SmartTable – Project

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***Abstract*— The SmartTable project is a unifying technology that allows a person to connect other smart devices. The central design problem for this project was the integration of several unique systems. It features an LCD screen, Fingerprint Scanner, Audio System, User Application, and additional supportive technologies. By unifying the systems, the SmartTable creates a streamlined digital experience.**

Index Terms— Embedded programming, Power systems design, Optics, LED Screen, Fresnel Lenses, Bluetooth, Class D Amplifier, HDMI, User Interface

I. Introduction

The impact of advancements in science and engineering has had astonishing effects on automation. Technology has become embedded into many parts of ordinary life. It can be manifested in things as simple as a self-checkout at the grocery store to more complex systems such as automobiles supported by machine learning algorithms. In anticipation of the continued integration of technology into everyday life the SmartTable came into being. That is, the motivation behind the design of the SmartTable Project was to create a device that would blend with and support the technology used in a person's daily life. It must be compatible with commonly used technology, i.e., computers and smartphones and serve as a piece of technology itself.

The major features to be utilized by the user were an LCD screen, Fingerprint Scanner, Audio System, and User Application (Android Device). In addition, other electrical and optical components were needed to connect the SmartTable's features. Those components were the Power Supply and Projection Lens as well as a Bluetooth module. The following sections will discuss the individual designs of each of these systems/components.

II. Wireless Communication

Since one of the objectives of the project is to make the table smart, a user interface is a necessity to accomplish this objective. Therefore, using the Bluetooth (BLE) was agreed to be the best communication technology since it permits a variety of electronic devices to connect wirelessly over a short distance. The features controlled wirelessly are the table light , which will be turned on and off, the brightness of the projector display(which will be set to three different modes; high, low, and medium brightness), and the speakers of the table that will allow the user to transfer any sound from the device to the speakers.

Using the ESP32 module, a smart phone with an android operating system (OS) would be able to wirelessly interface the SmartTable. The reason the ESP32 module was chosen to perform the wireless communication of the project instead of the other compared modules is due to its dual core processor. Its Xtensa dual code 32bit LX6 microcontroller can run up to 600 DMIPS, it can operate on classic Bluetooth as well as the Bluetooth Low Energy (BLE) which will allow old and new devices to control the SmartTable, built in Digital Analog Converter (DAC), Universal Asynchronous Receiver Transmitter (UART), and many other built-in peripherals, in addition to its effective cost, high security, and module size.

For a better audio output when transferring the Digital data from the phone to the speakers. The ESP32 built in Pulse Code Modulation (PCM) was used by connecting Channels 1 (pin 16 for BCK), Channel 2 (pin 25 for WS) and Data out (pin 22) to an external Digital to analog Converter (DAC). Since the ESP32 will be used for user interface as well as wireless audio transfer, the CPU of the ESP32 will not be able to perform the same tasks at once. However, the ESP32 module has a Direct Memory Access (which allows the communication between the android phone and the speakers to be direct. However, since the team members in this project are Electrical or Photonics, it was challenging to figure out how to program the ESP32 to directly output the audio to the speakers without using the CPU. Therefore, it was decided to use a second ESP32 for the audio purposes only and another ESP32 for user interface.

Using Arduino IDE, the ESP32 Microcontroller was programmed to establish the connectivity with the user, control Projector brightness, wireless speaker communication. Figure 1 represents the software designed flow chart.

Setting the communication between the user and the SmartTable wirelessly signifies that a user interface should be introduced in the project. Providing the control of the SmartTable through the interface allows the user to reach, configure, and manipulate the features in an efficient manner. Users would expect certain things when thinking about a SmartTable with a projector implemented in it along with a light source and speakers. Some of these expectations 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. The software used to create the application that functions as the SmartTable remote is Android Studio. The software provides the fastest tools for app developers to build a fast secure and creative application compatible with any android device.

