# Medlock Automated Pill Disbursal System

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***Abstract* — The objective of this project is to create a pill disbursal system to help combat the issue of Opioid Addiction. With the use of a two-tier notification system, LCD display, and built in security system, the Medlock system should be able to present an at home solution to help combat the problem of drug misuse and addiction.**

***Index Terms* — Software Design, Signal Processing, Pulse Width Modulation.**

## I. Introduction

In the United States, the abuse and illegal distribution of prescription drugs is a large-scale problem. In 2016, the United states alone "63,632 Americans were killed by drug overdose"[1]. According to the CDC 66% of those overdoses were from prescription of illicit opioids. Without measures in place to stop such actions the problem will never be fixed. In hospitals, there are machines that manage the distribution of medicine so that nurses or patients cannot steal medication. To properly attack the issue there must be an at home equivalent. Ideally with the help of pharmacists the Medlock will be the at home answer.

Medlock is an at home pill disbursal system with the idea to stop the abuse of prescription drugs, specifically opioids. The ideal scenario is that the Medlock will replace the prescription pill bottle used now. The pharmacists would be responsible for handling refills as usual. The difference would be once the pharmacist finishes refilling, the user won't be able to take out multiple pills at a time without setting off the security sensor. Therefore, in this scenario it would force the user to wait for their pills the proper amount of time and reduce the possibility for abuse. That said, as a backup scenario, the Medlock can also act as an at home disbursal center for those who struggle to remember to take their pills, such as the elderly or generally anyone forgetful.

The Medlock combined has three main systems: pill disbursal, LCD display, and security. The main priority of any pill dispenser is obviously to get the user their pills. Medlock has an efficient disbursal system ran by the CC2650 microcontroller as well as several peripherals such as LEDs and Servos which will be discussed in further detail later. The LCD display keeps track of the amount of pills the user has left on top of what you would expect to see on a prescription drug label, such as dosage, medicine name, etc. Lastly and importantly Medlock has a simple but effective security system which alerts pharmacists of misconduct with the pills or at least with the casing.

The Medlock is a first-level product that will hopefully help start a more active approach to combat opioid addiction. With the systems in place, it can serve as an effective option for those struggling to fight a prescription drug addiction as well when used appropriately. Even more exciting is the ways Medlock can still grow and improve even after the conclusion of Senior Design.

## II. System Definition

The overall project has 5 major portions, each with their own set of goals and specifications to suffice. They are 3 software portions, 1 hardware and 1 general: 1) The pill disbursal system which contains a two-tier notification system, 2 servo motors, a push button and 1 LED. This portion is the main function of the Medlock as it handles the actual pill disbursal. 2) The LCD display which includes an Arduino Uno connected to the PCB and acts like a label on a prescription pill bottle. 3) The Security system which consists of an infrared sensor and an LED, this system is to notify the pharmacist of any openings of the casing. 4) The hardware system includes the PCB, USB connection, and battery system and runs the whole product. 5) The Casing/Component section includes all requirements that aren't already defined such as casing, and project dimensions.

### *A. Pill Disbursal System*

For this project to be successful it must first and foremost be able to measure the time between pills, notify the user when a pill is ready and ultimately dispense the pill. The disbursal system has two notifications, the first is an LED that turns on when the pill is ready. The second is a piezo buzzer that turns on if the user still hasn't disbursed the pill within a specified time period after the pill becomes available. The other aspects of this system are a timer implemented in the software to measure time between dosages. Lastly two servo motors which are used to dispense the pills when the button is pushed, below is a list of requirements for this system.

- White LED turns on when pill is ready.
- Piezo Buzzer turns on if pill hasn't been disbursed within specified time of it being available.
- The pill disburses only when the LED is on and the button is pressed.
- The timer properly measures time in between dosages.
- Piezo Buzzer times out after specified timeout time.
- Servo Motors switch when half the pills have been disbursed.
- System turns off when no pills are remaining.

