topography, and uses.

- **Buck Converter**: This topology is used to convert a DC input voltage to a lower DC output voltage that would be required per application. An important note for this particular topology is that the power and energy thought the system must be conserved so as the buck converter is able to step down from the supply to the output voltage for the device attached to the load the current the load can experience will likewise be proportionally stepped up. Some general forms of buck converts can attain up to 2A of current though the connected load device. This is information needs to be imperative and kept in mind when a designer or engineer is considering the proper implementation of a Buck converter into the system.
- **Buck-Boost Converter**: This topography is used when a designer or engineer would like control over a range of output voltages while at the same time controlling the current through the load connected device. This is most commonly accomplished through the use of connecting a Boost and Buck convert together as the name suggests. The output voltage can then be designated to what is needed for the application and connected device while controlling the current flow.

A Buck converter is one of four widely used and generally accepted non-isolated DC-to-DC conversion topographies. The Four being Buck, Boost, Buck-Boost, and flyback , As shown in the below figure's conversion topographies, the input is to the left, the chosen connected load is to the right where the box is, and the switch is typically comprised of a MOSFET, of BJT.

A Buck converter is a DC-to-DC power converter used to step down the voltage to a lower voltage while simultaneously stepping up the current from the input to the connected load. A Buck converter is considered a class of SMPS or switch mode power supply and contain at least two semiconductors with at least one energy storage element (capacitor, inductor) to regulate the ripple voltage to usable level for the chosen load device. Buck converters can be used as a highly efficient alternative to linear voltage regulators. The two operations for the Buck converter are transistor on mode and transistor off mode. During the transistor on mode the current flows to inductor building up the electromagnetic field while at the same time the diode in reversed biased will prevent the current flowing down that node of the circuit. The transistor is typically connected to a periodic signal allowing the transistor to "turn on and off" with the rising and falling edge of the signal. This allows the voltage across the load to build to the highest point in the ripple. At this time the transistor will be 'turned off" due to the falling edge of the signal allowing the voltage across the load to fall to the lowest point in the ripple at which point the rising edge of the signal will "turn on" the transistor repeating the process over again maintain a usable voltage for the given device connected to the load. This is displayed in the graph below:

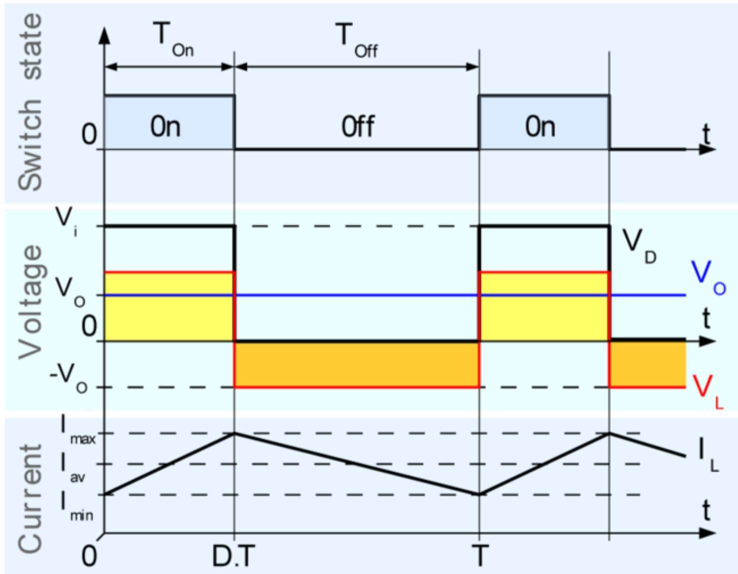

Figure 4: Voltage and current over the load, given rise and fall of signal

When designing Buck converter regulator to meet a specific need, or even for a particular case in electronics, the designer must follow logical and reasonable steps in order to produce a proper and usable part for the system and configuration as well as repeatability and portability of design.

- Step 1: To Start to design a Buck converter regulator system the designer must first know what input voltage will be provided to the Buck configuration (V_{in}) as well as the needs of the connected device that will be receiving the output voltage (V_{out})and the Load (I_L) current form the Buck configuration. The Designer also need to consider the duty cycle that will be turning on and off the MOS component driving the system. The duty cycle equation is given by: $DC = \frac{v_0}{v_i}$

- Step 2: When designing a Buck convert configuration or system the designer then needs to consider the power that the Buck converter is delivering to the load. This being the product of the Output voltage with the Load current though the connected device. Now depending on how efficient the Buck system configuration is the Output power should basically be the input power provided to the Buck converter configuration.

- Step 3: The next step the designer will have to consider when designing a Buck converter system is determining the power transferred per pulse to the load connected device. This is accomplished by dividing the power provided to the load connected device with the switching frequency. For example, if the load connected device is receiving a 50 Watts with a switching cycle of one second, this would give you 50 joules every second.

- Step 4: The last step to consider when designing a Buck converter system or configuration is to calculate the inductance needed. This is done through the equation: $L = \frac{2E}{I^2}$

Here the E is representative of the energy per pulse as calculated above, the (I) is representative of the input current.

When a project or application needs the use of a DC-to-DC Buck converter the designer needs to have a wide range of considerations and implementation factors. There are always many factors to consider across the entire circuitry and system however the key factors for the proper implantation of a buck converter are as follows:

- **Input Voltage Range**: When properly implementing a Buck converter a designer must consider more than just the data sheet for input voltages (V_{in}). Many Data sheet for standard buck converter systems given a wide range of input voltages to a proportionally wide range of output voltages, however the designer must consider what the Load voltage is necessary to operate the device connected to the load while looking at what the input voltage to the Buck converter is being delivered. The Input voltage being delivered to the Buck converter must always be higher than that of the Load voltage necessary for V_{out}. A classic example of this is: If the Load device you are running requires a steady 3.3 Volts, the corresponding voltage being delivered to the Buck converter should be that of 3.8 Volts or higher.

- **Ground Current:** To determine the best Buck converter regulator configuration or system to use for any given application the designer must look to the data sheets, operation thresholds, efficiency, and the I_Q. In this particular case the I_Q Current is representative of the DC-Biases Current that is not being delivered to the load for any given time. System configurations with Lower I_Q values are proportionally representative of higher efficiency ratings and thus should be a goal to achieve. However, depending on the system configuration, the designer may opt for higher values of I_Q variance due to the needs of the system.

- **Output Voltage and Accuracy:** The output voltages from the Buck converter are specified on the Datasheets from manufacturers to be accurate over given operating temperatures. This is important because the components that comprise a standard Buck converter are active, and the designer must always be mindful to either properly dissipate the excess heat or to operate the device within a proper value range. Once active device semiconductors reach specific temperature thresholds the electron-hole pair generation rate would be significantly higher than the doping concentration in the material and render the component inoperable. Most datasheets give an accuracy rating for their given output voltages at ±2% at 25°C.

- **Line Regulation:** The designer should be cognizant of changes in the input voltages that would cause a change in the output voltage for the Buck converter to the load. This could potentially be devastating to the continual operation of the connected load device.

- **Load Regulation:** The designer should be cognizant of changes in the output voltage that could cause a significant change in the load current through the given load device. Most Buck converter systems and configuration are designed to maintain a steady level for the output voltage, however, working with real systems there are always uncontrollable variables.

- **Load Transients:** Like the aforementioned load regulation if the designer does not properly account for the possibility of a change in the load current the system could experience what is called transient load errors, which could cause damage, and possibly system troubles.
- **Current Limit:** Many Buck converter systems and configurations take into consideration both the positive flow current and negative flow current. The majority of commercially based Buck converter systems and configurations are designed to forcibly limit the amount of current not only flowing from the input to the load but also through the FET components (when applicable).

When designing Buck converter regulator to meet a specific need, or even for a particular case in electronics, the designer must choose the components in a logical and reasonable fashion. This section will briefly talk about what to look for when choosing components and designing a Buck converter regulation system for a particular need.

- **MOSFETS:** It is common practice and preferred to use P channel MOSFETs which significantly reduce the driving requirements for the system, however, it is important to be cognizant of the fact that P channel MOSFETs are in the ON state when the gate is low so the use of an inverting signal would be crucial. Texas Instruments recommends the use of a IRF5210 with reasonable and widely acceptable resistance of 60 mΩ while maintain a drain to source voltage V_{DS} = -100V. Texas Instruments states that it is important to include a gate driver to reduce the losses in switching.
- **Diode:** For most generally accepted and use Buck converter regulator systems and configurations the Diode does not experience high levels of voltage across the component; however, the Diode does must be able to handle and operate correctly though higher current loads. A decent and acceptable choice for such a case would be to implement a Schottky Diode when designing the system or configuration. Using such a diode with a low forward voltage drop would go a long way to giving the system or configuration higher levels of efficiency.
- **Capacitors:** Depending on the need from each system the values for capacitors needed could vary wildly. The precise values to use per system can be calculated when deciding the ceiling and floor values in the ripple around what would be considered nominal output voltage for the connected load. Texas Instruments typically suggests values between 100uF to 680uF.

4.2.4. Linear Voltage Regulator and Components

A linear voltage regulator is a fundamental constituent for almost all power delivery systems and standard modern systems in some form or another. The integrated circuitry components that make up the standard topography of a linear voltage regulator are very cheap and easily incorporated into most systems and designs which is part of the reason they have become so prevalent and mainstream. This section will be introducing and briefly discuss the basics of voltage regulators with commonly used and implanted configurations.

Linear voltage regulators are designed to be able to provide a consistent voltage ,DC, to the device connected to the load regardless of a uptake need for current in the load device, provided the voltage and current needed to functionally operate the device connect meets the range specified by the output voltage for the linear voltage regulator. This is accomplished through the successful implantation of a linear control feedback system. The flow of current that is allowed to pass through the transistor is regulated by this linear control system as shown below.

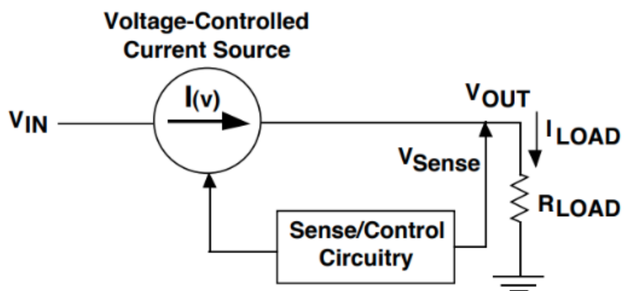

Figure 5: Linear controlled voltage regulator

This control system closely monitors the voltage measured at the Output node (where the load device would be connected), and then takes that value and using a feedback loop is able to adjust the flow current through the transistor that resamples a control signal. This Feedback loop typically contains a comparator to maintain stability. A common mistake made by designers when creating their own system configuration or when implanting standard form regulators is the transient response for the linear voltage regulation system. This transient response is how long the system will take to reach an actable steady state after incurring a change in the systems. When implementing a linear voltage regulator, it is always imperative for the designer to know that linear voltage regulators are not always the most efficient devices to use but may be proffered in lighter load situations over a more robust system. This linear voltage regulation system often comes up inefficient because the active components of transistors are often used as though they are a resistor, and this issue lead to the system often wasting a significant amount of energy in the form o heat. This heat is in fact proportional to the power though the linear voltage regulator multiplied by the difference in the input voltage and the output voltage form said system. These systems can often be performed much more efficiently through the use of a switching mode power supply; however, the linear voltage regulator requires no use of inductors or transformers which take up more real0etsae when designing and implementing the desired system. The components needed to functionally operate a liner voltage regulator allow the designer more room and real estate for other system needs or to lower cost. One topographical commonality between all linear voltage regulators is that input voltage into the regulator must be higher than that of the output voltage provided to the connected load device.

When designing or implanting a series linear voltage regulator is it vital to consider and understand the topography of commonly used variants. The most commonly accepted and used variations of series linear voltage regulators are the standard regulator (NPN Darlington), the low dropout or LDO regulator, and the Quasi low drop out regulator. When considering which topography to adhere to it in imperative to understand the main difference that separates these variations is what is called the drop out voltage. The drop out voltage for linear voltage regulators is the considered the minimum voltage over the linear voltage regulator (form V_{in} to V_{out}) in order for the system to be able to maintain output voltage regulation for the connected device load. An example for understanding this is: Say a designer is planning to power a device that requires 3.3 V, and the linear voltage regulator requires a voltage form V_{in} to V_{ou}t over the configuration to be 2 volts in order for the regulator to operate correctly, this would mean that the supply voltage for the connected to the Vin terminal of the linear voltage regulator would have to be equal to (3.3+2) 5.3 volts or exceed that value in order for the entirety of the system to be able to operate properly. It is important to note that a linear voltage regulator that requires less voltage across the configuration or dropout voltage would dissipate less energy and would thus be much more efficient. This being said, the low dropout topography has the least voltage in order to function and would be the most efficient whereas the standard regulator requires the most and would thusly be the least efficient. Another key factor when a designer is looking to which topography to incorporate is the ground current. The ground current is as the name suggest ,the current that has been supplies from the connected source and is not being utilized by the system, but instead is slowing through the ground pin and as such is being wasted also factoring into how inefficient or efficient a linear regulation can be. A standard regulator has the lowest ground current whereas the low dropout regulator topography has the highest ground current.

When looking at the topography of the linear voltage regulator the designer can look at the pass device section as outlines in figure below. In this is how the three major variation of linear voltage regulators are configured. This is shown in a side by side comparison below. The low drop out regulator is generally accepted a better choice when a designer is planning to use a linear voltage regulator in conjunction with a batter to supply power to their application.

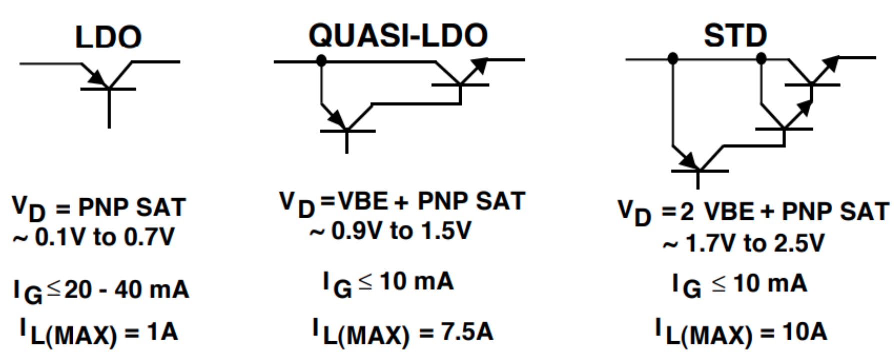

Figure 6: The 3 most common type of linear voltage regulators

For the selection of the voltage regulators the only thing to keep in mind is how the circuit will work and after does extensive research as stated above the only thing left was to know the voltages needed. Since the project will contain a microprocessor in the HDMI the group is designing, and 5 volts and 12 volts will be required for the audio system. The Three of regulators that are going to be used and are already in hand therefore unless the something is wrong with the components there's no reason to wait or purchase the regulators. However, they still in to be tested which will be conducted and talk about in great detail in section 7.1.5. The NCP117ST33T3G will be the 3.3 volts at 1A, LM7812CT/NOPB output is 12 volts at 1A, and finally the L7805CV output voltage is 5 volts at 1.5 A as shown in the table below. The most important thing to keep in mind about the regulator is to provide them with a greater voltage then the intended output voltage. Another thing benefit to these regulators is that the maximum input voltage is 35 volts therefore each one of them do not have to be specially treated. This save times in the overall design while also providing flexibility. To view the entire design aspect of the power supply please refer to section 5.1.6 this section will also go into greater detail of every component and there propose.

Table 9: Regulator components

Name	Description	Manufacturer	Price
NCP1117ST33T3G	Linear Voltage Regulator IC 1 Output 1A SOT-223	ON Semiconductor	$ 0.46
LM7812CT/NOPB	Linear Voltage Regulator IC 1 Output 1A TO-220-3	Texas Instruments	$ 1.54
L7805CV	IC REG LINEAR 5V 1.5A TO220AB	STMicroelectronics	$ 0.50

4.3. Wireless Communication Technology

The literal definition of communication is simply exchanging information between a sender and a receiver. In order to communicate, the receiver plays a major role since it recognizes (approves) that the interaction of the sender and the message was successfully realized. Regardless of the type of communication one is facing, many factors such as emotions, cultural and religious believes, medium of communication, and many others will affect the information transferred between the pair. Therefore, the involvement of the three main players in the communication game; senders, receivers and information does not always imply that communication is achievable. In other words, the word communication is more than just the transmission of information, it requires the success of imparting the information which makes the realization of communication very problematic. The complexity of communication is the main reason why good maintainable communication around the globe is very competitive and desirable by employers. Nothing is more expensive than an accurate, effective, cheap, and unambiguous communication system to realize.

As mentioned earlier, in order to have a communication system, at least one sender, receiver, and a message should be involved. Each with a specific role to fulfil the communication requirements. The communication process is as shown in figure 22 below. The sender, who is universally known by the person, has the goal of transmitting information for a specific purpose. The information in this part is "encoded" which means that the message has been built using mixture of verbal and non-verbal cues. Finally, the receiver, the person the message is delivered to and who "decodes" the message transmitted, acknowledge the reception of the information. In communication, there may be more than one recipient, however, interference may happen, and the information could get mixed between the senders and recipients. As an example, when communicating with a group of people from a different background, the choice of words and body language or any other means may affect the communication which may cause some misinterpretations despite the type of communication-verbal (face to face, phone, television, radio, other media), non-verbal (gestures, appearances, location, body language), written (letters, emails, social media, internet...), and visualizations (graphs, logos, images...).

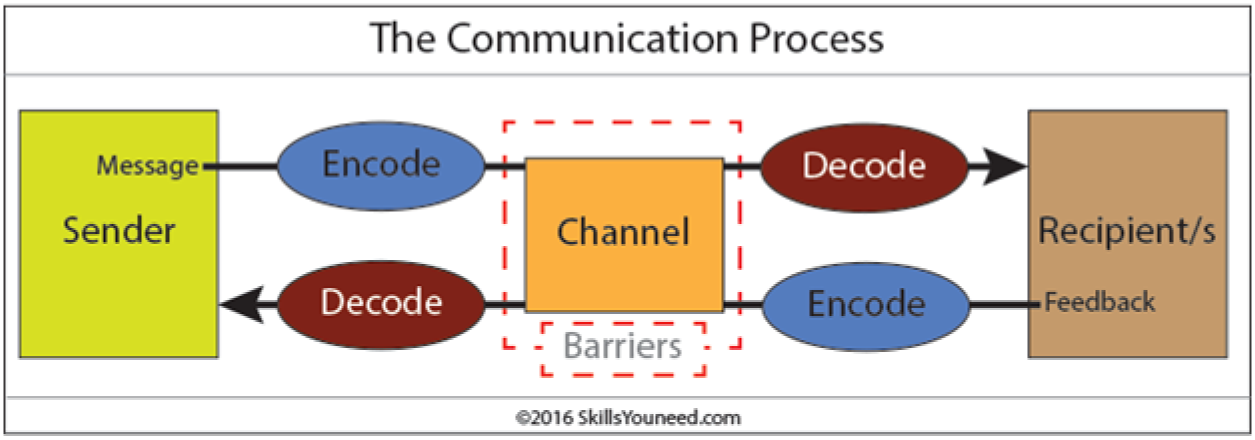

Figure 7: Basic communication process

4.3.1. Types of Communication

Effective communication necessitates overcoming any barriers to communicate at each stage in the communication process. Therefore, in order to send a message, the channel (medium) in which the message will be transmitted should be appropriately chosen depending on the type of communication used. Using the inappropriate channel can lead to a communication failure especially for complex information which mostly require suitable channels for an accurate and efficient transmission. Communication channels include the following:

Face to face communication channel (personal communication): one of the most effective and popular communication used since the human's existence. In this case, the recipient and sender's role are indistinct. The reason why this type of communication is very effective is the physical, the voice and facial expressions presence which helps the recipient to interprets the intends of the sender. Moreover, the sender can also evaluate whether the message transmitted is successfully received.

Broadcast media Communication channels: as an example, TV and radio channels. Most Broadcast media channels address the message (information) to more than one recipient. This type of communication is used in businesses that require the attention of many audience. The message is presented in a visual, auditory, or both and transmitted in a broadcast channel.

Mobile Communication Channels: is mostly used for private, commercial, or a more a more complex message delivery. The interesting feature about mobile communication is its full-duplex mode; the transmission is simultaneously bi-directional. The end services (sender and recipient) use the same channel to communicate

Electronics Communication Channels: include emails, internet, ethernet, social media platforms…, nowadays, these types of channels along with the mobile communication channel are used for distant interactions. It is definitely a less personal technique to communicate but it so far proved its efficiency in the communication word.

Written communication method: when no interaction is necessary, written communication take place and facilitate the transmission of messages. From writing an email to a college or an employer, sending a text message (SMS or social media such as messenger), to receiving a letter from a bank or an advertisement from your local shopping store, written communication has impacted our daily lives since the day languages were introduced to this day, written communication has always replaced the face-to-face channel when needed.

4.3.2. Introduction to Wireless Communication:

Wireless communication is a method of transmitting information from one device to another without using any physical channel yet still allows the propagation of signal through an unguided medium. the reception of the signal that is floating in the free space is accomplished by antennas-electrical devices that transform an electrical signal to an electromagnetic wave (EM) and the other way around in order to allow the transmission and reception of signals. During the last centuries, wireless communication has been the fastest growing and most desirable technological area.

In the communication field. In wireless communication, the information is transmitted through the air using electromagnetic waves such as infrared (IR), Radio Frequencies (RF), Satellite, etc. In the present day, wireless communication has become part of our daily lives. The most common uses of wireless technologies in our daily lives are GPS, smart phones, remote controls, Bluetooth, Wi-Fi, and many other types of wireless technologies.

Wireless communication dates from the early observations of magnetic and electric properties made in the 17^{th} and 18^{th} centuries by the Greek, Chinese, and Roman. From the telegraph development and the detection of radio waves developed by Branly, the first wireless telegraph was demonstrated by Guglielmo Marconi in the 1897 which led to the birth of the first Radio followed by the radio station called “Marconi Station”. Then later in the early 19s Marconi successfully introduced transoceanic communication to the word. From then, wireless communication technology has known a huge development and improvement and become one of the most important mediums of communication nowadays.

In order to successfully realize communication, the involvement of a sender, recipient, and information is mandatory. However, to achieve an effective wireless communication, the system is divided into three main elements as shown in the Figure below:

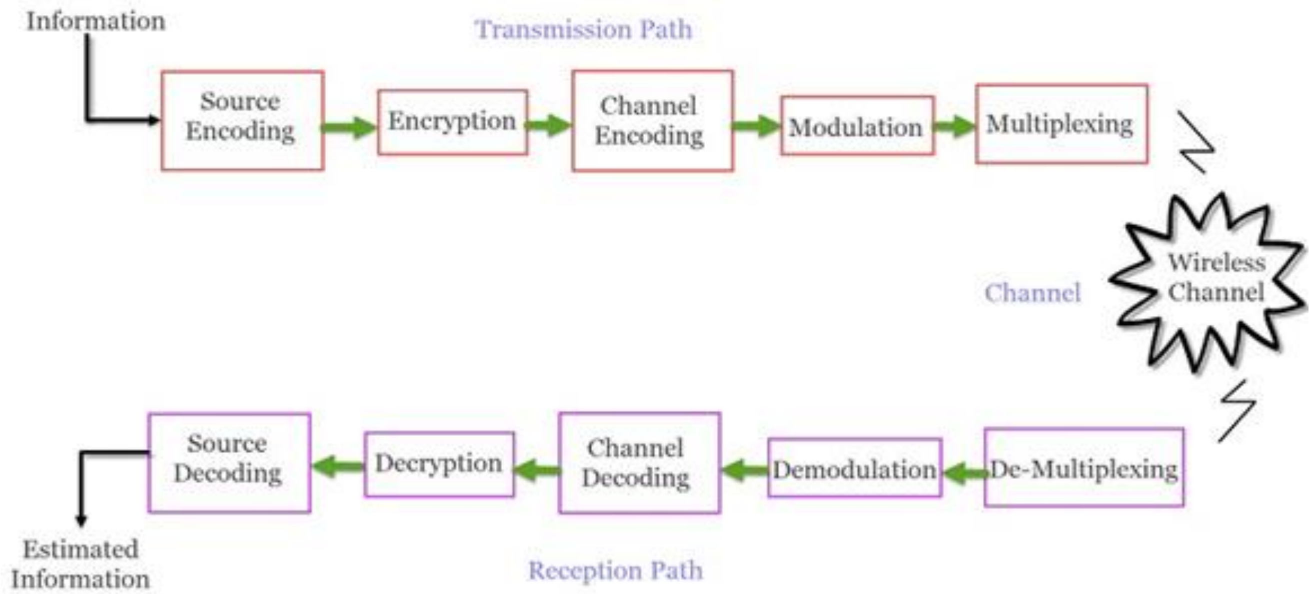

Figure 8: Elements of wireless communication system.

In the transmission path the signal (information) is first converted from isn't base form to an electrical quantity in order to apply the signal processing techniques. The redundant information from the signal is filtered followed by the encryption of the signal which consist of securing the information for security purposes. Since the signal will be send through an unguided medium, channel encoding is applied to the signal to reduce the effect of noise, interreferences and other impairments. During channel encoding, some redundancy is applied to the signal to prevent any external noise to interfere with the information transmitted. Next, the signal is modulated using the required modulation techniques; Phase/Frequency Shift Keying (PSK, FSK) to then be transmitted through an antenna. Using some multiplexing techniques such as Time Division Multiplexing (TDM) or Frequency Division Multiplexing (FDM), the signal is multiplexed with other modulated signals to be send through a valuable bandwidth.

Channel in the wireless communication system is the medium is which signals are being transmitted through (In many cases a free space). As mentioned in the previous sections, wireless channel is unguided and unpredictable due to the randomness in nature. Therefore, there is a high probability that the received signal may contain errors due to the distortion, noise, interreference of.

The reception path is like the transmission path but going backward. First, signals are detected by an antenna from the wireless channel. They then are demultiplexed in order to obtain each signal separately. Each signal is then demodulated. The redundant bits are removed from the demodulated signals using a channel decoder. Signals are then decrypted which makes them unsecure, and finally the signal passes through a source decoder to convert its electrical form to the original form.

Wireless communication is playing an important role in the telecommunication field which allow as to say that telecommunications these days has become mostly wireless. As previously mentioned, wireless communication technology transmits information over a medium (air) using electromagnetic waves (EM).

In order to understand the different types or wireless communication systems, lets first discuss their different classifications which will be used to identify in which applications each type (module) could be used. Wireless communication systems can be classified in 3 categories: Simplex, half-duplex, and full duplex.

- **Simplex:** communication is a one directional communication. (i.e., Radio broadcasting systems, TV...)
- **Half-duplex:** is a bi-directional communication but with a delay between the transmitter and receiver (i.e., walkie-talkie)
- **Full duplex:** is a bi-directional communication with no delay; the transmitter and receiver can communicate freely with no obstacles (i.e., mobile phones...).

The following are some different types of wireless and telecommunications technologies commonly used nowadays:

Infrared (IR): Is a type of communication uses infrared radiation; an electromagnetic energy that has a longer wavelength. This type of communication is mainly used in the short and specified range communication where the devices or systems should be selected to operate as a transmitter and receiver with no object blocking the up-link and down-link paths. IR communication is mostly used as a source in the communication system.

Satellite: Signals (a beam of modulated microwave) in this type of communication are sent near a satellite which is situated in the space. The satellite then captures the signal and amplifies it to send it back to the antenna receiver (earth station)

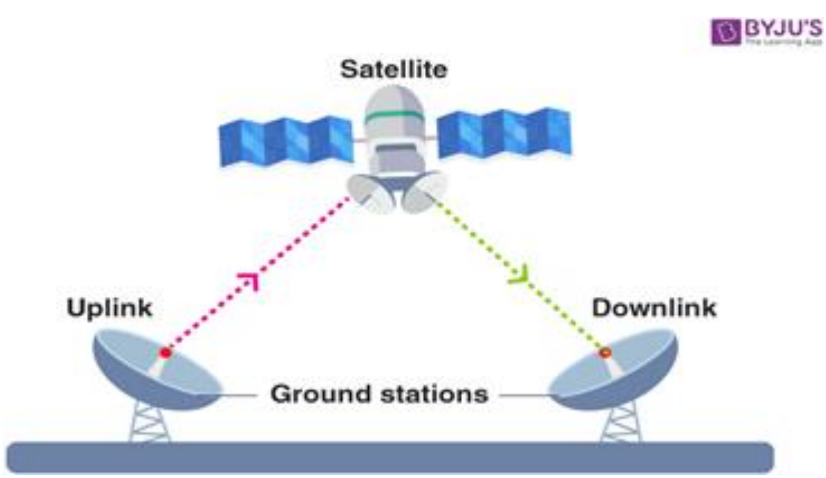

Figure 9: Satellite communication process

Wi-Fi: Is another communication mean that uses routers to transfer information wirelessly while allowing users that are within the router range to access the network. These networks need to contain a password in order to block intruders to access the information of the users. Some of the very common electronics that uses Wi-Fi networks these days are smartphones, computers, and home automation systems.

Mobile: The development of mobile communication has been improving in a very rapid rate. This mode of communication is known to authorize multiple users to communicate in across a single frequency band without interference between the users.

Bluetooth: is a wireless communication technology standard that uses short-wavelength Ultra-High-Frequency radio waves with a range of [2.4GHz, 2.485GHz] to permit the user to connect a variety of electronic devices wirelessly for data transfer over short distances; approximately 10 meters.

Figure 10: Multiple devices Bluetooth connection

The development of wireless communication in the telecommunication field has been and is still the core of technologies in evaluating the mankind. If it weren't for the Marconi first radio communication which introduced data transmission in channels of communication, the word would probably still be struggling with the evolution of technology. As the mankind demands increases, scientists try to find new technologies to speed the rate of communication. Therefore, wireless communication has known many generations, especially in the mobile industry.

Wireless communication technology has numerous advantages & Disadvantages. Wireless networking and systems have facilitated the struggle of wired communication is many ways:

a. **Cost:** in wired communication, the maintenance and insulation of wires, cables, and other infrastructure is very costly. However, when wireless communication was introduced, wired communication was eliminated hence the overall cost of the system was lowered.
b. **Flexibility:** was the definition of wireless means, no physical connection between the interacting devices is present. Yet, and this is the main advantage of wireless

communication, the user is also offered the freedom to move around a specific range while connected to the network.

c. **Implementation:** wireless communication is known by its ease to being setup and installed. Its equipment is very easy to configurate as no physical connection is needed. In addition, the time required to setup a wireless system such as Wi-Fi and Bluetooth, is very less compared to the wired communication installation.
d. **Reliability & coverage:** since no cables are necessary, the chances that a failure will occur in the communication process is very minimal. As mentioned in the cost section, no maintenance will be needed in case of environmental damages. Furthermore, wireless communication could be reached globally; in other words, even rural areas, battlefields, and other places where wiring is not feasible can be connected to the word thanks to the wireless communication.
e. **Security**: the first concerning issue about wireless communication is security. As communication is done through free space, some intentional interference may occur hence less secure medium is introduced.
f. **Health Concerns:** human body is very responsive to any type of radiation which can be hazardous. The levels of RF or IR energy can still cause some body damages if the radio frequencies at the beginning of the installation aren't designed properly.

As scientists keep inventing (improving) wireless communication technologies, their applications become more and more widespread. Since decades, wireless applications have included security systems, television remote control, wireless speakers, wireless power transfer, hand free headphones, etc. some examples of some projects containing different types of wireless technologies such as Robotic vehicle controlled remotely from a smart phone, home automation system based remote control from an Android application, locating and tracking.

Now that the basic concepts of wireless communication along with its elements, types and technologies, advantages, and disadvantages, and finally applications were discussed at the beginning of this section. It is very easy to conclude that using wireless communication in projects that require communication between at least one device is the best choice to make. The flexibly will provide a better mobility to the users, the implementation will be instantly regardless of location, the efficiency of connectivity is also high when no interreference is present, in addition to the low cost of the system. Another point which makes the wireless communication the best technology to use in one's project is the amount of space the hardware takes.

4.4. Bluetooth Module

Bluetooth is a wireless technology that allows the exchange of data between different devices among a short distance due to the wavelength responsible for transmitting the information. The maximum connectivity range for a Bluetooth is 30feet when no obstacles are introduced during the transmission. These waves are categories as the Ultra-High-Frequency where the frequency range is [2.402GHz – 2.480GHz]. Bluetooth is brand is universally recognizable. Up to 92% of the consumers in the universe use Bluetooth. This is the main reason why many companies around the word use Bluetooth work mark and logo when advertising their product which contains the wireless connectivity.