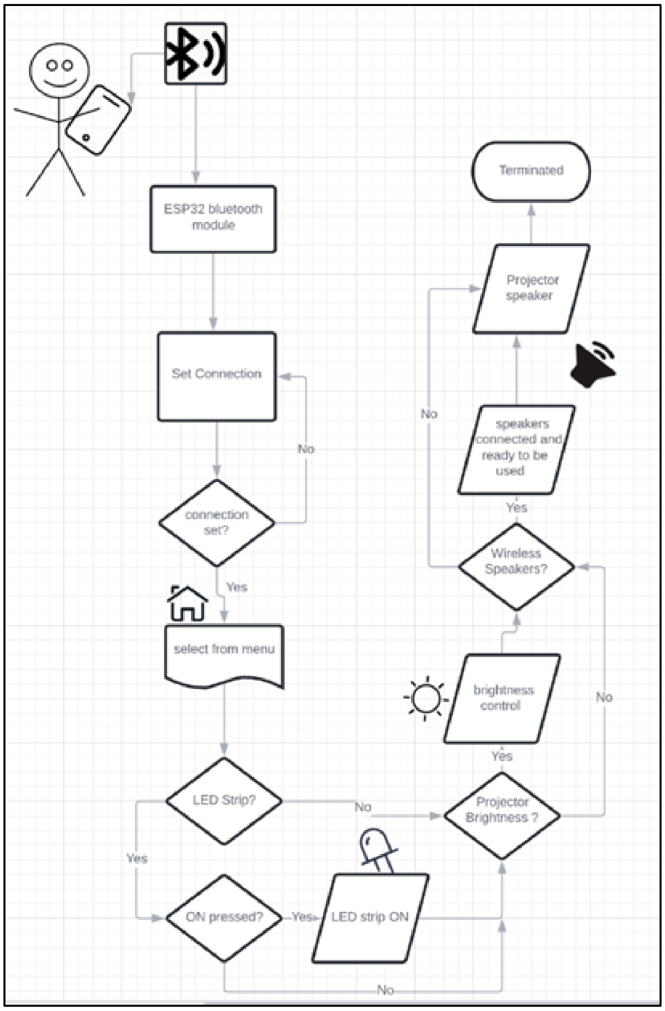


Fig. 1. Software Flow Chart

A. Fingerprint Reader

Using fingerprint detection for security are one of the technologies humans use in their daily activities. Most applications for the fingerprint used in mobile technologies are 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 SmartTable 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. To give a purpose and have the SmartTable function as a secured storage, the feature of fingerprint recognition was decided to be included in this project.

The fingerprint reader module was first programmed to enroll the fingerprints used to test the system. Since the module comes with a memory where the fingerprints are stored, the only thing that was left is to implement the circuit designed and tested using the Arduino IDE serial monitor and the valid fingerprints. Using a 16x2 LCD display, the SmartTable will consist of some messages notifying the user about the state of the fingerprint module, sensor problems, invalid fingerprints, etc. The schematics of the fingerprint design are shown in Figure 2:

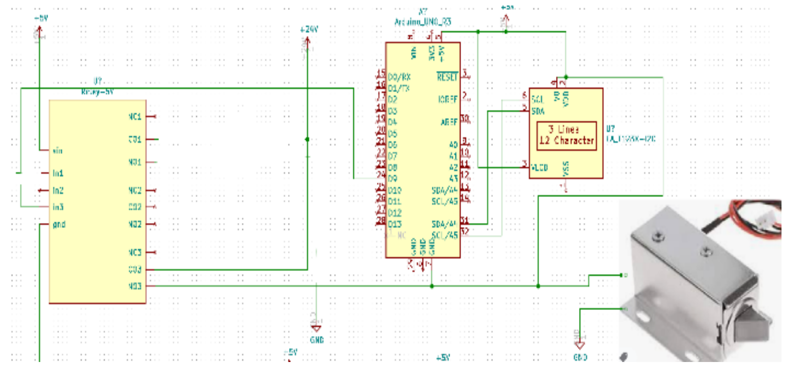


Fig. 2. Fingerprint drawer lock schematics

B. HDMI

The most important feature in this SmartTable is the projector. 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 5.0" LCD. The TFP401 chip is an TI DVI/HDMI decoder which can decode any resolution from 25 MHz pixel clock (up to 1080pixel) to a lower resolution. The pixel of the screen can be modified to any resolution desired. This project uses a 800X480 pi (40 pin TTL display). The TFP401 was programmed using a HDMI/DVI decoder board through Raspberry pi. To modify the resolution of the Board, the EDID was reprogrammed using the Arduino IDE since the TFP401 does not scale the video.

