Handheld LED Display

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***ABSTRACT* -- THE PURPOSE OF THE PROJECT IS TO DESIGN A HANDLE-HELD LED DISPLAY THAT ILLUMINATES TEXT THAT CAN BE SEEN FROM A DISTANCE, PRELOADED WITH MESSAGES GIVEN BY THE USER. WITH USB OR OPTIONAL BLUETOOTH CONNECTIVITY AND A CONVENIENT PROGRAMMING INTERFACE, USERS WILL BE ABLE TO LOAD A MAXIMUM 4 PRESET MESSAGES TO THE DEVICE MEMORY FOR QUICK SELECTION. THE DISPLAY WILL CAN DISPLAY UP TO 2 LINES OF READABLE TEXT. ADDITIONALLY, USERS WILL HAVE THE ABILITY TO ADJUST THE BRIGHTNESS OF THE LEDS USING BUTTONS LOCATED WITHIN PROXIMITY OF THE DEVICE HANDLE.**

***Index Terms* — Ceramics, coaxial resonators, delay filters, delay-lines, power amplifiers.**

I. Introduction

When considering situations where communication of a visual message to a person or crowd at a distance is needed at any given moment, there aren't many reliable products available. Currently, such devices that are hand-held are not commonly produced. However, there are a few products available that are similar, with a programmable LED display and reasonable size for transporting. The issue with these products is that they are either not hand-held capable, very expensive, or have a small screen size with minimal resolution. Also, programming some of these becomes somewhat complex for users, since configuration of these devices may not have been designed for programming novices.

The goal of this project is to design, build, test, and debug a hand-held LED display that, with production documentation, will be available at a reasonable price. To achieve this goal, only the necessary feature additions were selected, as excessive enhancements to the project would raise the cost for the consumer. From this, the decision was made to include improvements such as: lightweight, low cost, compact encasing, wireless interface, optimized battery life, larger message capability, and in-use brightness adjusting. Considering these features, as well as opportunities to mass produce the device, this product should provide something that consumers would purchase if properly marketed.

II. Project Description

The purpose of this project is to produce a rechargeable, cost-effective, handheld LED display. Our goal is to make the display where users will have the ability to see messages from the LEDs clearly at a distance of at least 10 meters away, with optional text and configuration of the characters. To achieve this, over 1,300 LEDs will be used, forming a matrix of 24 rows and 56 columns that all fit in a compact encasing. This way, maximum brightness will be produced, and text will be clearly defined over a span of numerous, small LEDs. Messages can also be loaded in a scrolling fashion when the numbers of characters exceed the lateral space of the display, or text will be automatically centered on the display when messages can fit within the display. Users will have access to a wide variety of characters including letters, numbers, and a certain number of symbols and punctuation.

Loading messages on the screen will be made easy by a simple GUI, where users can adjust their text and other options, and then simply upload the message to the device. The GUI will be available from a computer disk that will have the ready-to-run software stored. The user only needs to run the CD and follow the on-screen prompts to start the program and become connected to the device. Messages can be uploaded to the board by using the provided USB cable and connecting to your PC, or by connecting wirelessly to your mobile device through Bluetooth. Connecting through Bluetooth will be made possible through an included Bluetooth Low Energy (BLE) module and an app that can be downloaded to a mobile device. Users just pair their device to the display with the Bluetooth pairing button on the rear of the display encasing, and the connection will be established for use any time both devices are active. Both interfaces will be made for easy operation, but will still have full functionality for all the available features.

One unique feature of the display is the ability of the user to add up to four preset messages for which they will be able to switch through during use. Four buttons on the back of the device will allow the user to quickly select any of their four desired programs. Switching programs will automatically occur once the button is pressed for that preset message, and the message will remain on the display until another button is pressed by the user. As the user changes these presets from their computer or mobile device, the new message will be illuminated on the display, so users can see their new changes instantly.