### *B. LCD Display*

The LCD display is responsible for showing the user's name, name of medication, dosage, and the number of remaining pills. The LCD display is a 16x4 display that is controlled by an Arduino Uno external to the PCB. This system has a GUI created through Visual Studios that allows the pharmacist to insert the information previously stated. The Arduino is connected to the PCB microcontroller (TI CC2650) through a pin and is notified anytime a pill is dispensed, allowing for the update of pills remaining. Below is a list of requirements for this system.

- The display shows user name, medication, dosage, and remaining pills.
- The variables previously mentioned are received through the GUI via computer.
- The Arduino continues running through attachment to external battery allowing for future portability.
- The pill count updates each time a pill is disbursed.
- When no pills remain the display reads "Out of Pills".
- Display toggles on and off to save power.

### *C. Security System*

The Security System is responsible for notifying the pharmacists that the Medlock was improperly opened. The system is just an infrared sensor and an LED. If the case is opened the LED is activated. If the user comes back for a refill with that LED on then the pharmacists knows it has been opened and can choose, at their discretion, whether to provide any more refills for the patient. Below is a list of requirements for this system.

- A counter is incremented when the case is opened.
- When that counter hits the specified number, the red LED comes on and stays on.

### *D. Casing/Component Section*

This section is all the general things that aren't hardware or software requirements. This portion includes the casing, size, and general components. Below is a list of requirements for this system.

- Casing is smaller than 6x6x2 inches
- Can hold 15+ pills
- Has all components mounted inside the casing

## III. System Design

This section details the design of the system. Choices regarding every aspect are discussed and ultimate decisions are made based on the requirements described above. These include the casing of the device, hardware, and software components.

### *A. Device Casing*

All the components the device consists of are seated and secured in a casing. This is to allow for convenience as well as to keep the user from coming in contact with the internals of the device; this is to help keep the user safe from the components and minimize the chance that a user would intentionally tamper with the device. The material of the casing could make a difference in terms of mounting parts, ventilations, and overall aesthetic of the design. Due to this being a prototype, it needs to be easily modifiable and not so expensive in the situation where it needs to be scrapped.

This led to the casing itself being cut from 5.22mm thick wood with a carbon dioxide laser. The decision to use the laser to cut the casing out of wood was made because it was the cheapest option that also gave a very secure and suitable casing for a prototype. The exterior of the casing is made of six pieces that form a rectangular prism with the dimensions of 5.5 inches long by 5.5 inches wide by 2 inches deep. The pieces were cut with a finger design on all the edges to allow for all of the faces of the casing to fit together seamlessly, this would also allow for easy permanent assembly of the pieces. On the front face of the casing there are two holes that fit standard 5mm led lights, an 85mm by 42.10mm slot for the LED display, and a 25mm by 12.5mm exit hole for the dispersed pill to come through to exit the device casing.

In addition to all the areas on the front face to display information to the user as well as receive the dispersed pill, there are two areas on both left and right edges of the front face where two small cabinet locks are installed. Two locks were used because the finger cuts on all of the edges of the casing did not allow for hinges; using two locks would keep the front face attached to the rest of the casing without any need for hinges and also increase the overall security of the device, making it more difficult for the user to get to the inside of the casing. On both sides of the casing there are three horizontal slots to allow for proper venting, the slots are small enough to make it very difficult if someone were to try and tamper with the device internals by going through the vent slots.

On the top of the casing there are two holes to allow for power supply and data input. One of the input holes is to allow the PCB to be powered through a micro USB cable, this also serves as a data input cable to load code on the MCU on the PCB. The second input hole contains an Arduino input jack to allow for input data received from the user through the GUI to be displayed on the LCD screen. All the sides of the casing except for the front were permanently attached by using clamps then applying wood glue, this allowed for a snug fit while the wood glue expanded and dried. The inside of the casing was left completely open upon initially cutting the casing. After the casing had been assembled the internal components were added to the inside of the casing. A thin layer of buffer wood was used to mount all the internal components, the buffer wood was attached to the casing using glue, and then the components were mounted to the buffer wood with screws, this was so that the components were not attached directly to the casing. Each component had a custom-made mount that was made after fitting all of the components together in the case; this was to ensure that all of the components fit properly as well as securely.