III. Audio System

The audio system supports any device that has Bluetooth compatibility and will allow the user to play sounds from their devices. When choosing an amplifier for the design, a class D amplifier was chosen. The class D amplifier was chosen because it is efficient and cost effective. The strength of the signal for a class D amplifier will remain intact while also reducing power dissipation. Typically, a class D amplifier consists of four major components, a sawtooth/waveform generator, a comparator, a switching circuit, and a low pass filter.

For the SmartTable, the amplifier components will differ from the conventional approach. It will be configured to have a 2-way layout and the major components will be a Timer, Comparator, Hex Inverter, MOSFET Driver and 2 MOSFET, Audio Input/Output, Low Pass Filter.

A. Timer

The timer used is a TI TLC555IP. A 1 μF capacitor was placed between the audio signal and comparator and the timer is connected to the non-inverting input of the capacitor. This serves as a high pass filter for the audio signal that ensures the media is not damaged by errors. The timer receives a 5-volt supply from a linear regulator. The goal of the timer is to produce a triangle wave of up to 200 kHz however the timer has the capacity to operate at frequencies up to 2 MHz.

B. Voltage Regulator and Comparator

Voltage Regulator: The audio system requires both a 12 V and 5 V source. To save space and reduce costs, rather than having additional power sources, a voltage regulator was implemented. The voltage regulator is embedded in the construction of the audio system. It utilizes the input of the 12 V source and regulates it to the required voltage and is used solely by the audio. The 5 V regulator powers the timer, the MOSFET driver, the HEX inverters, and most importantly the comparator.

Comparator: A problem that was encountered during the audio design process was that the voltage of the incoming audio signal from some devices, in this case a smartphone, could be half of a volt or less. To solve this issue, the comparator will modulate the incoming audio frequency (no greater than 20 kHz) into a high frequency square wave. The output of the comparator is fed to the negative rail of the op amp power supply. The output is zero if the V- voltage is greater than the V+ voltage. However, in this case the V+ is greater than the V-, hence the output will jump to the positive rail of the op amp power supply; the output in this case is 5 volts. Because the voltage of the audio signal is higher than the triangle voltage produced by the timer, the output of the comparator gets pulled high/low and produces a modulated audio frequency in the form of a 200 kHz square wave. The component used for the comparator was a TI LM393.

C. Hex Inverter

This component inverts the signal of the high frequency wave. The inverted signal is necessary to be able to feed it to the MOSFET driver. The component used for the HEX Inverter was the TI SN74HC04.

D. MOSFET Driver

The purpose of the MOSFET driver is to turn on/off the two MOSFETS. The PNP according to the low voltage levels and the NPN according to the high voltage levels. This results in a high frequency square wave. Because the driver turns the MOSFETs on/off in their ohmic region power dissipation is reduced. The MOSFET component was the IR2113 from Infineon Technologies.

E. Diodes

To reduce error, a feedback system was created using two diodes together with rectification from the power supply to provide proper DC voltage using a single diode. The feedback system uses the output signal and is fed back to the input passing it through the system. The diodes are ideal for an audio system that allows the positive DC voltage to pass and filters out negative voltage. The UF4007 has a forward bias voltage of 0.6 V. Another detail to consider is the total capacitance vs reverse voltage, which begins with a capacitance of approximately 30 picofarad at a VR of 0.1 volts and the capacitance decreases as the voltage increases. As a result, the UF4007 was also used as a rectifier for VB of the MOSFET driver.