According to the Bluetooth official website, these are some specifications and features:

Table 10: Bluetooth Specification

	Bluetooth Low Energy (LE)	Bluetooth Basic Rate/ Enhanced Data Rate (BR/EDR)
Frequency Band	2.4GHz ISM Band (2.402 – 2.480 GHz Utilized)	2.4GHz ISM Band (2.402 – 2.480 GHz Utilized)
Channels	40 channels with 2 MHz spacing (3 advertising channels/37 data channels)	79 channels with 1 MHz spacing
Channel Usage	Frequency-Hopping Spread Spectrum (FHSS)	Frequency-Hopping Spread Spectrum (FHSS)
Modulation	GFSK	GFSK, π/4 DQPSK, 8DPSK
Power Consumption	~0.01x to 0.5x of reference (depending on use case)	1 (reference value)
Data Rate	LE 2M PHY: 2 Mb/s LE 1M PHY: 1 Mb/s LE Coded PHY (S=2): 500 Kb/s LE Coded PHY (S=8): 125 Kb/s	EDR PHY (8DPSK): 3 Mb/s EDR PHY (π/4 DQPSK): 2 Mb/s BR PHY (GFSK): 1 Mb/s
Max Tx Power*	Class 1: 100 mW (+20 dBm) Class 1.5: 10 mW (+10 dbm) Class 2: 2.5 mW (+4 dBm) Class 3: 1 mW (0 dBm)	Class 1: 100 mW (+20 dBm) Class 2: 2.5 mW (+4 dBm) Class 3: 1 mW (0 dBm)
Network Topologies	Point-to-Point (including piconet) Broadcast Mesh	Point-to-Point (including piconet)

Advantages

- Quick connection establishment between two devices.
- It has a lower power consumption:
- It has a better range than the IF technology
- Bluetooth is very cheap and universally used.
- No obstacles break the connection.
- Many products are Bluetooth adapted.
- Less interference occurs due to the use of Frequency Hopping Spread Spectrum (FHSS)

Disadvantages

- The bandwidth is lower than a Wi-Fi technology.
- Devices should keep a specific range in order to stay connected
- Security is very minimalistic since it is using RF which give an easy access to hackers.
- Critical information should never be transferred through Bluetooth.

- Compatibility in Bluetooth is a major issue. Regardless of its popularity in different industries, there still are some issues with Bluetooth especially the fourth version; Bluetooth 4.0 connection with low energy technologies is not compatible with other version.

Uses

- Bluetooth uses vary depending on the services. Some of the most uses of Bluetooth these days are:
- Wireless speakers or headphones: many uses nowadays connect their smart phones wirelessly to a device such as cars, Alexa, headphones….
- Hand-free headsets: in ear devices connected to the smart phones through Bluetooth for call on the go purposes or multitasking.
- Even thro it is unsecure to transfer data through Bluetooth, Bluetooth can still transfer large files in case of Wi-Fi signal loss.
- In the medical field, Bluetooth is used to automatically log information from medical equipment's like stethoscopes, glucose monitors, etc. into a computer or electronics log. Bluetooth in the medical industry is less time consuming and facilitates the accessibility of equipment.
- For personal health purposes, Bluetooth can be used to follow the exercise routines.
- Bluetooth enables users' electronics such as phones, camera, televisions, speakers, printers, etc., to share and control data between Hosts.

4.4.1. Bluetooth Modules

As mentioned previously, wireless communication and specifically Bluetooth provides a reliable, safe, and cheap way for data transfer, therefore many projects use Bluetooth modules to establish communication between devices. Some of the most used Bluetooth modules in various projects are the following:

HC-06: ($7-$10): The HC series are the very popular among hobbyists and engineers. it is easy to setup with MCU's and is very compatible with android smart phones. The HC-06 only works as a slave. It is not possible to change its mode to master which means it can only receiver data. Some specifications of the HC-06 module are:

Table 11: HC- 06 Specification

PCB Size	39.5mm X 20.5mm X 1.6mm
Operation current	40mA
Operating voltage	3.3-6V DC
Communication protocols	Bluetooth 4.0
Communication range	<100m
Operation mode	slave

HC-05: ($6-$8): Like the HC-06, its range is about 30ft (9meter). However, HC-05 can be used as a master and a slave; it sends and receives data. The specification of HC-5 are:

Table 12: HC-05 Specification

PCB Size	28mm x 15mm x 2.5 mm
Operation current	30mA
Operating voltage	4-6V DC
Communication protocols	Bluetooth 2.0
Communication range	<100m
Operation Mode	Slave- master

RioRand Bluetooth 4.0: ($13): Module is easy to control through simple ASCII AT commands over the UART. The ranger of this module is boasted to be 70 meters by the manufacturer. some specifications of the RioRand are:

Table 13: RioRand Bluetooth Specification

PCB Size	26.9mm x 13mm x 2.2 mm
Operation current	50mA
Operating voltage	3.3V DC
Communication protocols	Bluetooth 4.0
Communication range	<70m
Operation Mode	Slave- master

XS3868 Bluetooth Stereo Audio Module ($5): This module operates on android and iPhone devices. Its small size comes in handy in certain projects. The specification of the XS3868 are:

Table 14: XS3868 Specification

PCB Size	49mm x 22mm x 2.2 mm
Operation current	400mA
Operating voltage	3.6-4.2V DC
Communication protocols	Bluetooth 4.0
Communication range	<70m
Operation Mode	Slave- master

Bluefruit Ez-link: ($21-$40): One of the best modules out in the field. It ranges can get up to 32 feet. No additional software or costumer hardware to communicate wirelessly. It automatically detects and updates its serial baud rate. It works perfectly with a window or a MAC computer (Linux is not supported). Some specification of the Bluefruit module are:

Table 15: Bluefruit Ez-link Specification

PCB Size	**41mm x 20.5mm x 4 mm**
Operation current	**50mA**
Operating voltage	**3.3 V DC**
Communication protocols	**Bluetooth 4.0**
Communication range	**<10m**
Operation Mode	**Slave- master**

4.5. Microcontrollers

Microcontrollers are use in almost every facet of modern human life. Modern life would look drastically different not given the advent of monolithic topography in electronics learning the rise of integrated circuits, which are the basic building blocks for the for any processing or micro controller system configuration.

The needs for every project vary drastically and as such many components that make up the general form of embedded systems and microcontrollers also vary drastically. There are however commonalities between all embedded systems and microcontrollers. The embedded system has to preform specific functions and as such the whole of a microprocessor must contain many components vital to its functionality thus leading to a nickname of a computer on a chip or even a single chip computer. This is illustrated in the figure bellow:

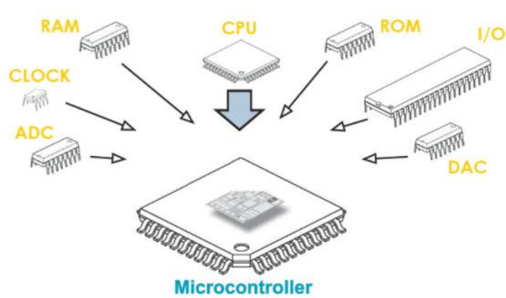

Figure 11: Illustration of a Microcontroller

The commonality between the vast majority of microcontrollers as defined and labeled below:

- CPU: The CPU is the Central Processing unit and as the name suggests this is where the processing, computing, and decision making takes place in the system. The CPU is comprised of an Arithmetic Logic Unit as well as a control unit which divides the tasks and instruction sets accordingly.

- Memory: This unit located inside the structure of an embedded system or microcontroller is comprised of several constituent, however there are only two vital memory for the system to function properly.
    - ROM – This unit of memory stands for read only memory and its composition is mainly used for program memory. This section contains valuable instruction sets executable for the processor to be able to work efficiently and correctly.
    - RAM - This unit of memory stans for random access memory and is primary used for storing information the designer or programmer dreams imports. Often this unit of memory is referred to as Read and Write memory.
- I/O Ports: This unit within the structure of an embedded system and or microcontroller allows for the vital function of interaction with the environment outside the system, his being the Input/Output ports. This interface provides
- BUS: Most designers do not consider this when thinking or even discussing microcontroller architecture, however, this component is vital for on board functionality. A buss is basically a bundle of wires, these wires allow bit wise communication most prudently communication to and from the processor.
- Timers and Counters: Almost all functionality and operations within the microcontroller or embedded system require some form of timer and or counters. This vital functionality is most commonly accomplished through a piezoelectric crystal that resonates with a certain period creating an accurate timer. The timer and counters can also serve additional tasks in conjunction with creating proper operational functionality, like creating a pulse width modulation, and clock controls.
- Serial Port: This feature is vital for the embedded system or microcontroller to be able to communicate with other devices, for wither programing or even just a transfer of information. In smaller applications this is most commonly accomplished through a series of pins. The most common form of serial port communication is called UART or Universal Asynchronous Receiver/Transmitter.
- Interrupts: This feature in embedded systems or microcontrollers can be accomplished in many ways and is a vital component if the application requires responses to stimuli. This is most commonly accomplished through working in tandem with the timers.
- Analog to Digital Converter: This feature and system is included in microcontroller or embedded systems to have the ability to convert continuous in time signals and information to a machine usable digital discrete bit. This circuitry
- Digital to Analog Converter: This system is very similar to the ADC as mention above, however, this circuit configuration work opposite of the ADC. The digital to analog converter converts machine usable digital discrete bits to a continuous in time flow of information. This is most commonly seen in devices that are able to play music through speakers to the user.

There will always be a tradeoff to using one system over another for any given application. This tradeoff is vital when an engineer is wither deciding what to implement in their system given an application or even when designing the entire system form the ground up. This section will briefly touch of some advantages and disadvantages when a designer is choosing to incorporate a microcontroller into the system.

- **Advantages**: When a designer incorporates a microcontroller, and even which micro controller to use, into their system the advantages are numerous. One such advantage is that there would be no need for superfluous externals including interfacing, or input output ports because all of this is included in the system topography and configuration. Give that there is no need for extra input and output ports the ones provided are completely programmable to fit any given application they are placed in. Using a micro controller removes the need for a robust operating system and many user interface peripherals. This in turn lowers the cost or production, the general real estate need for operations and functionality,
- **Disadvantages**: Micro controllers are remarkable and are used extensively in modern everyday life. This being said, a microcontroller is not always the best solution for every application. The lack of robust operating system, like that found in computers, can limit the instruction set and even the number of instructions an embedded system can conceivably compute in a given time, as well as the instruction set having to be written in. This leads to most embedded systems and micro controllers underperforming or even flat out not being an option when the application needs a higher level of computational power

TYPES OF MICROCONTOLLER

There are various architecture and microcontroller topographies for a designer to choose or work with, however this section will primarily discuss commonly used microcontroller and embedded systems.

- STM32F103C8T6: This particular product is constituent of the STM32F103 family topography and features a high-performance ARM Cortex that process 32-bit data at a 72MHz clock speed. The development board based on this chipset is the Blue pill.
- ATmega328: This is one of the most commonly used chipset and staple used when designers need an option without the bulky constituents of the entire Arduino development board. This Chip set has 32 registers with 23 general purpose input and output ports. This Chips set works with the Arduino platform and has a vast community support.
- PIC16F877A: This Chipset is considered one of the oldest that is still commonplace in today modern world. This chipset uses an 8-bit topography and most what a lot of designers start with when learning architecture and proper implementation of microcontrollers. Unfortunately, this board is not commonplace with higher end needs because of its limitations and stature.
- Attiny85: This chipset is most desirable when a designer is looking to minimize the real estate used when choosing a microcontroller for smaller applications and project designs. Some notable aspects from this topography are it has a total of eight pins, the CPU processes 8-bit architecture, contains eight kilobytes of programable memory, and can communicate through UART, I2C, as well as SPI. This product is also ideal for uses in low power consumption.

- MSP430G2452: This system is a constituent of the MSP430 family topography and is superior option when considering capability, power, and reliability. This system is commonly used as part of the Texas Instruments launchpad development board and commonplace in schools for learning architecture and embedded development. The system CPU runs on 1 16-bit architecture notably having eight ADC channels, a 16-bit timer, having both I2C and SPI communication protocols, and supporting a current usage rate of 220 µA at the clock speed of 1MHz
- ESP32: Like the Arduino chipset the ESP32 has a wide variant of development board systems utilizing its particular chipset. This system is an option to consider when a designer is looking for a low power consumption choice in their production application. Most of the development board utilizing this chipset have integrated wireless and dual-mode Bluetooth. This chipset notable features are: containing a power amplifier, as well as a system for security for encryption and cryptographic hardware acceleration, with secure boot, The central processing unit runs a 32-bit architecture at a clock speed of 240MHz, contains a Hall effect sensor, LED pulse width modulator with support up to 16-channels, contains an internal IEEE 1588 Precision Time Protocol, 18 channel 12-bit ADC as well as two 8-bit DAC's, has the capability for I2C/UART/SPI/I2S communication.
- ATMEGA32U4: This chipset is an option to consider when a designer would like to use a low power consumption choice. This chipset is feature in many Arduino based development boards and as such runs on the Arduino platform with a vast community support. Some notable feature and continents are: the chipset runs on an 8-bit architecture, 12 channel 10-bit ADC and DAC, is ready for pinout design for JTAG communication for on chip programing and debugging, runs at a clock speed of 16MHz and is able to achieve sixteen million instructions per second though this architecture, also contains an option without a crystal for low-speed modes.
- STM8S103F3: This chipset offers potential designers a high performance 9-bit processor architecture option while utilize as little real estate as possible. Some notable feature includes: a clock speed of 16 MHz, contains extended instruction set, a variety of clock controls with four master clock sources (low power crystal, external clock input, user-trimmable 16 MHz RC, low-power 128 kHz RC), Contains the ability to communicate through I2C SPI and UART, a 10-bit ADC, there are pins enough for 28 input and output programable interfaces. As well as the Input and output chipset topography is structured to be immune against current injection.

4.6. Fingerprint Reader

The nature of fingerprints makes it ideal for automated recognition systems. Once the fingerprint is captured, the system identifies its minutia points which happen to occur where the ridge lines begin until it merges with the other ridge lines. The minutia points are then mapped to make lines between each point. This map of lines is basically how points are related. This map is then transferred as data stream called minutia template and stored in the database in order to be used for verification. The most fascinating thing about this process the impossibility to recover or recreate the biometric image of the fingerprint going backward. The process of how the fingerprint recognition technology works is shown in Figure 33 below:

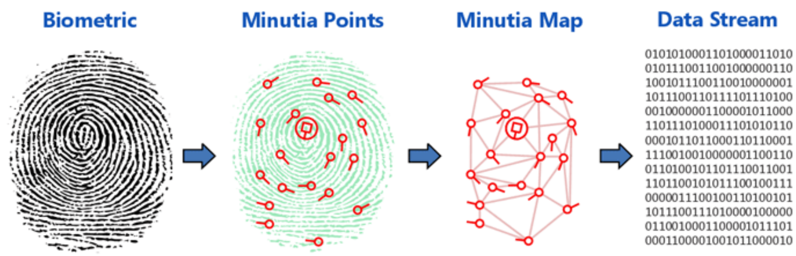

Figure 12: Fingerprint recognition process

In order to collect an accurate digital image of the fingerprint from the surface where the fingerprints if covered, variety of sensor types such as optical, capacitive, ultrasound, and thermal are used. The most common sensor used in this list is the optical sensor to take images of the fingertip's ridges.

There are two main techniques used for fingerprint matching. The first is called minutia-based matching which has been explained earlier, and the pattern matching technique. Pattern matching is simply the comparison of two or more images to identify any similarities in the patterns. Pattern matching is mostly used in to detect duplicate pattern and is very common in the criminal justice systems. However, the technique used in the mobile communication and for security purposes is the minutia-based technique.

The fingerprints recognition systems that use the minutia-base technique contains a sensor, minutia extractor, and minutia matcher; the optical and semi-conduct sensors are used in the fingerprint acquisition system because they're results are very accurate and their have high efficiency for clean and hydrated fingers. The extraction of minutia includes three stages; the pre-processing, minutia extraction, and finally post –processing stage. A detailed stage process is shown in Figure below.

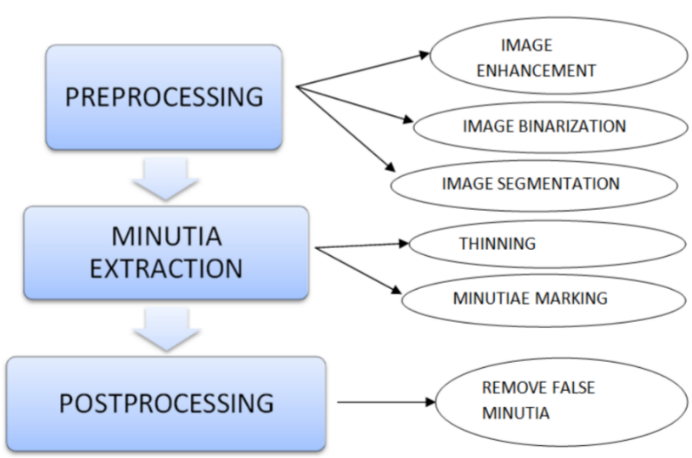

Figure 13: Extraction of minutia

Fingerprint recognition technology is used in different services such as:

1. **Mobile authentication**: used to unlock mobile phones and secured access for applications.
2. **Civil identify systems**: governments use it to identify and verify civilians of different purposes; voting, border security.
3. **Physical Access Control**: Education instructions and businesses use fingerprints for time clocking and to manage facilities access.
4. **Onboarding**: organizations such as banks and store storages use it for identification of prospective customers and employees to prevent fraud.
5. **Identity management**: to prevent duplicate and fake identifications, organizations use fingerprints recognitions.

Types & Products:

Many applications these days rely on fingerprint sensors for safety, security, and identity recognition purposes. Especially in mobile communication, fingerprints sensors are spread worldwide in smartphones, home applications, and other industries. The most used fingerprints sensors used these days are Optical and Capacitive sensors:

- Optical sensors work by shining a bright light over the fingerprint and take a digital photo of the fingertip. The digital image is achieved by the light sensitive microchip since it converts the ridges and valleys of the fingertip into binary numbers (1s and 0s) to create the personal user code the figure below shows how the optical sensor works. One of the disadvantages of this technique is that the images may sometimes be duplicated.

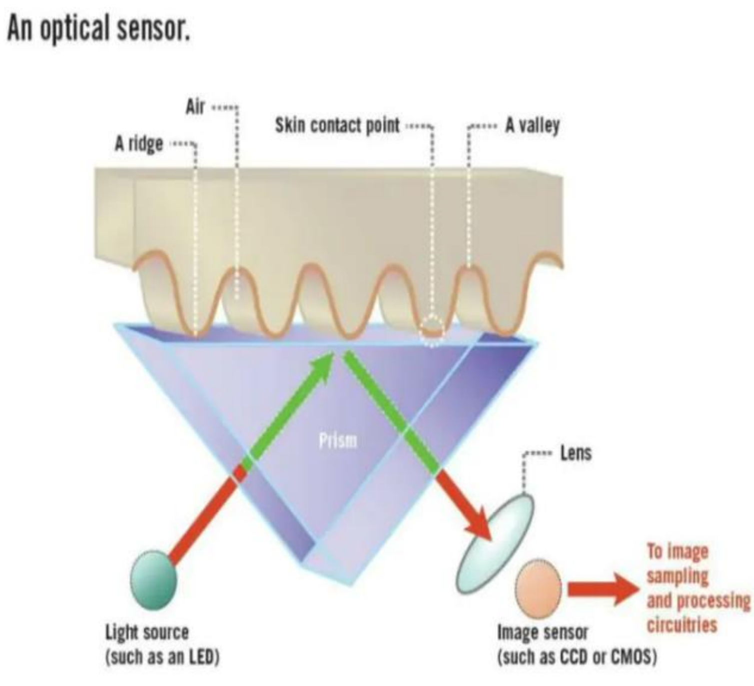

Figure 14: Light source taking a digital image of a fingerprint

- Capacitive fingerprint sensors are more common on phone nowadays. This technique is similar to the touch screen technique; using the human conductivity which creates an electrostatic field, the digital image of the user's fingerprint is made. For the fingerprint sensor; the capacitive fingerprint scanner tracks the valleys and ridges of the fingertip using a tiny capacitor array of circuits. Once the finger in placed on the scanner, the ridges that are placed over the conductive surface changes the capacitor value (the charges stored in the capacitor). For the valleys, the gap between the capacitive surface and the finger surface does not affect the charge of the capacitor. To track these changes, an operational amplifier integrator circuit is used. The information is converter to digital by an Analog-to-Digital converter (A/D) then analyzed to create a personal identification. The capacitive fingerprint technique is considered more accurate and expensive to achieve since the digital data will not be duplicated; the value calculated on the capacitor will be different from a person to another.

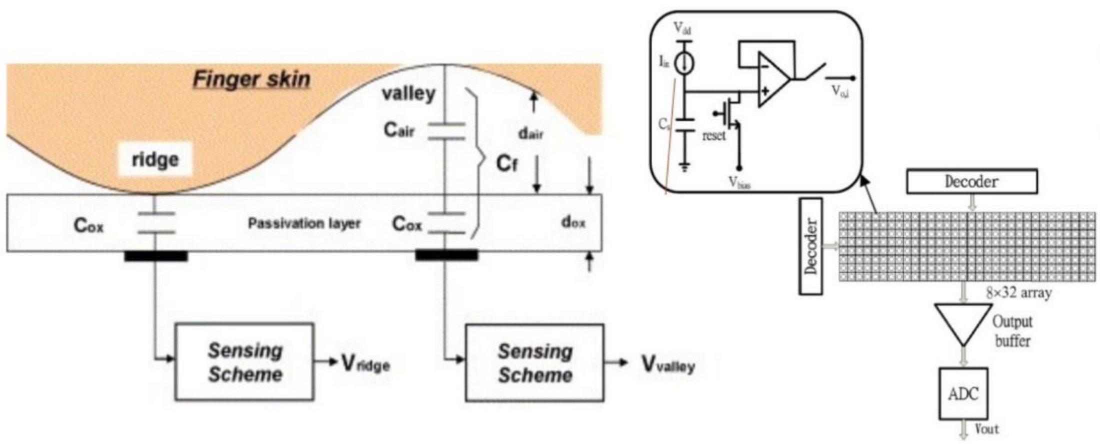

Figure 15: Theory and architecture of a capacitive fingerprint sensor

- **Mikroe fingerprint sensor with two LED Ring:**

Table 16: Mikroe fingerprint module Specs

Dimension	28mm x 23.5mm x 19mm
Supply voltage	3.3V DC
Finger acquisition current	20mA
Finger detection current	2uA
Baud rate	(9600*N) bps N=1~6 (default N=6)
Sensing array	192x192 pixel
Image acquisition time	<0.2s
Image resolution	508 pixel/Sin
Storage capacity	200 prints
Cost	~ $29

- **AD-013 Fingerprint sensor module:**

Table 17: AD-013 Fingerprint sensor module Specs

Dimension	29mm x 19.6mm x 6.06mm
Supply voltage	3.3V DC
Finger acquisition current	40mA
Finger detection current	18mA
Baud rate	57600 bps
Sensing area	160 x 160 pixel
Image acquisition time	<0.6s
Image resolution	508pixel/in (dpi)
Storage capacity	40 prints
Cost	~ $20.00

- **GT-521F32 & GT-521F52 fingerprint scanner modules:**

Table 18: GT-521F32 & GT-521F52 fingerprint scanner modules Specs

Dimension	22mm x 23.5mm x 19mm
Supply voltage	3.3-6V DC
Finger acquisition current	20mA
Finger detection current	5uA
Baud rate	9600 bps
Sensing area	14 x 12.9 mm
Image acquisition time	<1.5s
Image resolution	450dpi
Storage capacity	200 prints
Cost	~ $55.00

- **Parallax 29126 fingerprint scanner:**

Table 19: Parallax 29126 fingerprint scanner Specs

PCB dimension	50mm X23.2 mmX25mm
Camera Dimension	45.7mm x 23.5mm x 19mm
Supply voltage	3.3-7.5V DC
Finger acquisition current	50mA
Finger detection current	<0.5s
Baud rate	9600-57600 bps
Storage capacity	1000 prints
Cost	~ $64.11

- **SEN0188 fingerprint reader sensor:**

Table 20: SEN0188 fingerprint Specs

PCB dimension	53mm x 19.7mm x 20mm
Camera Dimension	14.5mm x 19.4
Supply voltage	3.8-7V DC
Finger acquisition current	<65mA
Finger detection current	<1.0s
Baud rate	9600 bps
Storage capacity	1000 prints
Cost	~ $35.00

4.7. Projector Technology

Imaging lenses: Specialized and specific use lens systems

The lenses learned about in the classroom are your typical concave and your convex lenses. Of course, through the fundamental basics, we can evolve these types of lenses to more complex and specialized lens system designs. The foundation of these further complex lens designs is then usually built on by previous lens designs. This iteration of design is the driving force behind creating new lens designs for special cases.

One example is the evolution of the retrofocus lens—usually found in rangefinder cameras, box cameras, and view cameras. The retrofocus lens evolved into a fisheye lens because of the desire to produce strong visual distortions intended to create a hemispherical image. Soon after, designers used the fundamental basic idea of a retrofocus lens and applied it to create a zoom lens in combination with telephoto lens properties. To nail this home, afocal lenses were designed conceptually from zoom lenses.

As discussed, designing lenses are as fundamental as building a circuit board for electronics. We start off with a basic design, understand the conceptual basics of that design, and evolve it by combining and manipulating the parameters associated with the types of lenses used in the system. In the following sections, I will show you some on the fundamental lens designs that will be important to consider for the optical projector system and possibly for the laser keyboard projector system.

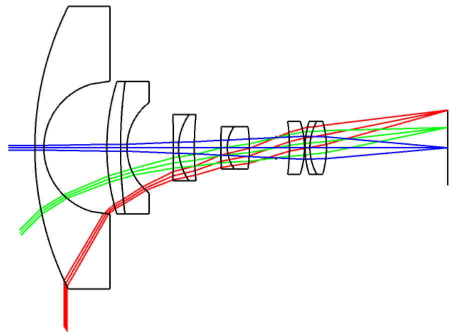

Figure 16: Fisheye lens- field of view

Fisheye lenses are typically used to image a spherical object onto a flat surface. Whereas a simple lens will image a flat object onto a flat surface. Knowing the fundamental difference between the two lenses as discussed earlier, the retrofocus lens is like the fisheye lens—that is, both have a negative front group and a positive rear group of lenses. Keep in mind that the term "group" is to be distinguished from "elements." Groups are either separate elements or two or more elements fixed together. Elements are the individual glass lens elements withing the lens itself.

In professional and commercial design cases, the fisheye lens is designed to have complex negative and positive lens groups in order to maximize the image resolution of an object. In addition, the fisheye lens is optimized to achieve a field of view of one-hundred eighty degrees, or more, for photographic lens designs. It is especially popular among the photography industry due to its demand for its distorted and underwater-like effects. Often, a one-hundred eighty-degree field of view lens that images a circular image is called a circular fisheye, and a lens that images the corner field of view to be one-hundred eighty-degree is sometimes called a diagonal fisheye lens. This is especially popular for people who desire the fisheye effect for art, film, and other imaging purposes.

Based of geometric optical design guides and books, there are many ways to image a spherical object onto a plane. I will discuss the following types of imaging techniques:

- Equidistant projection
- Orthographic projection
- Stereographic projection
- Equisolid angle projection

There are three parameters that I will use: y is the image height, f is the focal length, and theta is the half angle of view.

Equidistant Projection

Equidistant projection is the mostly used, which is also called f-theta imaging. That is, two parameters are used in this technique, as you might have guessed: the focal length (f) and the half angle of view (theta). The definition of an f-theta lens is as follows:

$$y = f * \theta$$

Even though most people associate fisheye lens systems to photography, the f-theta system is also widely used in laser scanning systems for laser beam printers. The lens design is called f-theta lenses.

Orthographic projection takes the cross section of a sphere and projects that cross-section directly on a plane. This is a form of parallel projection, in which all the projection lines are orthogonal to the projection plane, resulting in every plane of the scene appearing in affine transformation of the viewing surface.

The definition is as follows:

$$y = f * \sin(\theta)$$

A key characteristic of this type of fisheye imaging technique is its even and constant distribution of image illuminance across the field of view. Consequently, the fisheye lens has a larger distortion than most typical imaging systems. In addition, the cosine fourth law does not hold, and the image's edges are less likely to drop in relative illumination.

Stereographic Projection

Stereographic projection images are imaged at the equator, which is twice as close than in an orthogonal projection. In geometry, the projection is defined on the entire sphere, except at one point: the projection point. The sphere is mapped onto the plane containing its equator. A typical point is connected on the surface of the sphere to the "north pole" by a straight line in three-dimensional space. Then this line will intersect the equatorial plane at some point.

The definition is as follows:

$$y = 2f * \tan\left(\frac{\theta}{2}\right)$$

Equisolid Angle Projection

The Equisolid angle projection is where the area of the image has a direct proportionality to the solid angle of the object. Calculating the area of the image requires the calculation of the solid angle of the object—used mostly for metrology purposes. Regardless of the incident angle, the solid angle subtended by a unit area on the image plane is constant. This concept is key to obtaining and successfully executing this technique.

The definition of an Equisolid angle projection is as follows:

$$y = 2f * \sin\left(\frac{\theta}{2}\right)$$

Zoom Lenses

Fun fact: the name zoom lens derives from one of the early lens companies, Zoomar, which has now become the definition of a variable focal length lens. Systems like Gaussian brackets were mathematically introduced to calculate zoom systems.

Over time, Canon published a paper on zoom lenses that is still used today. Zoom lenses can be traced back to the converter and teleconverter lenses that convert the focal length of a system as an attachment for a camera system. A camera that is like this description is the Fuji X100 series, which is a fixed lens digital camera that has both a wide-angle conversion lens and a tele conversion lens to change the focal length of the lens.

Mathematically, the original master focal length f_m is converted to the new focal length f_t by the magnification /beta of the converter. The definition of this conversion is as follows:

$$f_t = \beta * f_m$$

The zoom lens is fundamentally simple in this way, because the zoom lens has several fixed focal length groups in the lens system that change position to give a different magnification. Very much like someone moving a magnifying lens from their eye front to back along the optical axis orthogonal to your eye's surface, they will observe an image getting bigger or smaller.

In addition, there are two types of zoom: optically compensated zooms and mechanically compensated zooms.

The optical compensation zoom system has one linearly moving part and does not use a cam system for movement. A cam is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion. The focus is within the depth of field by using clever positioning of the lenses.

The mechanical compensation system, however, has at least two moving parts with a cam system—that is requiring at least a variator lens and a compensator lens. Though, in today's world of optical and lens design, all zoom systems have very complex movements. In the following section, we will see how the zoom lens system is broken down for essentially lens design purposes.

To start, we ask ourselves: what defines a zoom lens? As discussed above, we see that a zoom lens is comprised of: (a) it can change its magnification, (b) the focus point is fixed, and (c) the performance is above a certain level at any zoom point. It should be noted that photography lenses are not zoom lenses because most do not satisfy (b), which in that case is a varifocal lens, because we usually need to refocus a lens.

Interestingly for a video system, staying in focus while zooming is critical as the picture would go out of focus as we zoom in or out. These varifocal lenses, known as the zoom lenses, have a higher degree of freedom, and more compact and large zoom ratios can be made. The main components of a zoom lens are:

- Focusing lens
- Variator
- Compensator
- Master lens

The focusing lens is used for focusing from infinity to focusing at a finite distance. The variator is the lens that moves over the largest distance and changes the magnification of the system. The compensator compensates the focal point of the system from the magnification change induced by the variator. Finally, the master lens is the main imaging lens of the system, and is responsible for the focal length, known as F-number, and back focal length of the lens. The master lens group typically generates a higher order aberration to minimize the aberrations from the prior components.

There exists zoom systems that have a compensator that doubles as a focusing lens, and some zoom systems have two variators with one variator doubling as a compensator. But even if a lens group doubles functions, the components are still there. It may be a little tricky to decode these lenses, but if we know the properties of each component it is easy to find them in the system.

