Final Report
Olfaction Satisfaction

Team 8:
Pearl Yeung
Chris Ambler
Emily Heuer

NSF Engineering Design Projects:
Olfactory Stimulation Device

Client Contact:
Dr. Hallowell
Passion Works
21 S. Campbell Street
Athens, OH 45701
740-593-1356
# Table of Contents

Abstract 3
1 Introduction 4 - 6
2 Project Design 7 -
   2.1 Alternative Designs 9 - 18
      2.1.1 Design One 9 - 12
      2.1.2 Design Two 12 - 15
      2.1.3 Design Three 15 - 18
   2.2 Optimal Design 18 - 61
      2.2.1 Objective 18 - 20
      2.2.2 Subunits 21 - 59
         2.2.2.1 Structure 21 - 27
         2.2.2.2 User Interface 27 - 29
         2.2.2.3 Display 29 - 31
         2.2.2.4 Fragrance Dispersion System 31 - 36
         2.2.2.5 Circuitry 37 - 46
            2.2.2.5.1 Main Circuit 37 - 38
            2.2.2.5.2 Sound Chip Circuit 38 - 39
            2.2.2.5.3 LED Components Circuit 39 - 42
            2.2.2.5.4 Solenoid Circuit 43 - 45
            2.2.2.5.5 Power Supply 45 - 46
      2.2.2.6 Switches 46 - 47
      2.2.2.7 Microprocessor 48 - 59
      2.2.3 Analysis 59 - 61
         2.2.3.1 Experimental Analysis 59 - 60
         2.2.3.2 Air Flow Calculations 60 - 61
   2.3 Prototype 61 - 87
      2.3.1 General Description 61 - 85
      2.3.2 Testing 85 - 87
3 Realistic Constraints 87 - 90
   3.1 Engineering Standards 87 - 88
   3.2 Realistic Constraints 88 - 90
4 Safety Issues 90 - 91
5 Impact of Engineering 91 - 93
   5.1 Economic Impact 91 - 92
   5.2 Social Impact 92
   5.3 Global Impact 92 - 93
6 Life-long Learning 93 - 94
7 Budget 94 - 96
8 Team Member Contribution to the Project 96 - 97
   8.1 Pearl Yeung 96
   8.2 Chris Ambler 97
   8.3 Emily Heuer 97
9 Conclusion 97 - 98
10 References 98
11 Acknowledgements 99
12 Appendix 99 - 102
   12.1 Additional Information 99 - 101
      12.1.1 Existing Market 99 - 101
      12.1.2 Patents 101
   12.2 Specifications 102
      12.2.1 Electrical Parameters 102
      12.2.2 Mechanical Parameters 102
      12.2.3 Environmental Parameters 102
Abstract

*Olfaction Satisfaction* is an olfactory stimulation device designed for Passion Works Studio, which provides aid and services to severely disabled adults. Individuals with severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide stimulation of the individual’s senses, in particular the olfactory sense. Activities such as watching television or playing video games are too complex for such individuals to adequately enjoy. For this reason, simple interactive devices are needed to stimulate the individual’s senses of touch, sight, and hearing. The sense of smell, however, is largely without stimulation in many devices and, as a result, the individual’s sense of smell is left without stimulation. Therefore, the purpose of the *Olfaction Satisfaction* device is to stimulate the olfactory senses in conjunction with the other senses of touch, sight, and hearing. This provides the individual with a more complete stimulation of the senses.

Designed with the purpose of meeting the client’s needs, the *Olfaction Satisfaction* device not only does so, but also addresses issues that are found in current devices on the market today. Analysis of existing designs shows that there is a lack of devices possessing olfactory stimulation technology designed to meet the needs of disabled adults. Although the need exists for designs geared towards disabled children, the needs of disabled adults cannot be ignored. Designed with disabled adults in mind, the *Olfaction Satisfaction* device meets a market demand that has been previously overlooked. Able to be renewed with new and different scents, the *Olfaction Satisfaction* device becomes a new sensory experience every time the scents are changed, making it both cost-effective and easy to clean and maintain. In consideration of these points, it is easy to see how this device will have a positive impact on the quality of life of the user and make an easy to maintain addition to the Passion Works Studio.
1 Introduction

The purpose of the project is to develop an olfactory stimulation device for the Passion Works Studio, which caters to the needs of severely disabled adults. Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide stimulation of the individual’s senses. Activities such as watching television or playing video games are far too complex for such individuals to enjoy. For this reason, simple interactive devices have been developed previously to stimulate the individual’s senses of touch, sight, and hearing.

However, the sense of smell is largely without stimulation in these devices and, as a result, the individual’s sense of smell is left without stimulation. Therefore, the purpose of the olfactory stimulation device is to stimulate the olfactory senses in conjunction with the other senses of touch, sight, and hearing. This provides the individual with a more complete stimulation of the senses.

It is important to note, however, that the design of Olfaction Satisfaction is purely for recreation or entertainment purposes. Devices designed with the purpose of teaching or improving coordination are ineffective and undesired by the client. A device with an easy to use interface that offers a more complete stimulation of the senses is the main requirement by the Passion Works Studio.

In addition to this basic requirement, a safe, durable and battery powered design is also desired in order to meet with the needs of the disabled adults who will use it. Power cords can be tripped over, chewed on, and choked on by some; hence a battery powered device is preferred. Furthermore, external protrusions and moving parts are a known hazard to the client’s safety; therefore a smooth outer exterior is needed. Furthermore, the possibility of rough handling of the device makes durability a big factor to its lifetime and usefulness. For this reason, it is necessary for Olfaction Satisfaction to possess a secure chassis and a durable outer cover.

It must be emphasized, however, that the disabled individuals require a device that is simple to use. It is known that devices that are too complex to use will frustrate and anger the disabled individuals. Hence, the olfactory stimulation device will emit scent upon input from a simple adaptive switch interface that is controlled by the user. Finally, the device must be durable and be able to withstand repetitive actions (i.e. repetitive activation of the device) that the disabled adults have been known to perform.

The Olfaction Satisfaction device aims to improve the quality of life of disabled adults by providing them with a device that stimulates their olfactory senses in addition to their tactile, visual, and auditory senses. Providing a battery powered, wire-free entertainment device that delivers a more complete stimulation of the senses than conventional devices on the market today. This device will ultimately satisfy a market niche for biomedical devices designed disabled adults which has been left unsatisfied by current devices on the market today.
Conventional stimulation devices made for disabled adults only stimulate their visual, tactile, and auditory senses. The end result is that the olfactory sense is left unstimulated and unused. Due to the constraints of technology, incorporating some method of stimulating the olfactory sense into a product’s design was too costly or impractical. As a result, this important and effective source of sensory stimulation was left untapped. Technology has advanced, however, and so has the design of stimulatory devices for the disabled. It is clear, then, that the most up to date design must include some method of stimulating the sense of smell.