Another feature available on the handheld screen, which is accessible by two buttons, is adjustable LED dimming. With a button provided for either raising or lowering the brightness, users can easily adjust the illumination intensity to make their message clear during the day, or reduce the harsh brightness at night. Dimming on the display will be controlled using pulse width modulation, a method for altering the percentage of time for which the LEDs are ON versus OFF over a continuous cycle of toggling, also called the duty cycle. As the user adjusts the brightness through the input buttons, the duty cycle of the LEDs is changed accordingly. Of course, this toggling will occur as a frequency that the human eye will not be able to detect, making the display seem constant for the LEDs that are ON.

This frequency consideration is also taken into account for another aspect of the screen manipulation, which is the data refreshing. The LEDs will be controlled in by activating certain rows and columns that correspond to a particular light, rather than controlling each of the 2,000 LEDs individually. While this saves complexity and cost, this approach is not effective for static control of certain patterns of LEDs. Therefore, data needs to be transmitted in series of refreshing, where either columns or rows are continuously cycled ON, while the other pushes data at each iteration. Our final product will also use this approach and 'refresh' the screen at, again, a frequency that is fast enough that humans cannot notice.

The electronics will have to be secured by some form of hardware. We have devised a slim, rectangular profile encasing that will not only provide protection for the circuitry, but also a clean look where users can easily find and interact with the ports on buttons available. The buttons are set in the back of the encasing, close to the bottom for easy access when the user holds the handle. The handle will be attached underneath the display encasing. To make the handle comfortable for the user, the shape will be made cylindrical and the length will be such that the user can grasp the handle along their full palm.

The last objective that is crucial for the success of the device when presented is the longevity the device can operate after a full recharging of the battery. A battery with a long life is needed for the portability of the device to be sufficient. The batter life should last at least for around 45 minutes, which we believe to be a reasonable duration for mobile technology, especially for devices that operate under such considerable power consumption. Our team has optimized this with two important characteristics: a battery that has the maximum storage capability at a low cost, and hardware/software components that are configured for the lowest electrical usage possible. Together, these characteristics provide the device the longest available lifespan, while still giving the user every available feature.

Considering all the above aspects of this project, the device should deliver on the promise of a fully functional product. The straightforward and clean layout designed for this entire project was made to keep the technical details organized and allow room to continuously optimize the design to increase performance. Our sponsor and project guide, Michael Young, expects a fully functioning product for which, if he is interested, will also purchase the final device at a price of $350. While our expenses have accumulated over testing trials, updated purchases, and additions to the original design, the goal is to keep the base price of the device down as low as possible. In that way, this project is not only a mission to complete tasks by a certain deadline, but to also produce the best viable product at the most feasible single unit price possible.

III. LED ILLUMINATION

The LEDs selected for this project must be small enough to fit within a small profile, while still providing sufficient illumination for visibility. Size not only includes the packaging, but the type of leads as well. So, to reduce excessive board space, LEDs with wire leads are not preferred. These wires tend to protrude outward from the LED package, costing valuable board area. Instead, surface mount LEDs with integrated contacts are much more space efficient, as the solder contacts are embedded with the outer surface of the package. This removes considerations needed for extended leads and solder pad space, leaving only the area assignment to only the package itself.

The dimensions of the package are intended for less than 5 mm in length, and less than 2 mm in width. LEDs are offered in nominal size, and based on availability and desired dimensions, 1206 LEDs are the optimal choice. 1206 refers to the dimensions in terms of inches, correspond to a length of .12 inches and a width of .06 inches. In millimeters, these dimensions convert to about 3.2 mm long and 1.5 mm wide, meeting the desired criteria. Such packages are also classified by packaging height, which is not as crucial to consider as lateral measurements, but compact design is the reoccurring goal. From this, and again based on availability, the choice was made to choose a height of 1 millimeter, which is typically flat in design.

Dome bulbs are also offered but such bulbs tend to take much more vertical space.

