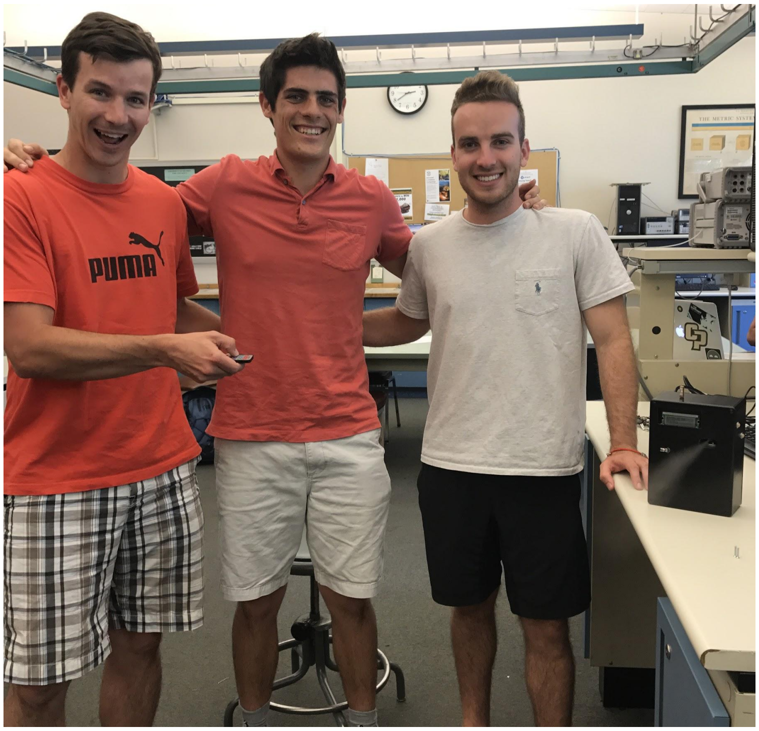
Make Scents
Senior Project Report

Electrical Engineering



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Acknowledgements:

We are really grateful because this team managed to complete the Senior Project within the given time frame of the 2016-2017 school year. This project could not have been completed without the effort and co-operation with the group members as well as the counsel and guidance from our advisor Clay McKell. We would like to sincerely thank our advisor for meeting with us on a frequent basis and helping steer us on the right path for the project's completion. We are also very thankful for the EE and ME department for allowing our team the readily access of tools and measurement equipment needed for the project. Last but not least, we would like to thank Jenna Arocha for helping brainstorm the initial idea of an air freshener for this Senior Project.

Abstract:

The purpose of this project was to create a smart air freshener. A complete user-friendly system that is programmable and simple to use for customers of all ages. Many constraints were met in order to achieve the final product and the necessary requirements. This Senior Project helps maintain a clean scented room of any size with its programmable functions to set spray times per the user's request. Final system incorporates a user operated remote controller that catches the signal using an infrared sensor. The ease and simplicity of this air freshener makes it stand out in the competing market of personal air fresheners.

Overview:

The idea for this project is a "smart" programmable air freshener. The point of automating an air freshener is to waste less spray and make each refill last as long as possible. This would cause the cost to maintain a nice air freshener to significantly drop. The device will be programmable to spray at up to three user programmed times in the day as well as in user defined time intervals of hours or minutes. The system will utilize a wall adapter for ease of use whenever accessible to a standard room electrical outlet.

The packaging of the device makes for a decent system as well. The spray canister is easily accessible and therefore can be replaced very simply as needed. A reset button has been placed inside the device in order to allow the user the ability to reset the system, without making it too simple to accidentally press in normal system use. The IR sensor has been placed in a fair location to ensure optimum range. A hole has been cut out to allow for the spray to exit the system without being caught by the enclosure. Additionally, the LCD is in a clear location that is useful for the user to program the device. Overall, Make Scents is a programmable air freshener controlled by a remote that can be utilized in various ways to satisfy a consumer's sense of smell.