Making the front element the focusing lens or making the lens an inner focusing system. Figure out which system you need for the focus system. The front focus is most straightforward and robust. It is also the optically logistic way to focus a lens. However, if the front element is large, this can mean moving a large chunk of glass to focus, which is harder to do mechanically, requires more precision, and can cause focus backlash (overshooting the focus point).

Also, some focusing systems do not work well when the distance of the object to the front of the lens cannot change. Some systems require that the total length of the lens from the first element to the last element not change. Which brings us to inner focus, which seems like the perfect solution, since the focus is in the inner location of the lens. The lens can be made small so that movement is smoother and more precise, and the total length of the lens doesn't change. However, inner focus is harder to achieve optically, since the focus must work for all zoom positions, and the focus is likely on the same pathway as the variator or the compensator.

Optical Ray Tracing

An introduction to the use of lenses to solve optical applications can begin with the elements of ray tracing. Figure below demonstrates an elementary ray trace showing the formation of an image, using an ideal thin lens. The object height is y1 at a distance s1 from an ideal thin lens of focal length f. The lens produces an image of height y2 at a distance s2 on the far side of the lens.

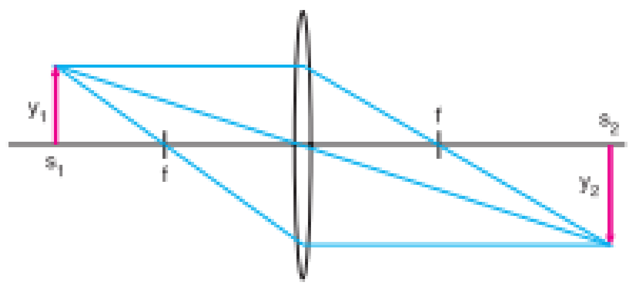

Figure 17: Optical Ray Tracing

By ideal thin lens, we mean a lens whose thickness is sufficiently small that it does not contribute to its focal length. In this case, the change in the path of a beam going through the lens can be considered to be instantaneous at the center of the lens, as shown in the figure. In the applications described here, we will assume that we are working with ideally thin lenses. This should be sufficient for an introductory discussion. Consideration of aberrations and thick-lens effects will not be included here.

Three rays are shown in Figure 1. Any two of these three rays fully determine the size and position of the image. One ray emanates from the object parallel to the optical axis of the lens. The lens refracts this beam through the optical axis at a distance f on the far side of the lens. A second ray passes through the optical axis at a distance f in front of the lens. This ray is then refracted into a path parallel to the optical axis on the far side of the lens. The third ray passes through the center of the lens.

Since the surfaces of the lens are normal to the optical axis and the lens is very thin, the deflection of this ray is negligible as it passes through the lens. In addition to the assumption of an ideally thin lens, we also work in the paraxial approximation. That is, angles are small, and we can substitute θ in place of sin θ.

Magnification

We can use basic geometry to look at the magnification of a lens. In Figure below, we have the same ray tracing figure with some particular line segments highlighted. The ray through the center of the lens and the optical axis intersect at an angle φ. Recall that the opposite angles of two intersecting lines are equal. Therefore, we have two similar triangles. Taking the ratios of the sides, we have φ= y1/s1 = y2/s2 This can then be rearranged to give y2/y1 = s2/s1 = M. The quantity M is the magnification of the object by the lens. The magnification is the ratio of the image size to the object size, and it is also the ratio of the image distance to the object distance.

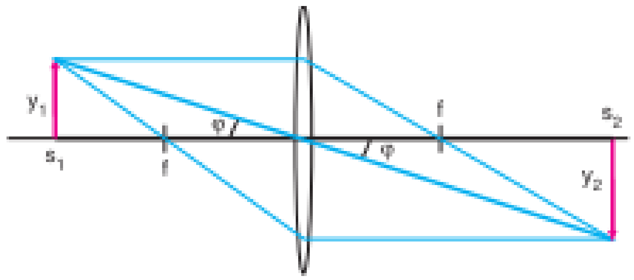

Figure 18: Magnification

This puts a fundamental limitation on the geometry of an optics system. If an optical system of a given size is to produce a magnification, then there is only one lens position that will satisfy that requirement. On the other hand, a big advantage is that one does not need to make a direct measurement of the object and image sizes to know the magnification; it is determined by the geometry of the imaging system itself.

Gaussian Lens Equation

Let's now go back to our ray tracing diagram and look at one more set of line segments. In Figure below, we look at the optical axis and the ray through the front focus. Again, looking at similar triangles sharing a common vertex and, now, angle η, we have y2/f = y1/(s1-f). Rearranging and using our definition of magnification, we find y2/y1 = s2/s1 = f/(s1-f).

Rearranging one more time, we finally arrive at 1/f = 1/s1 + 1/s2. This is the Gaussian lens equation. This equation provides the fundamental relation between the focal length of the lens and the size of the optical system. A specification of the required magnification and the Gaussian lens equation form a system of two equations with three unknowns: f, s1, and s2. The addition of one final condition will fix these three variables in an application. This additional condition is often the focal length of the lens, f, or the size of the object to image distance, in which case the sum of s1 + s2 is given by the size constraint of the system. In either case, all three variables are then fully determined.

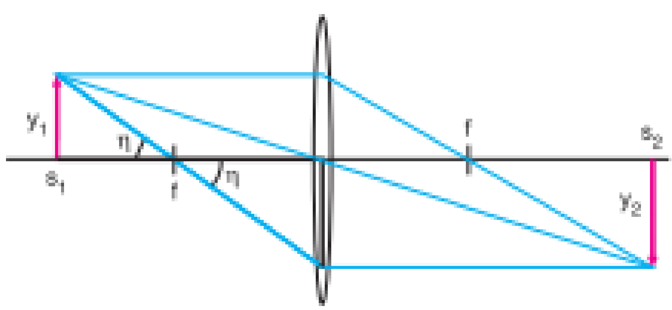

Figure 19: Gaussian Lens

Optical Variant

Now we are ready to look at what happens to an arbitrary ray that passes through the optical system. Figure below shows such a ray. In this figure, we have chosen the maximal ray, that is, the ray that makes the maximal angle with the optical axis as it leaves the object, passing through the lens at its maximum clear aperture. This choice makes it easier, of course, to visualize what is happening in the system, but this maximal ray is also the one that is of most importance in designing an application. While the figure is drawn in this fashion, the choice is completely arbitrary, and the development shown here is true regardless of which ray is actually chosen.

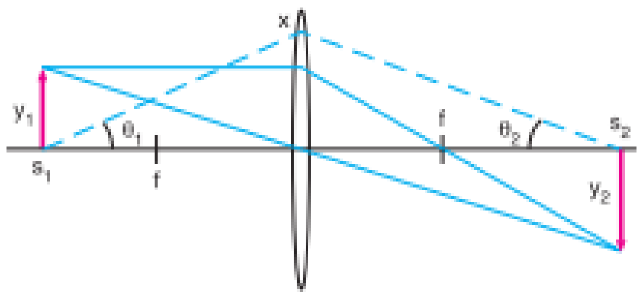

Figure 20: Optical Variant

This arbitrary ray goes through the lens at a distance x from the optical axis. If we again apply some basic geometry, we have, using our definition of the magnification, $\theta 1 = x/s1$ and $\theta 2 = x/s2 = (x/s1)(y1/y2)$. Rearranging, we arrive at $y2\theta 2 = y1\theta 1$. This is a fundamental law of optics. In any optical system comprising only lenses, the product of the image size and ray angle is a constant, or invariant, of the system. This is known as the optical invariant. The result is valid for any number of lenses, as could be verified by tracing the ray through a series of lenses. In some optics textbooks, this is also called the Lagrange Invariant or the Smith-Helmholz Invariant. This is valid in the paraxial approximation in which we have been working. Also, this development assumes perfect, aberration-free lenses. The addition of aberrations to our consideration would mean the replacement of the equal sign by a greater-than-or-equal sign in the statement of the invariant. That is, aberrations could increase the product, but nothing can make it decrease.

Collimating light from a point source

Another common application is the collimation of light from a very small source, as shown in Figure 6. The problem is often stated in terms of collimating the output from a "point source." Unfortunately, nothing is ever a true point source and the size of the source must be included in any calculation. In figure 6, the point source has a radius of y1 and has a maximum ray of angle θ1. If we collimate the output from this source using a lens with focal length f, then the result will be a beam with a radius $y2 = \theta 1 f$ and divergence angle $\theta 2 = y1/f$. Note that, no matter what lens is used, the beam radius and beam divergence have a reciprocal relation. For example, to improve the collimation by a factor of two, you need to increase the beam diameter by a factor of two.

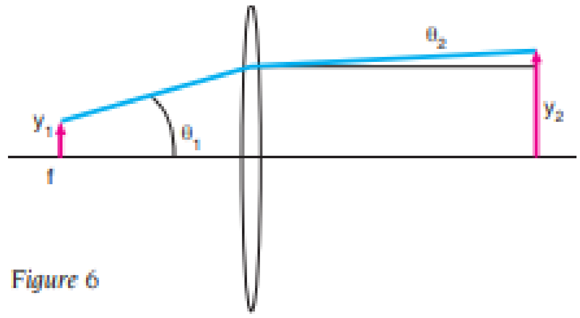

Figure 21: Collimating Light

Since a common application is the collimation of the output from an optical fiber, let's use that for our numerical example. The Newport F-MBB fiber has a core diameter of 200 µm and a numerical aperture (NA) of 0.37. The radius y1 of our source is then 100 µm. NA is defined in terms of the half-angle accepted by the fiber, so θ1 = 0.37. If we again use the KPX043, 25.4 mm focal length lens to collimate the output, we will have a beam with a radius of 9.4 mm and a half-angle divergence of 4 mrad. We are locked into a particular relation between the size and divergence of the beam. If we want a smaller beam, we must settle for a larger divergence. If we want the beam to remain collimated over a large distance, then we must accept a larger beam diameter in order to achieve this.

5. Project Design & Component Selection

Advancements in technology, globalization, and access to a seemingly infinite amount of information have made it a little easier for engineers to find suitable components to build and test their designs. Nonetheless, the plethora of available information can be a hindrance rather than a boon if the designer does not understand their goal or how the selected pieces will come together. A harmonious synchronization of all parts is essential for a successful project. Component selection for intelligent and cost-effective design requires that the engineer understand the functionality of each piece.

After researching relevant background information and weighing the advantages and disadvantages of several types of components, protocols, and implementations for various hardware and software features of the smart table, the design of the hardware and software must be determined with the requirements and specifications in mind. More specifically the team's design decisions came down to our engineering concerns based upon the House of Quality table in section 2.4. This design and implementation section will discuss the details as outlines below:

- Hardware and software Block diagrams with details about the component's functionality.
- A detailed design of how the MCU will be connecting all the components, and constituents
- Schematics about the systems and its subsystems such as the wireless communication, lighting, power, fingerprints systems, speakers, and projector.

Only the components that best suit the needs of the smart table have been selected, for reasons ranging from affordability and ease of implementation. Some of the component parameters to consider are reliability, cost, tolerance, electrical and mechanical parameters, and range of application.

5.1. Hardware Design

Advancements in technology, globalization, and access to a seemingly infinite amount of information have made it a little easier for engineers to find suitable components to build and test their designs. Nonetheless, the plethora of available information can be a hindrance rather than a boon if the designer does not understand their goal or how the selected pieces will come together. A harmonious synchronization of all parts is essential for a successful project. Component selection for intelligent and cost-effective design requires that the engineer to understand the functionality of each piece.

After researching relevant background information and weighing the advantages and disadvantages of several types of components, protocols, and implementations for various hardware and software features of the smart table, the design of the hardware and software must be determined with the requirements and specifications in mind. For instance, if selecting a RAM one can consider the memory size, access time, and number of ports.

Only the components that best suit the needs of the smart table have been selected, for reasons ranging from affordability and ease of implementation. Some of the component parameters to consider are reliability, cost, tolerance, electrical and mechanical parameters, and range of application.

The hardware design of the smart table consists of various part and circuit designs which include the Bluetooth audio system, power supply, Bluetooth system, microcontroller, projector system and physical structure. As stated earlier there were certain standards and specification that each design must meet. During the design process all the devices were selected and will be examined by their objective, function, and specification. The overall scope of the project and its block diagram can be seen below, and every subsection will provide more information within each subsystem as well each individual block diagram.

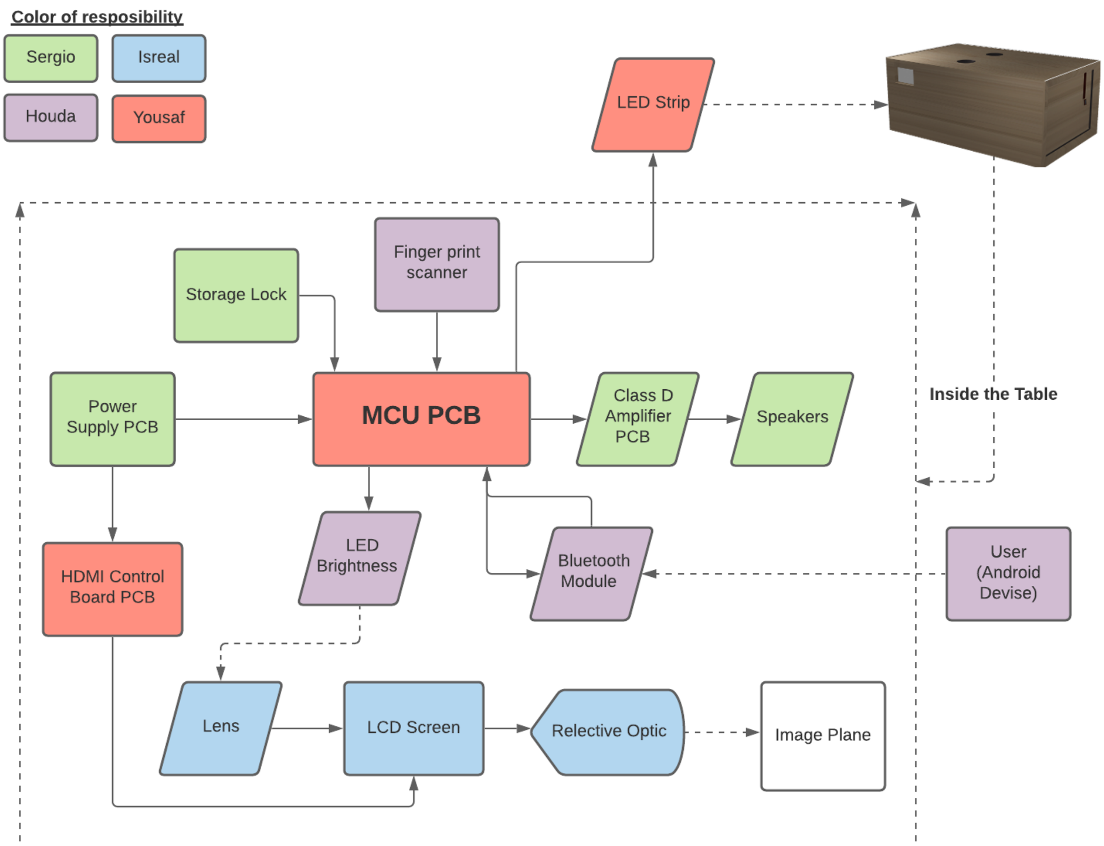

Figure 22: Overview System Block diagram

The hardware block diagram begins by describing how every subsystem is connected and at the center is the MCU which allows the user to control the hole system. Starting with the power supply which will be distributed to every device as needed and safety measures will be taken to avoid affecting other system like fuse/other means which is discussed in the sections below. The audio system along with the fingerprint will both be wireless through a Bluetooth module which is controlled via the MCU. The projector subsystem consists of three key factors the actual projector, adjustable brightness level, and a controller all which will be connected through the MCU. Due to the various systems the group opted to divide the individual systems per person as shown in the figure above. The final step process on the hardware side will be incorporating all subsystems in the MCU which every member will contribute to build. If future feature is added or changes are made to the overall system, the figure above will be updated accordingly.

5.1.1. Physical modeling of table

With every professional product and any idea for that matter it is imperative to have visuals. Some projects leave the visuals up to the readers imagination through giving their proposal many descriptive elements. Our team has opted to provide many descriptive elements, from previous sections, s as well as a visual simulation outlining our projects continents as well the overall shape and placement for each system. This section outlines, shows, and discusses each as presented below. It is important to note that This will not be a final reorientation of the smart table project, as the physical reorientation will be updated accordingly through many iterations of design updates and overall implementations.

- Front view of the smart table. Shows the projector port on the top left, as well as speaker ports located on the top of the smart table.

Figure 23: Smart table front face view

- The smart table at a slight angle, highlighting the secure storage area to the right locked with a fingerprint scanner located in the center right on the right face of the smart table.

Figure 24: Smart table angle view

- The team felt it was important to show a view with the front face of the smart table taken off so that the inside of the box is viewable. In this simulated view that projector lenses, LED, and LCD screen are able to be viewed as well the secure storage box.

Figure 25: Inside view of smart table

- This view was to highlight the placement of our PCBs as well as a better angle of the projector port showing the lenses, the LCD screen, and the driving LED for the projector.

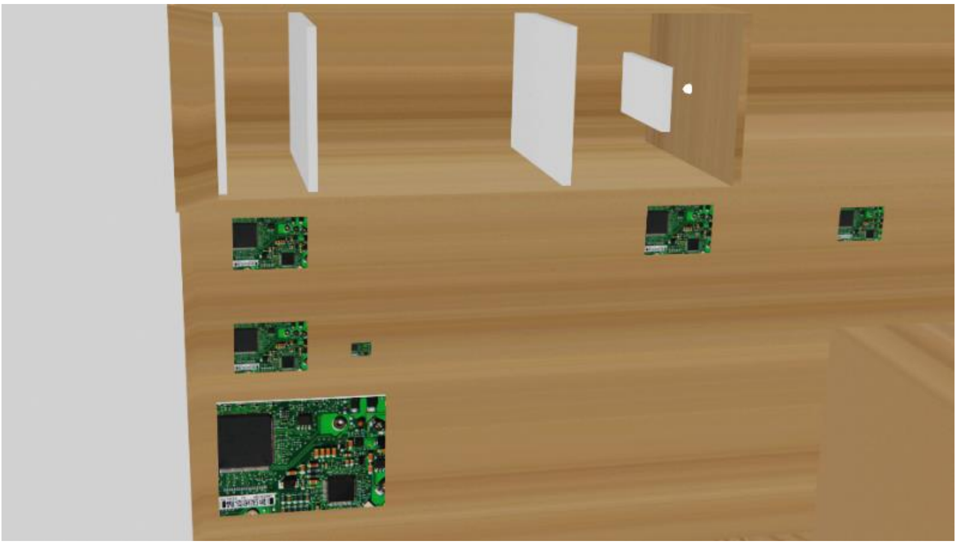

Figure 26: Projector system and PCBs

- Our team agreed that it was important to show any reader an intended placement of the final smart table project in the suitable placement environment. As shown here the smart table has been placed in a simulated Livingroom.

Figure 27: Livening room placement

- The final view for the physical simulation of the smart table shows the smart table projecting the user desired output onto the wall in the user simulated Livingroom.

Figure 28: Projection viewing

5.1.2. Design of Audio Speaker

The audio system will be fully wireless and can be connect via Bluetooth. When researching audio systems there were many approaches that can be taken. However, a decision had to be made and the important key factors were efficiency, cost effective, new approaches, and challenges Taking these key factors in mind the audio system will consist of a type D amplifier and will be configured to be a 2-way layout that focuses on low and high frequencies one through each speaker. The components to build an effective speaker system are listed in the table below and states the component and type as well as the quantity which will be use in the construction. This section discusses every part and why it was chosen and the purpose within the design.

A typical class D consists of four types of components which are a sawtooth waveform generator, comparator, switching circuit and a low pass filter. The sawtooth waveform generator generates a high frequency sawtooth waveform for the input audio signal. The frequency of the sawtooth waveform is usually selected 10 times the maximum frequency of interest in the input audio signal. The main job of the comparator is to digitize the input of the audio signal by mixing it with the chopping sawtooth waveform. The low frequency components of the digital signal will represent the input audio signal. Even though the output of the comparator is a digital representation of the input audio signal, it doesn't have the power to drive the load. The primary task of the switching circuit is to provide enough current and voltage gain for the amplifier. This switching circuits is generally designed around MOSFETs. Finally, the low pass filter is used to filter out low frequency components from the output of the switching circuit. The output of the low pass filter will be a scaled replica of the input audio signal and a feedback system is recommended to correct any errors. This defines a basic class D amplifier as shown in the figure down below and the table below shows all the components used to design and build the audio speaker systems.

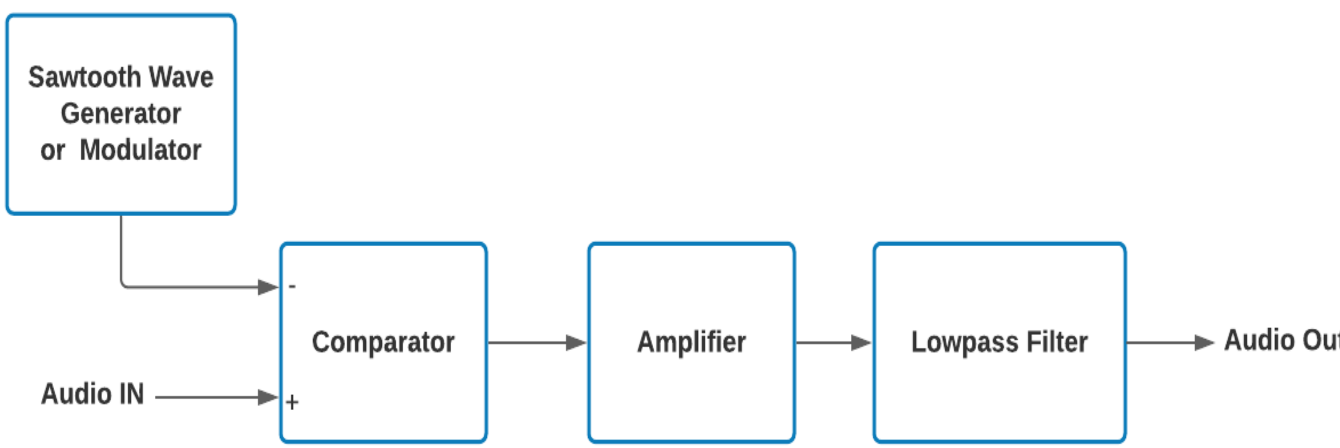

Figure 29: Basic Class D Block Diagram

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Figure 30: Overall Audio Speakers Components

Components	Type	Quantity
TIMER	TLC555	1
COMPARTOR	LM393	1
HEX INVERTER	SN74HC04N	1
MOSFET Driver	IR2113	1
MOSFETS	IRLZ44N	2
DOIDE	UF4007	3
VOLTAGE REGULATOR	LM7812	2
RESISTORS	(2k, 10k)	(1, 7)
CAPACTIORS	(1nF, 47u, 220nF, 1.1uF, 22u,)	(1, 3, 2, 1, 1,)
INDUCTORS	16.5uH	1

Timer: To protect the system the first thing that was done was to place a 1 microfarad capacitor between the audio signal and the comparator. This will High pass filter the audio signal and help ensure that the media play doesn't get damaged just in case any errors occur. Then it is connected to the non-inverting input of the comparator and on the Inviting input a timer is connected which creates a triangle wave. This triangle wave can have up to an input frequency of 200 Kilohertz. For this component a simple 555 timer is suitable and choices to purchase the TLC55 LinCMOS Timer. Because its power is low across the full range of power supply and operates at frequencies up to 2 MHz which is more than enough to produce a 200 Kilohertz wave. The TLC555 timer has a trigger level equal to approximately one-third of the supply voltage and a threshold level equal to approximately two-thirds of the supply voltage making this idea. The timer will be supplied by 5 volts from a linear regulator. Details of the component listed below:

- **Part Number:** 296-1858-5-ND
- **Manufacturer:** Texas Instruments / TLC555IP
- **DESC:** IC OSC SINGLE TIMER 2.1MHZ 8-DIP
- **Type:** Through Hole
- **Price:** $ 0.92
- **Instantaneous quantity**: 2,845

COMPARATOR: The comparator job is to modulate the incoming audio frequency which is no more than 20 Kilohertz into a high frequency square wave. The comparator output goes to the negative rail of the op amps power supply which is zero if the V- voltage is greater than the V+ voltage. However, in this case the V+ is greater than the V- the output will jump up to the positive rail of the op amps power supply which is 5 volts. Because the voltage of the audio signal is higher than the triangle voltage which is produced by the TLC55 timer the output of the comparator gets pulled high and vice versa. producing a modulated audio frequency of 200 kilohertz square wave.

The LM393 consist of two independent voltage comparators that are designed to operate from a single power supply however for this project only one is require and provided by UCF labs. The LM393's offset voltage also ranges from -9 volts to +9 volts and both the LM393 positive rail and TLC555 power supply need to be 5 volts in order to modulate the signal.

- **Part Number:** 296-49724-ND
- **Manufacturer:** Texas Instruments / LM393PE4
- **DESC:** LM393 DUAL DIFFERENTIAL COMPARAT
- **Type:** Through Hole
- **Price:** $ 0.45
- **Instantaneous quantity**: 6,832

HEX INVERTER: This creates an inverted signal of the high frequency wave which is feed to the MOSFET driver and necessary. The SN74HC04 chosen for the inverter and contain six independent inverters each preforming the Boolean function Y = -A in the positive logic. However, only one of the inverters will be utilized and 5 volts will provide to the VCC in order to power the device and this is also a cheap option.

- **Part Number:** 296-1566-5-ND
- **Manufacturer:** Texas Instruments / SN74HC04N
- **DESC:** IC INVERTER 6CH 6-INP 14DIP
- **Type:** Through Hole
- **Price:** $ 0.57
- **Instantaneous quantity**: 18,968

MOSFET DRIVER: The high frequency square wave is connected to the MOSFET driver and by incorporating a driver to turns on and off the two MOSFETS will prevent power loss. The IR2113PBF is was chosen for this project as its both a high and low side driver another main factor is was the V_{OFFSET} which can be operates from up to 600 volts max. This provides a perfect range for picking the type of MOSFET. The configuration of the driver is shown below as well as the pin layout table:

- **Part Number:** IR2113PBF-ND
- **Manufacturer:** Infineon Technologies / IR2113PBF
- **DESC:** IC GATE DRVR HALF-BRIDGE 14DIP
- **Type:** Through Hole
- **Price:** $ 4.23
- **Instantaneous quantity**: 1,806

Table 21: MOSFET Driver Pin Layout

Symbol	Definition		Min.	Max.	Units
V_B	High side floating supply absolute voltage		V_S + 10	V_S + 20	V
V_S	High side floating supply offset voltage	(IR2110)	Note 1	500	
		(IR2113)	Note 1	600	
V_{HO}	High side floating output voltage		V_S	V_B	
V_{CC}	Low side fixed supply voltage		10	20	
V_{LO}	Low side output voltage		0	VCC	
V_{DD}	Logic supply voltage		V_{SS} + 3	V_{SS} + 20	
V_{SS}	Logic supply offset voltage		-5 (Note 2)	5	
V_{IN}	Logic input voltage (HIN, LIN & SD)		V_{SS}	V_{DD}	
T_A	Ambient temperature		-40	125	°C

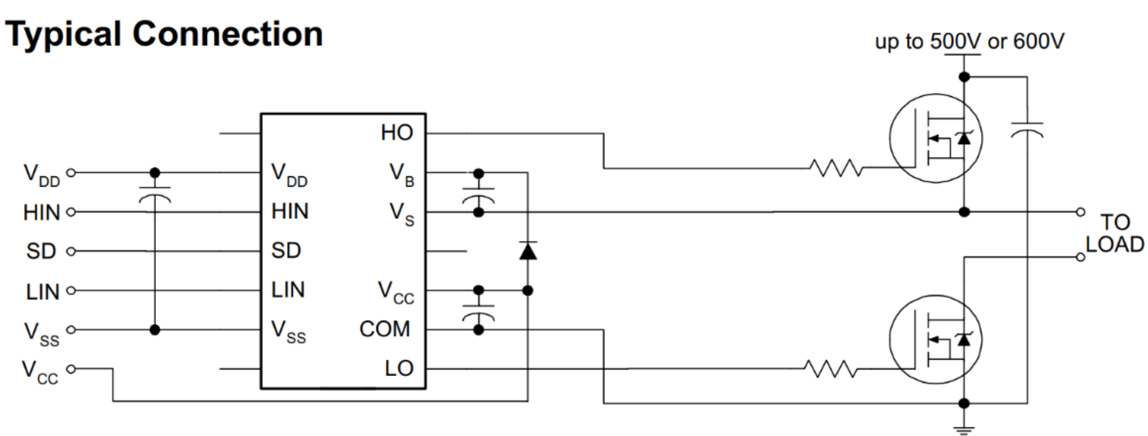

Figure 31: MOSFET Driver connection

MODFETS: The high side one according to the high voltage levels and the low side one according to the low voltage levels. There for creating a powerful high frequency square wave at the output and since the MOSFETS are switched on and off on their ohmic region with a low drain to source voltage drop, insures very little power loss. The two MOSFETs will be configured similar to the figure below however, there are slight differences such as instead of the 500 volts the VCC will be there and the drain of the bottom MOSFET will be connected to the Vs and the source of the top MOSFET. For a visual description please refer to the audio speaker schematic down below.

- **Part Number:** IRLZ44NPbF-ND
- **Manufacturer:** Infineon Technologies
- **DESC:** MOSFET N-CH 55V 47A TO-220AB
- **Type:** Through Hole
- **Price:** $ 0.98

- **Instantaneous quantity**: 2,985

DIODES: For this configuration to ensure minimal error, a feedback system was created using two diodes as well as a rectification from the power supply to provide proper DC using one diode. The feedback system uses the output signal and is fed back to the input passing it through the system. The diodes are perfect for an audio system that allows the positive DC volt through and prevent the negative volts to pass through. When choosing the type of diode, the most important thing is the forward and reverse characteristics. The UF4007 has a forward voltage of 0.6 as shown in the figure down below another aspect is the total capacitance to reverse voltage which begins with a capacitance of around 30 picofarad at a V_R of 0.1 volts and the capacitances decreases the voltage increases. As a result, the UF4007 was also use as a rectifier for V_B of the MOSFET driver.

- **Part Number:** UF4007TR-ND
- **Manufacturer:** ON Semiconductor
- **DESC:** Diode Standard 1000V 1A
- **Type:** Through Hole
- **Price:** $ 0.58
- **Instantaneous quantity**: 49,527

LOWPASS & HIGHPASS FILTERS: By adding a low pass filter after the MOSFET'S original the audio signal is recreated. This filter's out all the high frequencies and leaves us with our original audio signal but now it is amplified. The high pass is designed to make the signal greater AC variance which is required for a speaker. The Inductors are a basic Fixed inductor however for low pass filter a 50-volt ceramic cap with a X7R dielectric capacitor is used. This is because the purpose is to get rid of the high frequency content of the square wave and a good amount of high frequency current is going to flow through the capacitors, therefore electrolytic capacitor would not be enough. However, for the low pass filter the electrolytic capacitor of 1000 farad are used for the AC signal and the as stated in the beginning the capacitors in between the audio and the comparator are also electrolytic.

Ceramic Capacitor

- **Part Number:** 399-C340C125K5R5TA-ND
- **Manufacturer:** KEMET
- **DESC:** CAP CER 1.2UF 50V X7R RADIAL
- **Type:** Through Hole
- **Price:** $ 2.54
- **Instantaneous quantity**: 198

Electrolytic Capacitor

- **Part Number:** BJ-CPT24-630
- **Manufacturer:** BOJACK
- **DESC:** Electrolytic capacitors
- **Type:** Through Hole
- **Price:** $ 0.25
- **Instantaneous quantity**: N/A

Inductor

- **Part Number:** BJ-IDT20-200P
- **Manufacturer:** BOJACK
- **DESC:** High Quality Inductor
- **Type:** Through Hole
- **Price:** $ 0.30
- **Instantaneous quantity**: N/A

Power Supply: Finally, the power supply will be powered by two voltage regulator the first is the LM7805 which reduces the voltage to 5 volts. This will power the TLC555 timer, comparator LM393, Hex inverter, and IR2113 MOSFET driver. The second regulator is the LM7812 and provides 12 volts to the V_B and the V_{CC} of the MOSFET driver IR2113. The specifics of the regulators and the power are stated in the power supply section please refer to section 5.1.5 for more details.