### *B. Hardware Design*

Specific choices in hardware were judged based on two main purposes. The first is chosen based on the necessities the user should have when interfacing and interacting with Medlock so the complexity of the device wouldn't be so excessive that both the patient and the pharmacist can use it with ease. The other purpose is to make it as compact as reasonably possible since the device is ideally made to be portable. This also means to consider how the medication is being held inside and ensuring its security.

### *C. Power Input*

The power system on the Medlock will be a dual input system. The main power input will be from a micro-USB mimicking the 5V input seen on the CC2650 launchpad. A switch will be used to allow another source of power. The portable nature desired by the pill dispenser calls for a battery. The switch will allow changing between USB and battery power. This will allow further testing without compromising the testing of the peripherals. A micro-USB supplied from a laptop has a 500mA current available to the input. This current becomes questionable should more than just one of the servos be running at any given time. To compensate for this the LCD will be powered using an external source in combination with the Arduino controlling the LCD.

The headers provided for the battery will lead to a 5V step up regulator. This will ensure that the main power rail of the board will be receiving 5V. It will be necessary for any end users choosing to attach batteries that they meet the specifications necessary. The battery being used will be a 3.7V battery with up to 6A of discharge from the battery. This is significantly higher than the micro-USB option. With a total capacity of 7800mAh the battery will also easily last multiple days in a normal use case. The header connection will allow much cheaper breakout boards to be developed. The breakout board will contain a battery charging circuit and once an acceptable one is found; a full prototype board could be produced.

### *D. Power control*

Throughout the board there are voltage regulators making sure that the appropriate amount of voltage enters the peripherals as well as allowing the appropriate amount of current to reach the devices. The regulators start at the entrance of the battery to the board ensuring that a 5V main rail is available throughout the board. This single rail reaches to the 7 regulators. The main rail is carrying the majority of the current in the system and is made using a 10mil trace instead of the 8 mil traces used all over the rest of the board. Liberal use input capacitors help to mitigate noise going into regulators and the CC2650. To properly power the CC2650 3.3V is applied to three separate pins on the MCU. This provides 3.3V output on all the GPIO pins. The 3.3V is combined with a 4mA current on most pins and several 8 mA pins. The flow can be seen in figure 1.

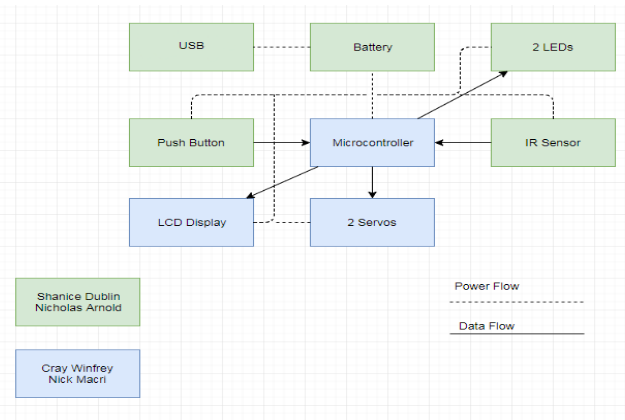


**Figure 1 Power and Data Flow**

The LEDs each have their own regulator controlling the voltage supplied. The piezo buzzer requires both a regulator and a transistor to create a powerful enough PWM signal being controlled by the MCU. The two servos share a single regulator and are a majority of the current draw on the system.

## *E. MCU*

To program the MCU a 10-pin header will be placed on the board that mimics the output connection on the launchpad. This will allow programming of the MCU by switching the launchpad XDS110 output from internal to external power. Removing the jumpers in the center of the board will allow the output of the XDS110 to switch from entering the onboard chip to entering the external target chip. The MCU will be controlling both LEDS, both servos, taking input from buttons, and taking constant input from the IR Sensor. The MCU also communicates with an Arduino UNO allowing control over the LCD. The Arduino has a separate power supply that is external or a 9V battery via a connector. The setup for the MCU connections can be seen in figure 2.