As for illumination intensity, color emission of an LED is yet another important aspect to consider. From the previous section containing background on LED wavelength and brightness, colors in the longer wavelength side of the EM spectrum have lower illumination potentials, but are much more efficient with power consumption, versus the much brighter colors near the UV spectrum. Although brightness is important to remember during the selection process, current consumption, translating to power usage, is imperative to the electronics on the panel for the functionality of the device. Also, since brightness is mostly related to the amount of forward current, LED colors that are slightly lower in intensity may be driven to produce marginally higher illumination than rated in the datasheet by simply adjusting the source to provide more current. Additionally, LEDs of even the dimmest color are able to deliver effective brightness at reasonable viewing distances, making illumination quality more trivial of a characteristic during lighting selection.

Based on the considerations above, the optimal selection of LEDs for the sake of the project is red, 1206, flat lens lights. Reducing the size any further of the device package would decrease the illumination capability of the panel overly to the point where the display message would be indistinguishable across a room. Also, choosing red for the color of the LEDs saves a substantial amount of device power after realizing the potential current draw with over 2000 of such LEDs. Any brighter color would drain the supplied battery significantly faster, detracting from the effectiveness of the product.

IV. DISPLAY CONTROL

For the device to properly display a message, a method of strobing through the screen with the desired output data must be implemented. The reason for this is that if we have a certain pattern that intermittently uses LEDs in repeated rows or columns, there will be unintentional illumination of more LEDs that are in between the desired ones. Also, considering the number of LEDs that are included in the matrix design (1,344) there will not be enough output pins on the MCU to control all every single LED. The solution to these issues is to use a form of multiplexing, where a few data lines from the MCU can control a large set of outputs. Then, the MCU can send data in packets that reach every row and column of the matrix, without using numerous pins.

There are many different schemes for multiplexing, but the method we chose was to use cascaded shift registers for both the rows and columns. The MCU sends data through the cascaded registers in strings of binary logic, which will illuminate the corresponding LEDs. A simplified schematic of the design that was constructed is shown in Figure 1. As for strobing the matrix, the rows are configured to sequentially illuminate, each time with a new set of data being loaded into the columns. If this is done fast enough, the human eye will only perceive a static image. After conducting some research, the frequency that can be detected by the human eye is only around 40Hz. This means that the matrix will have to strobe, or refresh, about 40 times per second. The way this is accomplished is by sending a logic 'HIGH' to the input of the registers that control the rows, and clocking that logic through the cascaded registers while keeping all remaining outputs as a logic 'LOW'. Since the MCU we chose operates at 16 MHz, reaching higher than 40 Hz of data transfer is easily manageable.