Requirements:

Table 1: System Requirements

Specification	Limit	Solution
Must display and maintain accurate current time.	Be as accurate as possible with minutes, seconds, and hours.	GPS sensor used to pull constant time stamps.
Must offset hours depending on the region selected by user.	---	Menu option to select region where each region has a preprogrammed hour offset correlating to it.
Must Spray at programmable times of day.	Alarms can only be set for valid times of day.	Menu option for user to program in three different alarm times to system. Code limits user to only entering valid times.
Must Spray on a timer based system throughout the day	Time between sprays can be up to 99 for hours and 60 for minutes	Menu option for user to program timer settings. Clear instructions listed with limits if necessary.
Must Spray at the push of a button if desired	---	Activate servo motor on button press
Timer must reset if sprayed for any reason.	---	Reset timer count after every spray
IR sensor must accurately read each button press	---	Testing run to ensure that the function being run matches the expected function of the button pressed
System must have a full rest mode that prevents any and all spray features and ignores all button presses other than the rest mode exit key	---	Disable all features when rest mode is activated
The system should notify the user what alarms are activated and how much time is left on the timer if enabled	---	Display to LCD which alarms are enabled and the time left before next spray if the timer is on
Time should have option to toggle between military and civilian time.	---	Set code to toggle displayed time based on button press

Time should have option to toggle daylight savings times.	---	Set code to toggle an hour offset for daylight savings time

Button Specifications:

Each button on the remote controller has at least one function. This list describes the purpose of each button as well as when they can be activated. With the exception of the system rest mode, no menu is accessible unless other states have been fully completed. For example, the user must fully complete the programming for alarm time before they may edit region number. In the code, each button was given a numeric value in order to track which button was pressed. This was done in the form of a variable called pressed. The description of each button will show the value given for pressed. The code state diagram in Appendix B shows some of the functionality of these buttons using their respective pressed values.

1. 0-9
    a. 0: pressed = 10
    b. 1-9: pressed = 13-21 respectively
    c. In the Alarm menu and the timer menu, these buttons will set times as described by the specific instructions displayed on the LCD. 0 and 1 will sometimes select one of two options as instructions list as well.
2. Play/Pause
    a. pressed = 6
    b. If pushed, no spray will occur, no time updates will occur, the only button that will change anything again is play/pause to turn system back on.
    c. Can be activated at any time.
3. Ch-, Ch, Ch+
    a. Ch-: pressed = 1
    b. Ch: pressed = 2

c. Ch+: pressed = 3
d. Region set and toggle options. Once region set is pressed, Ch will be the region set exit button. Ch+ moves up through the regions and Ch- moves down through the regions.

4. Next, Prev
    a. Next: pressed = 5
    b. Prev: pressed = 4
    c. Alarm number toggle. First press of Next will launch the alarm state machine to set in the alarm timer. The LCD displays specific instructions for steps to program alarms.
5. EQ
    a. pressed = 9
    b. Depending on the current menu, this button acts as the “enter” key, selecting the current choice, or moving to the next menu option
6. Vol+
    a. pressed = 8
    b. Will open the time between spray menu. This triggers a state machine that displays instructions to the LCD for the user to easily program the delay between each spray
7. Vol-
    a. pressed = 7
    b. Spray and restart current timer.
8. 100+

a. pressed = 11
b. Daylight savings toggle fall/spring.

9. 200+
    a. pressed = 12
    b. Toggles military time vs civilian time. Current alarms are converted to the new time system as well.

Design and Construction:

1. Printed Circuit Board
    a. The goal for holding the components together with all the proper connections was originally to use a printed circuit board. The school had just recently received its own milling machine that enables cost effective and quick production of the boards.
    b. Initial testing was done on breadboards to ensure that the system was working to begin with.
        i. Each component was tested for how they worked
        ii. Components were put together and the system code was run to ensure components work together
    c. After everything was tested and worked correctly, EAGLE cad schematics and board design files were made. Once made, the milling machine was used to cut the board to the specs. Figure 1 shows the board design after the mill process was completed.