The MCU supports a Bluetooth Low Energy antenna being attached. This antenna will be connected via RF pins on the CC2650 for the option of providing communication to an external device for another level of notification to the user to remind them of their medication disbursal. The current device does not support communication over this feature, but the option was left in to provide the ability of future expansion.

## *F. LCD*

One of the first things the user will notice as a detail of the dispensary, aside from the casing, is the screen that gives information on the innards of the device. A bright, clearly legible display had to be considered to account for the transition between indoors and outdoors for the highest range of visibility. The character limit of the screen was desired to contain about the same amount of information normally seen on a standard pill bottle. Aside from the visual aspects, the weight, cost, simplicity, and availability of the screen were studied since 16x4 screens aren't as

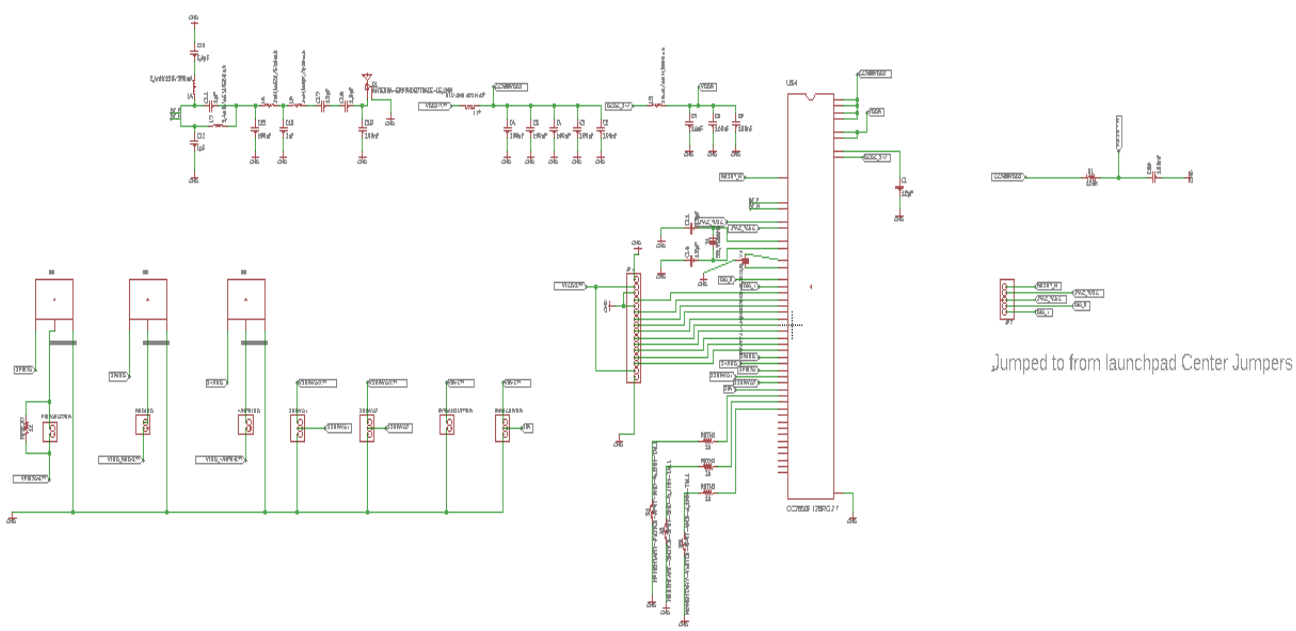


**Figure 2 Microcontroller with Peripherals**

readily accessible as 16x2 screens.

These considerations led to the choice of the Newhaven Display NHD-0416BZ-NSW-BBW which is a 16x4 character LCD display with a transmissive polarization display mode which fulfills the visibility requirement. In addition to this, it comes with a built-in ST7066U LCD controller to program characters on the screen easily.

### *G. Visual and Audio Alerts*

The LCD screen is only one level of alert when it comes to notifying the user of their pill being ready. It was decided to include two different colored LEDs to flash during different situations. Thusly, a white and red LED were needed for the device. The requirements for such were decided on view angle and brightness.