The Block diagram and the schematic below shows how the overall system design of the audio system. The block diagram represents an overview of the system with the major component's row however for a more specific description please refer to the schematic which in demonstrates every component in the form of the circuit.

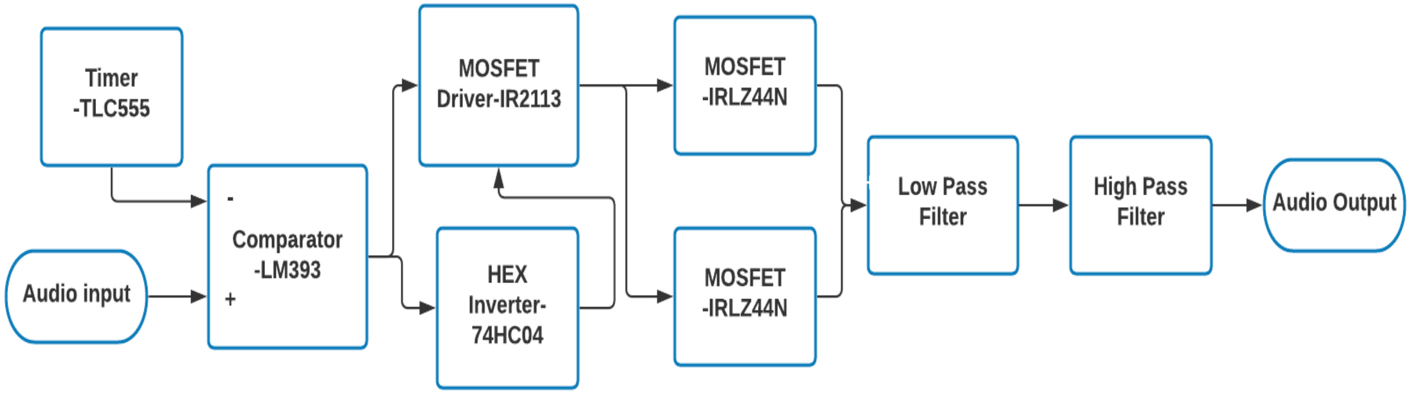

Figure 32: Audio speaker block diagram

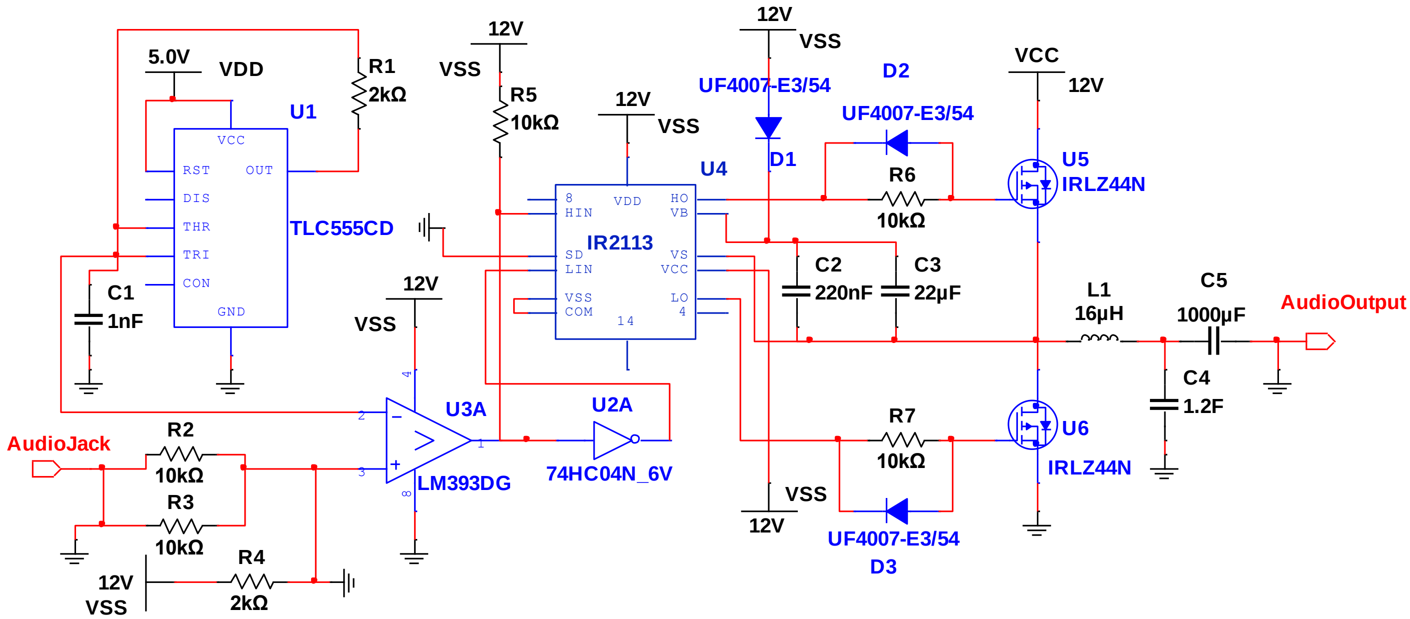

Figure 33: Audio System Circuit Design

5.1.3. Bluetooth Module

After comparing the different Bluetooth modules discussed in the research section. The HC-06 Bluetooth module was selected because of its suitable features to the project requirement and specifications. Bluetooth modules are known to be critical components since it deals with the information exchange between the smart table and the user. The HC-06 will be sending some orders to the microcontroller to be executed. The main role of the Bluetooth in this project is to forward the following received information from the user to the microcontroller to be achieved.

- Send/receive information about the state of the components
- Control the Brightness of the Projector LED.
- Set the connection between a device and the speakers through Bluetooth and controlling the volume.
- Compatibility and several device connections are allowed.

The diagram below shows an overview of how the Bluetooth module combined with the MCU will be achieved:

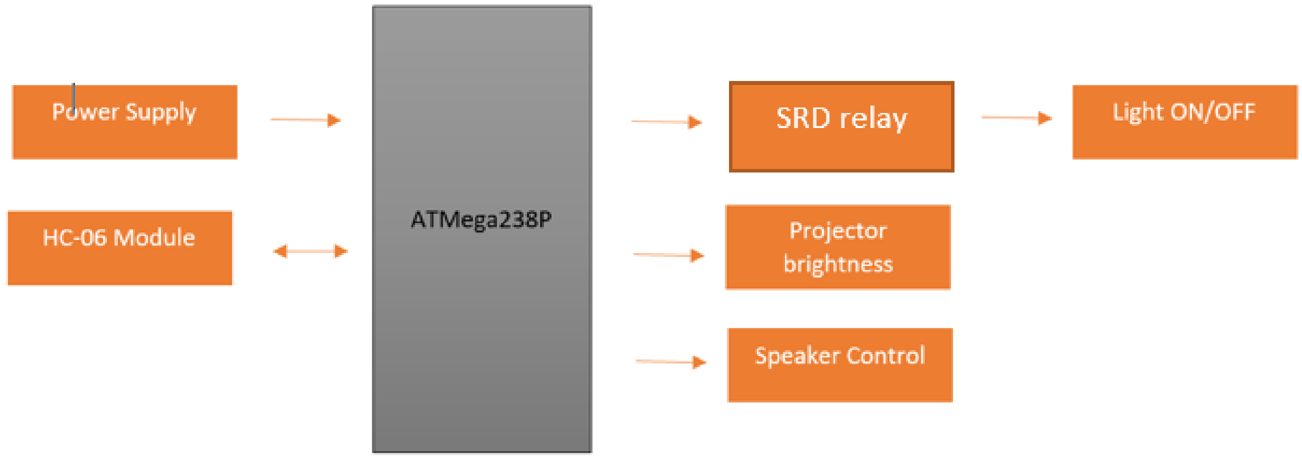

Figure 34: Bluetooth module Block Diagram

As it was previously been mentioned in section 4.4.5. Bluetooth Modules, the HC-06 module is very popular and found in the market, its implementation is straight forward since it only works in the slave mode and since in this project the Bluetooth will basically be sending information to the MCU and receiving it from the user; no master mode will be needed. The HC-06 is from class 2 and as it is known to be compatible with many devices including some of the newer technologies. Its communication range is set to work at 10 meters maximum; and since the smart table will be placed in one place and will be functioning only when the user is around d the house, the distance range should not be a connectivity issue. In addition to all these specifications, the cost of a single module was found to be very cheap approximately from $7 to $9 depending on the provider.

The powering of the Bluetooth module will be obtained from the MCU which contain a 3.3-5V-DC power supply pin. The MCU working power supply is from 1.8 to 5.5V-DC, the Bluetooth module working power supply is at 5V-DC. However, the RX pin working voltage is at 3.3V-DC, and since the UART_RX has no pull up resistor the user should introduce a voltage divider across the UART_RX pin; a 2.2K and 1K resistor values would be perfect to achieve a 3.3V-DC across the RX pin. For safety purpose and in order to control the brightness of the LED, 1Kohm resistor was used between the Tx and RX pins of the MCU and the LED. Before connecting the speaker to the MCU, an Amplifier was introduced in order to have an effective and accurate sound.

The configuration of the HC-06 to the MCU is very simple and clear because all the pins in the Bluetooth module are labeled. Since the HC-06 is set by default to the slave mode and which also is the only mode an HC-06 Bluetooth module can have, there was no need to access the settings of the HC-06 using the AT-commands. The interference between the MCU and the Bluetooth module was achieved using the UART interface using a baud rate of 9600. This means that this table will not be communicating information back to the user however it will only be executing the user's orders.

A detailed configuration of the HC-06 is shown in the **Figure below:**

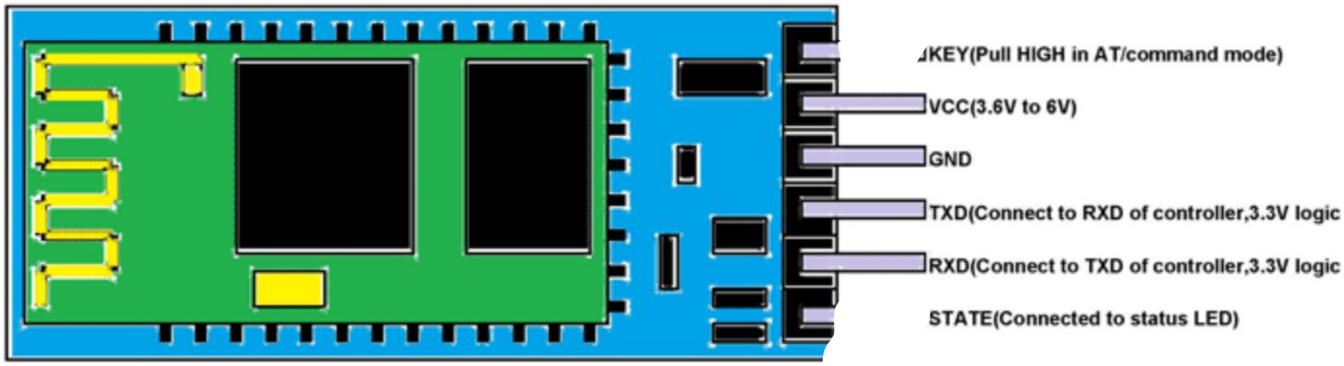

Figure 35: HC-06 design configuration

As it was mentioned before, the RXD pin should contain a voltage divider for the chip to function the figure below shows how the connection of the HC06 to the MCU should be configured.

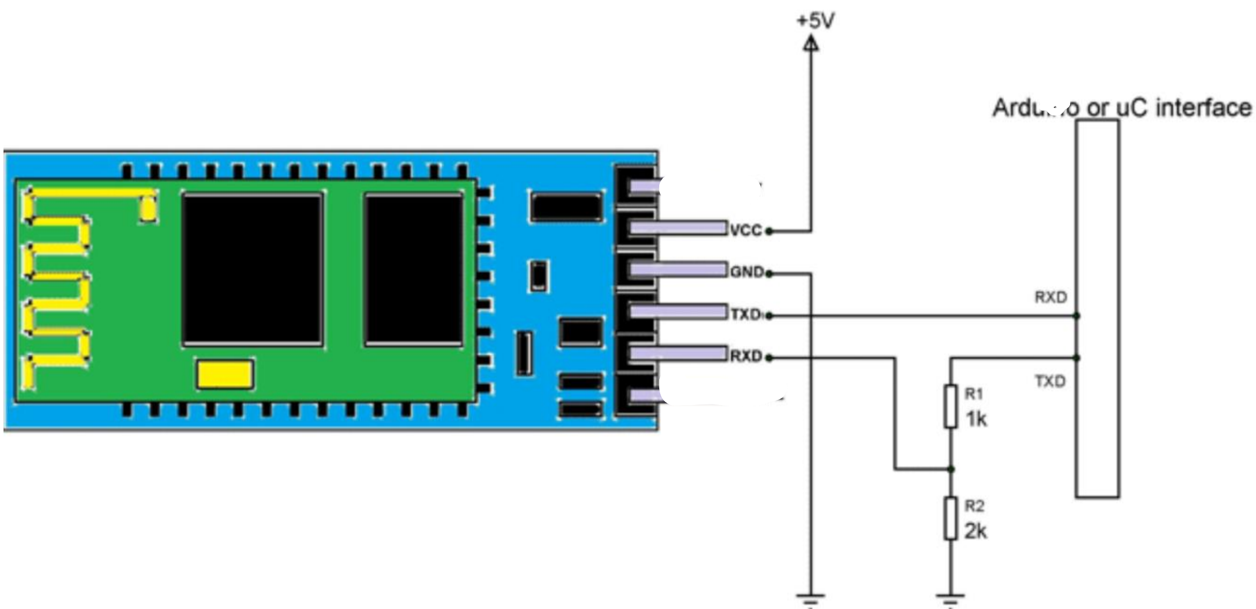

Figure 36: HC-06 to MCU configuration

In order to design the Bluetooth module, the Kicad software was used to design the schematics of the Bluetooth module systems. Since the LED strip require a DC voltage between the range of 24V-35V, several SRD relays were introduced in the design in order for the overcome some similar issues. Therefore, the interaction of the Bluetooth module with the board schematics are as shown in the Figure below:

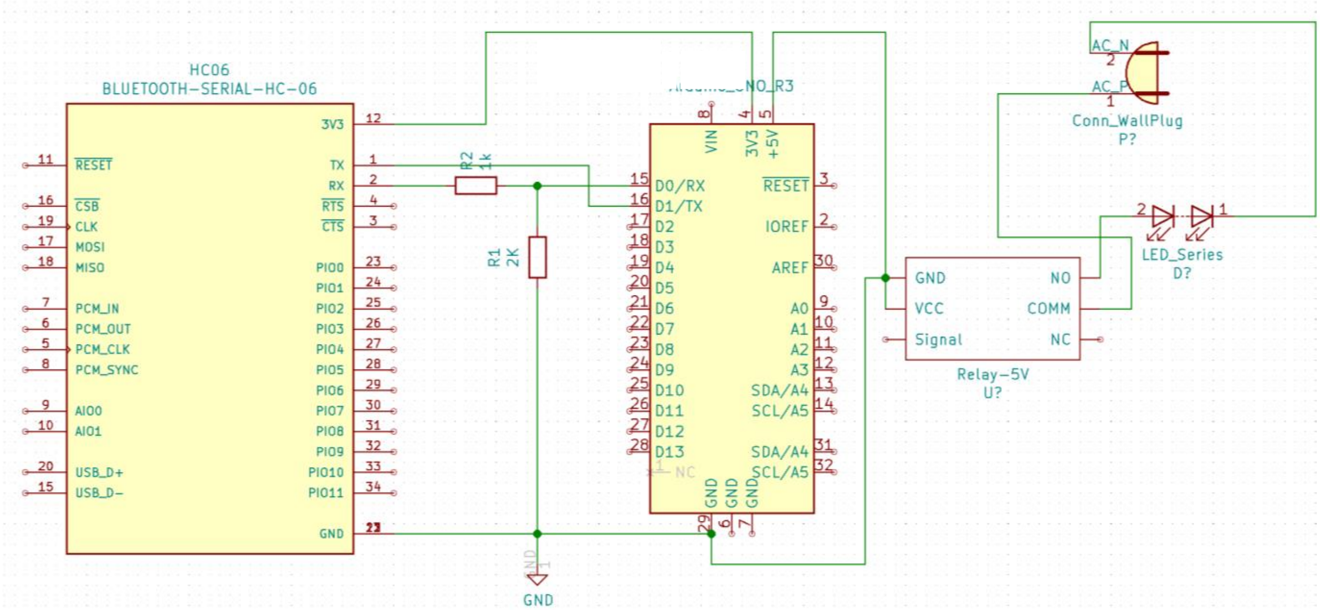

Figure 37: LED strip Bluetooth control schematics

The schematic used for the LED brightness which is controlled by the HC06 Bluetooth module is shown in the figure below; the resistance between the LED and the Arduino board is called the ballast resistance; it is mostly used to limit the current flowing through the LED for safety purposes. Only if the voltage.

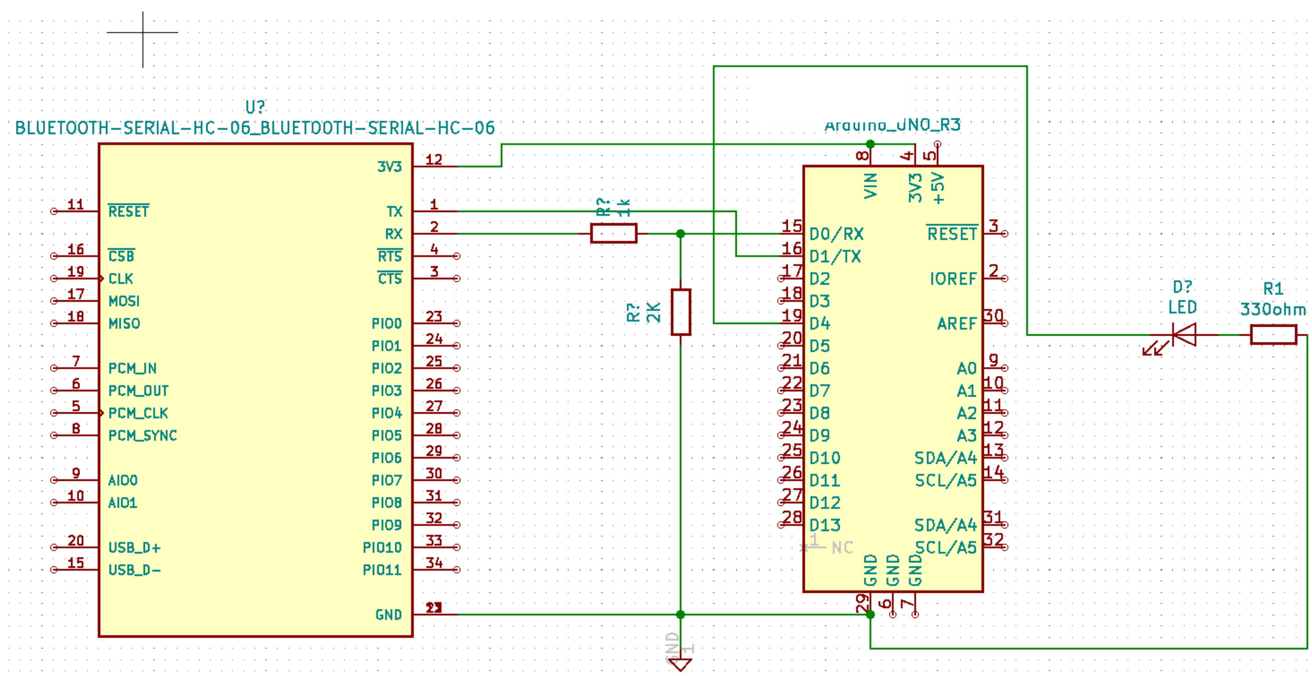

Figure 38: LED brightness Bluetooth control schematics

The audio speaker designed in the audio speaker section will be used for the wireless speaker in the smart table. Since the audio speaker already contain all the components which prevent any distortion, noise, and unwanted outside signals; the following design will only introduce the schematics of Bluetooth module with the board to connect the audio speaker wirelessly and the wireless control.

HC-06 Bluetooth Module (for programming, Debugging)

- **Part Number:** 909-BLE-SERIAL-HC-06
- **Manufacturer:** Olimex Ltd.
- **DESC:** Bluetooth Modules (802.15.1)
- **Interface type:** Serial
- **Mounting type:** SMD/SMT
- **Price:** $ 10
- **Subcategory:** Wireless & RF modules

LED Strip (for implementation)

- **Part Number:** HL360-BR636
- **Manufacturer:** lumificient technologies LLC
- **Price:** $ 2.95
- **Subcategory:** development tools

Relay (for implementation)

- **Part Number:** MIKROE-3357
- **Manufacturer:** MIKROE
- **DESC:** SRD-05VDC-SL-C electromechanical Relay
- **Price:** $ 18
- **Subcategory:** development tools

5.1.4. Fingerprint reader

Using fingerprints has nowadays become one of the technologies human use in their daily activities for security purposes. The most applications for the fingerprint is used in mobile technologies in order to access the smart phone or to identify the right user of the device. In this project, it was decided to implement a small storage in the smart table for the user to lock up anything important or for regular things that could be out of children's reach such as alcohol or guns for example. In order to give a purpose and have the smart table function as a secured storage, the feature of fingerprint recognition was decided to be included in this project.

The two most common fingerprints technologies used these days are the optical and the capacitive sensors. For more accuracy and secured usages, the capacitive fingerprint sensor has shown more success and efficiency than the optical fingerprint sensor due to the precise conductivity calculation the capacitors provide to map the ridges and valleys of the fingerprint. In this project, the optical sensor suits the requirement of the project more than the capacitive one. After reviewing the different fingerprint sensors in section 4.6.4 types & products of the fingerprint reader, the SEN0188 seemed to fit the specifications needed to accomplish this project; its baud rate is compatible with the MCU used for this project and have a high-speed DSP processor. The dimension of the fingerprint will fit perfectly when assembling the table. The power supplied to the device is compatible with the MCU used. The number of prints the fingerprint sensor can store was not given a higher attention since a household would at most hold five people, therefore the decision of choosing the SEN0188 was mainly made because of all its specification and its low cost compared to the other devices researched.

The SEN0188 sensor consist of 6 pins in total, in this project only four pins will be user to interpreted information between the fingerprint scanner and the MCU. The order of wiring used for this fingerprint goes starting from the left is Ground which translate to a black wire, then the RX and TX respectively, the fourth pin is used to power supply-red wire. The fifth pin is used as an SOUT (induction signal output) and the last pin is a VTOUCH (touch induction power input); these last two pins will not be used in this project. The figure shows the wiring set up of the SEN0188 module with the MCU:

Figure 39: SEN0188 set up

Table 22: SEN0188 pin configuration

Pin Number (right to left)	Name	Type	Function Description
1	Vtouch	In	Touch induction power input
2	Sout	Out	Induction signal output
3	Vin	In	Power input
4	TX	Out	Data output. TTL logical level
5	RX	In	Data input. TTL logical level
6	GND	----	Signal ground. Connected to power ground

The diagram of the SEN0188 configured with the MCU and the LCD which will be displaying the state of the fingerprint information; fingerprint recognized, not recognized, fingerprint read, etc. is shown in Figure below:

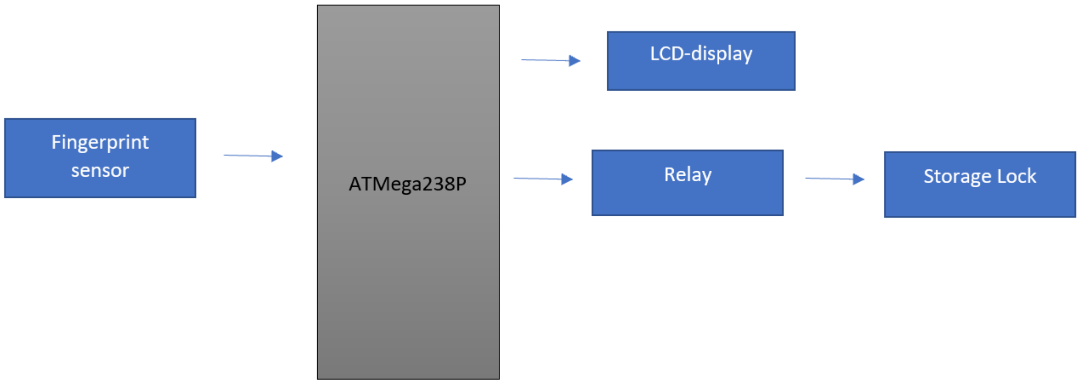

Figure 40: Fingerprint & MCU configuration

The fingerprint reader module comes with fingerprint algorithm programed on a board of the optical sensor. The only thing left was to program send commands to the fingerprints in order to store the different fingerprints which will later be recognized to access the storage. The schematics of the fingerprint design are shown in the figure below:

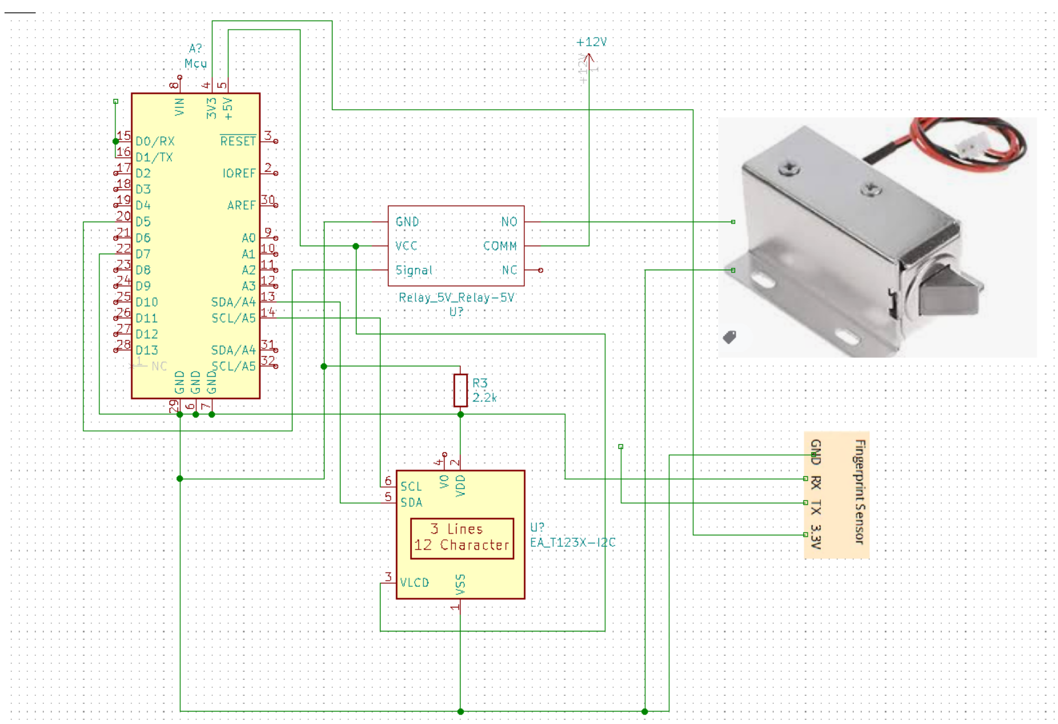

Figure 41: Fingerprint schematics

Since the door lock only function when 12v-DC is supplied to it. A relay was used for the purpose of opening the lock once the fingerprint is recognized.

SEN0188- Fingerprint Sensor (for programming, Debugging)

- **Part Number:** SEN0188
- **Manufacturer:** DFRobot
- **DESC:** Optical Fingerprint sensor
- **Interface type:** UART (TTL logical level)
- **Mounting type:** SMD/SMT
- **Price:** $ 35
- **Subcategory:** Fingerprint Sensors

Relay (for implementation)

- **Part Number:** MIKROE-3357
- **Manufacturer:** MIKROE
- **DESC:** SRD-05VDC-SL-C electromechanical Relay
- **Price:** $ 18
- **Subcategory:** development tools

5.1.5. Microcontroller

Every electronics project and electronic system needs a central control unit for the various systems implemented, and our teams smart table project is no different. This section outlines and discusses why we chose each major component in the design process as well as the manufacturers, price, and part number. We collaborated and chose to use the ATEMGA 328 system for our central processing unit also designated the micro control unit in our diagrams. We chose this unit for a various number of reasons ranging from the vast community usage and debugging as well abundantly of functionality form this low cost readily available IC chip set. We needed to use two sets of chips sets for our microcontroller. The first is the ATMEGA 328B. This chipset was used for a communication and programming when loading the firmware and designed chip usage software. The next IC chip set we used would actually be the central Processing unit responsible for the decisions and information routing, which is the ATMEGA 328 P. The data sheet for both outline proper usage constraints as well as schematic system structure and placement and for optimal functionality leading to our team needing to collaborate to design the passive components, power needs, and peripherals.

ATMEGA 328 B (for programming, Debugging)

- **Part Number:** 556-ATMEGA328PB-AU
- **Manufacturer:** Microchip Technology / Atmel
- **DESC:** 8-bit Microcontrollers - MCU ATMEGA328PB 20MHZ IND TEMP
- **Type:** SMT
- **Price:** $ 1.34
- **Instantaneous quantity**: 4964

ATEGA 328 P (CPU)

- **Part Number:** 556-ATMEGA328P-PU
- **Manufacturer:** Microchip Technology / Atmel
- **DESC:** 8-bit Microcontrollers - MCU 32KB In-system Flash 20MHz 1.8V-5.5V
- **Type:** SMT
- **Price:** $ 2.08
- **Instantaneous quantity**: 13497

Micro USB Port (Programming / Debugging)

- **Part Number:** 538-48037-1000
- **Manufacturer:** Molex
- **DESC:** USB Connectors TYPE A RA SHLDED PLG SMT AU
- **Type:** SMT
- **Price:** $ 1.25
- **Instantaneous quantity**: 17912

Jumper Pins for testing

- **Part Number:** S1222E-08-ND
- **Manufacturer:** Sullins Connector Solutions
- **DESC:** Connector Header Through Hole 8 position 0.100" (2.54mm)
- **Type:** Through Hole
- **Price:** $0.80
- **Instantaneous quantity**: 71468

Various Resistors

- **Part Number:** 311-8.25KFRTR-ND (will change with Resistor value)
- **Manufacturer:** Yageo
- **DESC:** RES SMD 8.25K OHM 1% 1/4W 1206 (will change with Resistor value)
- **Type:** SMT
- **Price:** $0.10
- **Instantaneous quantity**: 57478

Various Capacitors

- **Part Number:** 399-9156-2-ND (will change with Capacitor value)
- **Manufacturer:** KEMET
- **DESC:** 0.1µF ±20% 16V Ceramic Capacitor Y5V (F) 0805 (will change with Capacitor value)
- **Type:** SMT
- **Price:** $0.13
- **Instantaneous quantity**: 12722

LEDs

- **Part Number:** 754-1116-2-ND
- **Manufacturer:** Kingbright
- **DESC:** Green 570nm LED Indication - Discrete 2.1V 0603 (1608 Metric)
- **Type:** SMT
- **Price:** $0.30
- **Instantaneous quantity**: 2,016,820

Inductor

- **Part Number:** BRL3225T150K
- **Manufacturer:** Taiyo Yuden
- **DESC: i**nductor Power Chip Wire wound 15uH 10% 100KHz Ferrite 0.53A 0.684Ohm DCR 1210 T/R
- **Type:** SMT
- **Price:** $0.11
- **Instantaneous quantity**: 13158

Power constraints: For the designing and implantation regarding the power for our teams MCU and power continents are discussed in detail in section 5.1.6 to keep with overall flow and consistency of the project report.