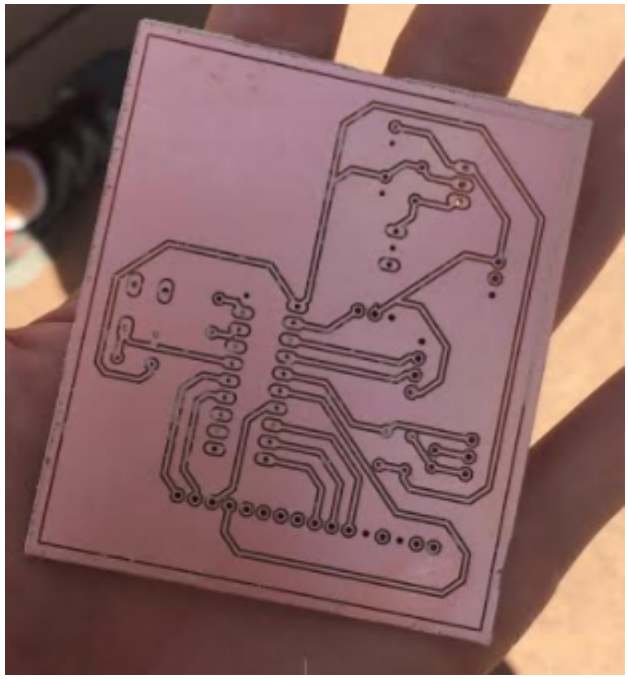

Figure 1: Completed PCB after mill manufacturing

d. Despite the availability of the milling machines, and the ease of rework for the printed circuit boards, the final system required use of a perf board and soldering connections all by hand. As the milling machine is new, people are not experts yet at running the machine. This caused several pieces to break over time, and a third board could not be made. The PCB design was good experience and helpful for schematic design of the final system.

2. Project Enclosure

Figure 2: Project Enclosure Frontal View

a. A standard project enclosure from the community Radio Shack. An 8’’ x 5’’ x 3’’ plastic box. Power drills and box cutters were used to create the necessary holes and cutouts for the components.

b. Holes were drilled for the spray to flow through, the GPS antenna to stay mounted, access to the reset button, power cables, and for the IR sensor to fit out of.

c. A rectangle was cut out of the box to make a hole for the LCD to fit into.

d. Two screws were drilled into the side of the device to mount the servo motor to the inside of the enclosure. The holes were measured to be placed at the best height for the servo to reach the spray canister when it was necessary.

e. The nozzle to the can was held in place by an additional perf board held by the screws and nuts. This support was necessary to prevent the spray from moving directions after the servo motor pushed down on the nozzle.

f. Once the enclosure holes were all made, the perf board was hot glued in a position to allow the components to all fit in their designated holes. The power module and the reset button were glued in line with their holes, and the GPS wire was strung through its hole and glued to the edge.

Figure 3: Open View of Project Components

3. IR sensor and Remote Controller

   a. The infra red sensor originally seemed like it might have been a lot of work to deal with. However upon further analysis of its data sheet and testing was done to ensure each button’s output, the sensor became one of the simplest but most interesting parts of the project.

b. As seen in figure 4, there are a lot of things going on inside the IR sensor. The remote sends a modulated signal through the air that the sensor can pick up, amplify, filter demodulate and convert to a square wave. This provides an excellent digital signal for the microcontroller to decipher and use to run specific features.

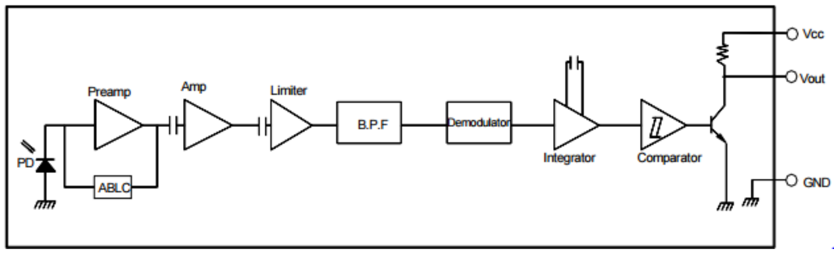

Figure 4: IR sensor block diagram

c. Figure 5 shows the full output signal of the IR sensor (top) along with the clock signal used by the MSP430 to read data (bottom). It is important to note that up until the start of the clock signal, the data signal is just a start sequence that was equivalent regardless of what button was pressed.