F. Low Pass Filter

By adding a low pass filter after the MOSFET output, an amplified version of the original audio signal is reconstructed. When constructing the Low pass filter the type of speaker was taken in consideration and load impedance in this case a 4 ohm was chosen. Equation (1) below was used to calculate the values for the capacitor and inductor.

$$fc = \frac{Z}{2\pi L} \text{ (1)}$$

The next step is to select a value for the inductor that allows for a cut off frequency of approximately 40 kHz. The value selected for the inductor was 15 μH . This value is used to evaluate equation (1) as shown below. This signifies that the original voltage amplitude will be lowered by three decibel or 30 % of the original amplitude.

$$fc = \frac{4\Omega}{2\pi * 15\ uH} = 42.4\ kHz \text{ (1)}$$

$$c = \frac{1}{2\pi * fc * z} \quad \rightarrow \quad c = \frac{1}{2\pi * 42.4\ kHz * 4\Omega} = 1\mu F \text{ (2)}$$

Finally, the cut off frequency is used to calculate the capacitance, equation (2), and is determined to be 1 μF. The amplifier gain ranges from 20 to 32. This range depends on the power supply, which will be 12 volts resulting in a gain of 20. The output will consist of 15 watts that will be connected to two 4-ohm speakers. The speakers have a frequency response of 80 Hz to 18 Hz and have power output max of 180 watts.

IV. PROJECTOR

The purpose of the video projector is to provide a visual entertainment system for the SmartTable. The cost of the projector was under two-hundred dollars which includes the following six components for the projector design:

A. Design Constraints and Specifications

The design constraints of the projector were the following:

➔ Projected image size must have a (insert definition) ratio and must have a minimum viewing distance of 5 feet and not exceed 8.5 feet.

➔ Projector must operate over 15 minutes.

➔ Projector must not exceed the 32” storage size of the SmartTable.

The average distance between a viewer and a television at a typical home is between 5 feet and 8.5 feet. In addition, the average television size is approximately 47”. To calculate the image size of our projected image, we must first determine the magnification of the system using:

$$M = \frac{d_i}{d_o} \quad (3)$$

The object distance (d_o) is approximately 135 mm and the image distance (d_i) is approximately 1524 mm. The magnification factor (M) is calculated to be 11.24. The projected image size can be approximated by multiplying the horizontal length of the LCD, which is measured to be 4.35", and the magnification factor resulting in a theoretical projected image size of 49.1”. Experimentally, a large format lens with a focal length of 135 mm was used to project the image from the LCD object. The projected image was physically measured to be approximately 48.8” and the experimental error was calculated to be 0.3%.

When crafting the video projector design, the image size above was the fundamental piece of information needed to determine the attributes of the other components. Since the large format lens was calculated to be 135 mm, the LCD object was going to be placed 135 mm (one focal length) behind the large format lens.

To create projected image, light must transmit through the LCD object. The video projector must be able to display an image for any given range of colors in the visible spectrum. Therefore, a 100W LED with a broad color spectrum was chosen with its spectrum shown below:

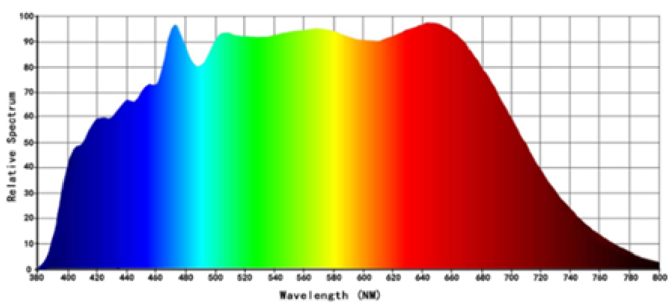


Fig. 3. LED spectrum (380nm-800nm)

Light control is required to ensure the object is fully exposed to the incoming LED light. To do that, a Fresnel lens with a 90 mm focal length was used to collimate the LED light. It is important that the Fresnel ridges are pointed toward the light source. Next, a second Fresnel lens with a 150 mm focal length is used to collect the collimated light for two purposes: (a) propagate the light evenly through the LCD object and (b) converge the light at its focus point, which the large format lens is positioned. This time, the Fresnel ridges of the second lens must point towards the large format lens.