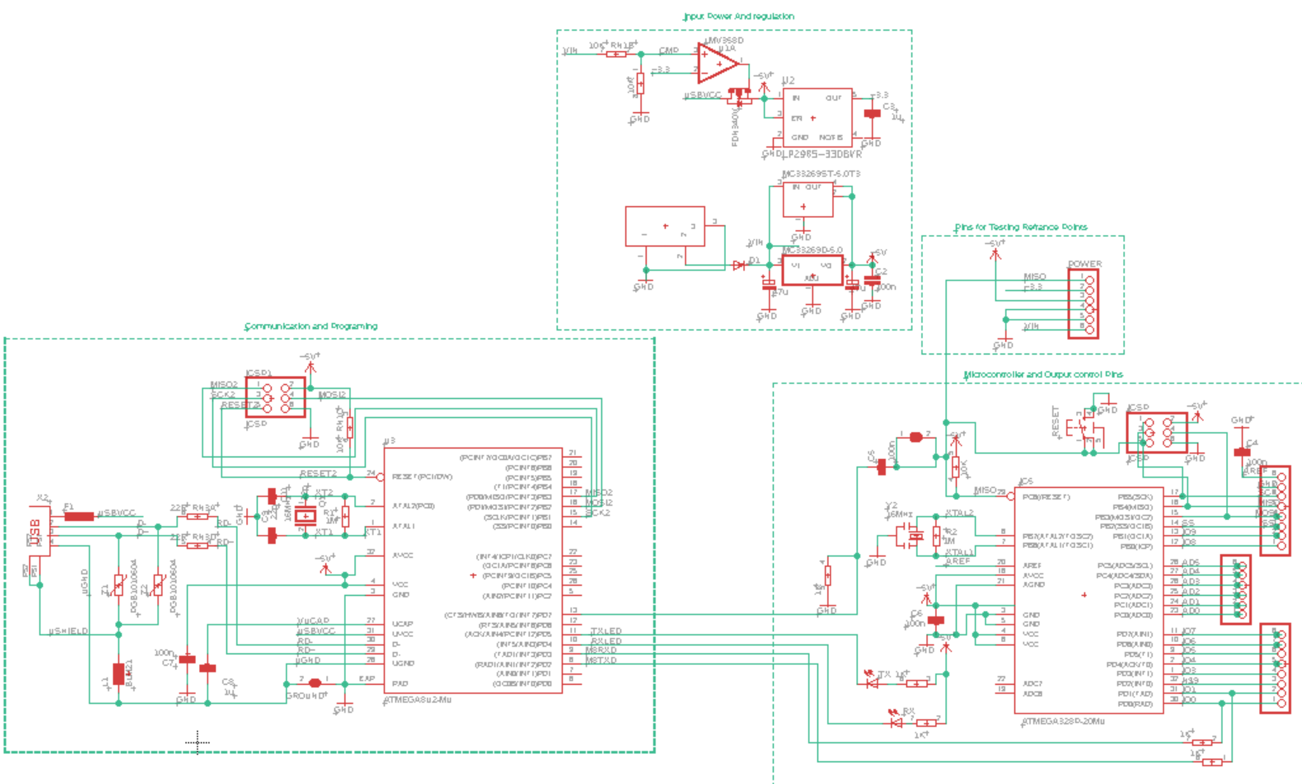

Figure 42: Central control Microcontroller for smart table

5.1.6. Power Supply

The power supply will be an alternating current to a direct current or AC to DC and it will provide power to the inter overall system. When researching types of power system an AC to DC power supply is the most convenient approach or this project as the inter system consists of multiple subsystems. These subsystems include the audio speaker system, The AC to DC power supply was designed to be efficient, low cost, stability and with this in mind the components were chosen with these parameters. This section will explain the design of the power supply, what each component are, the purpose and uses.

An AC to DC consists of a rectifier that is used to convert the transformer output voltage to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage. The filter removes most, but not all of the AC voltage variations; the remaining AC voltage is known as ripple. Starting with the transformer which is either designed to increase or decrease an AC voltage, in this case its designed to decrease to a manageable voltage. Then this voltage goes through a rectifier and the rectifier consists of a set of diodes in series allowing the positive reduced AC to go through and not the negative voltages. Next is the filter which is typically configured with an inductor and capacitor. This is the process of creating a smoothing DC current without any voltage drops hence the inductor is to help with the rippling and the conductor is used to provide power when the voltage decrease. The Basic AC to DC block diagram is shown below and is the steppingstone for the design of the power supply then after a table of every component is shown.

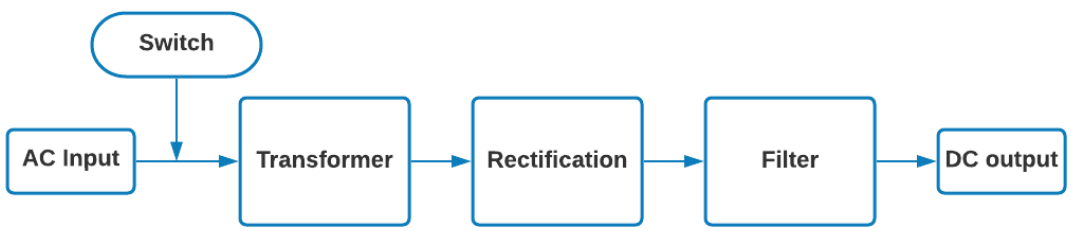

Figure 43: Basic AC to DC block diagram

Table 23: Power supply components

Components	Name	Quantity
SWITCH	Single Pole Toggle	2
TRANSFORMER	166N24	1
FULL BRIDGE RECTIFIER	GBJ2506	2
FUSES	F2320	4
BUCK COVERTER	FAN5333ASX	2
REGULATOR	NCP1117ST33T3G - 3.3V	2
REGULATOR	LM7812 - 12V	2
REGULATOR	LM7805 - 5V	2
CAPACTIORS	560 uF	4
INDUCTORS	30 mH	1

Switch: Starting with a safety measure in the form of a switch. Although a switch is not essential for the design of the power system it can be beneficial for the user and components. The switch will be incorporated in between the AC outlet and the transformer. Not only will this allow the user to disable the power to the inter system but also cut the power just in case of an emergency. A R52-01451-02W was chosen for the switch and is used for in housing for lights, fans, outlets etc. This switch is also easily purchasable from any local chain store such as The Home Depot Lowes, ACE Hardware, Tractor Supply and much more. It's also extremely affordable making it the idea choses for this project as the outlet provides 120 AC volts at 10-amp specific detail over the component shown below.

- **Part Number:** R52-01451-02W
- **Manufacturer:** Leviton
- **DESC:** 15 Amp Single-Pole Toggle Light Switch, White
- **Type:** Screw in
- **Price:** $ 0.68
- **Instantaneous quantity**: 1024

Transformer: The transformer is intended to either decrease the AC voltage and only utilize what is needed and in order to know the type of transformer needed the first thing is to know how much power is going to be required from the inter system. The audio system will require two voltages the first being 5 volts and the second being 12 volts. The MCU will provide power to the Bluetooth and the projector so at maximum the highest volts required is 24 volts at 1 amp. Therefore, as stated above the wall outlet contents 120 Ac volts at around 60Hz will have to be reduced to 24 AC at 4 amps. The 24 volts will provide the maximum voltage needed and the 4 amps will ensure that multiple devices are powered up as regulators will be use.

- **Part Number:** HM548-ND
- **Manufacturer:** Hammond Manufacturing
- **DESC:** PWR XFMR LAMINATED 96VA CHAS MT
- **Type:** Laminated Core
- **Price:** $ 34.00
- **Instantaneous quantity**: 25

Fuse: When designing the power supply, the thought of inputting a fuse in between the transformer and the rectifier to ensure that the rectifier receives the right amount of volt. This can prevent any component from damaging or blowing protecting the reset of the circuit. The fuse 0251010.MXL was chosen because of the 5 A at the 125 AC and a 24 DC. The most important aspect of the fuse is to break if either the amperes exceed the intended current or the volt spikes and although the voltage is reduced by the transformer something could go wrong protecting the rest of the system.

- **Part Number:** F2320-ND
- **Manufacturer:** Littelfuse Inc.
- **DESC:** FUSE BOARD MOUNT 10A 125VAC/VDC

- **Type:** Through Hole
- **Price:** $ 0.90
- **Instantaneous quantity**: 5,571

Full Bridge Rectifier: The roll of the full bridge rectifier is to convert the AC voltage to DC voltage. Typically, when building a bridge rectifier four diodes are used and placed parallel to each other however, bridge rectifiers are sold as a single unit. When choosing a rectifier there are several perimeters to look at first starting with the maximum repetitive peak reverse voltage, maximum average forward rectified current and the forward voltage drop. The maximum repetitive reverse voltage is important because this V_{RRM} determines the maximum voltage the rectifier can handle and for this application it only needs to handle 80 volts or more. For the peak average forward rectified current or the I_F this will determine the maximum current each diode can take and handle without blowing up. Even though the AC passes through the transformer and reduces the voltage the current is not compromised having said this the current continues to be 10 amperes. The forward voltage drop or the V_F is the voltage which is lost to thermal heat over each one of the diodes the lower the voltage the more efficient and this voltage must be subtracted from the AC voltage to determine the final DC voltage. Taking all these specifications the GBJ2506-F was chosen as it contains the values of a V_{RRM} of 600 volts which is more than 80 volts and it has a value of 1.05 IF at a VF voltage of 12.5 amperes. Based on the GJ2506-F specs this is more than sufficient enough for the entire table and is calculated for 15% hit room. Another thing to consider is how much watts of heat is going to be generated and this can be determined by multiplying the I_F x V_F = Heat Loss. Depending on the value of your heat loss it may be a good idea to incorporate a heat sink.

Table 24: Rectifier Specification

Characteristic	Symbol	GBJ 25005	GBJ 2501	GBJ 2502	GBJ 2504	GBJ 2506	GBJ 2508	GBJ 2510	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Forward Rectified Output Current (Note 3) @ T_C = 100°C	I_O	25							A
Non-Repetitive Peak Forward Surge Current 8.3 ms Single Half Sine-Wave Superimposed on rated Load	I_{FSM}	350							A

- **Part Number:** GBJ2506-F
- **Manufacturer:** Diodes Incorporated
- **DESC:** BRIDGE RECT 1PHASE 600V 25A GBJ
- **Type:** Through Hole
- **Price:** $ 1.32
- **Instantaneous quantity**: 14,959

Inductor: An inductor is place in between the rectifier and the capacitor and is designed to help the capacitor smooth out the rippling of the sine wave. The inductor was calculated to have a value of 30 mH however this may change depending on how the testing goes and will be adjusted accordingly.

- **Part Number:** SSHB21HS-R10300
- **Manufacturer:** KEMET
- **DESC:** Common Mode Chokes / Filters 1A 30mH 21mm Dual Mode
- **Type:** Through Hole
- **Price:** $ 2.81
- **Instantaneous quantity**: 112

Capacitor: In this power supply the capacitors are used as to smooth out the ripples of the AC sinewave after rectification with smoothing capacitors to produce a much more stable power. The ripple is voltage drop between each cycle of the sine wave with the capacitor holding the voltage close to the peak of each wave. For smoothing out the sine wave electrolytic capacitors are used, and the formula down below was used to calculate the value of the capacitor. When purchasing the capacitor, it's important to buy a higher rate then what is needed but close to the calculated capacitor value in order to save money.

$$\frac{Current \times Half\ cycle\ time}{Acceptable\ voltage\ drop} = Microfarad$$

The calculated is calculated to be around 2.3 microfarads of course the chances of finding the exact part can either be extremely difficult or expensive therefore four UCY2C561MHD were placed in series. The UCY2C561MHD voltage range is from 160 to 500 voltages and the frequency at 150 microfarad which is more than enough and provides a 20% hit range. The final thing to keep in mind is the polarity of the capacitor when placing them onto the breadboard or PCB. For more specification view the table down below:

Table 25: UCY2C561MHD Specifications

<table>
<tr><td>Category Temperature Range</td><td>−40 to +105°C</td></tr>
<tr><td>Rated Voltage Range</td><td>160 to 500V</td></tr>
<tr><td>Rated Capacitance Range</td><td>6.8 to 680μF</td></tr>
<tr><td>Capacitance Tolerance</td><td>±20% at 120Hz, 20°C</td></tr>
<tr><td>Leakage Current</td><td>After 1 minute's application of rated voltage at 20°C, leakage current is not more than 0.04CV+100 (μA)</td></tr>
<tr><td>Tangent of loss angle (tan δ)</td><td>Measurement frequency : 120Hz at 20°C
<table>
<tr><td>Rated voltage (V)</td><td>160</td><td>200</td><td>250</td><td>350</td><td>400</td><td>420</td><td>450</td><td>500</td></tr>
<tr><td>tan δ (MAX.)</td><td>0.20</td><td>0.20</td><td>0.20</td><td>0.24</td><td>0.24</td><td>0.24</td><td>0.24</td><td>0.24</td></tr>
</table></td></tr>
<tr><td>Stability at Low Temperature</td><td>Measurement frequency : 120Hz
<table>
<tr><td colspan="2">Rated voltage (V)</td><td>160</td><td>200</td><td>250</td><td>350</td><td>400</td><td>420</td><td>450</td><td>500</td></tr>
<tr><td rowspan="2">Impedance ratio (MAX.)</td><td>Z−25°C / Z+20°C</td><td>3</td><td>3</td><td>3</td><td>5</td><td>5</td><td>6</td><td>6</td><td>6</td></tr>
<tr><td>Z−40°C / Z+20°C</td><td>6</td><td>6</td><td>6</td><td>6</td><td>6</td><td>−</td><td>−</td><td>−</td></tr>
</table></td></tr>
<tr><td>Endurance</td><td>The specifications listed at right shall be met when the capacitors are restored to 20˚C after D.C. bias plus rated ripple current is applied for 12000 hours (10000 hours for 20L or less, 500V) at 105˚C, the peak voltage shall not exceed the rated voltage.
<table>
<tr><td>Capacitance change</td><td>Within ±20% of the initial capacitance value</td></tr>
<tr><td>tan δ</td><td>200% or less than the initial specified value</td></tr>
<tr><td>Leakage current</td><td>Less than or equal to the initial specified value</td></tr>
</table></td></tr>
<tr><td>Shelf Life</td><td>After storing the capacitors under no load at 105˚C for 1000 hours and then performing voltage treatment based on JIS C 5101-4 clause 4.1 at 20°C, they shall meet the specified values for the endurance characteristics listed above.</td></tr>
</table>

- **Part Number:** 493-13069-ND
- **Manufacturer:** Nichicon
- **DESC: CAP ALUM 560UF 20% 160V RADIAL**
- **Type:** Through hole
- **Price:** $ 2.87
- **Instantaneous quantity**: 69

Voltage regulation & Boost converter for HDMI Board: The processing of the board system as well as the LCD screen has specific power requirements. The processing done on this board needs steady DC regulation leading the way for an on-board voltage regulator. This chosen regulator is a low drop out switching voltage regulator as outlined in detail in previous sections on how switching regulation work and how to design one. This low dropout switching regulator can provide fixed output voltage ranging from 1.5 V all the way to 12 V given the proper setup and arrangement, with a system drop voltage of 1.2 V as well as a maximum current of 1 A. We will be using this particular low drop out regulation constituent for controlling the voltage to the IC processing unit on the HDMI board. The Texas Instruments IC needs a steady 3.3 Volts for functionality. Once the processing power requirements had been chosen the team moved on to the powering requires for the LCD display. We as a team chose to implement a boost converter to power the needs of the LCD screen. This particular LCD needs 5V steady regulation for functionality with minimal amperage.

Voltage regulator

- **Part Number:** NCP1117ST33T3GOSTR-ND
- **Manufacturer:** ON Semiconductor
- **DESC:** IC REG LINEAR 3.3V 1A SOT223
- **Type:** SMT
- **Price:** $ 0.46
- **Instantaneous quantity**: 3701

Boost Converter

- **Part Number:** FAN5333ASXTR-ND
- **Manufacturer:** ON Semiconductor
- **DESC:** IC LCD DRIVER RGLTR DIM SOT23-5
- **Type:** SMT
- **Price:** $ 0.96
- **Instantaneous quantity**: 7543

Voltage regulator: These two linear voltage regulators are designed to produce a stable steady voltage and current source for and sensitive system or device. The LM7812 outputs 12 volts at 1.5 ampere which is designed to not only power the MOSFET driver of the audio system but the door lock as well. The LM805 is designed to output 5 volts at 1.5 ampere and I used to power up the timer of the audio system LCD screen and fingerprint reader. One thing to keep in mind is the maximum input voltage for both of these regulators is 35 volts however the minimum for the LM812 is 14 volts and the LM805 is 7 volts in order to provide both a stable 12V and 5V. If the regulator is place far from the rest of the power input capacitors may need to be placed for stability which helps with the transient response as shown below:

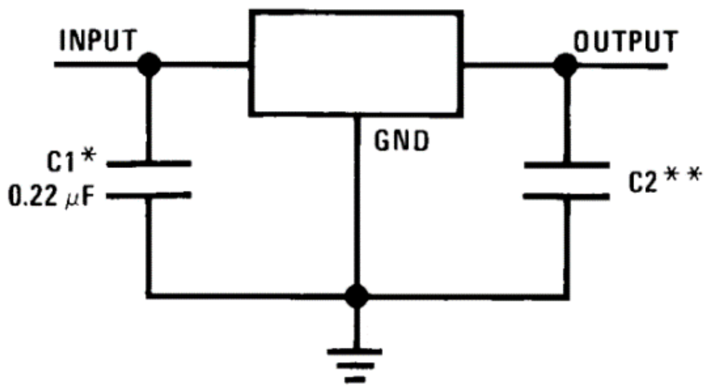

Figure 44: Voltage Regulator configuration

- **Part Number:** LM7812CT/NOPB
- **Manufacturer:** Texas Instruments
- **DESC:** Linear Voltage Regulators 3-Term Pos Regs
- **Type:** Through Hole
- **Price:** $ 1.54
- **Instantaneous quantity**: 3161

- **Part Number:** L7805CV
- **Manufacturer:** STMicroelectronics
- **DESC:** Linear Voltage Regulators 5.0V 1.0A Positive
- **Type:** Through Hole
- **Price:** $ 0.50
- **Instantaneous quantity**: 42,270

The Block diagram and the schematic below shows how the overall system design of the power system. The block diagram represents an overview of the system with the major component's row however for a more specific description please refer to the schematic which in demonstrates every component in the form of the circuit.

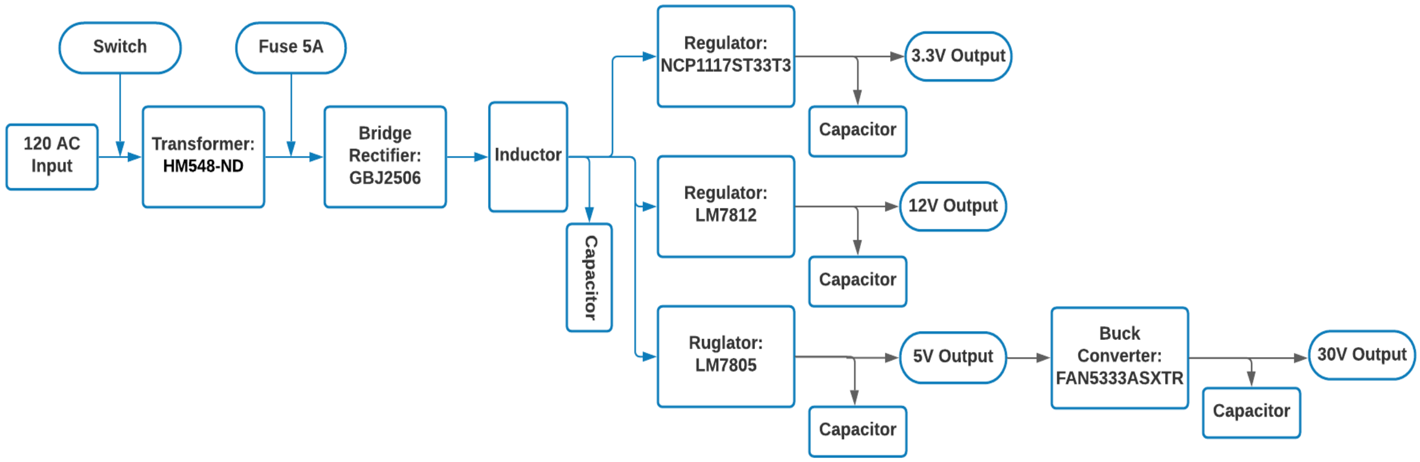

Figure 45: Power System Block Diagram

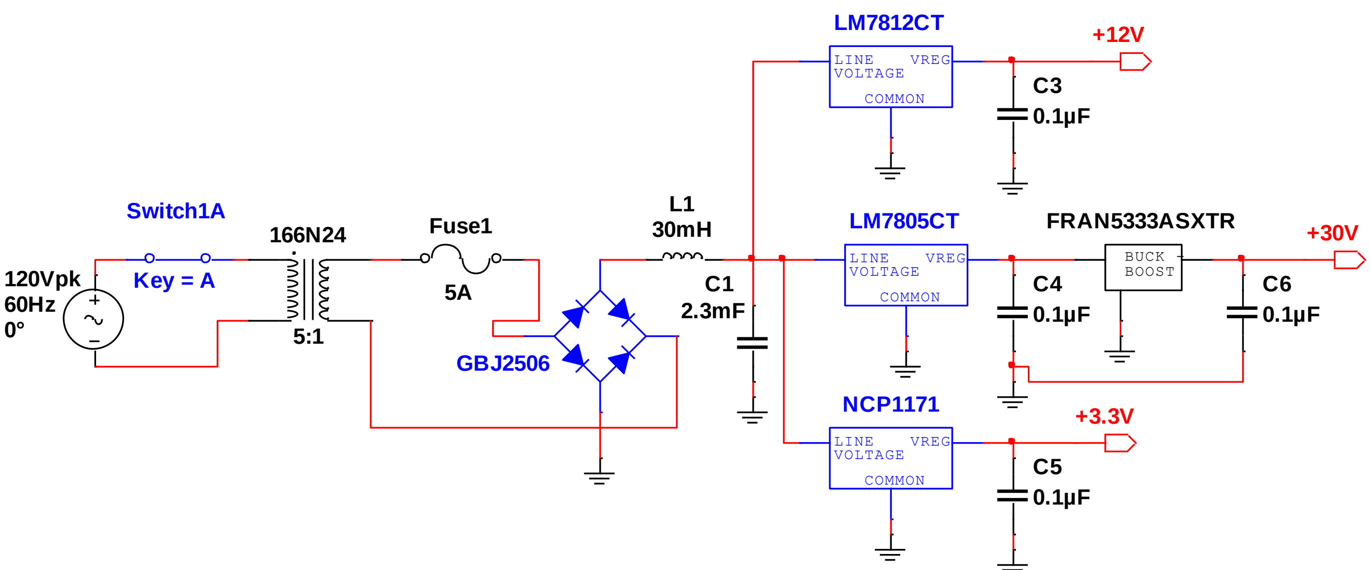

Figure 46: Power System Circuit Design

5.1.7. HDMI Control Board

There are many variations and different types of HDMI control boards. Most control boards are design specifically for each LCD screen. However, there are many similarities and functionalities between systems which allowed the team to collaborate and figure out together what was needed to further our smart table to the production life cycle. The design process and implantation were lengthy however it was very necessary. The team had decided to use a seven-inch LCD screen and an HDMI port feeding from the users desired input. Following a logical and orderly fashion the design process started with how to transfer the data coming in from the HDMI port (Pins) to the 40-pin ribbon / bus controlling the screen. The team chose an IC driver from Texas Instruments due to it availability and extensive data sheet as well as detailed explanations of how to properly operate the device. Using the complementary data sheet, we were able to start extending the design process accordingly and chose which components and constituents we needed. This section outlines the components that were chosen, why they were chosen for various design constraints, components pricing, as well a schematic design the team has collaborated to implement.

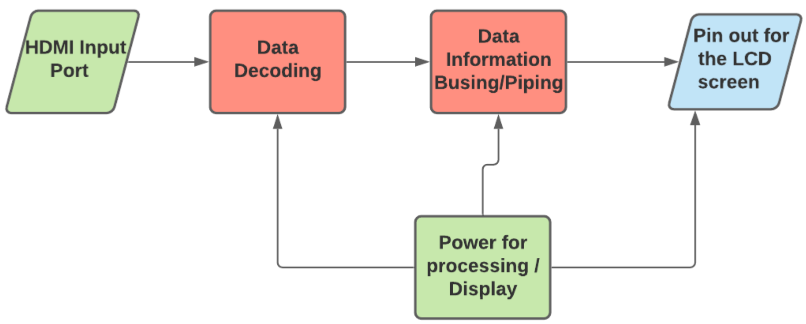

Figure 47: HDMI control board functional Block diagram for information piping to LCD screen

Central IC for HDMI decoding and Panel Bus:

As stated above we started the design process with what function system will be used to encode and transfer the data to the LCD screen. We chose this IC driver from Texas instruments. The data sheet shows an extensive feature list as well as how to properly operate the device under varying condition. This IC chosen has I2C programmability as well the ability to configure sate pins with the ability to properly pipe graphics to the chosen LCD screen given the HDMI port pins. With the data sheet we were able to determine which voltages were necessary and where as well as corresponding components for complete system functionality.

Digital HDMI decoder for BUS

- **Part Number:** 296-12666-ND
- **Manufacturer:** Texas Instruments
- **DESC:** IC DRIVER 3/0 64HTQFP
- **Type:** SMT
- **Price:** $ 6.60
- **Instantaneous quantity**: 6,451

Voltage regulation & Boost Converter

The processing of the board system as well as the LCD screen has specific power requirements. The processing done on this board needs steady DC regulation leading the way for an on-board voltage regulator. These chosen systems are discussed in more detail in section 5.1.6. The comments and main continents are listed below.

Voltage regulator for powering the LCD

- **Part Number:** NCP1117ST33T3GOSTR-ND
- **Manufacturer:** ON Semiconductor
- **DESC:** IC REG LINEAR 3.3V 1A SOT223
- **Type:** SMT
- **Price:** $ 0.46
- **Instantaneous quantity**: 3701

Boost Voltage regulator for LCD screen

- **Part Number:** FAN5333ASXTR-ND
- **Manufacturer:** ON Semiconductor
- **DESC:** IC LCD DRIVER RGLTR DIM SOT23-5
- **Type:** SMT
- **Price:** $ 0.96
- **Instantaneous quantity**: 7,543

Various Ports and components:

As with every system design various passive component are needed for general functionality and overall system processes. The various passive components were chosen through collaboration form the team as well as specific constraints for various configurations. The components are listed below with pricing, part numbers, as well as the manufacturer.

HDMI Port

- **Part Number:** HDMI MOLEX 47151-0001 DIMLAYER
- **Manufacturer:** Molex
- **DESC:** HDMI, DisplayPort & DVI Connectors .5MM RA SMT RCPT
- **Type:** Through hole
- **Price:** $ 1.96
- **Instantaneous quantity**: 9,458

Micro USB Port

- **Part Number:** 538-48037-1000
- **Manufacturer:** Molex
- **DESC:** USB Connectors TYPE A RA SHLDED PLG SMT AU
- **Type:** SMT
- **Price:** $ 1.25
- **Instantaneous quantity**: 17,912

Jumper Pins for testing

- **Part Number:** S1222E-08-ND
- **Manufacturer:** Sullins Connector Solutions
- **DESC:** Connector Header Through Hole 8 position 0.100" (2.54mm)
- **Type:** Through Hole
- **Price:** $0.80
- **Instantaneous quantity**: 71,468

Various Resistors

- **Part Number:** 311-8.25KFRTR-ND (will change with Resistor value)
- **Manufacturer:** Yageo
- **DESC:** RES SMD 8.25K OHM 1% 1/4W 1206 (will change with Resistor value)
- **Type:** SMT
- **Price:** $0.10
- **Instantaneous quantity**: 57,478

Various Capacitors

- **Part Number:** 399-9156-2-ND (will change with Capacitor value)
- **Manufacturer:** KEMET
- **DESC:** 0.1µF ±20% 16V Ceramic Capacitor Y5V (F) 0805 (will change with Capacitor value)
- **Type:** SMT
- **Price:** $0.13
- **Instantaneous quantity**: 12,722

Various Diodes

- **Part Number:** MM3Z24VT1GOSTR-ND (will change with Diode needs)
- **Manufacturer:** ON Semiconductor
- **DESC:** Zener Diode 24V 300mW ±6% Surface Mount SOD-323 (will change with Diode needs)
- **Type:** SMT
- **Price:** $0.14
- **Instantaneous quantity**: 26,901

Inductor

- **Part Number:** BRL3225T150K
- **Manufacturer:** Taiyo Yuden
- **DESC: i**nductor Power Chip Wire wound 15uH 10% 100KHz Ferrite 0.53A 0.684Ohm DCR 1210 T/R
- **Type:** SMT

- **Price:** $0.11
- **Instantaneous quantity**: 13,158

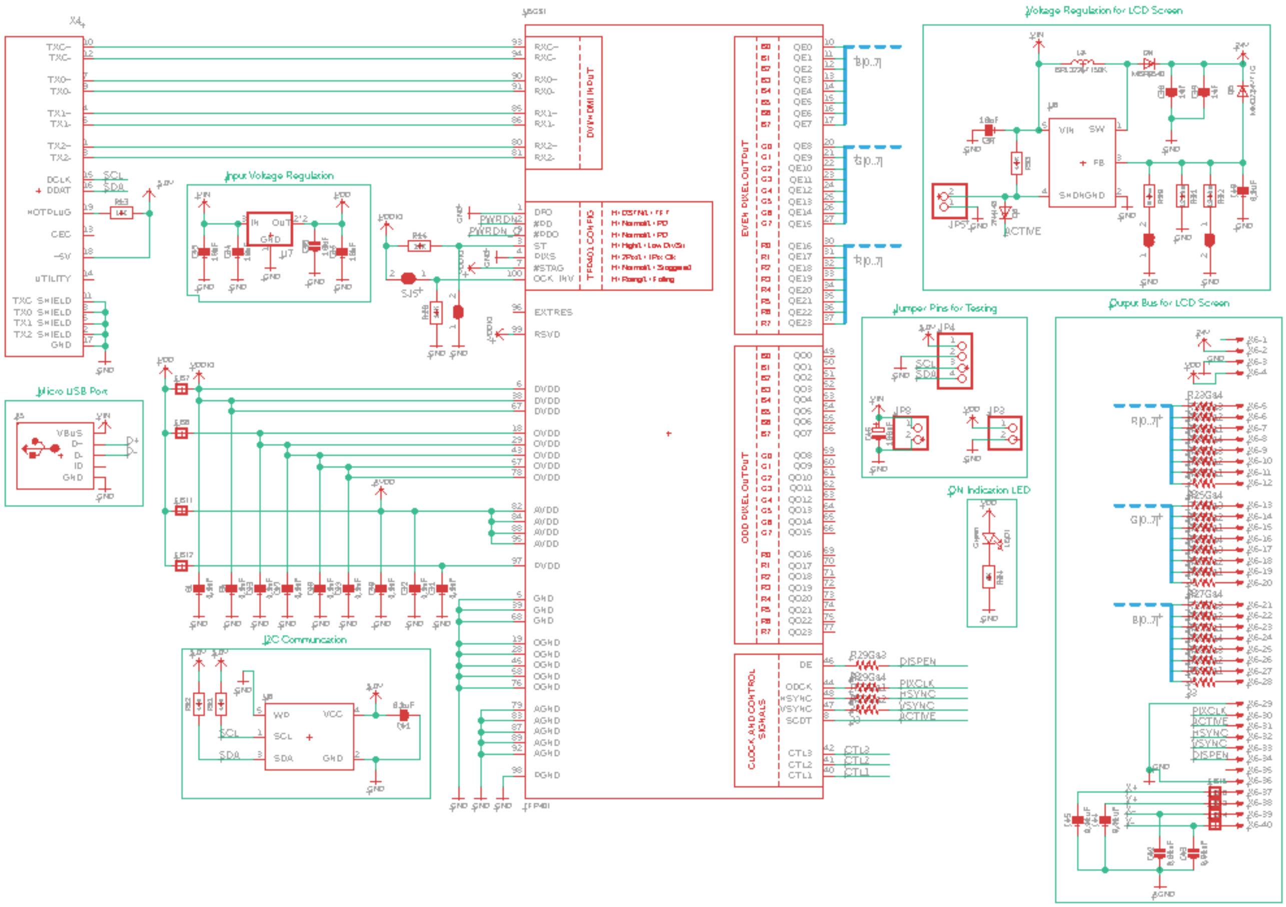

Figure 48: HDMI Control board schematic diagram

5.1.8. Projector

Optical Projector System

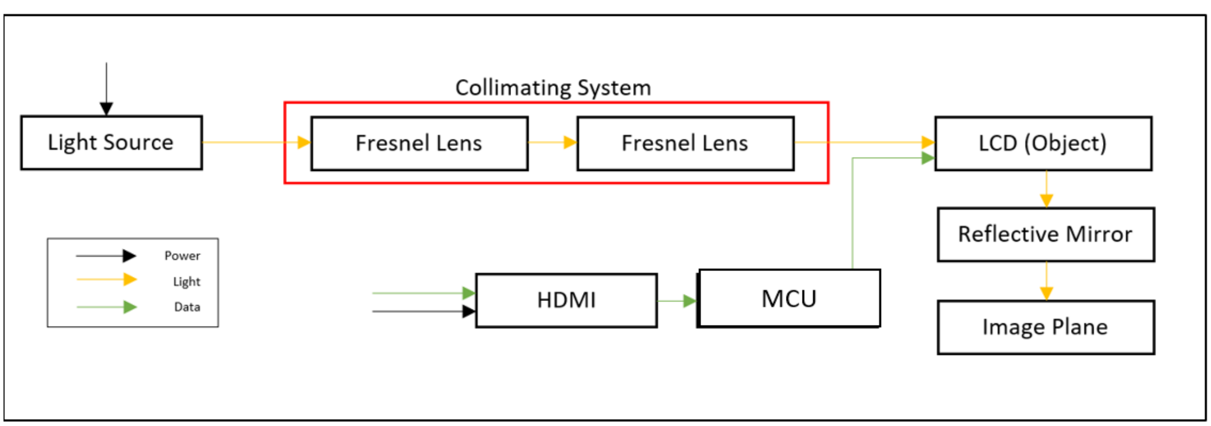

Figure 49: Projector System Block Diagram

Table 26: Projector System Components

Name	Type	Quantity	Price (Approx.)
High Power LED	Light Source	1	$ 99.00
Fresnel Lenses (f = 90, 60)	Lens	2	$ 30.00
5.5" LCD Smartphone Screen	LCD Object	1	$ 80.00
'Large Format' Camera Lens	Lens	1	$ 50.00
Front Surface Mirror (200mmx250mm)	Reflective Optics	1	$ 50.00

Light Source—LED

The LED stands for Light-emitting diode. It is a pn-junction diode mainly used as the source of light. It is not a new device, it has long been serving in the field of telecommunication, electrical engineering and in hard to reach places where common light fails to deliver.