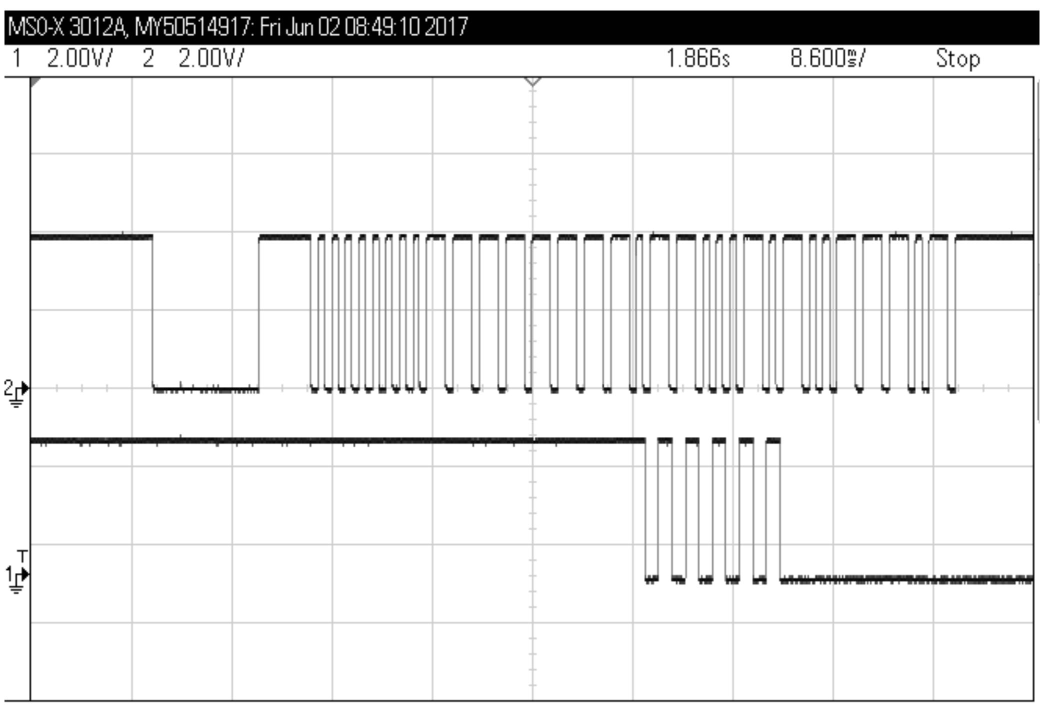

Figure 5: Remote control signal

d. The data rate for the IR sensor was around 1.2 ms. This meant that every 1.2 ms a new measurement needed to be taken of the data string. For each button, the entire 24 bit data address was recorded in a table in order to save for analysis purposes. After inspecting the data for each button press, it became clear that only the first 10 bits of any string would be enough to fully decipher which unique button was pressed. Figure 6 shows the first ten bits of data (top) and the clock signal (bottom) which is a signifier of when each bit of data was read by the microcontroller. Table 2 shows the full address for each button.

e. With the data pulse in Figure 6, the way the signal is to be read is interesting. For each bit of the data, the signal is high for half the time, then gives the data for the address in the second half. This is why it appears that the clock signal is "missing" signal data. It isn't missing information, it is skipping the load signal. The load portion is always high, so when there is a low bit, it is clear where the data and load split, but when the data is high, the data and load signals for the current and next data bit blend together.