Utilizing a free ray tracing software called Optical Ray Tracer, the design of the video projector was created with the above components and is shown in the following figure:

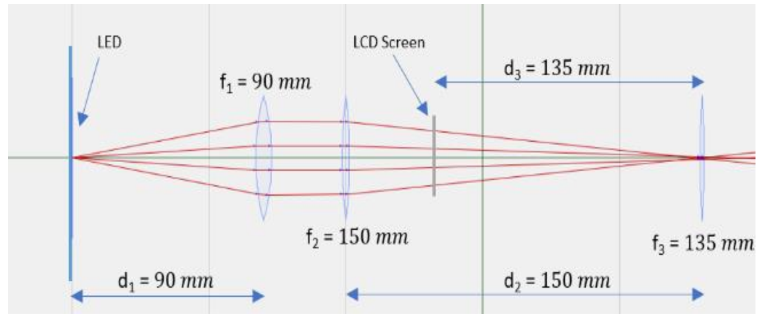


Fig. 4. Projector Design Schematic

B. Testing

According to figure 5, the LED chip is positioned 90mm from the first Fresnel lens (lens 1). Unfortunately, this is only a rough estimate of the relative position between these two components. The position of the lens 1 can be found by focusing a light source at infinity, the sun, at the position of the LED chip, as shown in the figure below.

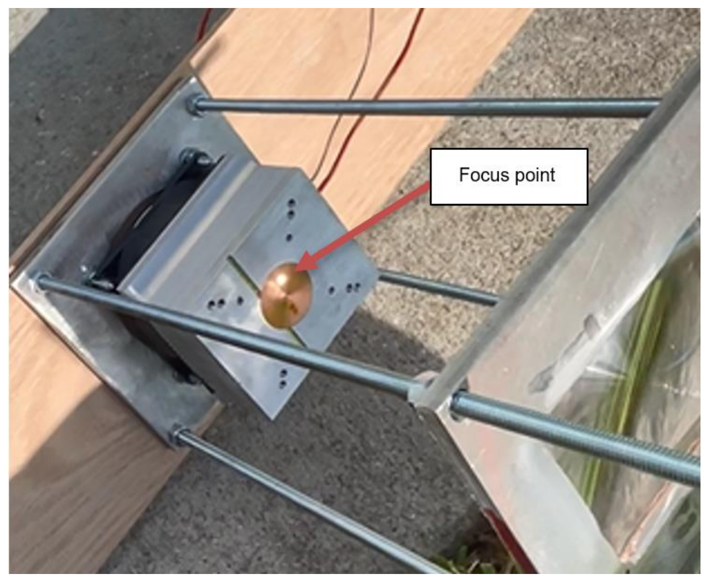


Fig. 5. The Sun focused at the lens focal point

The lens and LED chip positions are locked into place with nuts on both sides of metal panels that holds each component.

The second Fresnel lens (lens 2) is positioned as close to the lens 1 as possible. The position of the lens 2 can be placed anywhere because the light is collimated and will not affect the quality of the image in any way.

Next, the LCD screen was placed approximately 30mm away from lens 2, as shown in figure 2. The design was slightly flawed because both Fresnel lenses was not large enough in surface area to transmit light on the entire surface area of the LCD screen. Consequently, the image size of the LCD screen is effectively reduced. Ordering new, large Fresnel lenses with the same focal lengths was difficult because of 2-month shipping arrival time.

Finally, the large format lens was positioned at a location where the object's image was projected and focused on a wall approximately five feet away from the lens. As designed, the large format lens was approximately 135mm away from the LCD screen.