Through-hole LEDs L1-0-W5TH70-1 and L2-0-R5TH50-1 were chosen due to the wide enough view angle of 70 and 50 degrees for the white and red LED, respectively, and low maximum current draw of 15mA. The connection would be via headers on the PCB and powered by a regulator for their respective voltages of 2.7V and 2.2V.

As for the audio portion of the alerts, a small buzzer able to fit in the encasing of the device was needed. There were many technologies to choose from, but the end goal was to have one that fits the size constraints and also presents a clear tone that can be heard over the decibel range of 60dB which is around the sound range of conversation within a room. With this in mind, the PS1240P02BT piezoelectric buzzer was chosen. The sound pressure level is around 70dBA, a diameter of only 12.2 mm and height of 6.5 mm, and a through-hole component like the chosen LEDs. This type of buzzer allows for very little power consumption whenever there is a need for this to be active as well as the ability to move away from the PCB and closer to the casing so the sound of it won't be too boxed in and muted.

### *H. Security*

To detect if there has been some sort of intrusion of the box, multiple levels of security were considered and are accounted for. Implementation of a physical lock and an electrical detector/sensor was most desired since this would not only allow a record to be logged of the time and date of the action, but it would also show direct intention of opening the device. The design of the box isn't made so it is impossible to break into but is merely to aid in controlling the correct amount of dosages that are inside. As with the rest of the peripherals of the device, this too was chosen with the idea of being compact.

For the physical lock, a few options were examined with the objective of low and high security purposes in mind. However, for the sake of the prototype, a simple cabinet lock is used.

For the electrical detector, infrared break beam sensors were used and placed where the opening of the device would be. The transmitting and receiving ends are always facing one another so any obstruction in their path would cause a drop in voltage between the terminals in which a signal is sent to the MCU to use. With this in place, the MCU can log whether the device is open or something has broken the connection somehow. Due to the small enclosures, a sensitivity of only 3.6V was needed since that is the range and sensitivity does not increase with more power supplied.

### I. *Dispensary*

In order to push the pills out of their holding columns, a HXT900 9g servomotor is used. Both servo arms would come equipped with an attachment rod to slide into the pill column, thus pushing said pill down to a ramp at the bottom of the casing for the user to access. The full swing range of the servo arm is 180 degrees but it only needs to rotate around 120 degrees or less for the removal of the pill before resetting back to its original position. This prevents the stall current from drawing which can climb to as high as 750mA instead of its normal operating current of 250mA to 500mA. The pill column itself is situated inside the device on opposite ends with one servo each, arms fixed in a ready position to push out the pills from the bottom. They are spaced far enough away to avoid conflicting with each other, the PCB, and the rest of the enclosure.

One single pole, single throw button is used for momentary on-off switching that the user can press to perform a few options, one of which is to dispense the pill. This type of switch was determined to be the simplest to interface with as well as configure on a PCB since only one of the four pins need an input signal while the rest are set to the ground. Through hole components are chosen for two important reasons. The first being to alleviate the stress of the pressure on the PCB when the button is pressed and the second being so the board will not have to be pressed against the board since the thickness of the cap is thinner than the thickness of the wood used for the casing.