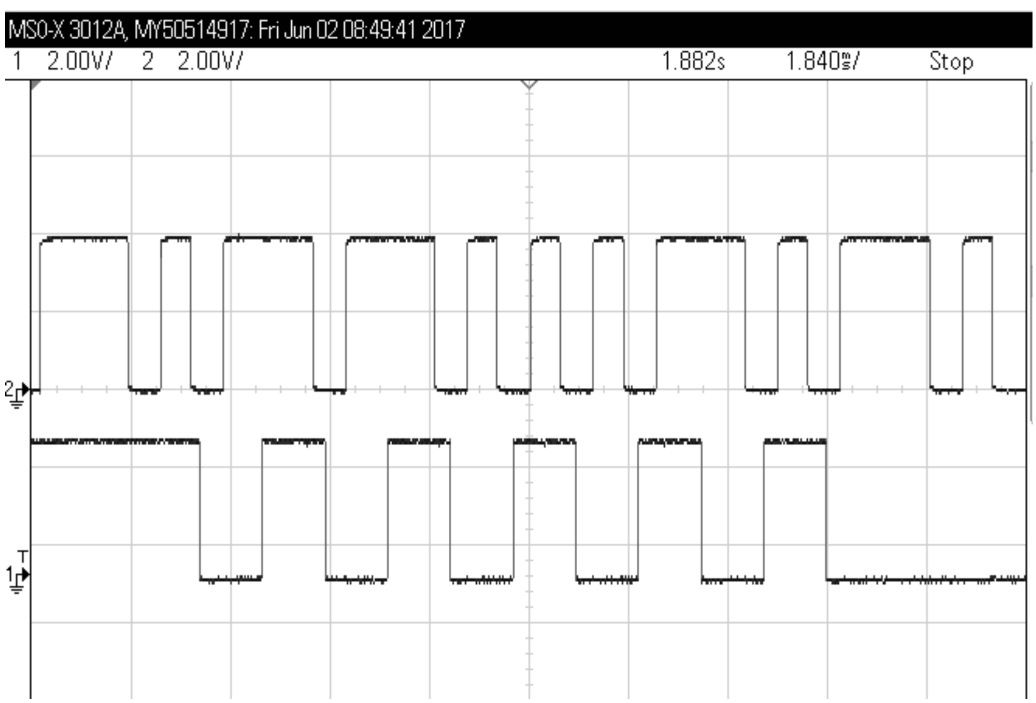

Figure 6: Zoomed in signal received by infrared sensor

Table 2: Button data, bolded = first 10 bits

Button	MSN	-	-	-	-	LSN
ch-	**b1001**	**b0000**	**b10**00	b1001	b0101	b0010
ch	**b0101**	**b0000**	**b10**01	b0001	b0101	b0010
ch+	**b1010**	**b1000**	**b01**00	b0001	b0101	b0010
prev	**b0010**	**b0001**	**b00**10	b1001	b0101	b0010
next	**b0000**	**b0010**	**b01**01	b0101	b0101	b0010
play/pause	**b1010**	**b0000**	**b10**00	b0101	b0101	b0010
vol-	**b1010**	**b1000**	**b00**00	b0010	b1010	b1010
vol+	**b1001**	**b0010**	**b00**00	b1001	b0010	b1010
eq	**b1000**	**b1000**	**b00**01	b0100	b1010	b1010
0	**b0101**	**b0010**	**b00**01	b0001	b0010	b1010
100+	**b1000**	**b1010**	**b00**00	b1010	b0010	b1010
200+	**b1001**	**b0100**	**b00**00	b1000	b1010	b1010
1	**b0010**	**b1000**	**b00**10	b1000	b1010	b1010
2	**b0001**	**b0100**	**b00**10	b1010	b0010	b1010
3	**b0101**	**b0101**	**b00**10	b0100	b0001	b0010
4	**b0001**	**b0000**	**b01**01	b0100	b1010	b1010
5	**b0010**	**b1010**	**b00**01	b0100	b0010	b1010
6	**b0100**	**b1010**	**b01**00	b1001	b0001	b0010
7	**b0100**	**b0001**	**b00**10	b0101	b0101	b0010
8	**b0100**	**b0100**	**b10**01	b0010	b1001	b0010
9	**b0100**	**b1000**	**b10**01	b0010	b0101	b0010

Test Cases

The following tests were run on the system in order to exploit any bugs that needed to be fixed. These tests were run until the tests were passed consecutively at least three times. It is important to test all the system requirements thoroughly before the system can be completed.