The LED has a leg over common orthodox incandescent light in terms of efficiency, low consumption power, compact size, longer range and an ability to retain the quality for a longer period. It comes with a wide variety of applications ranging from automotive headlamps, camera flashes, aviation lighting, traffic signal, medical devices to embedded and control system for the indication if the relevant projects are working properly. Let's dive in and get down to the detail of this little electrical component.

LED is a pn-junction diode that mainly used as a replacement of incandescent lights. It is based on the electroluminescence effect - A process where diode converts electric current to light when electrons change their state inside the LED semiconductors. The pn-junction is nothing but a combination of both N-type and P-type semiconductor materials. The material forming the junction diode is not identical to other mainstream didoes, as it comes with a transparent package, allowing the infrared and visible light to pass through the junction.

The LED I ended up using is part BC160H from a manufacturer called Yuji LED. It's quite expensive, but the colors that result from it with the final projector are absolutely on point. There are cheaper ones available on eBay that will do a similar job but do be aware that as they have larger diameters, you'll need to use a lens with a wider aperture. As these LEDs do kick out a lot of heat, they need to be cooled with a heatsink. I'm using one from an old computer, and as such it should keep the LED nice and cool while running quietly as well.

When the LED gets mounted to this, you do need to use some thermal compound so that the heat gets transferred effectively. You should be able to run it for a few minutes without fans for testing purposes, but when it gets warm to the touch make sure you turn it off and let it cool down. To hold the LED in place we're going to clamp it down with a new aluminum layer, which needs a hole made in it for the LED to see through, as well as a few holes for the screws etc. This hole can be made central by marking an X from corner to corner (like we did earlier).

This is important as if it is offset in any way it will harm brightness drastically. You may need to make some groves around its perimeter to provide space for the LED's solder pads. Make sure that these don't touch and short out on the aluminum, however. Once in place, the LED should be held firmly against the heatsink meaning that it's ready to test. Before we do that however I'll just point out the slot in this layer.

This slot is an air vent as the projector will rely on a zig-zag airflow path to keep each layer's component cool. To make a slot like this, mark it out accurately and then drill a hole within its perimeter. The jigsaw blade can now fit into this hole and you can cut out the shape by cutting a gradual curve from this hole until you reach a straight edge to follow. Do this a few times and you should be able to make your slots and shapes without issue.

Powering it on is unfortunately slightly more involved than just plugging it in to a power brick and having it light up straight away. This is because LEDs not only need a specific voltage, but they also need the current to be capped so that they don't draw too much current after warming up resulting in thermal runaway. If you have an LED driver that matches your specific LED then you're good to go, but in case you can't find one I'm going to share my preferred method. What we'll need for this is a voltage regulator that also has constant current capability. Before being hooked up to the LED it needs to be configured correctly.

To do this, hook it up to a power supply capable of providing at least 120w, like an old laptop or printer power brick. Once this power brick is hooked up to the voltage regulator board, being aware to get the correct polarity, you need to monitor its output with a multimeter and adjust the voltage trimmer so that it outputs a voltage that is LESS than your LED's rated voltage. Mine started at 30v, so I had to decrease the output voltage to 23v.

Once the voltage has been configured successfully to be below the LED's startup voltage, we can hook it up to the LED but with a power meter between it and the output of the voltage board so we can monitor the wattage and current that's flowing to the LED. Increasing the voltage whilst monitoring the current results in it glowing dimly at first, but it will get brighter and brighter.

Don't look at it directly as it's not good for your eyes. Make sure that you continually monitor the wattage it's consuming and stop when it reaches 100w (or whatever wattage your LED is rated for). Holding it there, adjust the other trimmer, which is current adjustment, so that the LED just starts to dip in brightness, and then turn it back slightly so it plateaus again at maximum brightness. This caps the current at whatever is required to sustain 100w on the LED.

Types of LEDs considered

YujiLEDs

The first option I looked at was the YUJILEDS® BC Series 4th generation 3030 SMD provides a no-compromise high CRI, high efficacy and remarkable chromatic consistency solution in an industry standard PCT package. Providing 95 CRI (min), this mid-power LED can be used in a variety of applications demanding high color quality and performance.

We're going to use what's known as a COB LED as the light source for this build as they're efficient, very bright, and available with high color quality and at a neutral white balance. COB stands for chip on board, and they're a type of LED that consists of a very small grid array, allowing for a lot of brightness from a small package. They come in a variety of color temperatures, wattage values, and color rendering indexes (CRI), with the recommended values being as follows:

- Power rating: 100w
- Color temperature: 5600k - 6400k
- CRI: 90 - 97

100w is the minimum amount of power you should aim for with this project, as any lower and the brightness of the projected image won't be good enough even in a dark room. For white to appear 'white' like a phone screen or computer monitor, an LED in the 5600k to 6400k range is ideal. I don't recommend dropping below 90 CRI though as the colors would appear washed out.

Marswall

- High Power LED Chip 100W Daylight White
- Color Temperature: 5300K-5800K (5600K)
- Voltage (V): 36-38 Volts
- Current (A): 2.5A
- Luminous Flux (LM):9500-10500 LM
- CRI Ra 95-98
- Material: Copper Brackets
- Working Temperature: -30-60℃

Note: It will work more than 30000 hours if the working temperature is less than 60 Degree Celsius. So, they need to work wih heatsinks or Thermal Silica otherwise the light will die due to too much heat.

OSRAM Opto Semiconductors

- Package / Case: SMD-2
- Illumination Color: White (Cool White)
- Wavelength/Color Temperature: 5000 K
- Luminous Intensity: 186.7 cd
- Luminous Flux/Radiant Flux: 563 lm
- Color Rendering Index - CRI: 80
- Viewing Angle: 120 deg
- Lens Color/Style: Tinted, Diffused
- If - Forward Current: 750 mA
- Vf - Forward Voltage: 6.2 V
- Length: 5 mm
- Width: 5 mm
- Height: 0.7 mm
- Minimum Operating Temperature: - 40 C
- Maximum Operating Temperature: 110 C

- Packaging: Cut Tape
- Packaging: MouseReel
- Packaging: Reel
- Features: -
- Brand: OSRAM Opto Semiconductors
- LED Size: 5 mm x 5 mm x 0.7 mm
- Product Type: LED - High Power
- Factory Pack Quantity: 1500
- Subcategory: LEDs
- Part Aliases: Q65111A7935
- Unit Weight: 0.007055 oz

Light Control—Collimation system

The light path is important, we need to use a set of Fresnel lenses to control it for a properly projected image. They must be larger than the LCD panel you are planning on using. Both Fresnel lenses must be mounted onto their own layers and remember to add a vent slot on each. Aim to get them as central as possible so that the light path remains aligned.

Use the X method for this and work out your rectangle cutout shapes by measuring out from this center. The first Fresnel lens must 'collimate' the light rays to make them parallel, so must be placed above the LED precisely at the Fresnel's focal length. Your Fresnel's focal length can be measured using the 'sun focusing' method. Remember, never look at the bright focused point. Ideally the focal length of this first Fresnel needs to be less than 100mm as it will 'capture' more light from the LED this way. Remember to mount it with its Fresnel ridges facing upwards. The second Fresnel on the other hand needs to be mounted above the first, with its Fresnel ridges facing downwards this time.

I recommend using some PCB pillar supports to space them out, and make sure that the vent slots are on opposite sides to enable the zig-zag airflow path. This second Fresnel takes the parallel light rays and points them to where the lens will be mounted later. Ideally you need to slide your lens layer up and down on the rods so that you can find its perfect placement, where the projected light does not vignette and instead just appears to be a white rectangle.

The position for this will be around the same as the focal length of the second Fresnel, which in my case was 160mm. Make note of the exact measurement for later, after which it's time to work on the image source.

CZ Garden Supply Store Brand

- Size Φ100 mm, Thickness:2 mm,
- Material: PMMA (Acrylic)
- Focal length 100 mm or 50 mm
- High Light Transmittance, High Efficiency in Focusing, High Precision.

Image Source—LCD Panel

There are two options you have regarding the image source. The first option is to purchase a small smartphone screen online that comes with an accompanying HDMI control board. This is my recommendation as it will make the build easier, and you will still get great image quality as 2560x1440 panels are available. If you want to use a smartphone directly however, for either keeping costs low or for other reasons like 4K, then that's possible too, although you won't be able to plug in external sources like game consoles or Blu Ray players.

Either way you will need to strip things down to the bare screen and remove its backlight layers to make it transparent, as well as unplug its LED strip. As smartphones are all different, I won't go into detail here, but a good source for phone strip own guides is iFixit. Don't take things too far by peeling off the back-mirror layer though - this is the polarizing layer and the screen won't work without it. You'll need to mount this accurately to the center of another aluminum layer, again adding a vent slot.

I used some right-angle brackets to hold the phone upright so that it could still be plugged into the LCD panel. This layer must also be made black with some vinyl wrap so that the lens doesn't bring into focus the shiny aluminum. To mount this in place I recommend holding it with some tape initially and then gluing the screen underneath with some epoxy. Don't let this go on the back of the screen itself however and ruin the image. The intention with this layer is to fit onto the top of a 'focusing rig' that allows it to be accurately moved up and down to find precise focus once complete.

Projection Lens—Large Format Lens

There are three major factors to consider while sourcing your lens for this project:

- image circle
- focal length
- aperture

Image circle is easy, as it just refers to the lens's coverage. A Full Frame camera lens for example has an image circle of only ~43mm across, which isn't enough to cover our smartphone screen. Vintage Large format lenses however have image circles that are WAY larger and should cover a smartphone screen with ease. I recommend looking for one on eBay and they can be fairly cheap, although this project has unintentionally pushed up prices as now, they're more in demand. There are some new lenses made for DIY projectors that can cover smartphone screens so it may be worth looking at. They're cheapest on AliExpress and you can find them by searching for 'do it yourself projector lens'.

The focal length of your lens needs to be chosen in tandem with the second condensing Fresnel, and the lens needs to have a shorter focal length than that of the second Fresnel so that it can focus on the LCD panel that is in front of the second Fresnel yet still remain in the Fresnel's 'sweet spot'. I recommend a 135mm lens as it plays well with a 160mm second Fresnel. If you can only find a 200mm lens for example, you will need to change the second Fresnel to one that's 220mm fl or longer. It's worth noting that the focal length of the projection lens defines the final projected image size too.

A shorter focal length will result in a larger projected image at a given distance. If you have a large space, you may want to use a 200mm lens or more otherwise your projected screen size will likely be too big / dim. My 135mm lens coupled with the 5.5" smartphone screen for example resulted in a projected image size that was 2m diagonally, even though the projector was only 2.5m away from the projection surface. This is great for small living rooms and apartments, but you'll need to adjust things depending on what space you're planning on using the projector in.

Note that the LCD size does affect image size too... with a larger LCD resulting in a larger projection. There's nothing stopping you from using a laptop LCD for example (so long as your lens's image circle is large enough), but you'll need a longer focal length to make the projected image useable.

Regarding aperture, the lens's aperture needs to be physically larger than the diameter of your LED to avoid a loss of light. As my LED had a mere 16mm diameter, it meant that I could get away with using a small aperture lens (f9). If you're using a cheaper (or brighter) LED with a larger diameter, you'll need to use a lens with a bigger aperture otherwise it will start blocking light.

Once the lens has been mounted to the center of its own layer it can be slid onto the rods and held in place with some nuts at the exact position you measured earlier when testing it with the Fresnel's. If you look closely, you'll notice that my lens has been mounted lower on its layer so that its front is flush. I did this on mine to allow the layer itself to be further away from the top of the smartphone, as the smartphone sticks up a lot and would have otherwise prevented the lens from being low enough to bring the LCD panel into focus. As the system is all vertical now, the projected image would land on the ceiling and be inverted resulting in text being backwards (a result of light passing through the lens). To fix this we'll be using a front-surface mirror.

As the reflective surface is on the front, it means that there is no image 'ghosting' which would be quite severe for a projector like this. You can buy these mirrors online, but to keep costs low you may want to make one yourself by using paint stripper on the back of a normal mirror and washing it off carefully - leaving you with a delicate but serviceable front surface mirror on this back side. It can be mounted to its own aluminum layer (measuring 200mm by 252mm, with some 1cm tabs) using some small brackets - mine were 3D printed. Once positioned above the lens at a 45-degree angle it should reflect the image forwards.

If for some reason you want to exclude the mirror in your design, you will need to make sure that you mount the screen upside down so that the projected image isn't inverted. At this point it is a good idea to add the wiring for all the components, as well as the cooling fans.

Nikkor

Nikkor-M 450mm f/9 with Copal #3 shutter is a famous lens among large-format photographers. The lens offers stunning optical performance and is a good choice for extreme sharp landscape or portrait photography. It has the ability to duplicate the most subtle color variations with extreme accuracy.

- Brand Name Nikon
- Focus Type Manual Focus
- Lens Mount Board Mount 65MM
- Lens Type Telephoto/lens
- Max Focal Length 450MM
- Min Focal Length 450MM

Graflex

The lens exhibits some lens separation (as seen in photos) but this will have very little (slightly less contrast) or no effect on your image quality. It will continue to make nice clear crisp images.

- Manufacturer: Graflex
- Focal Length 38CM (15’’)
- Maximum Aperture F/5.6
- Focus Manual
- Dimensions 4.75” x 3.75” x 3.75” (approx.)
- Weight 2.27 lb

5.2. Software Designs

Having different components connected to a single Microcontroller means that certain programming should be introduced to this project. The role of the microcontroller in this project is similar to the Read Only Memory (ROM) role; to create a minimalistic computer with a specific purpose, the ROM is combined with the Printed Circuit Board (PCB). For the programs that will have one specific function and will be used again and again with no modifications needed are mostly stored on the ROM. The PCB plays the function of the hardware of a computer in the electronics field by keeping the communication between the components and the user in case of a user interface case. The role of the MCU in this project is to translate the orders from the user to be executed. The team agreed to use the ATMEGA328P chip as the main microcontroller to achieve the connection of the Bluetooth module and the other components. On the other hand, the HDMI PCB will consist of TFP401 microcontroller which will be responsible to convert the HDMI inputted data to DVI. The use of this PCB will allow to convert any information displayed from a large LCD display to a 5.5” LCD display. The projector will then be projecting the information displayed in the 5.5” screen. The software implemented to program the ATMEGA328P and the TFP401 chips will take an input from the user, process it, and produce the output following the code algorithm designed for this project. The software basically will be reading and displaying information for the fingerprint part, controlling the different features the smart table will contain using user interface, and converting information from different screen sizes to a specific display size.

According to the display the project consists of, some resolution should be taken in consideration in order for the image displayed to be clear and with high quality. Since the team does not possess any computer with an HDMI port, a raspberry pi will be used to program the TFP401; an important note while programming the chip with a raspberry pi is to enforce the HDMI resolution using a configuration file (config.txt).

The Integrated Development Environment is an application that consist of a code editor, builder, and debugger. Using an IDE to program microcontrollers is very beneficial for programmers since it provides them with an all in one tool while programming products. since the ATMEGA328P can be programmed using the Arduino Integrated Development Environment (IDE) while prototyped using the Arduino Uno board, it was found very practical and time saving to use the Arduino IDE.

The user interface used in this project is going to be connecting the smart table to an Android mobile app which in this project will be the MIT inventor mobile application. The user interface has the purpose of controlling some features in the table such as the speaker's wireless connectivity and displaying the state of the Bluetooth connection, controlling the brightness of the projector as mentioned before, and the Led lighting.

An overall block diagram showing how the connectivity of the Bluetooth module, LED strip ON/OFF, LED projector brightness, the fingerprint, and the user interface describing how the software will be controlling the smart table will be shown in each section.

5.2.1. Bluetooth module

The smart table needs some sort of communication between the ATMEGA328P and the MIT inventor app downloaded in the Android device. The main reason why Bluetooth module was chosen over WIFI is because Bluetooth needs no internet to make the connection between the smart table and the Android device, however for WIFI, both the smart table and the Android device should have access to the internet.

Bluetooth establishes a direct connectivity to the smart table as long as the range of connectivity is the less than 10 meters for the HC-06 module used. This peer to peer connection between the HC-06 and the Android device eliminate the dependence of an outside network as well as it provides a more secure environment since only people in a certain range can access the smart table and they could be detected using the Android device the user is using. In addition to that, accessing servers and routers to maintain the connectivity of the smart table and the Android device seems to be time consuming and the security issues will always be considered. Bluetooth as well has its own potential danger in other industries especially in the medical field. But since the smart table does not deal with a health-related topic Bluetooth seems to perfectly win as a wireless communication technology.

In order to establish a communication between the Bluetooth and the ATMEGA328P, the Universal Asynchronous Receiver/Transmitter (UART) interface should be contained in both devices for the purpose of exchanging serial data through the transmit and receive pins observed in the microcontroller. The UART is a physical circuit implemented in the microcontroller when manufactured. In order to achieve the connection between the Android and the Bluetooth module, the baud rate should be set to 9600; as mentioned previously the HC06 is set by default to that baud rate, therefore, the only thing left to double check is the MCU baud rate when programming it. The flowchart of the Bluetooth module's software is shown in the figure below:

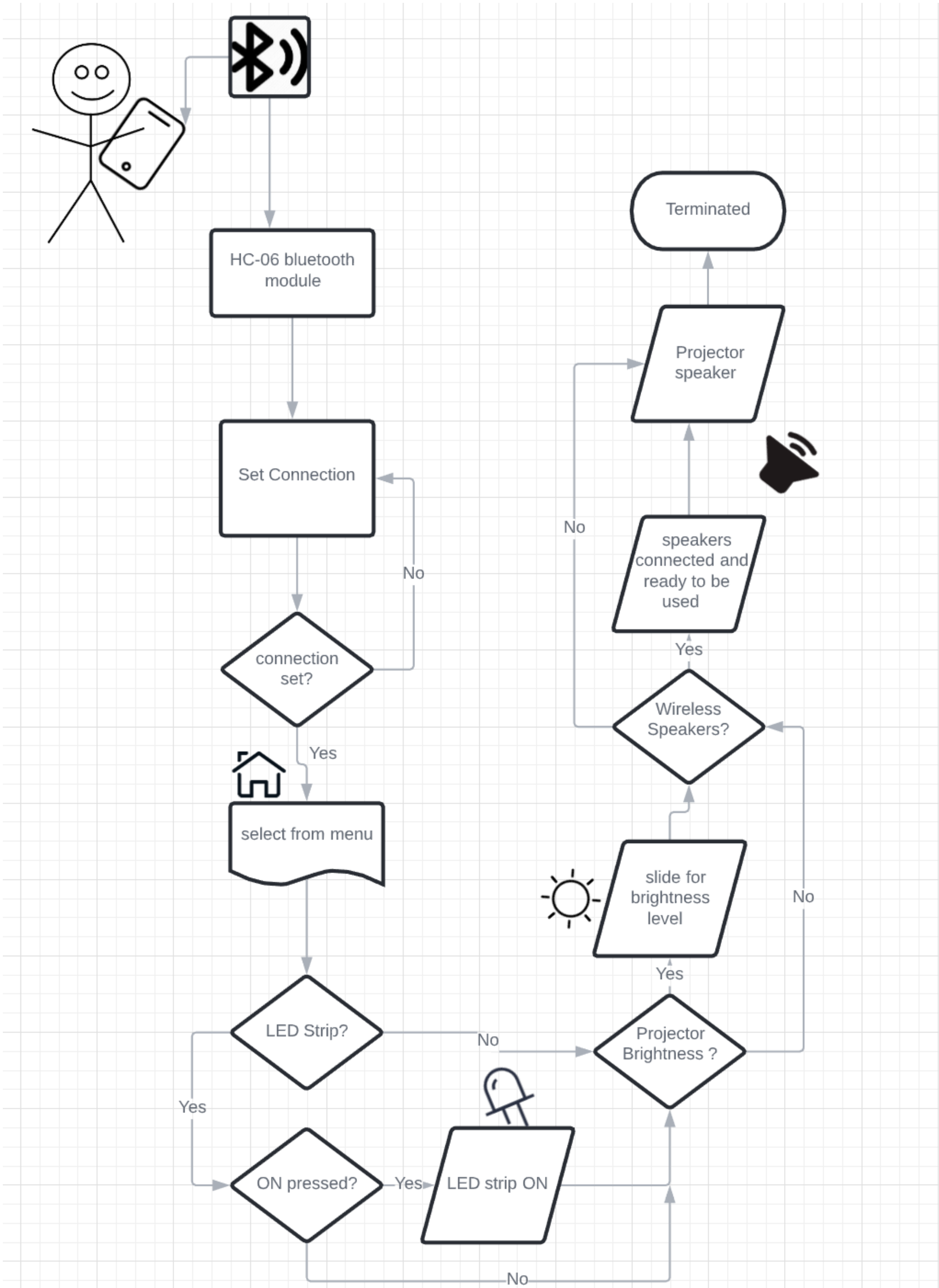

Figure 50: Bluetooth software Flowchart

5.2.2. Fingerprint Reader

The fingerprint hardware consists of a high-powered DSP chip that perform the image rendering, calculation, feature finding and searching. The connection between the fingerprint sensor and the MCU or any other system containing a TTL serial for the objective of sending packets of data to take images, detect prints, search for any existing prints in its system, etc. most fingerprints modules these days allow the user to enroll a numerous number of prints which could go up to 162 print directly to the module by storing them into a Flash memory designed to be manufactured with the fingerprint module. Since in this project most of the testing will be done on an Arduino uno board using an ATMega328P chip, the software serial pin configuration for the data exchange will be in pin 2 and 3 of the Arduino board. The library for the fingerprint was installed from the Arduino IDE Library Manager. If the devise used to program the fingerprint contains a hardware serial and not a software serial (USB-serial converter chip) at the beginning of the software, the user should define a mySerial [#define mySerial Serial1]. However, since in this project the Arduino is compatible with a Software serial, the software serial header (library) was used and the mySerial function used the pins 2 and 3 for the communication. The fingerprint baud rate should also be set to 9600 to be able to program the fingerprint.

Before being able to use the fingerprint, there are two basic requirement; the fingerprint module should first be able to enroll fingerprints which will be called ID's and each ID will be assigned a number in order to keep track of how many fingerprints the module stored. The second requirement is to identify the enrolled and stored IDs. The enrollment of the fingerprints is established through a windows software called SFGDemo, since it is the easiest way to establish the enrollment and also the only way to interface and test the software. To setup the fingerprint, a bland code is first uploaded to the Arduino MCU unit. The fingerprint module is then wired up where the Rx and Tx should be pinned to 2 and 3 of the Arduino. The fingerprint module was added as a device to the SFGDemo software and the COM port was chosen to be compatible to the Arduino. Some setting such as the security level, baud rate, etc., are available once the device is recognized in the software. The finger is then enrolled given an address (ID) and the fingerprint image is previewed then enrolled. Once the fingerprint is saved in the Flash memory, it is ready to be successfully used. For testing purposes, under the Arduino IDE serial monitor at the baud rate of 9600 the screen should display if the fingerprint was found once the finger was placed on the scanning area. A confidence level is then prompted to indicate how compatible the fingerprint matches the stored one; the range of compatibility varies from 0 to 255. For more details about the fingerprint state and other information, getFingerprintlDez () function was used. The algorithm designed for the fingerprint software is as shown in figure below:

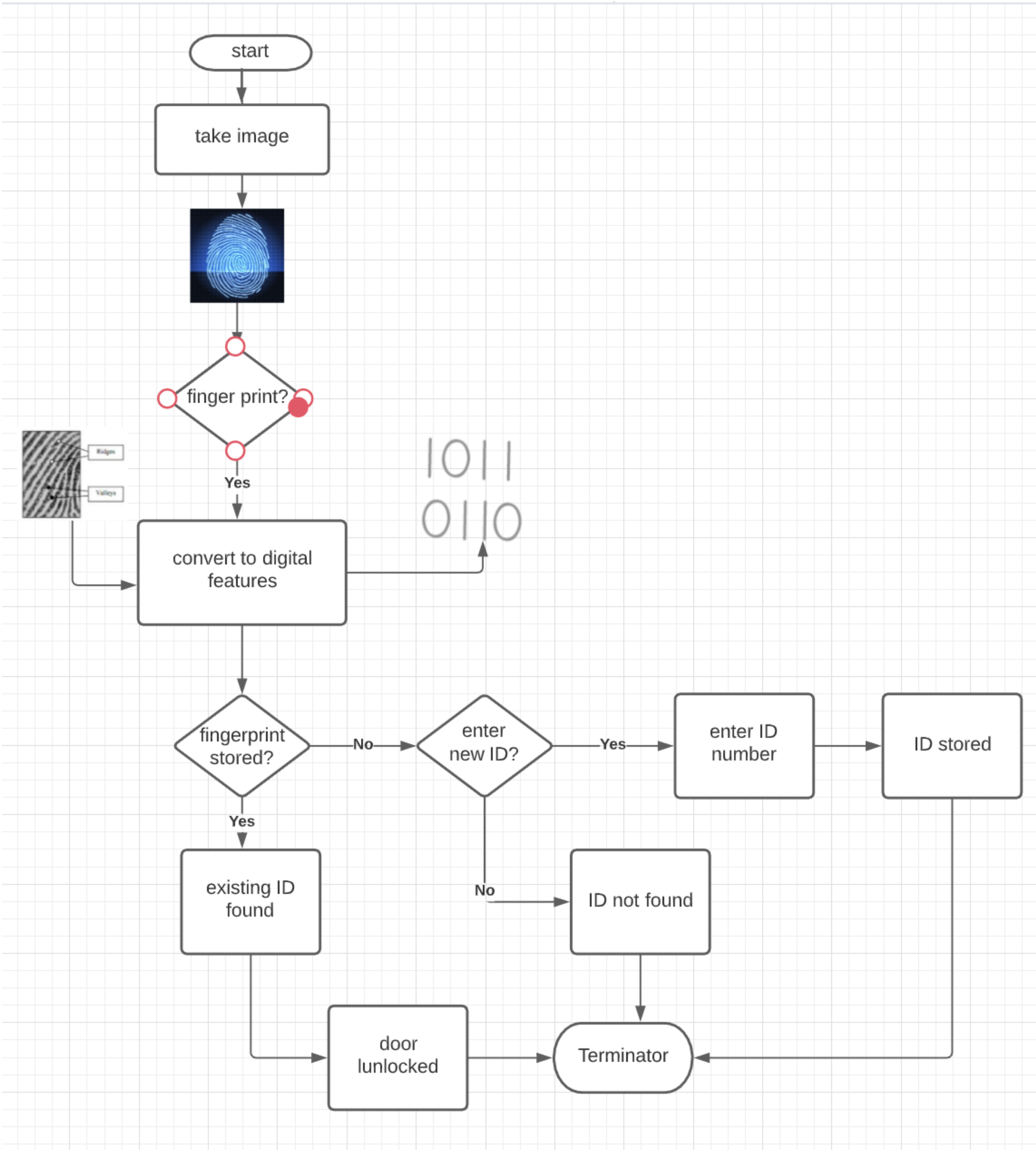

Figure 51: Fingerprint software Flowchart

5.2.3. HDMI/DVI

The most important feature in this smart table is the projector. The objective of the projector is to project computer screens on the wall for entertainment or work purposes. In order to establish this PC screen to the projector connection, the High definition multimedia interface (HDMI) was converted to a Digital Video Interface (DVI) to connect a video source to a display device which in this project is an LCD. The TFP401 is an TI DVI/HDMI decoder; it actually can decode any resolution from 25 MHz pixel clock (up to 1080pixel). The pixel of the screen can be modified to any resolution desired. This project uses a 1440X2560 IPS LCD (50 pin TTL display). The TFP401 will be programmed using a single board computer with a DVI/HDMI output which will be the raspberry pi. The raspberry pi can feed the video through the HDMI port. It also can drive display sizes from 4.3” to 7”. Since the display of our LCD is 5.5”, the resolution EDID used will be programmed to fit the LCD since the TFP401 does not scale the video. The EDID resolution can be reprogrammed easily using the Arduino board.

EDID is a device identifier that allows the computer to access the monitor information attached to it. this device identifier is stored in the board EEPROM which make it reprogrammable. therefore, based on the content the EDID receives once the LCD is attached to the raspberry pi. The resolution of the monitor will be set. In this project, the resolution will be set. the computer resolution will be modified to fit the LCD TTL display. In order to remodify the EEPROM, the HDMI is disconnected, and the pin configuration shown in the design section. Once the HDMI/DVI conversion is done, the audio of the HDMI will be connected directly to the HDMI.

5.2.4. User Interface

Setting the communication between the user and the smart table wirelessly signify that a user interface should be introduce in the project. Providing the control of the smart table through the interface allows the user to reach, configure, and manipulate the features in an efficient manner. Since nowadays the majority of the population is very familiar with applications and how to control several electronics wirelessly, and since the human brain is tend to appreciate the simplicity of the products; one of the main focused of the Android application was the on the design and functionality. In order for the mobile application to be compatible with the function of the software, a block design will be designed to control the application algorithm. the figure below is an example of the LED ON/OFF user interface block design.