In response to this market demand, several companies have produced designs for devices that will stimulate the olfactory senses of the user (for a more detailed analysis see Appendix, page 99 - 102). These companies are mainly toy companies, however. As a result, the devices are designed specifically for disabled children. While these designs are adequate for their own market niche (namely disabled children), they do not satisfy the needs of disabled adults. The Olfaction Satisfaction device is designed to offer disabled adults a superior and more diverse olfactory stimulation experience at a competitive cost to those on the market that are designed only for children.

An extensive patent search confirms this conclusion as well. No patents on devices focused on sensory stimulation and geared towards disabled adults were found. A search on the US Patent Office website for patents with the words ‘olfactory’, ‘fragrance’, ‘stimulation’, ‘scent’, etc yielded few devices designed with recreation or entertainment in mind. Most devices found were designed with medical purposes in mind (i.e. aroma therapy) or were designed for children (a list of such patents is found in the Appendix, page 101).

In addition to the current devises on the public market, there are also other NSF funded projects in progress that are intended to further explore olfactory stimulation technology and its use as a biomedical device. These designs, however, also have problems which make them unsuitable for use with a disabled adult. The Olfaction Satisfaction device has been designed specifically to meet the abilities and needs of disabled adults who lack adequate stimulation in their daily routine. With this in mind, it is easy to see how the Olfaction Satisfaction device has the capacity to greatly improve the client’s quality of life.

It is apparent from market research that no product currently exists that possesses all of the desired characteristics of the Olfaction Satisfaction device despite the obvious need. No product was found that provided olfactory stimulation for recreation purposes for disabled adults with the following properties: independent user operation (i.e. no supervision required, safe), battery operation, durability, stability, and adequate mobility.

Offering durability, easy maintenance, a cost effective design, and a user friendly interface, the Olfaction Satisfaction device promises to deliver a more complete stimulation of the senses than previous devices designed for disabled adults. Designed with versatility in mind, the Olfaction Satisfaction device contains 6 removable aerosol
canisters which allow it to stimulate with a variety of different scents. The removable canisters also allow for easy cleaning and maintenance.

*Olfaction Satisfaction* also includes the ability to remove and swap out different user interface components, making the user interface extremely versatile and able to meet the motor skills of a wide variety of disabled adults. Furthermore, this ease of use is complimented with a simple to understand user interface, ensuring that the user will receive stimulation in one form or another regardless of cognitive ability. So long as the user is able to activate an interface component, the device will respond.

Furthermore, the simple and durable design principle behind the device ensures that little to no supervision will be required when using it. It is designed to eliminate the possibility of the user harming his or her self if the device is mishandled. This same principle makes the design mobile enough to be used anywhere, but also stable enough to remain firmly in place when used.

With these features, it is clear that the *Olfaction Satisfaction* device has the capacity to become a frontrunner for biomedical devises designed to improve the quality of life of disabled adults through the use of olfactory stimulation technology. With this in mind, it is advantageous to consider and discuss the optimal design in detail and to also consider the designs that preceded it. Following this, a discussion on budget and project timeline is called for. Lastly, a concluding word is presented with final thoughts concerning the project and its impact.
 Upon careful consideration, Design Three with several advantageous modifications was chosen for the final design based on the desired specifications and special considerations. It was fairly obvious after review of the three initial designs that Design Three was clearly superior to Design One and Two. These first two designs were simply unnecessarily complicated, involved and relatively fragile. For instance, Design One employed an expensive step motor that added complexity to the device rather than efficiency. It also employed a problematic vacuum system that proved to be completely excessive after experimental calculations. Additionally, the cylindrical shape of the outer casing would have been very difficult to manufacture. The major source of complication in Design Two involved air flow control. The need for fragrance flaps made the device expensive, complex, and difficult to manufacture. In addition, the fragrance oils used for the fragrance source would likely have been very messy and unreadily available. The base designs were also inappropriate due to the fact that using a wood as a material is not allowed. Lastly, Design One and Two lacked the added enhancement of sound and sight stimulation present in Design Three.

Even though Design Three was clearly the superior design, it was still necessary to make several modifications in order to further optimize the device. The first and most simple of these modifications was to move the user switch interface holes from the front of the device to one of the sides. This eliminated any problems associated with interchanging the switches (the front is covered with a protective casing). In addition, the Optimal Design employs LED technology instead of Christmas lights. LEDs are less expensive and will last indefinitely. This reduces waste and expense. Along with the visual display, the sound effects were also enhanced. The circuitry of the design was also reevaluated in order to incorporate the changes and function more efficiently. The microprocessor program also had to be modified to accommodate these alterations. Lastly, the budget was reevaluated to decrease the total expense of device. This involved locating new parts and design compromises.

Modified Design Three met the following desired specifications: user-friendliness, durability, easy maintenance, versatility, and safety. In addition, Design Three also maintained the desired characteristics outlined in the project statement including a 2 feet by 2 feet footprint and battery operation. In terms of user-friendliness, Design Three combined user-specific control switches with a simple operating system. Design Three also presented the user with additional stimulation to further enhance the entertaining experience. Due to the design’s structure and material composition, the device can be considered to withstand everyday use. Its durability is also augmented by a protective casing surrounding the front panel. Design Three also offered the easiest user maintenance. With the addition of a fragrance access flap, the process of removing and loading fragrance sources became extremely simple. An additional access flap in the base provided an excellent way of accessing the battery for recharging. A rechargeable battery also reduces maintenance efforts by eliminating the cost of new batteries. Similarly, choosing LEDs as the light source eliminated the cost and effort of replacing other types such as Christmas tree light bulbs. Lastly, aerosol spray air fresheners were chosen as the fragrance source because can be purchased at a multitude of popular
grocery and drug stores. Design Three also exhibits versatility. The device offers a variety of scents which continually provide adequate stimulation. These scents can also be exchanged based on user input creating further variety. In addition to providing olfactory stimulation, the device also stimulates the sense of hearing and sight. Design Three also has several safety features. The air entrance and exit holes are adequately covered to protect the user and device from damage. The on/off switch, fragrance access panel, and battery compartment are key operated to prevent unwanted use. Finally, all electrical components are secure and electrically insulated within the device.

As mentioned, the choice of the final design was also based on several special considerations. These include: economic, manufacturability, sustainability, environment, health and safety, social, political, and ethical. Looking at the device from an economic point of view, it achieves a compromise between quality and quantity. While keeping costs at a minimum, Design Three was still able to meet the client’s need in an effective and valuable manner. Design Three was even able to incorporate additional features and still maintain total costs comparable to the other devices currently offered that lack all desired characteristics. In accordance with economic considerations, Design Three also maintained the best manufacturability potential. The majority of the device is composed of PVC sheeting, a material known for its ease of processing and machining. The remainder of the device build simply consists of electrical component assembly involving mostly soldering. It is important to note, however, that despite the apparent straightforwardness of the device’s manufacture process quality assurance will still need to be rigorously ensured. In addition to these considerations, it is anticipated that this device will sustain its usefulness for its entire lifetime. Design Three offers a quality, versatile product that cannot easily be outmoded both economically and functionally without replication.