Hardware

1. Servo testing while mounted to enclosure
    a. Ensure servo activated spray canister each time it is moved
    b. Ensure servo does not move from mount when activated
2. Wiggle each component that is glued to enclosure in order to ensure stability

User Interface

1. Test distance ranges
    a. Partner 1 holds remote at several distances from 0 to 15 feet and pushes buttons
    b. Partner 2 monitors screen to see when remote is too far from IR sensor
2. System tested with several users to ensure instructions are clear and effective

Software

1. Time/Region
    a. Test all the menu directions to ensure that all paths work as expected and perform the proper functions
    b. Check region count properly rolling over between 25 and 0
    c. Check offsets are properly working
    d. Check region names are displayed properly
    e. Daylight savings button is effective in adding or subtracting an hour from both the >UTC regions and the <UTC regions
    f. Military time works properly for all regions

2. Alarm
    a. Test all the menu directions to ensure that all paths work as expected and perform the proper functions
    b. Check proper alarm times are stored
    c. Check conversions from military to civilian time
3. System rest mode
    a. Ensure accessibility from any mode
    b. Check any changes or problems that occur from resting in the middle of a menu
4. Timer
    a. Test all the menu directions to ensure that all paths work as expected and perform the proper functions
    b. Ensure the timer is restarted when the spray button has been pushed
    c. Check that time remaining goes down as expected in the main screen
    d. Ensure that the spray interval is changed to 1 minute intervals if the user attempts to enter 0 hours and 0 minutes
5. Spray
    a. Make sure the device sprays when the spray button has been pushed
    b. Make sure timer is updated after spray occurs

Parts used:

Below is a table of all system parts used and unused but purchased. Unused parts were intended for use but were removed for various reasons. Miscellaneous parts include things like wire, resistors and capacitors, and other small components. The total cost of the system ended at $67.23. The total cost of development including unused parts comes to $176.43.

Table 3: Parts List and Cost

Part	Quantity	Cost Per Part	Total Cost	Used
MSP430G2553	1	$2.66	$2.66	Yes
GPS	1	$11.99	$11.99	Yes
IR Remote kit	1	$5.80	$5.80	Yes
Servo Motor	1	$7.80	$7.80	Yes
Project Enclosure	1	$11.00	$11.00	Yes
Power Bank	1	$5.99	$5.99	Yes
Air Freshener Spray	1	$6.99	$6.99	Yes
Miscellaneous Parts	1	$15.00	$15.00	Yes
PCB	2	$5.00	$10.00	No
Gas Sensor	1	$20.00	$20.00	No
Gas Sensor Module	1	$50.00	$50.00	No
Clock Chip	1	$0.84	$0.84	No
Battery Charger Module	1	$9.90	$9.90	No
18650 Li Battery	2	$8.73	$17.46	No
Battery Adapter	1	$1.00	$1.00	No

Problems and Solutions:

1. Air Quality Sensor
   a. The original goal for the system was to include an air quality sensor that would be able to gauge when a room needed to be freshened. The data sheet for the air quality sensor was very poorly written and once the equations were finally found to establish tests and analysis, the device was set up for testing. Data was inconsistent and inaccurate causing inconclusive information. The next attempt was communicating with Spec Sensors, the

part makers, in order to get a better lead. After talking with them, the conclusion was reached that no sensors currently existed to meet the needs of this specification. The current sensors are used to monitor specific gases in a room. Each chip has one gas. One chip measures respiratory irritants.

2. Servo Motor
   a. Motor mounting took a little bit more thought than initially planned. At first, the hope was to mount the motor to the actual spray can, but this proved to be quite a difficult feat. The difficulty came from trying to mount to the can while still leaving accessibility for the user to change out the can of spray. After simplifying design ideas from intensive mechanical solutions to more basic ones, it was found to be much easier to mount the motor to the side of the enclosure at a specific height above the can of spray.
   b. The other thing that the motor caused issues with was which pins on the microcontroller allowed motor control. Pin 2.3 and 1.0 were both attempted as pins to use, but were both unsuccessful. In order to access these alternative pins, different registers were required to be set, and despite searching through the user's guide and datasheet for the MSP430, the correct registers could not be found. Some registers were found, and pin 2.3 almost worked, however, one of the registers must have been incorrect, as the signals were being transmitted incorrectly. After moving pin out options around for the LCD, pin 2.1 worked for controlling the motor.
3. Power Distribution
   a. The power system was initially a USB battery bank module board charger produced by SMAKN. This module can charge lithium batteries like the 18650 3.7V battery to charge the system. The battery could be charged with the 5V micro USB input. Once the battery was connected, the module had separate voltage step ups and regulators that allowed for various output voltages. One output was supposed to be at 5V, but once attached to the