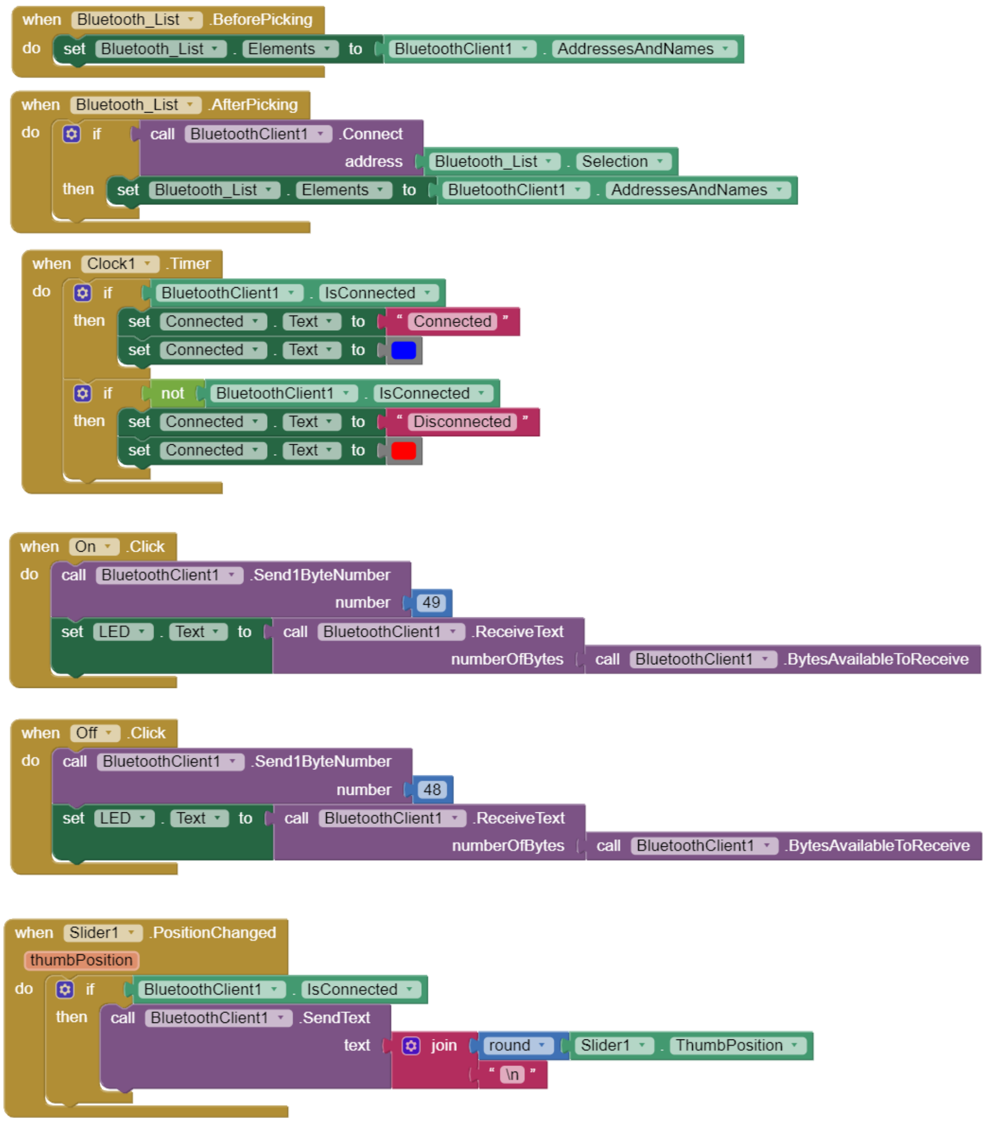

Figure 52: LED ON/OFF block design

Users would expect certain things when thinking about a smart table with a projector implemented in it along with a light source and speakers. Some of these expectation could be the control of the projector's brightness to fit the preferences of the user, the control of the Light source for more lighted environment, the connectivity of the speakers to any device containing a Bluetooth technology, etc. when the user will open the Mobile application, the first thing that will be displayed is the logo of the project. The second screen will pop up after certain second to display the menu of the smart table; the user will first have to connect the smart table to the phone using Bluetooth, then pick the desired feature to control. For example, if the user decided to pick the projector brightness, once the button is pressed a screen will pop up with a slider labeled Slide for the desired luminosity. Once the user is disconnected from the smart table intentionally or my mistake, all the features will be reset to no functionality for the purpose of power saving and hardware safety.

6. Project Prototype and Construction

Once the design for the system has been completed and reviewed by the team, the next stage for this projects life cycle is prototyping. This includes evaluating the designed system that has been physically constructed onto a printed circuit board. This section will discuss and contain the following:

- The procedure followed for designing the PCB (printed circuit board) using Altium
- The feasibility of the project constituents when looking for production and manufacturing
- An in-depth Bill of Materials table outlining all the physical constituents, containing the quantities and cost for each
- An actuarial analysis for the potential hardware and software issues that may come about or occur during this stage in the project's lifecycle

The group has acquired the necessary materials need for a realized and functional prototype, so that proper and structured testing can begin. The power constituents Bluetooth modules, Microcontroller, LEDs, and Projector constituents. The substance of the testing in this life cycle will be main comprised for the prototyping and printed circuit board, PCB, elements as well as some software components.

6.1. Design to Integrated Implementation

The culmination of the team coming together to plan and design the system will come to a fruition when said designs are physically realized into a functional printed circuit board (PCB). The fabrication of the PCB design can be fairly expensive depending on several factors. It can be completed entirely as hope when the right elements, chemicals, and materials are correctly implemented. However, the team has agreed that this step in the project life cycle should be conducted by third party in order to maintain the highest quality of professional standard. More importantly limiting some possible hardware failures or any catastrophic problems that could be faced when implementing the PCB. This option may be more expensive and, in some cases, an easier option, but going forward with the choice will help drive down costs in the long run.

6.1.1. PCB Design Procedure

The project's schematics and the PCB design for the Microcontroller units will be designed using the Altium and kicad software. This program was acquired through a stent license for learning and development through the University of Central Florida. Once the designed schematics have been properly implemented and the appropriate footprints have been chosen inside the diagram sheet, the PCB design can begin. Within this feature there are several professional constraints and standards to follow when laying out the printed circuit board. Once these professional standards have been implemented and the team is content with the arrangement of the components and overall layout, the software will then compile and export the design into a series of files called GERBER files. These exported files are in readable and understandable to humans and are in ASCII format. The contents of the exported GERBER files contain what features there are, how these features need to be implanted, and also where the implementations need to take place with the layout space of the PCB. These files are critical for manufactures in order for then to deliver a reliable and professional product. Our group will be using the RS-274X standard for GERBER files which produce the following files for manufacturing:

- **Copper Top and Bottom** – Once Altium has compiled the design and made the GERBER files, these two constituent files allow the software the manufacturer utilizes to layout and make the Top and bottom copper layers allowing for conduction pathways and planes. This is also known as a trace and these files will be labeled with a .cmp and .sol suffix.
- **Top Solder mask and Bottom Solder mask** – when fabricating the board, the manufacturer will place this thin layer of polymer directly to the bare copper trace layer in order to prevent oxidation as well as preventing unintentional shorts when the components are being soldered to the board (PCB). This piece is particularly imperative when choosing which manufacture to proceed with because we will have some smaller components, and this could easily become a huge time and costly constraint if not considered or thought of properly. This step when considered currently and properly implemented will lead to significantly less production time and less cost for the final project allowing the team to focus on more concerns over the total project. These files will typically have a .stc as well as a .sts suffix attached to the file name designating this feature.
- **Top Silkscreen and Bottom Silkscreen** – This set of files are vital for many stages of our testing as well as if anything were to go wrong or the group needed to reference our boards with our designs. These created files will be what the name implies, a silk screen of naming the continents of our product. The silk screen will contain the labels of each component and will tell the manufacturer (the machine producing the PCB) where to place the print and what print to place. For example, the board will be designated with R3 or C5 at the corresponding parts which are directly related to the schematic and easily correlated to a human looking at the production PCB. As stated above this will be vital when testing as well as finding potential errors or issues since the entirety of the board will be labeled and designated with correlated schematics. This feature will also help allow our team to maintain a proper bill of materials grating us less confusion as well as correct handle of the financial responsibilities. We have chosen to order the PCB’s in the standard green and have a silk screen remain in an easily readable white. These files contain a .plc and .pls suffix designating this silkscreen functionality.
- **Drill Legend** – This feature is important and applicable to our end project life cycle. The final production printed circuit board will have holes drilled thought the workspace for various functionality reasons as well as mounting to the project table. One of the functionalities that allowing the PCB to work over many layers is what is called a via. Vias are holes that are usually 0.012 inches that allow the copper tracings (conduction paths) to extend over two or more layers, which can become very complex quickly. Our board will consist of two layers to help drive down group production time, cost, and complexity, given that we only have two semesters to design, create, and implement the smart table.

6.1.2. PCB Fabrication Procedure and Professional Outsourcing

The aforementioned section refers to the simple fact that the group has chosen professional outsourcing in the production segment of the lifecycle in order to maintain a professional product in addition to allowing the team -as a whole- to work on more project details. Our team has collaborated to design the schematics needed for the constituents of the project, still there are few more chapters to go until we are ready for the final life cycle of this product. The team could collaborate to and use the necessary chemicals and milling equipment to successfully implement the designs to PCB, however as stated in the beginning of this section the potential overall cost would be too large and would most likely negatively impact the professional quality of our end product. As such as we have chosen to outsource the production of our realized design to JLCPCB to help streamline the project and maintain our goal of professional quality.

- **Outsourcing** – Our team has agreed upon the schematic design and the appropriate simulation as well as physical testing on the various systems has been completed (Discussed in the next section). we have obtained our various GERBER files and are ready to send to JLCPCB for professional production. JLPCB can produce our 2-layer PCBs, Stencils, and accomplish our SMT assembly all in one go with an impressive 24-hour build timer per PCB, per unit. However, most companies will take a longer time to get the finished product back to you due to COVID-19. Which is why we will be ordering three sets of each PCB to save time in the long run in case one board has any technical issues or have been mishandled in any way. We have come to expect the process for all the necessary PCBs to be less than $100, which may be costly but after the groups extensive testing we value the professional quality and streamlined production to our final functional goal.
- **Stenciling** – our teams PCBs will have several smaller end components and constituents which was have agrees a stencil will be help maintain the quality of our product as well as help drive down costs through error when we assemble a board. The stencil will be a metal sheet that has tiny cutouts or apertures for the corresponding placement of our components so that we as a team (and eventually the production machine) can apply solder paste with minimal risk of shorts when soldering the components to the PCBs.
- **Solder pasting** – Once the team is content with the quality and testing of our system constituents and PCBs, we will have the stencils used in the production of a solder paste application machine. Most usually production paste application machines apply the paste in a two-phase passing motion to guarantee the paste is proper applied. This production process does not cost very much and is a necessary component leading into the next phase.
- **Pick and Place machine** – When the team is constructing the board continents and soldering the components this has the highest likelihood of catastrophic failure per system board, which is why again stated as in the previous phase of PCB production: Once the team is content with the functionality of the PCBs we have constructed and done extensive testing we will have our GERBER files sent to a company for the high quality and precision of a pick and place machine, enabling a high quality and professional product when in the final phase of production and product lifecycle. After the stenciling and solder pasting machine has completed its two-phase pass through, the fabrication machine will use the .csv file to place the components accurately and efficiently in an X and Y coordinate system across the workspace of the PCB. The usual tolerance for a typical pick and place machine is 0.05mm error in the X and Y coordinates. In typical fashion most components are fed to the placement nozzle with a reel four at a time and placed down on the board before

receiving four more components. Once the machine has completed placing all the components the machine will then send the board into the next phase of production, the reflow oven.

- **Reflow oven** – This will be the last phase in the production life cycle for our project will be the movement of the printed circuit board form the pick and place machine into the reflow oven for cementing the solder for the surface mount components. This step occurs almost immediately after the pick and place machine to insure there is minimal issues with the solder paste hardening. Most commercial reflow ovens are long and the printed circuit board slides over rollers through the oven to solidify the components t the board. The heating process for the PCB must be done in a proper way to ensure the solder paste settles properly, reducing the risk of improper conductivity. The temperature through the reflow oven must have varying levels in order to solidify the most common of solder paste as shown below:

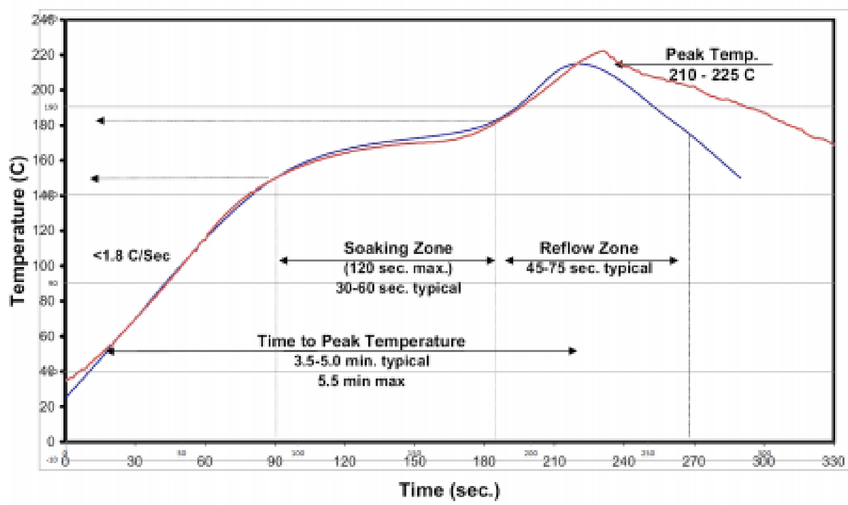

Figure 53: Kester Reflow Profile for common Alloys

After the printed circuit board has made its way through the reflow oven and cooled the board has been completed and is ready for quality control. Keep in mind this process is dependent on the quality control done when designing and prototyping. Our group will be soldering our first set of boards and conduct extensive testing as detailed in section seven. Only once the prototyping and testing has been passed and the team is contact with the functionality then will our designs be sent in for this entire fabrication process.

6.2. Potential Hardware Issues

This section outlines and discusses the potential hardware failures and issues throughout the product lifecycle. The possible failures will be coupled with contingencies to maintain a proper project timeline and plan, as well as helping to keep project cost low for the team. Considering the entire project must be designed, tested, and professionally implanted within two semesters there is very minimal room for error or project bottle necks. Therefore, it important to account for possible issues and develop proper contingency plans.

A common hardware issue faced by many teams and even by teams under corporations are time delays and bottle necking due to component delays. When components are delayed it causes serious project timeline inconsistencies and can lead to a team not being able to deliver a functioning product in a timely manner. As mention before in our document, this project has very serious time constraints and any significant delay could very well be unrecoverable. This problematic issue can be avoided with two key factors. The first factor being to be cogent when designing teach system to maintain that each system can function properly avoiding specific component dependencies. The second making sure that each ordered part is fully functional and operational.

When our team collaborates to make the schematics and then ultimately the PCB designs it is vital to make sure the proper design and standards the first time. It will take at least a week to get the first sets of printed boards back, let alone the time needed to assemble, prototype, and test. This would be huge negative pipelining issue and could have serious adverse reactions to completing the final product within our timetable. This problem could also lead to significantly more money spent on the life cycle of the project as well.

6.3. Potential Software Issues

In order to successfully write a program while ensuring that the software installed in a specific system is efficient and accurate, many design, scenarios, and measurement are taken in consideration. Therefore, testing the software with the hardware is one of the most crucial steps in a project. In order for the software to successfully control the smart table, the right powering of the components should be tested, the pin connection between the Bluetooth module, the ATMEGA328P, and the different sensors and components used should also be correctly configured in order to establish connectivity between the user and the hardware. To test the software used to control the smart table, each component of the Android application was tested separately to guarantee the functionality aimed for by the team. For the Bluetooth module, when trying to program the Bluetooth module into the ATMEGA328P, some baud rate problems were faced therefore using the AT command, we were able to modify the baud rate of the MCU as well as the Bluetooth module. In addition, since most HC06 modules are manufactured by default to be in the salve mode, no difficulties were faced when connecting the Bluetooth of the Android device to the HC06. About the LED strip lighting, some of the potential software issues would definitely be the defining the wrong pin configuration, miss-spelling the functions used in the codes, the wrong conditions are used for a specific purpose, for example instead of keeping the LED on inside a loop, the program would turn the LED off once the push button is off. For the brightness of the projector brightness, similar difficulties as the lighting of the LED could have been faced in this project. For the fingerprint software, some of the challenges of programming the fingerprint while displaying the state of the fingerprint were the enrollment of the fingerprint to identify the user and the fingerprint accept and deny algorithm. the first issue that was faced was the availability of the sensors library in order to be able to program it, and finding as well as leaning some new functions in order to establish communication between the fingerprint, MCU, and the LCD was pretty fun and challenging since the fingerprint will have a security functionality in this project, the software design was very detailed.

the user interface design was very specific, organized, and time consuming. The chose of using MIT inventor2 helped overcoming these obstacles because the software is very clear and easy to understand, anyone who is creating an Android application can monitor so their progress by downloading the application of MIT inventor2 to their Android phone, connect their project to their phone, and their can see how does the Android application actually appear on a regular phone. The potential issues that the programmer may face when creating the MIT inventor2 application is the block design which allows the hardware, software, and the Application to perform a specific task. For example, the wrong choice of condition can lead to the dysconnectivity of the Bluetooth module, the brightness of the LED should be set to a specific level however the brightness was not sufficient. Some algorithm mistakes can become an issue when designing and implementing the Android application.

6.4. Possible Constraints During Prototyping

There are numerous concerns for this project ranging from social issues, to expenses, all the way to attention to detail. For the social aspect it has become hard for everyone, not just our team to meet and organize ourselves properly. We have addressed this issue in several different ways. We have moved our group meets to online unless we need to meet up for collaboration when regards to the assembling, prototyping, and eleven testing (discussed in the next section). When we are together collaborating, it is important to adhere to CDC guidelines and take all the necessary precautions. As a team when we are assembling, prototyping, and testing it has become evident and even vital to have a set of precautions in order to maintain the strictest of details. When placing the components, it is very easy to misplace the wrong resistor or and other components which in the best of scenarios could lead to limited functionality and in the worst-case scenario could lead to catastrophic failure. We have thought ahead in this department as discussed in the PCB prototyping section. Our team will have a silk screen printed so that the PCB will be easily readable, and the team member assembling will know where everything goes. The same level of details is important to adhere to when testing as well. When it comes to expenses, we have collaborated together closely to constantly keep our expense located in the same table as well as keep them constantly updated when our designs change or have to be modified. This may not seem like much, but in the long run it will lead to less cost for the team overall will constantly keep the team on schedule as far as components are concerned.

We take our safety and the safety of those around us very seriously and given the current climate and state of things our team has attempted and continues to strive to drive our costs down as well as keeping our smart table as efficient and professional as possible. All our planning and work culminated to help the team achieve our goals within the time frame while also delivering a professional product as mentioned above.

6.5. Current PCB Designs

This section Outlines the current designs for our team's PCBs. It is important to note that this section's designs may change depending on the varying needs of the project and project constraints the team may face over the course of the two semesters. Our team has collaborated and culminated to these printed circuit board designs. Our team felt it would relevant and important to show the current designs PCB for prototyping. As the HDMI will be one of the hardest aspects of the project which contains both the hardware and software. The group decided to work ahead and start constructing a design for just in case something fails, and modification need to be done which is better than starting from the begin. The figure below shown the current design of the HDMI however this design still needs to be reviewed before it is sent to be made and then begin testing. The testing of the testing will made stated in the section below and for more information please refer to section 7.1.2.

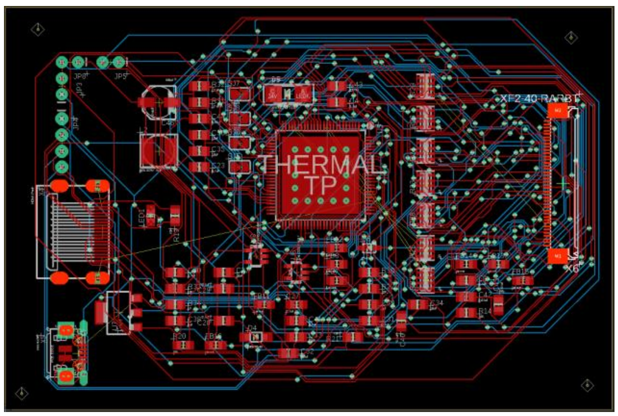

Figure 54: HDMI PCB Design

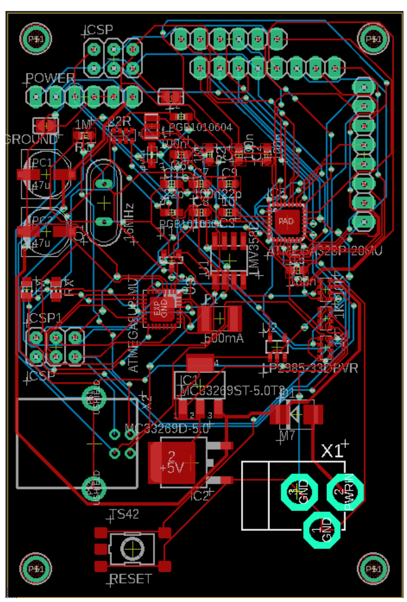

Figure 55: PCB Design for the smart table microcontroller

The PCB designs shown above were from our group coming together and collaborating, although some changes need be made to the designs. We also suspect that more changes will need to be made to each system before the project has reached its final production in its life cycle. The two PCB board designs above are for the HDMI control board as well as the board for the centralized micro control unit. Our team has ordered those two boards, and a few other bords so that we can begin assembly, prototyping, and testing before next semester to stay ahead. We are also concerned as a group about the amount of time needed for everything so the more, we get accomplished now the more we can prevent bottle necking in the long haul. This is factored in when considering one of our original goals to help drive down costs and work as efficiently as possible as a team. We have actually received one of the PCB we have designed for our projects power system. Below is a picture we have taken of our manufactured design that has arrived. We plan to have this system assembled as quickly as possible as well.

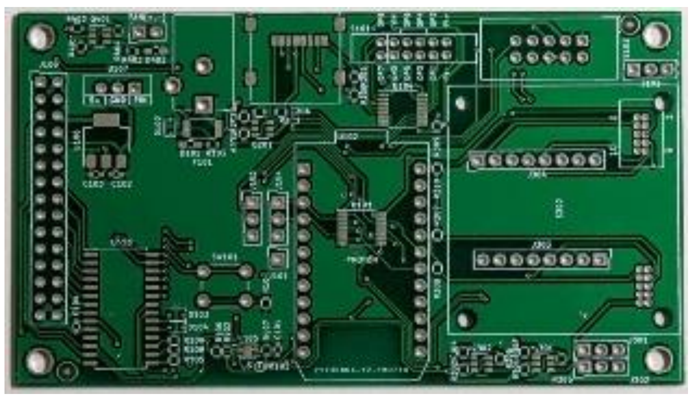

Figure 56: Received PCB for prototyping and testing

7. Project Testing Plan

This section will introduce various test procedures to ensure that each subsystem functions as intended. The testing procedure will be discussed in detail and will explain what test in be conducted.

This section includes:

- Hardware test requirement overview for subsystem within the smart table.
- Performance test on the main microcontroller (MCU).
- Procedures and environments for testing the projector, power supply, and HDIM Control Board.

7.1. Hardware Testing

There are several components/subsystems in the whole system that require specific consideration before compiling all of the parts into a completed project. In the hardware area, several components that need to be tested in order to ensure the completed project. The power supply circuit, which is illustrated in section 5.1.6. above does not requires testing. Such components include the resistors, capacitors, and fuses as the likely hood of any problems occurring from having is not common. Having said this it is expected that such devices has been tested by the manufacture of the IC, and as such testing devices like this is not something relevant to the scope of the project.

Generally speaking, one can assume that every component purchased is working properly and as intended from the factory. However, this is not always the case, it is the designer duty to ensure that everything works as expected before employing the part into the final design. This section is all about testing every individual part/component and examined and one would assume that if every individual part work properly that once everything is combined on the board that the components will not fail. The final design should be test nevertheless before combining each of the tested parts. This is important because if the individual parts work properly, but the total design does not work, then one can conclude that the design is the issue or flaw.

When testing the compiled hardware something important to keep in mind after the board is complied with the various working parts, its assumed to be a working board. The quickest way to test the hardware is to plug the final design into the mains power, then use a multimeter to test the various nodes that are mentioned in the circuit diagrams. For the hardware side, there is a complicated AC signals that need to be processed as the first step is to get the AC wall signal and reduce the volts using a transformer then into a DC waveform. Therefore, it will be an important aspect of the project not only for the Hardware but also the software. The software testing will require an oscilloscope in testing to ensure that the proper serial communications are being transmitted.

7.1.2. Microcontroller & HDMI Control Board Testing

As with all other testing it is imperative to properly test the HDMI board and microcontroller MCU board. The MCU and HDMI systems will have similar testing procedures and as such will be discussed in detail within this section. There are several characteristics that need to be considered when testing as listed and described below. However, first our group will be using the test pins that have been incorporated within the PCB design to make sure the board is receiving the proper voltages at given points and to use the UART connection for programming and debugging. Once both boards have passed their respective tests, our group will move on to the next phase of testing.

- Testing the current characteristics – For the chipset chosen in both boards (HDMI and MCU) our group will be testing the current characteristics. The chipset chosen should have a linear relationship between the current draw induced and the clock speed. Which in this projects case will indicate the chosen chipset is efficient and can still operate effectively under higher-than-expected loads.
- Testing the power characteristics – For testing the power characteristics of our chosen chipsets our group has come together to ensure the power consumed by the two boards is linear with respect to clock speed as similarly demonstrated when our group tested the current characteristics. This is an important test characteristic because the power dissipated over the board is marginal and the relationship stays linear even operating at higher than nominal conditions, indicating that there will very little chance of damaging either board under heavier operating loads, so long as it does not exceed the data sheet recommended performance settings.
- Testing the Temperature characteristics – All group members will also be coming to together and collaborating to ensure the thermal dissipation is nominal over each component and regulated through the appropriate data sheets and safety standards. If a particular component or even a constituent of the board need to be operated at higher than expected intervals it will be imperative to affix a thermal compensation unit. Our boards need to operate under various conditions, and it is ill-advised and impractical to monitor the thermal distribution of the system continuedly during after the end stage development lifecycle.

7.1.3. Projector Testing

Light Source—LED

A. Fatigue test for LED lighting

A fatigue test can help you assess the durability of functional parts for prolonged use. During the fatigue test, the inspector will test any adjustable or functional parts of the product. For LED lights, this might involve pushing buttons or switches several times.

First the inspector will use the part as intended at least 20 times in a row and sometimes up to 50 times depending on time restrictions. Then they'll check for any malfunction of the adjustable parts.

B. Hi-Pot Test for compliance with LED Lighting safety standards

The hi-pot test, or high-potential test, is one of the most important safety tests for LEDs. It's so important that most importers perform a hi-pot test on the entire sample size drawn for inspection.

Also known as a dielectric voltage-withstand test, the hi-pot test measures the electrical current that flows through the insulation of a product. A hi-pot test can help you measure current leakage and detect electrical, or dielectric, breakdown.

The tester will stress the product's insulation at higher voltage levels than those it would typically handle during normal use. The product should be safe to use at normal voltage levels if it's able to withstand a relatively high voltage for a short period of time.

There are two main LED lighting safety standards for hi-pot testing, including UL 1598 and EN 60598:

Table 27: Two main LED lighting safety standards

Market	Standard	Voltage	Test duration
U.S.	UL 1598	1200 VAC	1 second
EU	EN 60598	Class I: 1500 VAC Class II: 3300 VAC	3 seconds

C. Function Test for Lighting

A function test helps you verify whether your LED lighting product functions properly according to the user manual. This is another one of the most necessary lighting tests that warrants applying to the entire inspection sample size.

This test typically doesn't require any specific equipment. The inspector will check all the product's intended functions, such as:

- Turning the light on and off
- Checking proper illumination
- Confirming the light dims properly, if relevant

D. Endurance Testing

During the function test, the inspector tests each individual function of the product over a short period of time. But a lighting product can be used all day long and must withstand continued use. Lighting importers are responsible for ensuring their LEDs won't overheat or explode suddenly during normal use throughout the product's lifespan.

An endurance test, or running test, assesses the safety and functional performance of your lighting LEDs over time. The inspector should leave the light continuously running at the highest setting for four hours. The inspector carefully observes the performance of the product periodically during this time to check for any malfunction.

Afterwards, the hi-pot test and full function test should be repeated on the tested units to ensure the product is still safe and functional.

E. Item Drop Test

The item drop test is typically only conducted for portable electric luminaires, like small handheld lamps, flashlights and desktop lamps. This test ensures your customer's safety even if your product falls onto the floor.

An item drop test is required for shelf-mounted luminaires under the UL 153 standard. It's also mandatory for luminaires intended for use in hazardous conditions under the UL 844 standard.

The inspector drops a shelf-mounted unit from a height of 3 feet (91.4 cm) onto a tissue paper-covered, nominal 1/2 inch (12.7 mm) thick, knot-free softwood sheet supported by a concrete floor.

The inspector should confirm during and after the test that there is no:

- Flame or molten metal emission
- Product or test surface combustion
- Exposure of parts presenting a risk of electric shock

F. Lighting Source/Integrating Sphere Test

LED lighting importers typically market lights as meeting lighting testing certain brightness, color or efficiency standards. But how can you confirm production units actually meet these standards?

An integrating sphere test can measure the lighting source using common metrics.

This test requires an integrating sphere system with a spectroradiometer for spectral mismatch corrections and computing software. Most lighting manufacturers should have both the equipment and related software available on site already, as they're essential for LED lighting manufacturing.

The inspector places the LED light inside the integrating sphere and then observes the results via the computer software. The recommended sample size for this test is at least three units.

The inspector then records these metrics on the report compared to your spec:

- Color rendering index (CRI): A quantitative measure of the ability of a light source to reveal the colors of various objects faithfully in comparison with a natural light source, rated from 0 to 100. A higher CRI indicates a more accurate color rendering.
- Color temperature: Measured in degrees of Kelvin (K) on a scale from 1,000 to 10,000. A "warm" color temperature is typically 3,000K or less, while a "cool" color temperature is 4,000K or more.
- Lumens (lighting output): A measure of the total amount of visible light emitted from a light source. The higher the lumen rating the brighter the lamp appears to the human eye.
- Power consumption: The rate at which energy is generated or consumed, measured in Watts. LED bulbs typically range from 4 to 18 Watts—up to 90 percent lower than incandescent bulbs.

- Power factor: The ratio of real power (Watts) used by the load compared to apparent power (Voltage x Current drawn) into the circuit: Power factor = Watts / (Volts x Amps). Energy Star requires LED lamps of 5 Watts or greater to have a minimum power factor of 0.7.

Table 28: LED Specification

CRI (%)		Color temperature (K)		Lumens (lm)		Power (W)		Power factor (PF)	
Spec	Actual finding	Spec	Actual finding	Spec	Actual finding	Spec	Actual finding	Spec	Actual finding
>80	80.5	3000	2956	800	816.05	10	9.64	0.7	0.556
	80.3		2989		833.06		9.54		0.553

Light Control—Collimation system

In opposite usual lens Fresnel, one has badly conjugated focuses. Best focusing lens provides when its grooves are oriented forward to emission that must be focused. In the opposite case, focusing is followed by strong aberration. Like case of usual lens 2D focusing can be reached if all-round directed lamp emission will be collimated in paraxial beam.

Use the X method for this and work out your rectangle cutout shapes by measuring out from this center. The first Fresnel lens must 'collimate' the light rays to make them parallel, so must be placed above the LED precisely at the Fresnel's focal length. Your Fresnel's focal length can be measured using the 'sun focusing' method. Remember, never look at the bright focused point. Ideally the focal length of this first Fresnel needs to be less than 100mm as it will 'capture' more light from the LED this way. Remember to mount it with its Fresnel ridges facing upwards. The second Fresnel on the other hand needs to be mounted above the first, with its Fresnel ridges facing downwards this time.

I recommend using some PCB pillar supports to space them out, and make sure that the vent slots are on opposite sides to enable the zig-zag airflow path. This second Fresnel takes the parallel light rays and points them to where the lens will be mounted later. Ideally you need to slide your lens layer up and down on the rods so that you can find its perfect placement, where the projected light doesn't vignette and instead just appears to be a white rectangle.

The position for this will be around the same as the focal length of the second Fresnel, which in my case was 160mm. Make note of the exact measurement for later, after which it's time to work on the image source.

Image Source—LCD Panel

We could check LCD of a cell phone by any of the following methods:

A. LCD Testers:

There are testing machines available in the market for checking of LCDs. The problem here is that as all models have different LCDs, you will need to buy an LCD tester machine for all types and models and will run into hundreds! As all LCDs of smartphones, be it an iPhone or a Samsung Galaxy or an Xperia have different size connectors, with varying no of connecting pins, a universal LCD checking machine cannot be made. This is a major constraint and hence not at all feasible unless you deal in repairs or testing of thousands of units of a particular model.

B. Check it in same model cell phone:

The second option is if you have a working handset of the same model, you can easily put your LCD into that handset and check if its working or not. For eg. If you want to check the LCD of your iPhone 5s, you can check it in a working iPhone 5s. So, what if you do not have a working handset of the same model.

C. Check with a new LCD:

Replace your LCD with a new one. If graphics appear on the LCD, that will mean your old LCD is faulty. And if the new LCD also is not displaying graphics, it will mean your old LCD may be ok. And the problem may be in the PCB. The problem may be in the LCD connector, its connections, PCB or an IC controlling the display function.

Notes:

1. You cannot check LCD with a multimeter or an oscilloscope!

2. In Samsung phones, you can also check clarity of the screen with the code *#0*#. You can check red, green and blue colors with this code.