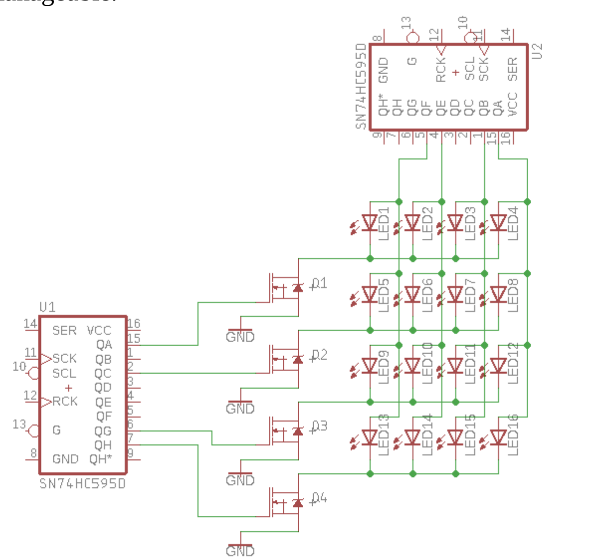


Figure 1 – Simplified schematic of the fundamental design

Another issue that was confronted with the matrix design is how to transfer all of the current flowing through the LEDs. The LEDs are connected such that the columns activate the anode and the rows activate the cathode. The anodes receive current from the column shift register, which transfers through to the cathode and row shift register to ground. The anodes are all connected in series to the column registers, so only a single LED capacity of current, 20 mA, is necessary to provide to each column. As for the cathodes, they are connected such the parallel currents from the columns are summed together through the rows. For 56 columns worth of LEDs, that comes out to a maximum of: $20\,mA \times 56\,LEDs = 1.12\,A$. Shift registers cannot 'sink' that much current to ground, so transistors were required to accompany the registers to handle that much amperage. The way the transistors are implemented is that the shift registers activate the gate of the chosen transistor, which allows the transistor to send transfer all of that current to ground. Also, MOSFET transistors were selected vs. BJT transistor for several reasons but mainly for the low cost of MOSFETs and the high efficiency of operation.

V. POWER SUPPLY

For the device to be portable, a battery must be provided to supply circuit power. Rechargeable batteries are preferable over disposable ones for the case of this project because Alkaline batteries require spring-loaded encasings that add unnecessary bulk, and rechargeable batteries are more cost efficient and convenient to test and operate. In terms of recharge ability, many types of batteries are available on the market to choose from, varying in types of chemical composition, voltage capacity, charge capacity, weight, size, and packaging. High performance batteries are ideal, but when considering cost, they are unnecessary. However, sufficient charge capacity for around 30 minutes of peak device usage is desired. Size and weight are also crucial for selection, since compact and lightweight device specifications is a goal of the project. Considering these factors and more, a particular type of battery needs to be selected.

Upon searching for viable rechargeable power sources, the only rechargeable options were found to be Nickel-Cadmium (NiCd), Lead-Acid Gel, Nickel Metal Hydride (NiMH), and Lithium Ion (Li-ion) [Battery solutions]. NiCD and Li-ion batteries are for smaller device applications, and also non-toxic options, unlike Lead-Acid Gel and NiMH sources. NiCD batteries, normally offered in nominal voltages as A, AA, and AAA batteries, are acceptable for small devices, but are not packaged in small, thin profiles that are needed for compact design. Instead, Li-ion batteries proved the optimal choice since such batteries are packaged in thin configurations and generate necessary voltages for driving LEDs (2-4 volts). Additionally, Li-ion batteries have energy capacities up to 2-3 Amp*hours, which is plenty of storage considering the LED current draw which should peak at around 1 Amp maximum.

VI. PROCESSING AND BLUETOOTH

The MCU that was chosen to operate the device is a newly developed integrated chip called the Simblee, or alternately known as the RFD77203. The significance of this processor is that it is capable to transmitting data over Bluetooth in addition to providing full processor functionality. Also, the chip has an embedded 16 MHz crystal and can support up to 30 inputs and outputs. This provides many advantages over other MCU options including lower cost, quicker implementation, and simpler design.

As proven by the implementation, the wide range of pins was necessary for all the desired functionality. Almost all 30 pins were assigned to a function including matrix data lines, USB communication lines, and user input lines. The frequency of 16 MHz was also crucial, being that the high rate of data transfer as well as an even faster PWM signal were part of the design consideration. Additionally, the processor requires only 3.3 V at 10 mA at any given point in time, meaning that there is incredibly low consumption of power for the decision making.

The Bluetooth on the chip is handled by an internal ARM-Cortex MCU and operates similar to most other standard Bluetooth modules. Configuration of the Bluetooth operation is relatively simple given the internet wide support and software libraries that are offered. Currently, the device will only communicate with an iOS device, for which a mobile application is available. Given the manageability of constructing Android applications, however, additional platforms are possible in the continuation of the project if desired. The Simblee also offers configurable low power modes as the module is built with Bluetooth 4.0, the most recent advancement in low energy Bluetooth technology.