As with any device, it is extremely important to consider the environmental impact of its manufacturing procedure and use. The major source of environmental concern with device is the disposal of the PVC, empty air freshener cans, and electrical components at the end of the device’s useful life. One of the biggest downfalls associated with the use of PVC entails its disposal procedure since it does not biodegrade at a significant rate. Large scale recycling is nearly impossible due to the extent of additives present in the PVC. These additives also interfere with the recycling process of other plastics (“PVC Plastics”). It has been stated, however, that when compared to other material choices PVC is actually favorable recycling wise. Special facilities now exist with the capability to deal with the complex process of properly recycling PVC (“PVC in Building & Construction”). The recycling of aerosol cans is also not straightforward. In addition to this difficulty, studies claim that substances contained in items such as air fresheners contribute to both indoor and outdoor air pollution (Bridges). These studies have yet to be accepted universally, however. Design Three reduces some electrical waste by using permanent LEDs and a rechargeable battery. It is also extremely important to consider the impact of the device on the health and safety of the individuals connected with the device including the user. The two biggest health and safety concerns associated with this device involve the PVC sheeting and the aerosol air fresheners. Many toxic byproducts result from the production of PVC including dioxin, ethylene dichloride, and vinyl chloride. These have the potential to cause cancer, endocrine disruption,
endometriosis, neurological damage, birth defects, and immune system damage if not properly dealt with. Chemical stabilizers remaining in the PVC such as lead or cadmium can potentially increase the risk of asthma, lead poisoning, and cancer if they leach, flake, or outgas overtime from the PVC (“PVC Plastics”). Although the production of PVC is uncontrollable, warranting a specific life span for the device after which risks become significant should be considered. Evidence also exists linking substances found in aerosol air fresheners to a multitude of medical conditions. For instance, it has been shown that excessive exposure may cause headaches, nausea, shortness of breath, eye, throat and lung irritation, skin rashes, burns and liver damage (“Indoor Air Pollution”). It might be necessary to set a daily time limit for device use per individual based on these observations. Additionally, aerosol air fresheners have the potential to explode when exposed to excessive heat. Explosions could result in serious injuries to nearby individuals (“Indoor Air Pollution”). Because of this, it will important to maintain an operating temperature below 120 °F.

One of the most positive aspects of this device is its social contribution. By providing acceptable stimulation to adults with severe disabilities, the device aims to improve the quality of life for these individuals. Because of this, it is unlikely to detriment society in any manner. From a political perspective, the device does not have a significant impact. Its design and use does not impinge upon the American with Disabilities Act or any other pertinent legislation. From an ethical perspective, the device does not raise any issues excluding those involved with its safety and environmental impact.

2.1 Design Alternatives

2.1.1 Design One

The first olfactory stimulation design illustrates a more cylindrical shape as seen in Figure 1. Therefore, it presents a more challenging and complex design that contains many components. Such components are the wooden carpet base, the chassis containing six different fragrance chambers with an accessible lid, user interfaces, air vacuum system, electrical circuitry, stepper motor and the fan assembly.
The wooden base provides stability for the cylindrical device and protection for the user. The user-friendly interface will consist of an on/off switch and two switches. The on/off switch will be a SPST master key switch so that it is only accessible to supervisors as oppose to the intended user. This single pole switch will have three positions (on-off-on) with position two as the key removable position (off position).

The two switches, on the other hand, will be tailored to the individuals and have the option to be interchangeable. These switches were specified from Passion Works to be a squish switch and a large touch pad that can be purchase at TFHusa.com. The electrical components will include an electrical circuit board and a power supply to provide power and control for the switches, stepper motor, fan, and vacuum fans. A total of six fragrance chambers arranged in a circular fashion will hold the six possible scented. Each fragrance is oil-base which will be absorbed into a sponge to comply with the spill-proof specification. Each six fragrance chambers will be easily remove and fitted perfectly to the chassis frame that utilizes the stepper motor to rotate the chambers.

There will be three fans incorporated in the device; one fan will dissipate the desire chamber scent by directly fixing it in the center of the chassis align with the outlet, while the other two fans are use in the air vacuum system. The air vacuum system will be place around the device with two openings, both facing the user interface. Each opening will be provided with a wire mesh for safety. The circular tube surrounding the device contains two inexpensive filtered muffin fans. One fan will primarily draw in air from
the environment and another will blow unscented cleansed air out of the system. This system will be continuously on as it clears the air so another scent can be chosen.

The structure contains two different parts; the cylindrical casing and the base, both using different types of materials. The materials use in the rectangular base will be constructed from sanded pine plywood sheets. Plywood was chosen on basis of its strength, stiffness, easy handling, and cost-effectiveness. A simple square frame will be assembled using 2 ½ inch drywall screws and wood glue. The remaining plywood pieces will be attached using the screws and glue to the top of bottom of the square frame creating a box. Carpet will be used to cover the entire box for safety purposes. Although sanded, the plywood has rough edges with the potential to cut, scratch, or splinter an individual. The ascetic appeal of the device will also be improved by covering the plywood box with carpet.

For the outer casing of the device and the fragrance chambers will composed of polyvinyl chloride or PVC. PVC was chosen due to its toughness, strength, durability, impact strength, excellent electrical insulation properties, corrosion resistance, ease of bending and processing, and affordability. In order to prevent damage to the device due to rough handling or mistreatment, it is essential that the outer casing have adequate strength and toughness. To prevent damage from accidents, the casing and chambers must also have sufficient impact strength. Since the device will be used frequently, durability is also important. Because one of the main concerns is user safety, it was crucial that the casing be electrically insulated to prevent harm from the electrical components inside the device. Additionally, resistance to corrosion will result in a greater longevity and efficiency for the chambers that will hold either fragrance cartridges or scented oil. Finally, fabrication ease and affordable minimize labor and cost. All these factors can be solved with using PVC due to its excellent physical and manufacturing properties.

The main circuit design is to operate the stepper motor, three fans, power supply and the two switches. In order to operate the stepper motor, a stepper motor driver is needed in the circuit. The stepper motor driver enables the circuit to provide enough current and voltage to power the stepper motor. It also controls the selector switch to rotate the chambers until the activator switch is selected to activate the fan in the chassis for scent dispersion. For the other two fans in the air vacuum system as stated earlier will be connected to the master on/off switch for continuous power operation. As mention before, this helps cleanse and recycle the air for new scent release.

Stepper motors are highly reliable, simple and cost effective that precisely provide a step-wise rotating movement to a designated angle. Every step or rotation is driven by digital pulses from input switch. There are many properties to explore in order to choose a desire stepper motor such as resolution, torque, dimension, and compatible driver board. Resolution is a term used in describing the degrees or radians, a stepper motor takes each step. For our device the resolution must be 60° or \( \frac{\pi}{3} \) radians that is derived by dividing 360° (full circle) by six (six scented fragrances in the top compartment) gives us how far each chamber must be separated. The torque requires must be enough to turn the six chambers each possessing a scented sponge. The dimension of the
stepper motor must be small enough to fit inside the center of the chassis. And an important component to operate the stepper motor is a driver board. A driver board is a circuit design, providing users to control the stepper motor functions such as the resolution, start and stop, and the incorporation of a switch controlling the motor. Gears would be put in place in order to send power to the fan motor at the center of the chassis. This is accomplished by connecting the gear on the stepper motor to an adjacent gear is connected to the top compartment. A chain or belt is used to rotate the top compartment from the gear of the stepper motor to the gear in the chassis. The two gears will contain teeth for better gripping of the chain/belt to rotate the chassis. Therefore, providing an open pathway for the fan leads to connected to the circuit and power supply.