3. As regards to being original or duplicate, it's better to buy them from good and reputed vendors. Again, if you have many LCDs, you can switch on the handset and compare the clarity with various LCDs yourself.

4. If no light (LED) is glowing, please check LCD brightness settings first before opening your mobile phone.

5. A faulty LCD can be of the following types:

- Cracked or broken
- A blot (round in shape which will spread rapidly!)
- Blank display with no graphics.
- An LCD with just graphics and no light (LED) glowing on it

Projection Lens—Large Format Lens

A. Inspecting the Lens

I'm going to be focusing on the kinds of things I do if I'm buying person to person and meeting the seller. As such, I'm focusing on how to quickly gauge the quality of the lens being sold, and ensure that it at least is functional, not so much putting it through extensive testing.

For lenses bought from a reputable dealer with a return window, I would conduct the same tests I would on a new lens, which is outside the scope of this article. My objective in inspecting the lens is to nail-down quickly the quality and functionality of the lens.

7.1.4. Audio Testing

The audio subsystem begins with first research different types of systems and types of amplifier. Once the class of amplifier was chosen the next step was the design aspect of the system. this step was carefully thought through and tested using software system such as LTSpice and Multisim. Comparing, Acquiring and purchasing all the components is the process in the construction. All the components need to be tested before placing them together in the breadboard. This section will describe the testing process of each of the components and the final assembly on the breadboard.

Timer: A 555 timer consist of three modes monostable, Bistable, and Astable. For the purpose of creating a class D amplifier the timer mode needs to be in Astable to it can produce an oscillating rectangle wave. To test the timer will be using a 5-volt, potentiometer, capacitor, diode and an oscilloscope. Normally two resistors would be needed for this test however the use of a potentiometer is better because it already contains two resistors. The potentiometer will go from pin six seven and eight and the capacitor is in pin two and pin four is held high and the diode will be connected to the output. At this point the Led diode should be blinking and the potentiometer is used to control the rate in which the Led diode blinks. So, by connecting one of the channels in the oscilloscope to the output the square wave should be visible and concluding that the timer is working as expected.

Comparator: The comparator can be tested simply by using a DC power supply and a multimeter. The first step is to power the comparator with 9 volts and by adding 5 volts to the inverting input then 3 volts to the noninverting input the output should be 9 volts. Another test can be the opposite were the inverting voltage is 3 and the noninverting is 5 volts the output should be 0 volts. if none of these test work then the component id defective and needs to be replaced

HEX Inverter: For the Hex Inverter a 74HC04 was purchased and to ensure this that this component is working properly the following parts are needed. The first being an oscilloscope to observe the input and output, the input will be the output of the 555 timer a square wave oscillation is present. For the purpose of testing the component the frequency is not the main concern but rather the output on the inverter. The output of the 555 timer is present in channel one and in channel two shows the mirrored version of channel one indicating the signal has been successfully inverted. For more indication when channel one goes high channel two should go low.

MOSFET: As stated earlier there is no reason to believe that any of the components purchased should not work as intended however one can never be too careful. The MOSFET is one such device and the first thing is to test for any burnt or shortages using a multimeter. To test for any shortages the positive lead of the multimeter is placed to the drain pin of the MOSFET and the negative lead of the multimeter is placed to the source pin of the MOSFET. In a working MOSFET there should be no connection however if there is this is an induction of a shortage between the drain and the source. To test for any burnt MOSFETS the on-state method will be used. Since the

MOSFET acts like a capacitor it can be charge briefly by putting the negative lead to the source and the positive lead to the gate but only briefly then touch the drain. Now touch the gain and drain with your finger which discharges the MOSFET there should be no connection afterwards implying the a working MOSFET.

MOSFET DRIVER: To test the MOSFET Driver another circuit will have to be constructed and the figure down below shows the circuit being built. The breadboard contains two voltages a 12 volt for the VCC for the driver and the cars light and 5 volts for the IC which will come from the Arduino. Keep in mind the Arduino is only used to test the MOSFET Driver and four of the IC pins are connected to ground. The four pins being the COM which in ground for the IC and second is the SD error pin which is not used. The third is the VSS which is grounds level for the logic input signal and the fourth is LIN which is the logic input signal for the low side MOSFET.

The Capacitor needs to be charged up to at least 10V to be able to switch the gate of the mosfets and when the mosfet is off, the gate is floating and the Vss pulls it down to ground. The Vss at 12V can charge the positive side of the capacitor at VB through the diode. Electrolytic capacitor was used, the first being 47 uf and another at 0.47 uF and the mosfet is applied now. The gate is connected to the Ho pin and the resistor of 10 ohms should be in between the HO pin and the gate. The drain of the mosfet is connected to the positive 12V and the source is connected to the Vs and to the load. The program for the Arduino is a simple blinking program but modify for 2 second. The Arduino is powered by the 5V power supply and pin 13 is connected to HIN and the Arduino has to be grounded. A 55W light bulb was connected to the source of the mosfet and the negative to the ground of the 12V. Everything worked perfectly, and the bulb blinked every 2 seconds making the driver usable for the final design.

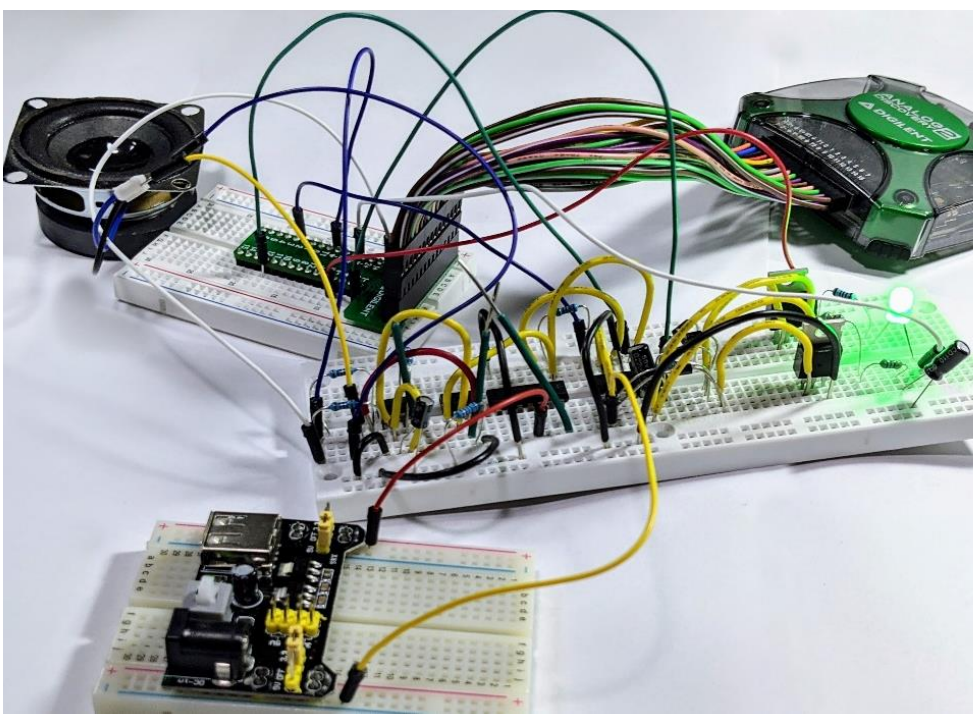

Figure 57: Audio System Testing

The Image above shows the design of the audio system and each of the individual component together after each of the components were tested as stated above. The construction of the audio system contains every part talked about in section 5.12 which illustrates all the components and the circuit design. For the testing process the ANALOG discovery 2 is was used to power the device and also to monitor the audio signal frequency with the Oscilloscope feature channel one is connected to the input and channel two is connected to the output in this case the speaker. Two power supplies are used both 12 volts and 5 volts, the 5 volts is supplied by the ANALOG and thee 12 volts by at 3- and 12-volts circuit supply shown in the figure above. The testing as a complete success and the as audio was produced through the 4-ohm speaker and now the final design process can begin with the PCB design.

7.1.5. Power Supply Testing

The power supply is the one of the most important system and careful plaining as taken to ensure that everything goes as expected. The first thing was to conclude what type of power supplied the entire system will be powered by. The consensus was the power outlet as there will be several subsystems and the group felt a battery power system wouldn't be practical. Afterward research was done as shown in section 4.2 then the design was thought of and created. Component were compared to ensure the maximum efficiency and to reduce the overall price. The design aspect of the power is in section 5.1.6 and this section will describe the details of the power components.

Transformer: The transformer is the most important component in the power supply as it will reduce the power making it less dangers. A 5:1 AC to AC transformer is being used to reduce the 120 AC to 24 AC this is about 20 percent of the original input value. To test this component a function generator will be used, which can easily be done. By using the function generator one can input any AC sinusoidal voltage into the transformer and if the output is 20 percent smaller than the input then transformer is working properly. However, if its more than the part cannot be used, and the most important thing is to ensure it can handle 24 volts. Any less and there would not be enough power of the entire system.

Full wave Rectifier: Once the voltage on the transformers output is correct which is 24 AC then the next component to test is the rectifier. This test is fairly simple to test by use than oscilloscope the and places the input on one channel and the output of the rectifier on another channel, the output should be somewhat linear/ DC voltage. If the output is still as sinusoidal then the rectifier is not working whatsoever and must be replace with a functional one. As stated, the output should be somewhat linear but not perfect the output should still contain some ripples. After this is achieved then the smoothing process can begin by adding the inductor and capacitor in series to eliminate the rippling.

Fuse: The fuse is one of the significant components because this will ensure the safety of the rest of the power system. The fuse is an easy part to test and it's important to test before implementing it into the final design and as stated above failure to do so may result in a catastrophic failure of the entire power system. Worst case scenario other components maybe destroy or cause a fire that could shot up not only to the power supply but also the wall outlet. The purpose of the fuse to shut down the system if any current increase from the intended calculation by cutting off the current flowing down steam. A 5-amp Fuse will be placed after the transformer which will reduce the voltage and thee fuse will ensure that the voltage is reduce properly before passing to rectifier. The fuse will be tested by applying an AC power and a resistor slowly increasing the voltage. Once the voltage excuses the 50 volts the fuse should break the connection.

Regulators: All the regulators will all be tested in the same manner as they are all simply switching regulators with different output values which are (12V, 5V, 3.3V). Each of the regulators has an input of 24 volts which is more than enough to stabilize each of the regulators output. All three regulators will be tested by using a DC voltage supply as the input and measure the output DC voltage with a multimeter. Every regulators output will be compared to the expected values, this will also indicate any power loss and determine if the component will be used in the final design or not.

Buck Boost Converter: Similar to the regulators the buck boost converter will be tested in the same manner. This particular converter is adjustable therefore it depends on the format in which the resistors are places therefore a power supply will be used and various resistors to. The first step is to input a voltage of 2V then test the output and if the output voltage increases then the boost converter is working as a step up. After that the next test is to input a voltage of 5V and produce an output voltage of 30 because in this design the buck converter will have an input of 5 volts through the output of the volt regulator. If these two tests are successful, then the components are properly working and can be implemented in the final design.

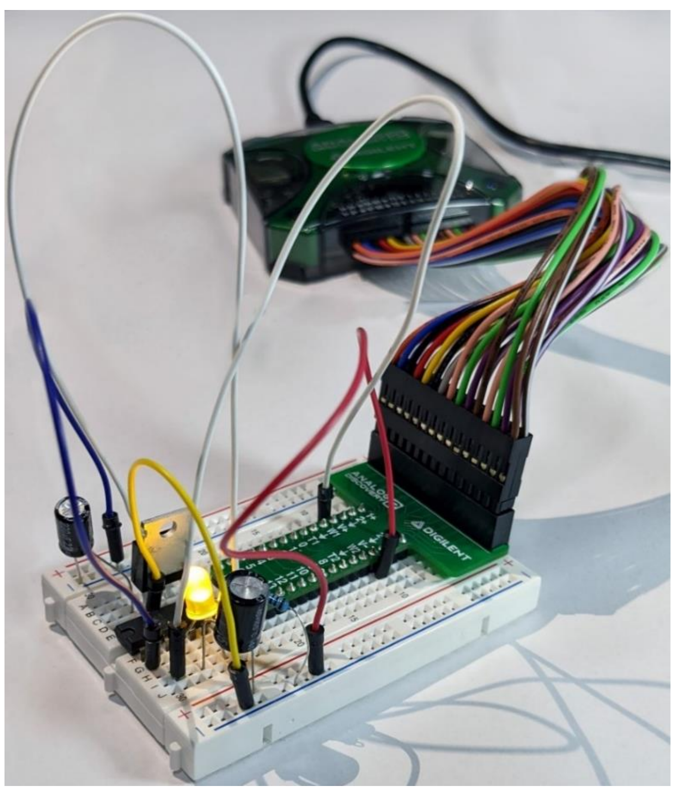

Figure 58: Regulator Testing

The image above shows the prosses of testing the voltage regulator using the ANALOG Discovery 2 as the power source. This test was fairly easy as the regulator only needs 2 volts higher than the intended voltage regulation and the capacitors are there to stabilize the DC output voltage. An LED was placed to test any regulations and if the voltage dropped the LED brightness would lower and it would be a clear indication of unstably. As stated above all the regulator were tested in the same fashion and they all preformed as expected and even the PCB prototype was created and shown in section 6.5 however, there's still more testing to be done before soldering any component.

7.2. Software Testing

Software testing is an important aspect in order to test every individual component works as intended and that there are no unexpended errors do not occur in the final produce. Software can easily be tested after applying any hardware since it allows us the test if the algorithm and the functionality of the hardware is accurate, efficient, and as designed to be. Using the Arduino board to test the software made the programming of the project very easy and saved the team time since the Arduino IDE is very popular and many forums discuss some common problems that can be faced. The first software that was tested is the Bluetooth module connection with the ATMega328P chip since the Bluetooth module is the main component to achieve wireless communication. Once the settings were modified and the connection was set, the test was made through an Android device to check for a successful communication. For the LED strip testing, using a relay made the power distribution over the Arduino and the LED strip easy to successfully work. The brightness of the projector was tested first using a regular LED which fits the specification of the LED used in the projector to make sure that the software and the powering were successfully designed then the LED used for the projector brightness was connected and ready to be tested. The fingerprint software had multiple testing stages. First is the enrolling code which allowed the fingerprint to allow the images taken to be enrolled and given an ID number. Second is the recognition/ identification of the fingerprint. The code used was tested using the serial monitor of the Arduino IDE since if allows to visualize more details about the inputted fingerprint image; finger ID#, the level of confidence the fingerprint sensor detected, and the validity of the fingerprint captured. Once the fingerprint was successfully set, the door lock was tested in order to make sure that it is able to be controlled by the fingerprint. The nest software tested is the HDMI/DVI. Since the raspberry pi is the small computer used to program the TFP401, many tests were made while the hardware was connected. The most important focus while testing the HDMI/DVI conversion is the resolution of the TTL display. The software was tested multiple times for a better image resolution, brightness, and data transfer.

8. Administrative Content

Engineering and designing require careful planning in order to be successful and as such, certain administrative tasks may require drafting and scheduling to construct the smart table in a timely manner. This section will introduce the teams schedule different times roles and budget for this project. The time and due dates for each step of the project is listed in the milestone table starting from the Initial document to the Final presentation time. Each group member is expected to maintain full administrative responsibility for the project. This information is subject to change over time base on the current circumstances and is essential to have the proper updated information.

This section contains:

- Milestone and timeline for the project
- Information on the Project roles of each member
- Financial cost and contribution of every system and group member and overall cost of the project.

8.1. Milestone Discussion

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This milestone will be broken two in two major section the first being senior design 1 and the second is senior design 2 (Fall 2020 to Spring 2020). In the first section research was conducted on different methods and many components as well as testing. The second section is senior design 2 were we began purchasing components and began testing. It was important to for the group to have a rough idea of timelines in order to work ahead while not forgetting the overall goal. The table down below represents our scheduling and deadlines. Overall, the main events were listed in the table below. Scheduling was an important aspect in ensure the 120 pages were written in a reasonable time as well as researching, designing, comparing parts and the PCB designs. The Table will be updated once senior design 2 begin and dates and tasks will be added to keep an organized schedule.

Table 29: Milestone Table

Number	Tasks	Start	End
Senior Design I			
1	Ideas brainstorming	8/24/2020	9/13/2020
2	Project idea selection	9/14/2020	9/14/2020
3	Project designs investigation	9/14/2020	9/16/2020
4	Project Budget investigation	9/16/2020	9/16/2020
5	Initial Doc- Divide & Conquer I	9/14/2020	9/18/2020
6	Project Scope Decision	9/20/2020	9/25/2020
7	Initial Doc- Divide & Conquer II	9/25/2020	10/2/2020
8	Quiz A – E	10/5/2020	11/6/2020
9	Individual Researching	10/5/2020	11/1/2020
10	60 Pages Report	10/26/2020	11/13/2020
12	Prototype designing	11/1/2020	11/13/2020
13	Ordering Components	11/14/2020	11/9/2020
14	100 Page Report	11/9/2020	11/29/2020
15	Final Document	11/23/2020	12/8/2020
Senior Design II			
16			
17	Assembling Prototypes	TBA	TBA
18	Prototype Testing	TBA	TBA
19	Prototype redesign (if necessity)	TBA	TBA
20	Finalizing Prototype	TBA	TBA
21	Peer Presentation	TBA	TBA
22	Final Report	TBA	TBA
23	Final Presentation	TBA	TBA

8.2. Project Roles

This section is about dividing the responsibly among the group member based on hardware, software, interests, and area of expertise. The roles or tasks that were delegated are color coded for visibility and simplicities sake. The roles/ tasks are shown in the figure down below, some group members share the same tasks and are expected to collaborate together in order insure a successful system. However, this delegation is not binding, because each group member has decided to personally take part in the total construction of the smart table. Under the table below a smalls illustration of components are shown these specifics the teamwork between group member. A small description is stated to the right of every image stating the group member in charge and the other group member who helped with the construction.

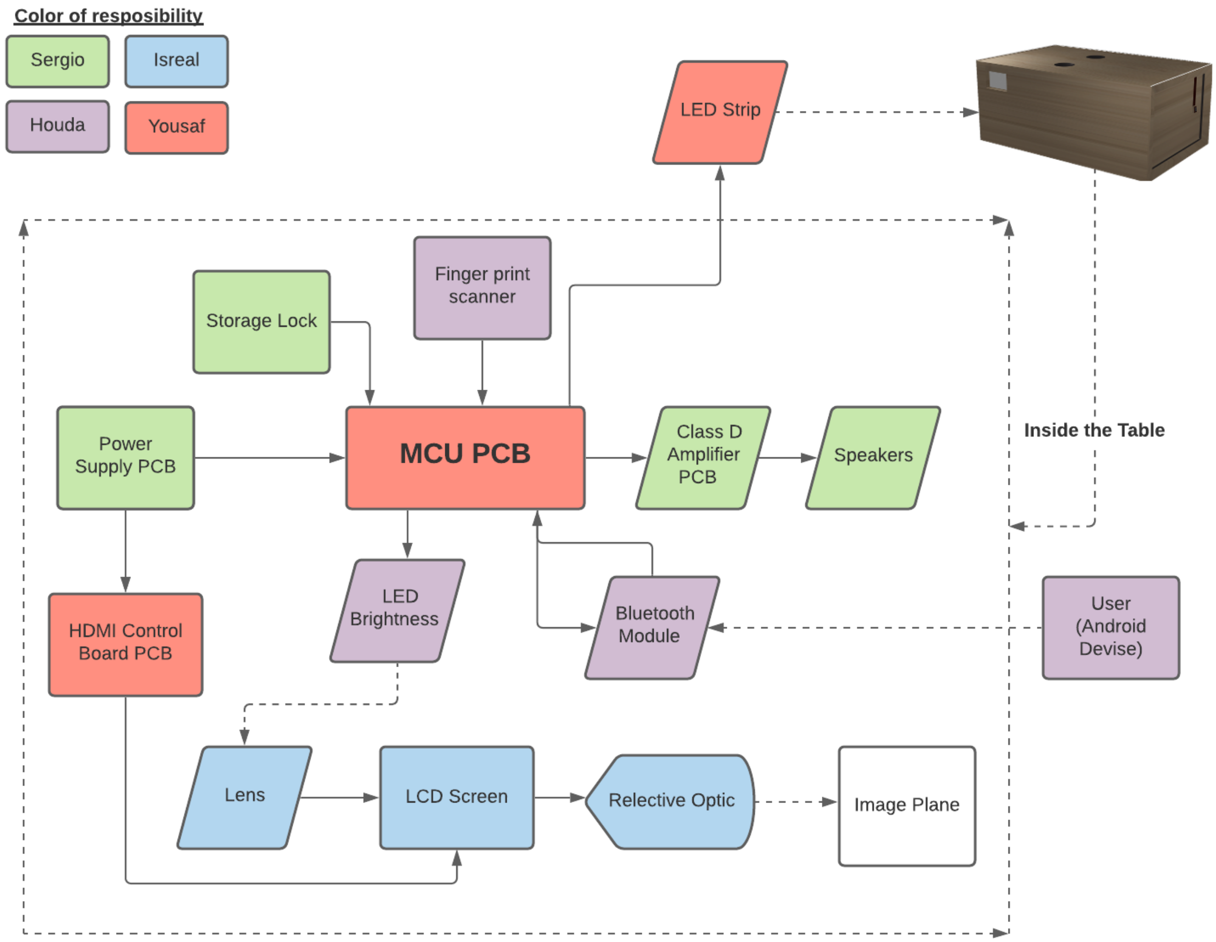
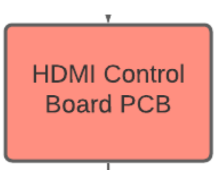


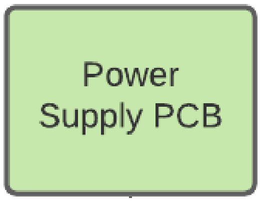
Figure 59: Dividing the Labor

Teamwork for various subsystems including small detail in the responsibly for each member:



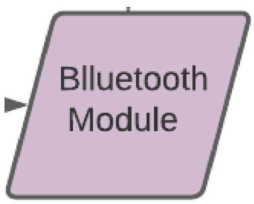
- YOUSAF – Lead designer
- HOUDA – Programing
- ISREAL – Works with LED
- SERGIO – Power

In the HDMI Board everyone worked closely together providing Power, PCB, Coding, and ensure a connection to the LCD screen.



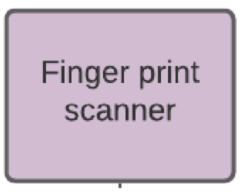
- SERGIO – Lead designer
- HOUDA – Bluetooth, LED, Fingerprint
- ISREAL – LCD screen
- YOUSAF – MCU, LED, HDMI

The power supply works closely with very everyone providing the individual subsystems will power.

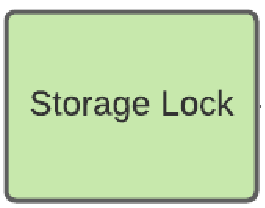


- HOUDA– Lead designer
- SERGIO – Audio System
- YOUSAF – MCU connection

The Bluetooth ensure the connection for the audio system and mostly importantly the connection to the MCU.

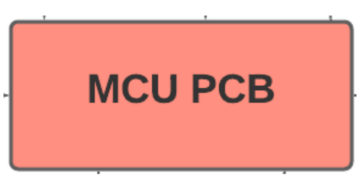


- HOUDA – Lead Designer
- YOUSAF – MCU Connection



- SERGIO – Lead Designer physical storage
- HOUDA – programming fingerprint reader

The construction of the physical storage and the fingerprint reader in order to open the storage unit.



- YOUSAF, HOUDA, ISREAL, SERGIO

Everyone worked together to ensure everything is connected properly.

8.3. Budget and Finance Discussion

Due to the current pandemic COVID-19 this semester the number of sponsors has dwindled, and we were therefore left to self-sponsor. With this in mind, when researching the group considered the cost of the overall system but wanted an efficient system so taking this into consideration the team opted to keep the overall project within a reasonable price range. Because this smart table incorporates multiple subsystems a cost table will be provided for each subsystem and an overall cost of the project. The tables will include a basic description, name or the parts, quantity, and the price of each part and total cost of the subsystem. As the project's system requirements change throughout the course of its implementation, the overall cost will also be adjusted accordingly. Keep in mind that resistors, capacitors and inductors will not be incorporated in the cost with the exception of the power supply because they are not your everyday components making them a very important purchase.

Table 30: Audio System Financial Cost

	Items/Parts	Description	Quantity	Prices Estimate $
Audio System	LM555 Timer	LM555	1	$ 0.56
	Comparator	LM393	1	$ 0.45
	HEX Inverter	74HC04	1	$ 0.57
	MOSFET Driver	IR2113	1	$ 4.23
	MOSFETS	IRLZ44N	2	$ 1.96
	Diode	UF4007	6	$ 2.04
Estimated Cost				**$ 10.81**

Table 31: Projector System Financial Cost

	Items/Parts	Description	Quantity	Prices Estimate $
Projector System	Light Source	High Power LED	1	$ 99.00
	Lens	Fresnel Lenses (f = 90, 60)	2	$ 30.00
	LCD Object	5.5" LCD Smartphone Screen	1	$ 80.00
	Lens	'Large Format' Camera Lens	1	$ 50.00
	Reflective Optics	Front Surface Mirror (200mmx250mm)	1	$ 50.00
Estimated Cost				**$ 309**

Table 32: HDMI System Financial Cost

	Items/Parts	Description	Quantity	Prices per unit $
HDMI control System	HDMI Decoder IC	296-12666-ND	1	$ 6.60
	HDMI Port	MOLEX 47151-0001	1	$ 1.96
	Micro USB	538-48037-1000	1	$ 1.25
	Jumper pins (Testing)	S1222E-08-ND	4	$ 0.80
	Boost Converter	FAN5333ASXTR-ND	1	$0.96
	Diode	Zener Diode	3	$ 0.14
	Switching Voltage Regulation	NCP1117ST33T3GOSTR-ND	1	$ 0.46
Estimated Cost				**$ 12.17**

Table 33: MCU Control Board Financial Cost

	Items/Parts	Description	Quantity	Prices per unit $
MCU Control Board	ATMEGA 328 B	556-ATMEGA328PB-AU	1	$ 1.34
	ATMEGA 328 P	556-ATMEGA328P-PU	1	$ 2.06
	Micro USB	538-48037-1000	1	$ 1.25
	Jumper pins (Testing)	S1222E-08-ND	7	$ 0.80
	Diode	Green LED	2	$ 0.30
Estimated Cost				**$ 5.75**

Note: The Capacitor was kept in because it not an everyday capacitor and is essential for the design

Table 34: Power System Financial Cost

	Items/Parts	Description	Quantity	Prices Estimate $
Power System	Switch	Single Pole Toggle	2	$ 0.68
	Transformer	166G100	1	$ 36.13
	Full bridge Rectifier	GBJ2506	1	$ 1.32
	Fuses	F2320	4	$ 1.25
	Buck Converter	FAN5333ASX	2	$ 0.96
	Regulator	NCP1117ST33T3G - 3.3V	2	$ 0.46
	Regulator	LM7812 - 12V	2	$ 3.08
	Regulator	LM7805 - 5V	2	$ 3.08
	Capacitors	560 uF	4	$ 5.68
Estimated Cost				**$ 52.64**

Table 35: Bluetooth & Other Components

	Items/Parts	Description	Quantity	Prices per unit $
Bluetooth & Other	LED	LED Strip	1	$ 26.99
	Bluetooth	HC-06	1	$ 10.57
	Fingerprint	Senor	1	$ 35
	Relay	Cit Relay	1	$ 18
Estimated Cost				**$ 90.56**

The as mention in the begin of this section the overall cost is shown down below which incorporates each on the individual subsystems and adds the cost of each to come up with the final cost. It is important to show the individual cost so that the reader get a clear picture of very system or they may only be interested in one specific component or part. As shown down below the total cost was kept below our original goal which was $ 800.00. However, this table and the ones above will be updated accordingly if need changes are made to the budget.

Table 36: Total Cost of Table

	Subsystems	Prices Estimate $
Overall Cost	Audio System	**$ 10.81**
	Projector System	**$ 309**
	HDMI Control System	**$ 12.17**
	MCU Control System	**$ 5.75**
	Power System	**$ 53.18**
	Bluetooth & Other	**$ 90.65**
Estimated Cost		**$ 481.56**

9. Conclusion

When this document was completed, the group come together for the purpose of reviewing the entire document to ensure that everything is correct and create was given to everyone in the reference section 9 down below. Overall, the work was our original work, and as state above any location where work was pulled from was given the proper credit. All four members listed in the title of the document have provided their area of expertise into this project and everyone has helped to create this paper with their own work and words.

It's important to note that the plan provided above through this documentation indicate that the project is reasonably successful. Having been said this the built of this project should be obtainable with the time period of one semester however this does not mean it will be an easy task. Difficulty will arise however, with all four members working together and a reasonable about of stress it can be done. This is all thanks to the hard work done this semester in researching, planning, scheduling, and designing. All the schematic designing took a lot of time it will reduce the time in actually building every subsystem and testing/constraints. Please reference to section 5 for all the subsystem designs.

The software design aspect of the project may be the hardest part in the in terms of learning new material to apply to the project and the majority of what is needed for the project is an area that needs to be learned. The disadvantage of the group is that there is no one who's an expert on software and no one is a computer engineer. Another issue may be in the scale of the project and even though the project is expected to be completed within a time frame of one semester however, this will not be easy to accomplish. A good portion of code will need to be developed and debugged for a successful product. The details of the software and flowchart can be seen in section 5.2 as well as other important relevant discussions.

One aspect of the design is creating a table from scratch which is what the group has decided to make which will incorporate each system. This part of the build will be a bit time consuming but should not be an issue if the size parameter of each system is known. One of our group members as experience working making tables and has every tool need to create any type of table needed. The goal is to make everything compacted while also making a reasonable sized table that can be placed in any household living room.

For the hardware of this project several components have been purchased for several of the subsystems. The designs where carefully thought of and each of these components that was purchased must be tested carefully to ensure the safety of the group and any further damage to the rest of the system. When ordering parts, the group held a meeting and came up with a list of the majority of the components and chose one manufacturer to purchase from. This was to avoid paying multiple shipping and handling which held with the overall cost of the project. The hardware aspect of the project so far has been successful from the designing shown in section 5 to comparing components and the testing of each component. For more detail about the testing section please refer to section 7 for both the hardware and the software aspect of the project. Although the table contain several components and subsystem with multiple PCB design since the group is made up of three electrical engineers the group is confident in our ability to have each system completed on time. When testing the components everything worked as expected and the construction of the power systems PCB is ready as a prototype. The hardware processes of the project is currently on schedule and working as expected but everything precaution is being taken to insure a successful PCB layout.

When the HDMI and the microcontroller boards were designed, programmed, and tested as the details mentioned in the previous section 6 and section 7, the purchase of the PCBs and the components were done through the JLCPCB and the Digi-key companies with the collaboration of the team members. Each team member was responsible assembling and soldering the components into the PCB boards. Our goal when prototyping is to help drive down costs while maintaining a fully functional and professionally designed production level product for the end user.

Appendices

Appendix A – Copyright Permission


Logo design Permission

yeagek10@gmail.com
Mon 12/7/2020 8:09 AM
To: Yousaf Ausaf

Hi Yousaf,

Absolutely, permission granted. Good luck with your project!

Thank you,
Kelley Yeager

Thank you! | Thank you so much! | Great, thank you so much!

Are the suggestions above helpful? Yes No

Reply Forward

Yousaf Ausaf
Mon 12/7/2020 7:39 AM
To: yeagek10@gmail.com

New Microsoft Word Docum...
55 KB

Kelley Yeager,
I am Yousaf Ausaf and am currently an Electrical Engineering student at the University of Central Florida. My group and I are working on our capstone project and really like the graphic design content you create, We were wondering if we could use one of the logo designs you have created for our projects central theme (see attached)
Thank you for your time,
Yousaf Ausaf

Appendix B – Datasheets

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[2] ATMEGA 328p, https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf

[3] ALUMINUM ELECTROLYTIC CAPACITORS , https://www.nichicon.co.jp/english/products/pdfs/e-ucy.pdf

[4] Bridge Rectifier , https://www.diodes.com/assets/Datasheets/ds21221.pdf

[5] MOSFET Driver , https://www.infineon.com/dgdl/Infineon-IR2110-DataSheet-v01_00-EN.pdf?fileId=5546d462533600a4015355c80333167e&redirId=119801

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Appendix C – Works Cited

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