VII. BRIGHTNESS ADJUSTMENT

When considering brightness control of lighting, the conventional method is to adjust the current or power supply to the light. The theory behind this technique is that by modulating the current input through the light, the lumen intensity of the light should change accordingly, since the operation of the light is a function of the current supply given a nominal voltage. Commonly referred to as analog dimming, this is the fundamental and intuitive method for dimming. This procedure, however, is undesirable in LEDs applications. The issue with analog modulation of brightness is the LED’s current to illumination non-linear relationship. As the current changes, the intensity doesn’t change proportionally, making precise linear adjusting difficult. LEDs also have narrow threshold limits for current driven operation, meaning that the range of adjusting is severely limited. Combined, these factors restrict lighting designers to few increments of dimming for a sometimes unpredictable or tuning-intensive result. In addition to these drawbacks, current modulation also affects the color “warmth”, or quality. So as the brightness from analog adjusting changes, the color wavelength may not remain consistent.

Instead, current LED circuit designs utilize PWM outputs to control the intensity of the lighting. PWM is the method of continuously toggling an LED and adjusting the 'duty cycle', or the amount of time that the LED is ON versus OFF. When this is conducted at a high enough frequency, the human eye can't distinguish from pulses, and thereby seems as if the LED is continuously on. Dimming is accomplished by reducing the period for which the LED is ON versus OFF, and inversely for brightening.

This solves the problem encountered with analog adjusting as the voltage and current remain constant with PWM, since only the period for a logic high/low is manipulated, not the source of power. Also, the relationship between PWM duty cycle and illumination intensity is entirely linear, allowing for easier and more precise tuning of LED brightness. With just implementation of a programmable timer that generates output at specified intervals, using PWM for LEDs is a generally straightforward approach.

VIII. PCB LAYOUT

After the design and functionality of the device were realized, the printed circuit board (PCB) had to be laid out. While that may seem like back-end design, this had a major impact on meeting the project specifications. The entire device was dependent on the effectiveness of the layout scheme in terms of cost, size, weight, and representation. After manufactured revisions and guidance from our sponsor, Dr. Michael Young, the decision was made to orient the rectangular 1206 LEDs at a 45-degree angle for maximum space efficiency. This made the difference of around 4 inches in length and 1.5 inches in width from previous orientations.

Also, the main PCB only contained the LED matrix, the shift registers, and the transistors. This came from the fact that the LED matrix required 2 layers for each of the rows and columns to be drawn in a lattice scheme. This meant that any more components would require either more board space or a board with multiple layers. Producing boards with more than 2 layers becomes very expesive depending on size and the goal was to keep the device size as small as possible. Instead, the decision was made to produce separate smaller boards that would just connect through pin headers. This produced a cost-efficient solution to the issue while keeping the board size at a minimum.

Every component that dealt with signal transfer, charging, USB interface, and user input was placed on separate boards. Only the shift registers and transistors are left on the board because transporting those components would have required a large amount of connections between boards and connectors that are rated for high amperage that would flow through the transistors. With the final design, only 13 pins are interfaced from the main matrix PCB to other boards, all of which are at below the maximum amperage rating of the pin headers that are connecting them.

As for the Simblee, the chip was installed using a pre-made pin-breakout board. The board has no other components but the Simblee, and headers that breakout the many pins it contains. The headers are soldered to our project PCB and integrated into the control portion of the project. The reason for this was the immense soldering difficulty by hand and the late unavailability of reaching out to a pick-and-place facility. The device operates the same as if the chip were placed on the board alone, but the breakout-board makes for ease of testing, transporting, and implementing. In production, of course, the expectation is that the chip itself would be alone on the PCB.

IX. PROGRAM STRUCTURE

The program structure consists mainly of a display function that is constantly tracking through a byte array and lighting the appropriate LEDs to match the data in the array. This function is the default state of the microcontroller in the sign, a state it returns to after every user interaction or scrolling interaction.