The basic function of this device is using two interchangeable switches; one will be a selector and another will be the activator. Activation of the first switch will activate the stepper motor, causing the fragrance chambers to rotate allowing the user to choose a desired scent. A small fan will be mounted in the center of the chassis, which upon activation of the second switch will activate the fan. Therefore the diffused scent will travel from the fragrance chamber into the atmosphere. Finally, a vacuum system will be continuously on as it clears the air so another scent can be chosen.

2.1.2 Design Two

Design Two (See Figure 2) has several main components. These include the base, exterior and interior casing, user interface, fragrance chamber, electrical circuit, and microprocessor. All of these components work together to provide a safe, entertaining experience for the user. The base provides stability for the device and accessibility for the user. The exterior and interior casing will protect the various components of the device from damage as well as prevent user injury by covering potentially dangerous components. The user interface will consist of an on/off switch and two user switches. The on/off switch will be a master key switch so that it is only accessible to supervisors as oppose to the intended user. The two switches, on the other hand, will be tailored to the individuals and have the option of interchanging the two switches. A total of six fragrance chambers will hold the six possible fragrances. Selection of the first switch will choose the desired scent. Activation of the second switch will activate the corresponding fan causing the fragrance to be diffused into the atmosphere. In addition to the six fans present in the fragrance chambers, a seventh fan is present to clear the air after each scent is dispersed. The electrical circuit and power supply will provide power for the switches, microprocessor, and fans. The microprocessor controls the selection and activation of the fans in the fragrance chambers through input from the switches.
The device will be attached to a rectangular base resting on the floor to provide stability and protection. This rectangular base will be constructed from sanded pine plywood sheets. Plywood was chosen on basis of its strength, stiffness, easy handling, and cost-effectiveness. Carpet will be used to cover the entire box for safety purposes and ascetic appeal.

Like the base, the exterior and interior casing will be constructed mainly of sanded pine plywood. In addition, the casing needs coverage for safety purposes. Elephant bark rubber was chosen for this purpose.

As mentioned in the general description, the user will be able to use two interchangeable switches to choose and select one of six available scents. The two possible are a squish switch and a large touch pad switch. In addition to these switches, a keyed on/off switch will also be present on the exterior of the device. It is located in the back to further decrease accessibility for the user and to enhance aesthetic appeal of the front of the device. Next to the on/off switch is a keyed battery compartment door. This door serves to increase functionality of the device by facilitating the battery changing procedure. The scents will diffuse through one of six fragrance dispersion holes on the exterior of the device into the surrounding atmosphere. Wire mesh will be used to prevent unwanted user entry and a flap will be used to prevent scent from exiting the device when it is not selected. In addition to the six fragrance dispersion holes, an air intake hole and an air venting hole will be located on the exterior of the device. The intake hole provides air for the multiple fans and the venting hole combined with a fan will pump fresh air into the surrounding atmosphere to disperse each activated fragrance.
The interior of the device holds six scent chambers divided by the plywood casing. The scent chamber (see Figure 3) itself will consist of PVC piping. PVC was chosen due to its toughness, strength, durability, impact strength, excellent electrical insulation properties, corrosion resistance, ease of bending and processing, and affordability. The design of these PVC holders will allow for easy removal and exchange of different scents. The different scents will be in the form of a sponge damp with scented oil or retail fragrance cartridge. Like the exterior hole of the scent chambers, the interior side will also possess a flap. This flap will also prevent fragrance dispersion at undesired times. Once the fan is activated, the air pressure generated by the fan will cause the interior flap to rise, diffuse the desired fragrance, cause exterior flap to rise, and disperse fragrance into the outside atmosphere. Once the fan is deactivated, the flap will lower to its original position due to lack of external force.

![Figure 3: Interior View of Single Compartment](image)

The electrical circuit is designed to operate the interface of the two switches and the seven fan motors. As previously discussed, each fan motor diffuses a specific scent, and the last fan motor is activated in parallel with the activator switch to cleanse the air as the user selects another scent. Figure 4 illustrates a schematic diagram on the operation of the main electrical components.
The Microprocessor is essentially the brain within the device. It will be responsible for activating each of the seven fans of the device based on input from the user. The PIC microprocessor must be programmed via assembly code. This code will be generated from the conversion of a C++ program using a code converter.

2.1.3 Design Three

Design Three (See Figure 5) has several main components. These include the base, casing, user interface, sound and visual elements, fragrance dispersion system, electrical circuit, and microprocessor. All of these components work together to provide a safe, entertaining experience for the user. The base provides the rest of the components with essential stability and protection. The casing will house the fragrance dispersion system as well as the visual and auditory stimulation systems. The user interface consists of two switches. The first termed selector switch will cycle through the six scent choices and the second termed activator switch will activate the desired scent. The sound and visual elements will provide additional stimulation upon activation of a particular scent. The operation of the fragrance dispersion system is rather simple. Once the device is turned on, a fan located in the back panel of the device will run continuously. It serves two functions. When a fragrance is activated, it provides the vehicle for diffusing the dispersed fragrance into the outside atmosphere. When a fragrance is not activated, it clears the chamber and surrounding atmosphere of the previously activated fragrance. It was determined experimentally that it takes roughly 12 seconds for the dispersed scent to clear the immediate area. The electrical circuit contains all of the electrical elements of the device including the sound and visual elements. The microprocessor will control all these electrical elements based on user input.
Figure 5: Design Three

The base is designed to rest directly on the floor to provide easy access to the user and will be constructed out of PVC sheeting. In addition, this particular PVC sheeting can also be painted or screen printed. The 2’ x 2’ x 0.5’ rectangular base will be composed of six individual sheets of PVC sheeting. Because the base has rough edges upon construction with the potential to harm the user, all the edges will be smoothed and rounded using a special tool.

The device casing will also be constructed of PVC sheets. The 2’ x 1.5’ x 8” rectangular case will be composed of eight individual panels. The top and bottom panel will simply be a flat sheet. The exterior sides will have a flap access to the fragrance source attached using a surface mount hinge and secured with a cam lock. The front panel contains several important features: switch adapter plugs, a speaker, light display, and fragrance dispersion hole. In order to protect the device and to prevent user injury, the front panel will be incased in clear PVC. The back panel will contain an air intake hole covered with plastic mesh that houses the fan and the on/off switch. The interior chamber sides will be used to form an interior chamber for fragrance dispersion inside the middle of the device.