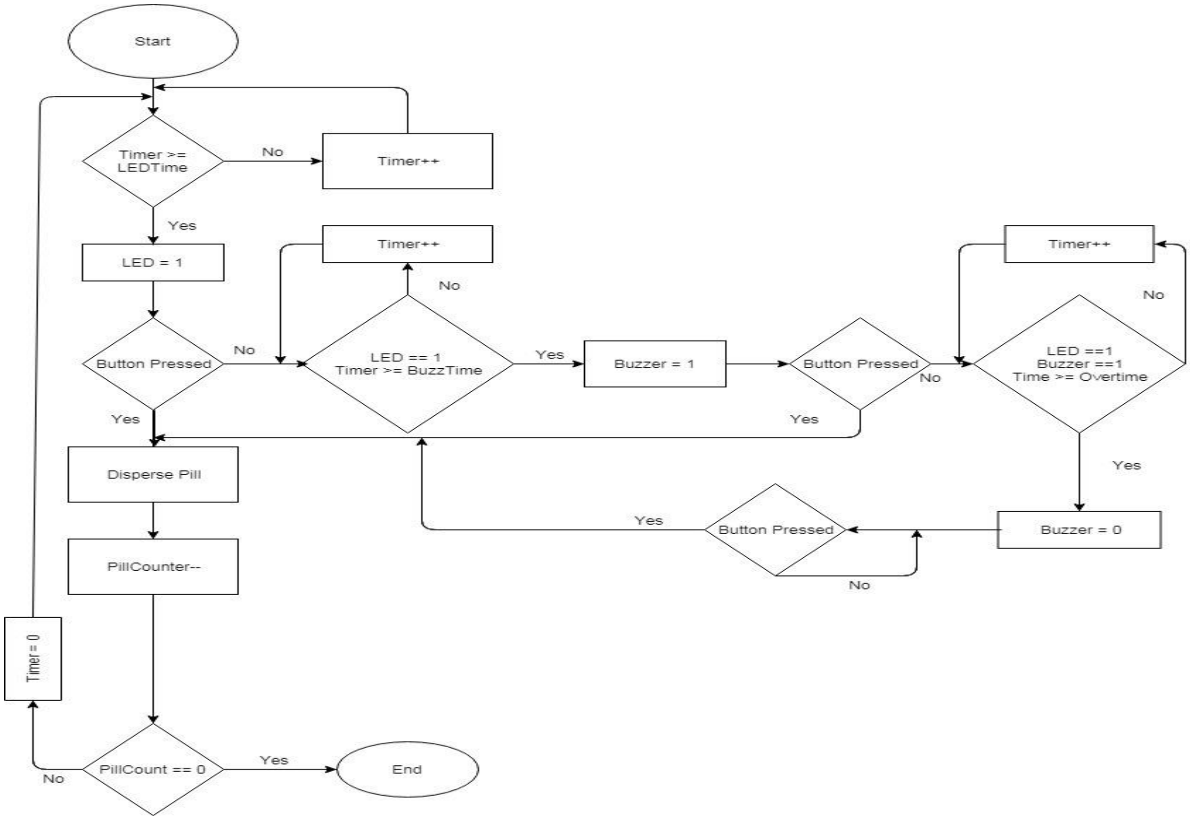


**Figure 3 Pill Disbursal System Flowchart**

*J. Software Design*

The software that runs the device has three main sections, those being the timer, dispersal system, and security. Further function breakdown is shown in figure 4. These three sections are all layered on the task stack that the CC2650's MCU offers. The way we implemented the task stack system was to assign priorities to all of the functions in our code. The clock received the highest priority since it is the first function to begin running and all the other functions execute depending on what stage the clock is on.

Once the clock time meets the requirements for a different function to execute the new function is given the top priority and will execute, the priority is then reverted back to its original state and the clock continues. For our code, the clock starts on boot up, once the clock hits the allotted time a white LED light illuminates by turning on a GPIO pin, meaning that the pill is ready to be dispersed, the clock continues to run while the light is turned on. If the dispersal button is not pressed within a given time a second alert is given. The first alert is a visual, the white LED illuminating; the second alert is a Piezo buzzer powered by a PWM signal, a buzzer was chosen to cover the two major sensory perceptions a human has. If the user has not dispersed the pill after the first alert two alerts the LED will continue to stay on, however the buzzer will turn off. After the buzzer turns off, the pill can still be dispersed, the reason the buzzer turns off is because if the user has not taken the pill at this point they are either preoccupied or they do not have the device in their possession. If this is the case the buzzer will turn off so that the device does not continue to make a high-pitched ringing and possible annoy the user or anyone around the device. The next portion of the dispersal system is the actual dispersal of the pills. In order to disperse the pills two servo motors were used. When the first alert turns on a push button can be pushed to disperse the pill. When the button is pushed an interrupt is thrown and the servo motor function is given top priority for a brief moment and a PWM signal is sent to the control pin of the servo motor in order to rotate the motor and push a pill out of the column it is being held in. Once a pill had been dispersed the clock resets and the whole process restarts. Figure 3 shows this process.