C. Design Challenges

The design came with its fair share of challenges. The quality of the 100W LED chip could have been better if a higher quality LED chip were bought. For an additional $100, an LED chip with the same flux and efficacy with a lower forward voltage could have been bought from YuriLEDs. This change could have decreased the amount of heat generated from the LED.

Additionally, the first LED screen bought had 2K resolution and a 1:3000 contrast ratio. Unfortunately, the LCD screen developed dark spots while testing out the system's lifetime of the LCD screen under intense LED light for 18 minutes and 38 seconds. This LCD lifetime test created a time operation constraint of 15 minutes. One way to prevent thermal damage is to provide the LCD screen with its own cooling system.

V. POWER SYSTEM

Our group has chosen to supply power to the SmartTable and its accompanying subsystems through the power provided in every household system, the wall outlet. We have taken the 120V AC and stepped it down using a transformer, and diode rectifier, to a manageable 40V DC while allowing the SmartTable a maximum peak current of 8 amps. This corresponds to the SmartTable's subsystems that were designed to draw no more than 320 Watts during maximum peak performance. From there our group needed to ensure each subsystem received as stable a DC voltage regulation as possible with minimal voltage ripple. We chose to design buck converts which are a form of switching regulator, to both step down and manage the voltage supplied to each subsystem. The regulation system design utilizes a 180K switching frequency and had 90% efficiency, with an output ripple voltage of no more than 10mV, as well allowing an adjustable output voltage based on variable resistance based on the equation below:

$$1.25\ x\ (1+\frac{R1}{R2})\ \ (4)$$

When designing a 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 the input voltage to be provided to the Buck configuration (Vin) as well as the needs of the connected device that will be receiving the output voltage (Vout)and the Load (IL) current form the Buck configuration. The Designer must consider the duty cycle that will turn the MOS component on and off. The MOS component is what will be driving the system. The duty cycle is given by:

$$DC = \frac{Vo}{Vi}\ (5)$$

Step 2: When developing a Buck converter configuration, or system, the designer needs to consider the power that the Buck converter is delivering to the load. The load is the product of the Output voltage with the Load current though the connected device. Depending on the efficiency of the Buck system configuration, the Output power must be the input power provided to the Buck converter configuration.

Step 3: Next, determine 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 50 Watts with a switching cycle of one second, this would yield 50 joules every second.

Step 4: The final step to consider when designing a Buck converter system or configuration is to calculate the inductance. Equation (6) below gives the inductance:

$$L = \frac{2E}{I^2}\ (6)$$

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

Our group had to design the SmartTable's power regulation needs to have a wide range of considerations and implementation factors. There are various factors to consider across the entire circuitry and system however the key factors for the proper implantation of a buck converter are as follows:

A. Input Voltage Range

When properly implementing a Buck converter a designer must consider more than just the data sheet for input voltages (Vin). Many Data sheet for standard buck converter systems give a wide range of input voltages to a proportionally wide range of output voltages. The designer must consider what 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 Vout. 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.

B. 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.

C. Line Regulation

The designer should be mindful 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.

D. 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 uncontrollable variables.

E. Load Transients

Similar to the load regulation design process, 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.

F. Current Limit

Many Buck converter systems and configurations take into consideration both the positive flow current and negative flow current. Most 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 a Buck converter regulator to meet a specific purpose, 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.

G. MOSFETS

It is common practice to use P channel MOSFETs, which significantly reduce the driving requirements for the system. Nonetheless, it is important to know 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 a resistance of 60 mΩ while maintaining a drain to source voltage VDS = -100V. Texas Instruments states that it is important to include a gate driver to reduce the losses in switching.

H. Diode

For most Buck converter regulator systems and configurations, the Diode does not experience high levels of voltage across the component. However, the Diode must be able to handle higher current loads. For higher current loads a Schottky Diode could be used. 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.