The two interchangeable user switches requested by the client are a squish switch and a large touch pad. These switches will interface with the device via two stereo jacks located on the exterior of the device. The on/off switch will be a SPDT key switch in order to prevent the user from turning the device off and on.
Besides providing olfactory stimulation, this design will incorporate sound and visual elements. Whenever the user selects or activates a desire scent, a several second long sound will be simultaneously activated to stimulate the sense of hearing. Multi-colored Christmas light bulbs will also be installed into the front panel of the device casing for visual stimulation. A collection of six of these bulbs will line the bottom edge of the front panel. Each of these will correspond to one of the fragrances choices. The light bulb corresponding to the currently selected fragrance will be lit. In addition to these six, a collection of 19 will cover the rest of the front panel. Upon activation of a particular scent, these lights will light up in a particular pattern.

The fragrance source will be an aerosol air freshener. These cans will be easy to remove and load into the device via the previously mentioned access panel. The can will simply be loaded horizontally into a holder constructed out of clear PVC piping. When the panel is closed, the aerosol spray can will be locked in place. Push Solenoids (See Figure 6) will be used to activate the spray on the aerosol air fresheners. A solenoid converts electrical energy into linear mechanical work. When the activator switch is pushed, an electrical signal will be sent to the appropriate solenoid. Once the solenoid is activated, the plunger will push on the aerosol dispensing button releasing scent into the interior scent chamber. The stroke distance needed to dispense the proper amount of spray will need to be determined. Also, the fans used will be equipment cooling fans.

*Figure 6: Fragrance Dispersion System*
As seen above, the circuit for this design is straightforward but contains many electrical components including the sound chips, solenoids, fan, PIC microprocessor, user switches, on/off switch, and light bulbs.

The microprocessor is essentially the brain of the device. It will be responsible for initiating the various elements of the device based on input from the user. For example, when the user activates a particular scent, the microprocessor will send the appropriate signal to the corresponding solenoid to diffuse that scent. In addition, it will also send the appropriate signal to the Christmas lights and sound chips.

2.2 Optimal Design

2.2.1 Objective

This olfactory stimulation device, termed Olfaction Satisfaction (See Figure 9), is designed for use by adults with severe cognitive and motor disabilities. It will be incorporated into a multisensory stimulation room located in the Passion Works facility. Its main goal is to provide olfactory stimulation in an entertaining form in effort to increase the quality of life for the aforementioned adults. In order to achieve this goal, the device will operate in the following manner. The user will be able to operate the device with two user-friendly switches, termed the selector and activator switch. To maximize user accessibility, two types of switches will be available for use. These will easily be interchangeable. Using the selector switch, the user will be able to relay among six different fragrance choices. For clarity and additional stimulation purposes, selection of a fragrance choice will be indicated by the activation of a corresponding red LED. Once the user has decided upon the desired scent, the user can then use the activator switch to activate the fragrance. Upon activation, the desired scent will be released into the surrounding atmosphere via holes on the front exterior of the device. After activation, the selector switch can be used once again to choose a different scent or the
activator switch can be used to activate the same fragrance again. This process of selection and activation can potentially continue indefinitely.

Figure 9: Olfaction Satisfaction

From this operation, the device can be broken into five subunits. These subunits are structure, user interface, display, fragrance dispersion system, and circuitry. The structure can be broken into two portions: the base and the device casing. Although the base is simple in design, it provides essential stability and protection for the device. It was designed to rest directly on the floor to provide easy access to the user. Most of the projected users are most comfortable lying/sitting on the floor with a bean bag or pillow for comfort. In addition, both the base and device casing will be constructed in such a manner to minimize user damage resulting from any mishandling of the device. The weight of the structure is also such that mobility of the device is possible while still maintaining stability. In other words, supervisors would be able to move the device but the user would not be able to tip or slide it during use. The base will contain a storage compartment and the electrical apparatus, while the casing will contain the fragrance spray mechanism and the fragrance source.
The user interface consists of essentially three components. The first of these components is the already mentioned selector and activator switches. These will interface with the device through plugs located on the exterior of the base. Because the switches come with cords, the user is not limited position wise during use of this device. The second component of the device is an on/off switch. In order to prevent the user from shutting the device off or turning the device on, the on/off switch will be a key switch only accessible to Passion Works supervisors. It will also be located on the exterior of the base. The final component is the fragrance and battery access located on either side of the device and the base, respectively. To prevent undesired openings of these panels, a cam lock will be used to hold each in place during operation of the device. The fragrance/battery access provides a simple and effective manner for removing and loading the fragrance sources and batteries. Battery-operation was chosen to eliminate safety-hazards involved with electric cords. Because of the simplicity and safety incorporated into these components, minimal supervision is necessary during use.

In addition to the olfactory stimulation, auditory and visual stimulation was added to enhance the entertaining experience of the user. The auditory portion consists of four sound effects and their associated speakers. When a new fragrance is selected, a short “ping” sound will be activated. Upon activation of that fragrance, one of three animal calls will be activated. The visual portion consists of two light displays. As mentioned, the first display consists of six red LED located on the front exterior of the device that correspond to each of the six fragrance choices. The second display consists of two similar LED patterns in multiple colors on either side of the front exterior of the device. Once again, activation of a particular fragrance will activate this light display.

The fragrance dispersion system consists of the components involved in diffusing a desired fragrance into the atmosphere surrounding the device. As mentioned previously, the device will have six possible fragrance choices. The fragrance source will be an aerosol can air freshener. A variety of possible scents is important because it allows the client to individualize the device, choosing scents that would be most compatible with the user. Along with this, it is also important that the fragrance source will be available at local retailers. By using an easily acquired fragrance source, the ease of maintenance is augmented. This system operates as follows. Once the device is turned on, two fans located in the back panel of the device will run continuously. This will generate air flow from the back exterior through an interior chamber into the front atmosphere of the device. It serves two functions. When a fragrance is activated, it provides the vehicle for diffusing the dispersed fragrance into the outside atmosphere. When a fragrance is not activated, it clears the chamber and surrounding atmosphere of the previously activated fragrance. Push solenoids will be used to activate the spray on the aerosol air fresheners.

The circuitry provides the power and control necessary to run the device. It’s based primarily on use of a microprocessor. It can be divided into electric circuit schematic, sound chip and speakers, LED components, solenoids, power supply, and microprocessor.
### 2.2.2 Subunits

#### 2.2.2.1 Structure

The base and device casing will be constructed out of Gray PVC sheeting. The PVC sheets thickness of the base will be 0.375”, the device casing will be 0.25”, and the protective screen for the LEDs will be using clear PVC sheets with a thickness of 0.0625”. There will be a total of forty-seven 1” length metal flat-head screws used throughout the assembly for the base and the casing. Nineteen 0.125” length metal flat-head screws would be use on the two access panel hinges. The rest of the assembly would be constructed by PVC cement glue.

<table>
<thead>
<tr>
<th>Operating Temperature</th>
<th>Tensile Strength</th>
<th>Impact Strength</th>
<th>Hardness</th>
<th>Dielectric Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>40° to 140° F</td>
<td>7500 psi</td>
<td>1 ft-lb/in²</td>
<td>Shore D: 89</td>
<td>544 V/mil</td>
</tr>
</tbody>
</table>

PVC was chosen due to its toughness, strength, durability, impact strength, excellent electrical insulation properties, corrosion resistance, ease of bending/processing, and affordability. In addition, the PVC sheeting can also be painted or screen printed. Because the base and device have rough edges upon construction with the potential to harm the user, all the edges will be smoothed and rounded using a filer or a deburred tool.