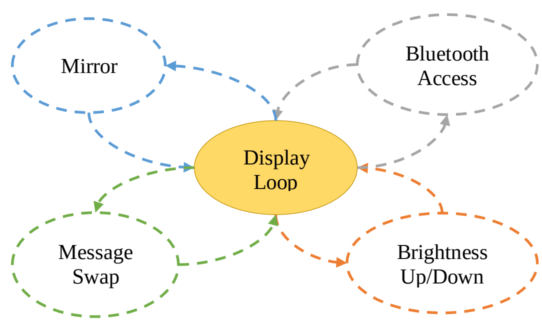


Figure 2 - A visual representation of the code states.

The scrolling functionality does not require user input beyond an initial setting. When the scrolling function is activated, between every display loop the code checks the internal clock. After sufficient time has passed, the code moves all the data in the display array one bit to the left, and then continues displaying the new data. This continues until a full character has been shifted. After an entire character has moved into the display area, a new character will be fed into the display array using a load character function. This process continues until the entire message has been loaded, and then repeats once the array is empty.

The remaining functionality of the board is based entirely on user input, specifically pressing the buttons located on the rear of the device. Each of the four message presets has a designated button that, when pressed, will load the display array with its associated message. After doing so, the code will return to the display loop, and should scrolling be enabled, it will load new characters from the newly selected message.

The mirror text function occurs when a user holds a message button for more than a second. This causes the text to be mirrors by changing the order of which bits are red in the display function. This allows for text to be read in reflection, should this be necessary.

The brightness functions impose a delay between iterations of the display loop, thus turning off the LEDs for the duration of the delay. This will make the LEDs appear dimmer by having them off for a longer period of time. This effectively implements pulse width modulation on the LEDs, through both the time it takes for the microcontroller to parse the array and the manually added delay. The user can then increase or decrease the delay by milliseconds at a time by pressing the up and down brightness buttons. The highest brightness will be a delay of zero, and the lowest brightness will be ten to twelve milliseconds of delay, with each button press adding two to three milliseconds.

The Bluetooth button will begin the Bluetooth functionality. Since the LED display is accomplished essentially through bit banging shift registers, consistently sending a Bluetooth signal is too costly for the microcontroller and imposes too much delay between display cycles, causing an undesirable brightness loss. For this reason, we added a button that activates the Bluetooth functionality until a new set of messages has been pushed to the device or the Bluetooth button is pushed again, should it have been pushed in error.

The mobile phone module is generated by the messages sent to the device when this occurs. The phone application used is the Simblee app located on the iPhone apps store. It allows for the connection of multiple Simblee devices, and in the event that there are many signs in one place they can be renamed. After connecting to a phone, the sign will send the data that generates the user interface on the Simblee application. From there, the user can change the messages and settings of the sign, and then commit the changes to the microcontroller. This data is transferred to the sign board and updates the variables in the code to reflect the user changes. After this message is received, the signboard returns to displaying the message in the slot it was previously displaying and turns off its Bluetooth activity.

X. RECHARGEABILITY

Since our device will be using a 3.7-volt lithium-ion battery as its power source, and our sponsor’s desired device has recharging capabilities, we have to design and implement a battery recharger circuit to recharge our lithium-ion battery.

For our device, we are designing and building a circuit that will be on-board our main device that will recharge the battery that supplies power. We will be using a 3.7-volt lithium-ion battery to supply power to the board, and in order to recharge this battery, the main part of the circuit will be the integrated circuit MCP73831. The MCP73831 integrated circuit will be the “brains” of the circuit, which is how it will know when the battery has reached its overcharging limit, and will tell the circuit when to shut off once that limit has been reached.

Since in our designed device we will be using a 3.7-volt lithium ion battery, which correlates to a maximum nominal voltage of our battery is 4.2 volts when being recharged. That means once our battery reaches 4.2 volts when being charged, the integrated circuit MCP73831 will detect that the battery is fully charged and will shut down the circuit as to not overcharge the battery. The MCP73831 integrated circuit detects when our battery reaches this voltage by continually measuring the terminal voltage. If lithium ion batteries are not carefully monitored this way when recharging, then they are at risk of catching fire, so that is why it is of upmost importance that the battery is monitored like how it is by the MCP73831 integrated circuit.