I. 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.

Our group utilized the XL4015 as the main component to base our buck converters around for several factors. The input voltage can range from 8 to 36V, the output voltage is adjustable with the equation above from1.25 to 32 V, has a minimum drop out of 0.3 Volts, Excellent line, and load regulation with a build in current limit protection function as well a up to 96% efficiency, with a maximum allowable current of 5A per buck regulation unit. The XL4015 has an internal block diagram as shown.

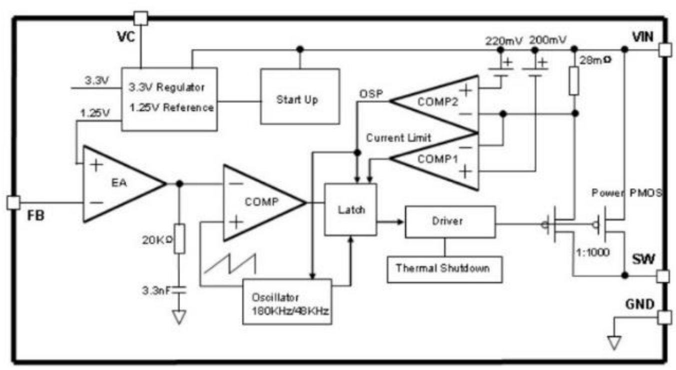


Fig. 6. Internal schematic for XL4015

The XL4015 is commonly utilized in a configuration that follows which can easily be adjusted for a variable output voltage.

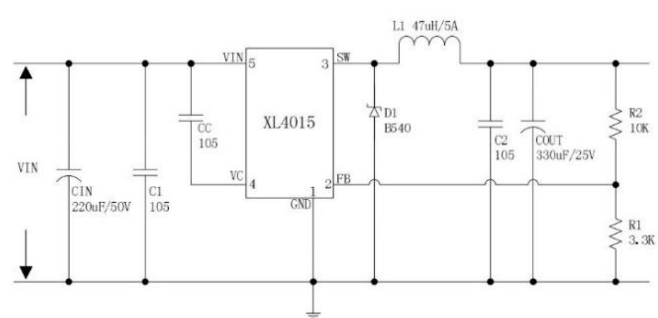


Fig. 7. Voltage regulation circuit level schematic utilizing the XL4015.

There are four unique schematics from which the PCB were created, these four unique schematics power the SmartTable's 4 major subsystems. For the Projection LED array, the first Buck converter provides a maximum of 56 Watts, which is broken down into 28 volts with a peak current usage of 2 amps. The second Buck converter provides a maximum peak power of 24 Watts, for the SmartTable's exterior dynamic LED lighting, as well as a cooling fan for the projection LED array, and the door locking mechanism. The power provided is consisting of 24V at a peak of 1A in maximum operating mode. The next Buck converter provides a maximum peak power of 12 Watts to the Audio system, the audio system requires 12 Volts and at maximum operation will pull 1 Amp. The last Buck converter will provide the Host MCU.

VI. PCB

Our group created the schematics for the individual system though their own design process. Once that was complete the group came together to prototype to ensure each system worked both independently and in conjunction with other systems. When the group was content with the progress the process of PCB design, routing, and fabrication began. Our group ultimately chose to use EasyEDA for footprint selection and PCB design due to straightforward use, design portability, shareability, and when designing the ability to in real time see component availability. The boards designed and fabricated were chosen to be two layers. Each individual system was not so complex as to require multiple layers for component trace routing. The components were ordered from LCSC Electronics due to the fact of ease of use and functionality working in tandem with EasyEDA as well real time component availability. EasyEDA allowed our group to see a three-dimensional model for each of our PCB designs as example shown here is one of our voltage regulation 3-D renders after designing:

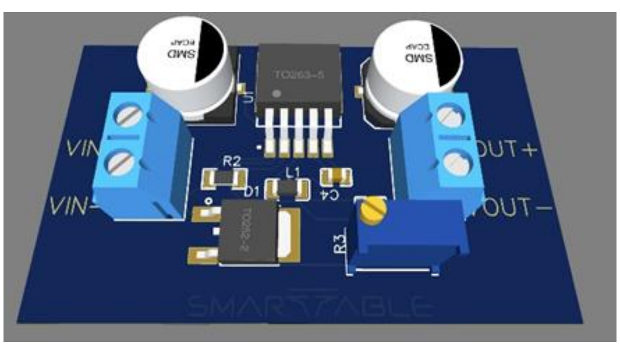


Fig. 8. PCB design render for a voltage regulation.