The assembly of the base PVC sheets will require PVC cement glue, six flat-head metal screws for the access panel hinge, and three flat-head metal screws to support the switches interface panel adjacent to the access door. The 16” (L) x 13” (W) x 5” (H) rectangular base (See Fig. 10 & 11) will be composed of six individual sheets of PVC sheeting with the following dimensions:

<table>
<thead>
<tr>
<th>Piece Description</th>
<th>Length</th>
<th>Width/Height</th>
<th>Number of Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top and Bottom</td>
<td>16 in</td>
<td>13 in (W)</td>
<td>2</td>
</tr>
<tr>
<td>Front and Back</td>
<td>16 in</td>
<td>5 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>Sides</td>
<td>12.25 in</td>
<td>5 in (H)</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 2: Dimensions of Base PVC Sheets**

![Figure 10: Front, Back, and Side Panels of the Base](image-url)
Some of the components available within the base are storage space for the switches, and electrical components such as the sound chips, PCB board, and the battery. The storage space would be separated with a divider plate from the electrical components. The exterior features of the base are the access panel and the user interface. The access panel contains a specific cam-lock to lock users from accessing electrical components within the base. The access panel provides easy accessibility to the storage space for the two switches and the battery compartment. Individuals will have no problems removing the battery from the base for recharging because it’ll be Velcro-ed to the base. In addition, the box containing the sounds chips, and the PCB box will also be safely Velcro- on the base. The Velcro strongly holds these components onto the base and allows personnel to easily remove them without the hassle of screws.

The user interface will be located adjacent to the access panel that includes the jack inputs for the activator, selector and on/off key switches (See Fig. 12). These components will be located on the side of the device in order to safely keep users from contacting with the components. Three screws were used to support and hold the user interface with the base, where two screws are use to hold the interface with the bottom panel of the base and another screw on the side of the base.

The main 14” (L) x 10” (W) x 18.5” (H) device casing with a thickness of 0.25” will be composed of eight individual panels with the following dimensions:
Table 3: Dimensions of Casing PVC Sheets

<table>
<thead>
<tr>
<th>Piece Description</th>
<th>Length</th>
<th>Width/Height</th>
<th>Number of Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top/Bottom</td>
<td>14 in.</td>
<td>10 in. (W)</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Sides</td>
<td>10 in</td>
<td>10 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>(Access Panels)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front/Back</td>
<td>13.5 in</td>
<td>18 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>Interior Chamber Sides</td>
<td>10 in</td>
<td>8 in (H)</td>
<td>2</td>
</tr>
</tbody>
</table>

The top and bottom panel will simply be a flat sheet (See Fig. 13). To assemble the top lid onto the case, there will be four screws on each corner to hold two corners of the interior chamber sides. For the bottom panel, the two longer sides (14 in) will hold the front and back panels with nine screws on each side. On the two short sides (10 in) of the panel, it will hold each one side of two access panel hinge with five screws. In addition four screws would be use to hold the bottom panel of the casing with the top panel of the base. Therefore to secure and tighten the screws onto the top panel of the base, nuts would be use.

![Figure 13: Top and Bottom Panel of Casing](image)

The exterior casing (See Fig. 14) will have two interior chamber sides (B), two access doors to the fragrance source (C), and the front and back panel (A). On each of the interior chamber sides there will be eight flat-head metal screws to hold the front and back panels of the casing. These sides would be detachable for maintenance in the fragrance chamber.

The techniques use to precisely make the screw holes on the 0.25 inch side of each device panels is to clamp down one of the panels to drill holes onto the 0.25 inch side and placing the panel with a larger surface area to drill. This can be done by manually drilling holes onto the panels. The first step is to know how many screws are required to hold the pieces together and mark down where each screw would be place on the panels. Then make screw holes on each side of the panel and tighten the panels together by screwing in the two screw holes created before drilling more screw holes on the other marked holes.
Figure 14: Exterior Panels of Casing

The front panel contains several important features: six fragrance indicator lights, four speakers, 18 LEDs light display, two fragrance dispersion holes, and two clear protective PVC front panels to protect individuals from the LEDs.

As mentioned previously, the main concern of the design is to provide users a safe and reliable device to operate. Therefore, to protect the device and to prevent user injury, the front panel will be incased in two 0.125” thick clear PVC. Since the casing will be 14” (L) x 10” (W) x 18.5” (H), a 24” by 14” sheet is needed to construct the clear panels. As you can see in Fig. 15, the dimension of each protective PVC panel is 5.5 in (L) x 12 in (H) with two side pieces (0.9375 in (L) x 12 in (H)) and a top piece (5.5 in (L) x 0.9375 (W)). These pieces are assembled together and attach to the front panel with clear PVC cement glue.
For the speakers and fragrance dispersion holes, it was first suggested to use plastic mesh to prevent unwanted entry into the device and to protect users. However, due to time and budget constraints, it was simple to create a pattern of exit holes with a drill (See Fig. 16).
The back panel includes two fragrance dispersing fans opening for ventilation. It is also important to have a protective mesh or grid over the holes in order to protect any unwanted things into the fan. Once the device is on, the fan is continuously on and it may cause injury to users if they play around with the openings. Therefore, two grids will safely protect individuals from contacting with the fan blades. As seen in Fig. 17, the two fan grids cover the fan openings with four screws use to secure the grids on the panel. The four screws are also use to hold and support the fan.

![Figure 17: Back Panel](image)

The access door will be attached using a surface mount hinge with a total of 10 metal screws on each hinge and, as mentioned, kept in place using a cam lock. There are two access panels on the side of the casing and as seen in Fig. 18, both panels contain a cam-lock and three aerosol sprays can holders. In order to identify which keys belong to which lock, the keys and locks are color-coordinated with two different colors; dark and light pink. The hinge is attached on the outside bottom portion of the panel with five metal screws. The aerosol spray can holders provide stability and position on which the lever activators and solenoids will activate the cans. Once the aerosol spray cans are loaded, users are able to subsequently lock the aerosol spray cans in place secure with the cam-lock.
2.2.2.2 User Interface

The two discussed switches requested by the client are a squish switch (See Figure 19) and a large touch pad (See Figure 20).

---

As mentioned, the exterior of the base will contain two ¼ inch stereo jacks for the switches to interchange as the selector or the activator. These jacks are cost-effective and simple to incorporate into the device casing for the switch inputs.

The on/off key switch will be on the next to the stereo jacks on the exterior of the base as explained previously. This SPDT single pole switch (See Figure 21) will have three positions (on-off-on) with position two as the key removable position.