circuitry, the voltage dropped significantly. Initial tests included current checks which yielded about 110 mA for the overall circuit. This was confusing, as the limit for the SMAKN board is 1A, way above the scope of the Make Scents device. Additionally, the main power chip on the SMAKN device maxes out at 200-300 mA, again well above the constraints of the project. It was then found that when the motor is being activated, the system draws 500 mA. This exceeds the power chip on the module, but not the overall module output limits, giving cause to believe that the power chip ratings are still important to constrain output use to. Another test was including a buffer from the output of the power supply to the input of the circuit. This helped bring the voltage a little bit higher, but not enough to supply sufficient power to the device. The final power decision was a power module that includes voltage regulators that drop the DC input from 12 to 5 volts. This 12 volts comes from an AC/DC converter that can be plugged into a standard US wall outlet.

4. PCB
   a. The boards made on campus proved to be less useful as time went on. The lack of solder mask to prevent solder from bridging to ground became a big issue. A lot of solder wick was wasted trying to fix poor connections between components.
   b. The PCBs also were missing some of the components necessary for the project, and had to be remade. This caused more solder wick to be burned through and more difficulties connecting parts.
5. GPS system
   a. Originally, the TX and RX pins were switched. The GPS_RX was connected to the MSP_RX and GPS_TX to the MSP_TX. What was really needed was for the GPS_RX to go to the MSP_TX and GPS_TX to go to the MSP_RX.
   b. Research had to be done on what sentences actually come out of the GPS. The ones that

had timestamps were found and then searched for and used to determine current time.

    i. The sentence searched for in this project was RMC (Recommended minimum)
    ii. This sentence gives the current GPS position velocity and time

c. String creations, when hours or minutes were below 10, needed to store a zero in front. The same issue resurfaced when triggering the alarm. It was fixed by comparing specific sections of the strings from alarm time to GPS time.
d. RX interrupt was constantly triggering, causing all other features to fail. There is a register in the MSP430 that is used to control the UART communication. This register contains bits that can be set to set limitations on the UART. The register is called UCA0CTL1. Setting the UCDORM bit in UCA0CTL1 caused the RX interrupt to be ignored until the UCDORM bit was cleared. This essentially disables the UART and therefore the GPS signal until the register is reset.
e. Small bug was that the hour string in the GPS time was sometimes a random 3 digit number. Fixed this by setting the hour to be the "previous" value if the current value was ever above 12.
f. Errors in actually acquiring a signal with the GPS antenna. Required maneuvering and relocation to catch the GPS signal itself to start the clock.

Version 2.0:

Given more time, or a chance to redo the system, there will always be a few things that may have been done to make the system better. Much of this falls to the category of needing more money to complete, but can still improve the project. Below is a short list of items that would improve the usefulness and worth of the device.

1. A power module that is either better documented, or better working would improve the system.
    a. Possibly a more expensive module would be necessary.

2. Including some sort of sensor to determine the amount of spray left to tell the user when to purchase more would be useful.
3. More Mechanical design and time could have been spent on building a better enclosure for the system.
4. A better PCB would have been worth spending a bit more money on in order to ensure the system would work well.
5. Surveys of public, to determine what features would be nice, or what would be a waste of engineering time.

Conclusion:

This project as a whole was a very educational experience. The project began in September of 2016 and ended in June of 2017. Fall quarter of 2016 was the planning and conceptualization phase. Winter quarter 2017 turned into the first developmental and purchasing phases. This concluded with Spring 2017 where things were all put together in order to get the system up and running. Many bugs and roadblocks occurred along the way to the completion of the project. The biggest obstacle was the idea of the gas sensor. After much research, it seems that the technology just is not at the point necessary to achieve the desired feature for the device. Several tests and bugs helped teach different tricks and ideas that could increase efficiency in code, or hardware design, or even both. Hardware and software were combined to create a successful Senior Project. Even mechanical aspects were touched in order to complete the final product. Using drills, saws, and blades, an enclosure was constructed that showed good experience in basic mechanical design. The enclosure showed the importance of taking physical measurements to make sure holes weren't too big, too small, or in the wrong place. Many obstacles were conquered which resulted in several learning experiences and team driven situations like leadership and patience.