The MCP73831 is an integrated circuit specifically designed for recharging 3.7-volt lithium ion batteries. The specific name of this component is called a linear battery charger controller with constant current and constant voltage. If you add a programmable resistor to this integrated circuit, it is how it is used specifically with 3.7-volt lithium ion batteries as a recharger. The voltage that the integrated circuit outputs to charges with is set at 4.2 volts, since that is the maximum nominal voltage that the 3.7-volt lithium ion battery can reach before it is in danger of catching on fire. The current that the integrated circuit outputs to charge with is set by the designer of the circuit by adding resistors and capacitors as external circuitry to reach the desired charging current that we want for our device, in our case to match the charging current needed by our 3.7-volt lithium ion battery. However, the maximum charging current that the MCP73831 integrated circuit can output is one ampere, so if a battery requires more than that to recharge efficiently, then another circuit would be required.

The MCP73831 also provides internal thermal protection, current limitation, and negative charge current. The MCP73831 protects the battery when it is fully charged by shutting down its outputted charger current once the battery reaches 4.2 volts. When this current is shut off by the MCP73831 once the battery is fully charged, there is a chance that current can flow back from the battery into the MCP73831. In order to combat this issue, an internal PMOS transistor blocks the negative charge current that would flow into the integrated circuit. Since there is an internal PMOS transistor, there is no need to add an external blocking diode to the circuit to prevent this current from entering.

XI. DEVICE ENCLOSURE

The final step in construction of the flip-sign is the enclosure. The enclosure is a rectangular box that holds all the necessary electronics and is equipped with an ergonomic handle. Some of the options for building this enclosure included 3D printing, plastic molding, and laser cutting. Plastic was the desired material in every case since it is durable in most conditions and lightweight. 3D printing is expensive in production and therefore unviable. Plastic molding is quick and cost effective for production, but is not ideal for the scope of this project in terms of cost. Therefore, the decision was made to laser cut the plastic sections of the enclosure, and then fasten them together. Laser cutting is very cost efficient for a single product since the production time is low and the generated parts are made with utmost accuracy.

Using a modeling software called Rhino3D, each individual piece of the enclosure was designed to be cut from plastic. Not including the handle, there are 6 sections that are required for the full design, each for a side of the box. To make assembly run more swiftly, there was also a need to include 'finger joints' in the sections (tabs cut in the edges of each section). That way, the pieces will fit together as desired without any need for tedious measurements or constant fitting. The image below in Figure 3 shows the drafted piece that is the front of the enclosure.

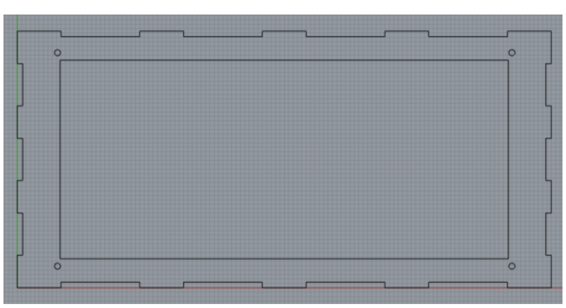


Figure 3 Enclosure front panel

As shown in the image, the tabs are cut all around the section where complementary tabs of the same dimensions will fit in to a flush edge. The PCB is fastened by bolts into each of the four drilled holes and will only have the LEDs visible in the panel's 'window'.

As for the handle, a hole is cut into the bottom panel for a screw that will tap into the handle and keep it secure. The handle originally was to be removable but various ideas for this concept would jeopardize the integrity of the handle or the connection between the handle and enclosure, so it was decided that the handle be a fixed part. The handle is not molded or cut by our design but rather retrofitted for the use of ergonomic capability and ease of construction. When production is considered, a separate handle design may be implemented where all such issues are resolved, but for the scope of this project, the handle was only purchased and implemented.

XII. COSTS AND BUGDET

The overall intention for project completion was to have not only an operational product, but a marketable and cost effective one. To accomplish this, every part and design method that was chosen reflected the ability for the product to be completely marketable, and competitive to similar products.