---

3 http://www.alliedelec.com/Search/ProductDetail.asp?SKU=870-9125&SEARCH=870%2D9125&ID=&DESC=SK13EAW01
Table 4: Key Switch Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Capacity</td>
<td>3A @ 125 VAC</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>1,500 VAC</td>
</tr>
<tr>
<td>Mechanical Life</td>
<td>3,000 cycles per min</td>
</tr>
<tr>
<td>Electrical Life</td>
<td>10,000 cycles per min</td>
</tr>
<tr>
<td>Operating Torque</td>
<td>0.026 Nm</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>25 - +70°C</td>
</tr>
<tr>
<td>Angle of Throw</td>
<td>45°</td>
</tr>
<tr>
<td>Maximum Panel Thickness</td>
<td>0.315 inch</td>
</tr>
</tbody>
</table>

As mentioned, the fragrance access door is located on either side of the device and the battery access door is located on one side of the base. To prevent unwanted entry, all three of these doors will be secured with a cam lock.

2.2.2.3 Display

The front panel of the device contains the visual and sound elements of the device (See Figure 22).

As discussed previously, the front panel contains six indicator LED’s that correspond to the six fragrances within the device. These indicator LEDs will simply screw into the front panel of the device. In addition to these six, a series of 18 LED’s will be used to create a pattern on either side of the front panel. These LEDs will simply snap into the front panel of the device. When the activator switch is activated, the LED pattern is also activated in the following sequence:
Following this pattern, all of the LEDs will blink several times in unison.

The sound elements consist of four sound chips and associated speakers. The speakers are arranged vertically on the front of the device. The top speaker corresponds to a “ping” sound chip. This chip will be activated each time a new fragrance is selected. This creates the combination effect of a new LED indicator being activated simultaneously with an audible sound. The other three speakers correspond to a Frog, Lion, and Dinosaur Voice sound effect. When the user activates a particular fragrance, one of these three sounds will also be activated in addition to the LED pattern. In general these
effects greatly enhance the amusement of the device. Not only will the user experience olfactory stimulation from the scent, but be witness to an enjoyable light display in addition to sound effects.

### 2.2.2.4 Fragrance Dispersion System

There are many different types and shape of retail aerosol spray cans but the design of the fragrance dispersion system was based on using Glade Aerosol Spray cans. Therefore, the only compatible aerosol spray cans use in the device is aerosol cans from Glade. The Glade Aerosol Spray product comes in a variety of scents including: apple cinnamon, butterfly garden, cinnamon sticks, clean linen, country garden, French vanilla, Hawaiian breeze, lavender meadow, lilac spring, melon burst, powder fresh, Rainshower, refreshing spa, strawberries and cream, suddenly spring, and tropical mist.

As mentioned before, a fragrance access door is located on both sides of the casing that facilitates removal and loading of these aerosol spray cans. Once the door is unlocked and opened, the aerosol spray cans can easily be removed or loaded into a fixed holder. This holder will be constructed out of five individual pieces of gray PVC sheets (see Fig. 24).

![Final Assembly](image)

From Fig. 24, the dimension of the holder is 2.375” (L) x 2.375” (W) x 8” (H). The design of the holder is perfectly constructed to fit the 2” diameter and 9” height glade aerosol spray can. The assembly of the holder would be constructed with PVC glue and then glue...
onto the access panels. The placements of these holders are about 1” apart from each other and 0.25” away from the side edge of the panels. The distance from the bottom of the panel to the holder is 0.375” giving clearance for the hinge screws. The distance from the top to the holder is about 1.625” for the cam lock clearance. The holders will apply a good amount of tightness to secure the cans but also allow slight movement for the user to easily remove the cans. The only difficulties on loading the aerosol can perfectly is the scent release button on the can must be facing the interior casing in order for the lever activators to have direct contact with the button (see Fig. 25).

![Figure 25: Load Aerosol Can](image)

The interior fabrication of the fragrance dispersion system can be seen in Fig. 26. Figure 26 displays the top view of the system with six individual compartments for the six aerosol cans. There are three separate scent releasing mechanism on each side of the casing. Each compartment contains an aerosol spray can holder, lever activator, solenoid, and solenoid holder. In order to separate these compartments there are six dividers within the casing. Four small dividers are use to separate each fragrance from interacting with each other and provide support for the threaded rod. There are two large dividers in the center of the device to provide separation from each side and hold the solenoids as they are activated. The dimensions of each four small dividers are 3” (L) x 0.25” (W) x 10” (H) and for the two large dividers are 10” (L) x 0.25” (W) x 9” (H). The placement of the rod through each four small dividers is 10.125” from the bottom to the top and 1” from the side.

Support is one of the crucial factors in having a working fragrance spray mechanism. These dividers provide support for the solenoids and the threaded rod because the force of the solenoid can easily move the threaded rod without the two small dividers for stability.
There are two 0.25" diameter threaded aluminum rods use to hold the three lever activator and two compartment dividers on each side. The two compartment dividers provide stability for the rod and levers as they are activated by the solenoid. The threaded properties on the rod present easy installation on the front and back panels by screwing the rod into the panels. In addition, it supports and securely holds the lever activators in place and provides the solenoid to freely release the desired scent.

The shape and dimensions of each lever activators can be seen in Fig. 27. An ‘L’ shape was chosen to activate the scent due to its simplicity and its ability to directly contact the release button on the tip of the activator. The tip of the activators contains teeth for better contact with the can. At first, there were different types of solutions on contacting with the can such as using sand paper, Velcro, or sticky substances. However, as these materials were tested, the conclusion was as time progresses the sand paper will destroy the scent release button and form debris all over the system that can lead to maintenance problems. The problem with Velcro was it doesn’t provide enough strength or grip to properly hold the release button. And finally, the sticky substances created a mess on the cans. Therefore, the best and successful method was to create little teeth on
the tip on the activators for better gripping strength. The location of the threaded rod insertion must be precisely made in order to provide direct contact with the release button. The position of the hole was determined to be 2 in. from the tip of the activator.

![Figure 27: Dimension of a Lever Activator](image)

Linear push solenoids will be used to activate the spraying mechanism on each of the aerosol spray can compartment (see Fig. 28). A solenoid converts electrical energy into linear mechanical work. When the activator switch is pushed, an electrical signal will be sent through the microprocessor to the appropriate solenoid determined from the selector switch. Once the solenoid is activated, the plunger will push on the lever activators to release the scent into the interior fragrance chamber. The stroke distance needed to dispense the proper amount of spray was determined by trial and error. Each solenoids required different stroke distances, however, it was approximated that an adequate stroke distance is about 1 in. Once the spray mechanism is activated, the fragrance will be released into the interior chamber, where it is sent out through the two air dispersion holes on the front panel into the outside atmosphere via fans.

There will be a time delay of 12 seconds before the next fragrance is release in order to clear any previous scents before activating the next scent. This was determine by experimentally analyzing how long a fragrance from the Glade aerosol spray can takes to dissipate (please see experimental analysis section). During the time delay, the users won’t be able to operate any of the switches and the LEDs light display pattern and the sound chips will activate.
Interiorly, a divider plate will be installed to separate the fragrance chamber on the top portion of the casing to the central fragrance dispersion system (see Fig. 29). The dimension of the divider plate is 13.5” (L) x 0.5” (W) x 0.125” (H). There will be three reinforcements on each side and beneath the divider plate. The reinforcements are shaped into right triangles and are attach to the interior side panels.