Once half of the pills have been dispersed the PWM signal for the first motor is turned off and the PWM signal for the second motor is turned on. The second motor

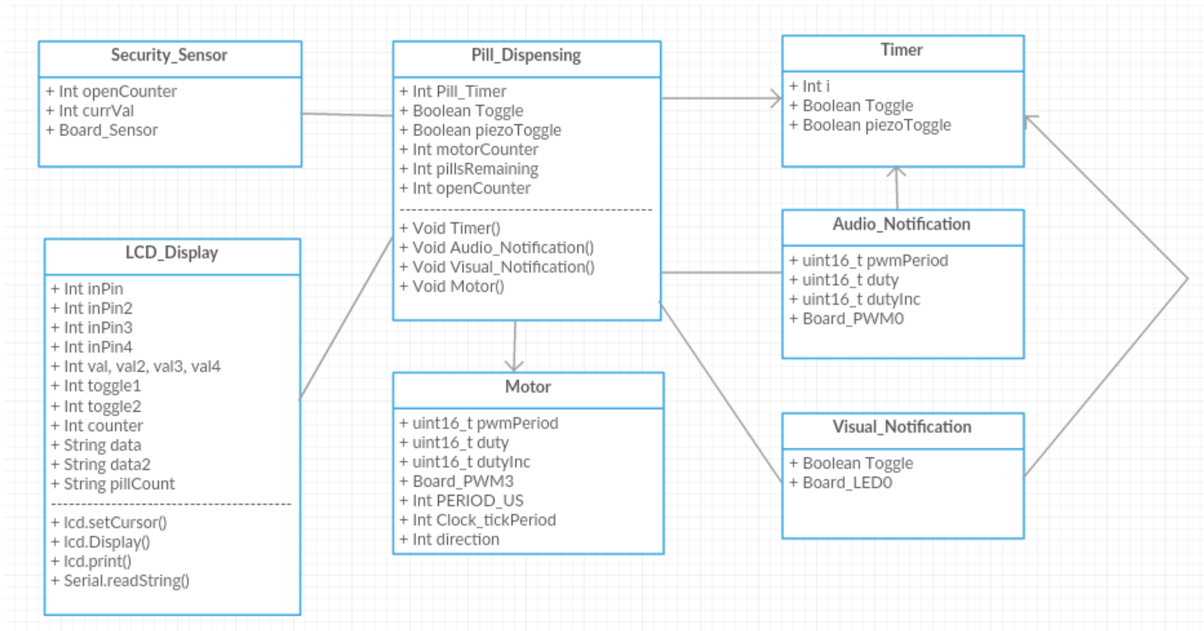


**Figure 4 Functional Diagram**

works the same way the first motor worked, if the button is pushed in the allotted time the PWM signal will be sent to

the pin and a pill will be dispersed. A variable called pill_counter keeps track of how many pills have been dispersed by decrementing every time the button is pushed in the allotted time. Once all pills have been dispersed the PWM signal of the second motor is turned off and all tasks on the task stack are given a priority of -1, meaning that all functions no long have priority on the stack and will not execute.

The final function that must always run is the security system. An inferred sensor is used to determine when the case has had an unauthorized opening. When the case is opened and closed a variable called open_counter in incremented, when the counter reaches two, meaning the case has been opened, refilled will pills, reset and closed, the next opening will trigger the security system. If an unauthorized opening of the case occurs the red LED on the face of the device casing illuminates and stays illuminated, this will show that the case has been improperly opened.

An LCD screen is controlled by an Arduino where the user inputs data through a GUI. The GUI takes in the user's name, medicine type, dosage, and pills left to be taken. The Arduino keeps track of how many pills are left in device by taking an input from the PCB through four different input lines. The PCB outputs a four-signal combination to the Arduino minimize the effect that static noise has on the data feed. Every time the first LED goes from being on to off the pill counter on the Arduino is decremented and displayed on the LCD. Once all pills have been dispersed the LCD will clear and display the text "out of pills." At this point the device has given all of its functions a priority of -1 and the device must be refilled will pills and reset. Figure 5 shows the LCD GUI.