The overall budget for a single successful product was $350, considering the costs of prototyping, design, and manufacturing. However, the overall purpose of the design was to reduce the price of mass producing the device to around $50 or less. Not every aspect of the current device reflects this idea for mass production, but most of the product selection and design scheme was with that intention. In the Table 1, it is shown how the cost effective the part selection is if thousands of the device are made.

The price was high for the single project, but when over 1000 devices are made, the unit price drops drastically. This is because, from the parts that were selected, the price of purchasing abundant iterations reduces the price. Based on that concept and the scheme we chose, the anticipated price would drop to around $57. This is slightly above the objective price, but with possibly finer part selection or manufacturing methods, the unit price under production could drop even more.

Table 1 - Production and Unit Price Comparison

Part	Unit	Production (~1000)
DMN2215UDM-7 MOSFET (x12)	6.36	1.85
Red LED SMD (x2000)	40	20
74HC595 Shift Register (x10)	5.72	4.76
CP2130 USB to SPI Interface	2.16	1.62
EXB-38V820 Resistor Array(x6)	0.72	0.03
Miscellaneous Resistors	1.5	0.01
Simblee MCU *Estimated*	17.01	10
LP2985 Voltage Regulator	0.58	0.25
MCP73831T	0.68	0.45
USB Port	0.7	0.36
SMD Capacitors(x10)	5.8	1.2
Encasing (Laser cut) *Estimated*	55	10
Tall Momentary Switches (x7)	3.5	0.73
Power switch	3.83	1
PCB Manufacturing *Estimated*	55	5
Total	**198.56**	**57.26**

XIII. CONCLUSION

With all the features and components previously described, we believe we have created a product that fits the specifications we set out to satisfy. The sign is light enough to hold comfortably, lasts for over an hour, and is easily modifiable by a user. The brightness settings allow for increased battery life and provide an additional feature for user satisfaction. Overall, we hope this sign board can become a viable commercial product, especially in the spectator sports market.

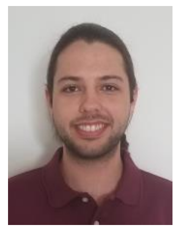
ACKNOWLEDGMENT

We would like to acknowledge our project sponsor professor Michael Young who gave us both the idea for the project and the direction and tools to help complete it. Your help has been greatly appreciated over the year of senior design. We hope the project lives up to your expectations.

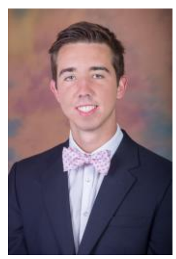
BIOGRAPHIES

Tyndall Darnell is currently a senior at the University of Central Florida. He will receive a Bachelor's of Science in Electrical Engineering in May of 2018. He currently works as a co-op electrical engineer at Lockheed Martin. He plans to enter the industry as an electrical engineer in June of 2018 at Lockheed Martin after graduating.

Peter Guarner is graduating with a Bachelor's of Science in Electrical Engineering and a Minor in Mathematics. He plans to start working after graduation, but in the Fall will start a Master's program at the University of Florida.



Sean O'Shaughnessy is currently a senior at the University of Central Florida, planning to graduate at the end of Spring 2018 with a Bachelor's of Science in Computer Engineering. He is planning to begin his career in the tech industry after graduation, but would like to continue education into a Master's program while on the job. He hopes to find employment at a tech company or defense contractor.



Tyler Stokes is graduating this semester, Spring 2018, with a degree in Computer Engineering and a minor in Business Administration. He is planning on entering the work force after college and eventually pursue a Masters in Business Administration (MBA). While in college he had the opportunity to gain experience with internships in Lockheed Martin's CWEP program and at Siemens. While learning a lot of technical skills in school he was also able to also learn outside of school with side projects which included building a First-person view drone and a dancing Christmas light show with a Raspberry Pi.

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