When the components and boards arrived, everything was hand soldered as shown here with the same Voltage regulation bard.

Fig. 9. Voltage Regulation PCB

The SmartTable will have a unique sciatica and PCB for the following, A host MCU utilizing the ATMEGA core structure, three different designs for voltage regulation ensure each system will have a continual supply of power with minimal voltage ripple, as well as a unique audio board system.

VII. Table Design

The design process of the SmartTable considered the choice of materials, component layout, table weight, future maintenance requirements, and aesthetics. The material chosen for the body of the table was wood. Wood was chosen because it was readily available to one of the group members. Wood is a flexible material and is a standard choice for coffee tables; the SmartTable is designed to be a modern version of a coffee table. Perhaps the most vital elements to address were the layout of the table and the weight distribution. The SmartTable implements several features, including but not limited to an audio system, fingerprint sensor, and projector. Although these are the major features, they each come with additional space requirements for their electrical pieces. It was necessary for the layout to be intuitive for the user but also consider keeping the table light and balanced in weight. It was decided that rather than having a table with an open design that it would have a sliding door mechanism to reveal the projector. This required a heavy door that could handle the additional weight from the electrical components that allow for automatic sliding. Moreover, when the doors slide open if the table is not balanced it is possible that it will tip over during expansion. The solution for this problem was to keep the table levelled by the insertion of two (1x2) s in each corner of the expanding portion of the table to prevent the table from tipping or coming apart when opening. Not only would the sliding door feature give the user easy access to the projector and keep it stored away when not in use, it allows for easy future maintenance. The final design element was aesthetics. Additional LEDs could be added to the table to create an interesting design.

VIII. Linear Actuator

As a final step the table was painted both white and black and a linear actuator was implemented. To take advantage of the design of the table, which opens midway, a controllable actuator was added as a feature. The linear actuator is an alloyed steel shaft accompanied by metal gears which allows it to push and pull the half of the table. The Actuator is capable of handling weights up to 300 lb., extends up to 14 inches and is powered up by 12 volts at 600 milliamps. The user will be able to control the actuator using the Bluetooth app either opening or closing the table.

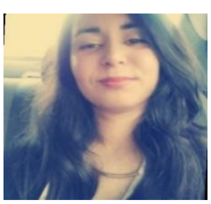
Acknowledgment

The authors of this paper would like to acknowledge the assistance and support from Dr. Samuel Richie, Andy's Auto Repair in Apopka, FL, and the University of Central Florida. Without their help, resources, and invaluable insight the groups seeming insurmountable goals could not have been accomplished.

Conclusion

Smart Devices bring intelligence and automation to almost any industry and are increasingly common in everyday life. What were once luxury tools are now an essential part of many households. A good smart device can pair easily with other devices and can make a space more energy efficient by giving the user greater control. The SmartTable provides increased functionality and efficiency of connected appliances by giving access to multiple tools at once; you can decide which features to use and which to keep off. The SmartTable is flexible and can accommodate computers, tablets, cell phones and any device with a USB or Bluetooth connection. Furthermore, it combines two engineering disciplines: Electrical Engineering and Optics & Photonics Engineering. The design of the SmartTable includes key electrical engineering topics such as power systems, circuit design, digital circuit design, signal-processing systems, and embedded programming. Tenacity, ingenuity, and a thorough understanding of these key topics were necessary for the successful completion of the SmartTable.

Biography



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Israel Castillo is currently a senior at the University of Central Florida. He plans to graduate with his Bachelors of Photonic Science and Engineering in May of 2021.

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