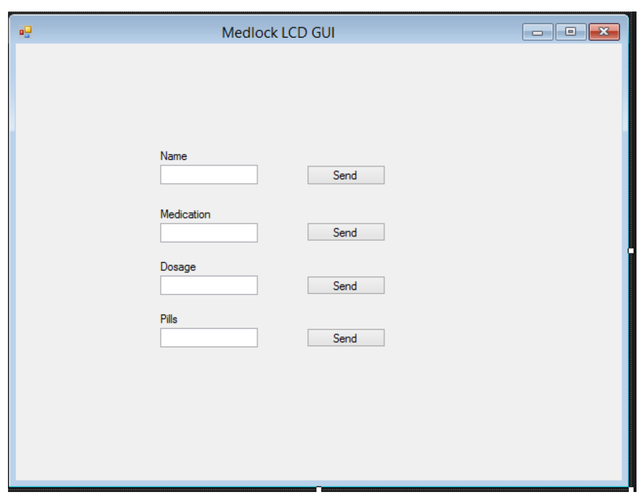


**Figure 5 LCD GUI Display**

## V. Conclusion

The main goal of Medlock is to provide a first-level protection to control substance abuse of prescription medicines in the United States. Though while this is the main goal, this device also maintains many other purposes including a reminder for users to take their pills and to take it at the appropriate time prescribed whether they are at home or outside with their device.

The hardware and software were chosen with the user in mind to create a device that is easy to understand and use but is more active in safety rather than the passive mode of security which is the safety cap on standard pill bottles usually meant for children instead of adults.

Possibilities for upgrading it are the addition of a wireless feature via the Bluetooth capabilities of the MCU. This would allow for the user to receive notifications on Android and/or iOS devices and have the ability to interface with a GUI on screen. The addition GPIOs of the MCU also allow for more features to add on such as a measure of the battery life, a slider volume for the buzzer alarm, and much more.


## ACKNOWLEDGEMENT

The authors wish to acknowledge Ileana and Jeff DiMario for allowing us to create the prototype of Medlock as well as sponsoring it for us. Their support and input has helped us with determining what is needed. The unending commitment to our success was a bright place as the semester came to a close and the pressure started to mount.

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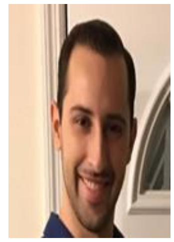
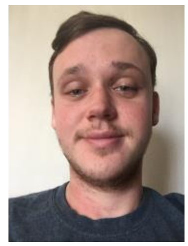
We would also like to express our gratitude to the professors who took time out of their lives to agree to review the project we hope will turn into a success.

We would like to thank the full UCF senior design team and program that ran it. Despite it being at times a very challenging and often aggravating experience, it should help us a lot in the future. You don't often get this kind of experience outside of the industry. Projects like this helps us to learn the ups and downs of the design process, and for that we are grateful.


## THE ENGINEERS



**Nicholas Macri**, a senior in computer engineering, will be graduating UCF with a Bachelor's Degree in May 2018. He has attended UCF for four years with an interest robot vision and databases; he plans to pursue his Master's degree in Business soon after graduation.



**Cray Winfrey**, a 22 year old senior in computer engineering, will be graduating with a Bachelors degree from UCF in May 2018. He attended UCF for four years and intends on either getting a job in the software development field or pursuing an MBA.

**Shanice Dublin**, is a senior receiving her Bachelors in Electrical Engineering from the University of Central Florida. She has worked in the failure analysis group of Texas Instruments which helped fostered a deeper interest in the field of semiconductors. She hopes that her contingency offer from Navair places her in a related field.

**Nicholas Arnold**, is a senior receiving his Bachelors in Electrical Engineering from the University of Central Florida. He intends to pursue work in embedded systems.

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