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Appendix A. Analysis of Senior Project

Project Title: Make Scents

Students: Dennis Tsuker & Bruce Mitchener

Summary of Functional Requirements

The system will be a "smart" air freshener. It will spray at designated times in the day (like an alarm) or after a set time has passed. An LCD will display time to the user. To control the spray times and the LCD as well as monitor battery levels, an MSP430 microcontroller with an infrared sensor and remote controller will be used.

Primary Constraints

Programming constraints include interfacing all the requirements to run together without one requirement causing another to fail. A smaller constraint will be how to design the enclosure for the system. Research will need to be conducted in order to determine the best mechanics of automated air freshening.

Economic

1. What economic impacts result?
    a. Human Capital:
        i. This system will bring many manufacturing, engineering, and sales opportunities to the table, creating many important jobs for people around the world.
    b. Financial Capital:
        i. Over time, this project will save customers money when compared to the competitor's products.
    c. Natural Capital:
        i. Proper recycling of the electrical components in this system, as well as the freshener refills will make for big natural capital

gains. This will be encouraged to all consumers.

d. Costs

i. The system costs around $50 to manufacture, which will place the retail price at about $70. The goal is to begin commercial manufacturing as soon as possible after the project showcase, with a goal of July or August 2017.

If manufactured on a commercial basis

It can be expected that around 1000 products be sold in the first year. manufacturing costs should be about 50 dollars. If sold for 70 dollars, the expected profit will be $20k. Refill tanks will also be necessary for the customers, so selling them these will also give additional profit.

Environmental

1. What environmental impacts are associated with manufacturing or use?
    a. Although progress is being made, current air freshening sprays tend to be slightly harmful to the environment. Additionally, the fabrication of electrical components also has some environmental issues.
2. Which natural resources and ecosystem services does the project use (directly and indirectly), improve, or harm?
    a. Depending on the air freshener purchased by the user, the chemicals involved in certain air freshener brands can take a toll on the ecosystem.
3. How does the project impact other species?
    a. The product should not impact other species, due to the fact that it is a household device. It should only be needed to improve the scent of the consumers' homes.

Manufacturability

Some issues in manufacturability are that the system is intended to be on the smaller end. Physical labor involved with enclosure design and attaching components to the enclosure, will increase system cost. These costs can be lowered with better overall enclosure design. Other factors include the fragility of parts in the system, calling for more delicate labor to manufacture each system.

Sustainability

1. Describe any issues or challenges associated with maintaining the completed device.
    a. Some challenges with maintenance of the device may include repairability. If parts such as the servo motor are to break, the system would require a completely new part to be fixed. Parts like the freshener will also have to be repurchased over time as the system uses up the original can's contents.
2. Describe how the product impacts the sustainable use of resources.
    a. The system reduces excess freshener being used, helping the user spend less money on refills that other systems require. Customers will still need refills, but these refills will be much less frequent.
3. Describe any upgrades that would improve the design of the project.
    a. To improve the design of this project, a way to track how much freshener is left in the system, a way to gauge need for spray in the room, or making the system run on rechargeable batteries.
4. Describe any issues or challenges associated with upgrading the design.
    a. Upgrading the design will be difficult because it will take reconfiguration of code in the system as well as reallocation of space in the physical system.

Ethical

This system could be a good way to make consumers have a more positive outlook on advancements in technology. It is a system that will require less work out of the user to offer more enjoyment of their home life due to pleasant smells.

Health and Safety

Our product is not dangerous, but if misused, it may cause some harm. Standing too close to the spray area may cause freshener to land on skin (which to those with very sensitive skin, may cause rashes or irritation) or even in the eyes of consumers. This can be combated with a warning label by the spray hole that can deter the user from coming too close.

Social and Political

The system must work according to advertised specifications in order to keep and grow our customer base. Additionally, the product will be sold in many companies' stores and must be able to uphold the standards of their practice.

Development

Development for this project will come from researching the sensors needed, enclosure design, and power options. Understanding of power systems running on rechargeable batteries, the mechanics of automated air freshening, and sensor integration techniques will be gained from this project. One other tool learned will be system packaging, as the system will need an outer casing.

Appendix B. Code State Diagram