The top portion of the casing is where fragrances are dispensed and two fans are used to diffuse the scents out of the chamber into the atmosphere. The divider plate provides a pathway for the fragrance to diffuse into a fragrance chamber and protect any fragrance debris from getting on the solenoids or the wires in the center of the casing. On the divider plates there are three 2.5” diameter holes on each side with a total of six holes for each aerosol spray cans to diffuse into the chamber.
As mentioned, two fans will be used to direct the fragrance as well as blow fresh air. These fans are known as DC brushless fan or equipment cooling fans. It is compact, cost-effective and easy for installation. Although many types of fans exist, the design of the fan use is a square fan that is easily mountable with four screws on each corner to the back of the device. The following are specifications of the fan:

**Table 5: Fan Specifications**

<table>
<thead>
<tr>
<th>Dimension (Width)</th>
<th>2”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension (Height)</td>
<td>2”</td>
</tr>
<tr>
<td>Dimension (Depth)</td>
<td>0.60”</td>
</tr>
<tr>
<td>CFM</td>
<td>11.7</td>
</tr>
<tr>
<td>Voltage</td>
<td>12 V DC</td>
</tr>
<tr>
<td>Amps</td>
<td>100mA</td>
</tr>
<tr>
<td>Power</td>
<td>1.2 W</td>
</tr>
<tr>
<td>Noise</td>
<td>28.5 dBA</td>
</tr>
</tbody>
</table>
2.2.2.5 Circuitry

2.2.2.5.1 Main Circuit

Figure 30: Main Circuit Schematic

Figure 30 depicts the main body of the device’s circuit. Due to the large size of the circuit, it is difficult to clearly show the entire circuit in one diagram. The main body of the circuit is mainly responsible for supplying power and control to the remainder of the circuitry. Overall power is drawn from a 12 Volt battery (See 2.2.2.5.5). A simple switch (the on/off switch for the device) controls whether the circuit receives this power or not. When the circuit is receiving the power, it sends 12 volts to the solenoid circuitry (See 2.2.2.5.4). In addition, the 12 volts are supplied to two fans in parallel. Whenever the switch is closed, the fans will run continuously. LM7805 Voltage Regulators are used to regulate the 12 volts down to 5 volts. The regulators have three pins: input, output, and ground. One regulator supplies the sound chips (See 2.2.2.5.2), the LED Indicators circuit (See 2.2.2.5.3), and PIC (See 2.2.2.5.6) and the other supplies the LED Pattern.
circuit (See 2.2.2.5.3). Two voltage regulators are needed because the LED Pattern circuit draws a great deal of current. Since the voltage regulators are rated for a maximum current, one regulator could not be used to power the sound chips, LED Indicators, PIC and LED Patterns. By using two regulators, the amount of current drawn is divided between the two regulators and neither reaches their maximum current rating. As mentioned, one regulator supplies the PIC with 5 volts at pins 1, 11, and 32. The PIC is also grounded at pin 12 and 31. In order for the PIC to function properly, it must be connected to an oscillator at pins 13 and 14. The oscillator must also be grounded. The remainder of the pins are designated as either an input or an output. The PIC contains 40 pins altogether. It should be noted, however, that not all the pins on the PIC are needed for this particular circuit. The two input pins are 8 and 9. They are attached to the selector and activator switch, respectively. A 10k pull-up resistor is also needed. (See 2.2.2.5.6 for more information). Based on the input from these two pins, the PIC will send output to the other pins accordingly. These pins control the sound chips, solenoids, pattern LEDs, and indicator LEDs. Pins 4, 5, 7, and 39 control the sound chips. Pins 15, 16, 17, 18, 23, and 24 control the solenoids. Pins 19, 20, 21, 22, 27, and 28 control the pattern LEDs. Pins 33, 34, 35, 36, 37, and 38 control the indicator LEDs.

2.2.2.5.2 Sound Chip Circuit

![Sound Chips and Speaker Schematic](image-url)

*Figure 31: Sound Chips and Speaker Schematic*
Figure 31 depicts the sound chip circuit complete with the associated speakers. As mentioned previously, there will be four sound chips: Lion, Frog, Dinosaur, and Ping. The upper schematic in Fig. 20 represents the Lion, Frog, and Dinosaur Sound Chip. Out of the box, the activation of these chips is triggered by a switch located directly on the board. In order to interface the chips with the PIC, an alteration will have to be made. The switch will be removed and a section of wire will be soldered on the “high” pin of the switch on the board. Each of the chips will then be grounded and connected to the 5 volt supply of the voltage regulator mentioned above. The section of wire will then be attached to either pin 4, 5, or 7 of the PIC. With this setup, a high signal sent from the PIC will cause the sound chip to activate just as if the removed switch was triggered. In short, when the user triggers the activator switch the PIC will send a signal to the Lion, Frog, or Dinosaur depending on the scent selected and activate that sound chip. The Ping Sound Chip, on the other hand, required no alterations. Its innate design lacked an internal switch; it requires only a 5 volt signal to activate it. Because of this, the Ping chip will be directly connected to pin 39 of the PIC and grounded. When the user triggers the selector switch, the PIC will send a signal to the Ping chip causing it to activate.

2.2.2.5.3 LED Components Circuit

Figure 32: LED Indicators Schematic on Interface

Figure 32 depicts the LED Indicator circuit. Its purpose is to activate six red LEDs based on input from the user as described above. When the device is initially turned on, the PIC automatically activates the first LED. This indicates that the first scent is chosen or ready for activation. When the user triggers the selector switch, the PIC will activate the
second LED and stop activating the first simultaneously and so forth. This activation interface with the PIC is facilitated by a 7405 Hex Inverter. This operation of the inverter is fairly simple. When the PIC sends a high signal (5 volts) to the inverter, it outputs a low signal to the corresponding LED. Since the positive end of the LED is permanently connected to 5 volts, the low signal simulates ground causing the LED to be activated. When a low signal is not supplied, the LED is not activated. Each Inverter can conveniently process six individual input and outputs. It also needs to be connected to 5 volts and ground. As mentioned above, the 5 volts connected to the inverter and each individual LED is supplied through one of the voltage regulators. A resistor is also needed between the output of the inverter and the negative end of the LED. Its purpose is to adjust the current passing through the LED to ensure the proper brightness. Figure 33 depicts this setup using only one inverter.

![Figure 33: Inverter Set-up](image)

The resistance value can be calculated from this diagram using the following equations:

\[ V = IR \]
\[ R = \frac{V}{I} \]
\[ R = \frac{(5V - 0.4V - 1.4V)}{20mA} \]
\[ R = 3.2V / 0.02A \]
\[ R = 160\,\Omega \]

This gives a resistance value of 160 \(\Omega\).
Figure 34 depicts the LED Pattern circuit. Its purpose is to activate 18 LEDs: 6 red, 6 green, and 6 yellow. As mentioned earlier, activation of a particular scent will also result in the activation of a light display consisting of these 18 LEDs. This circuit also employs a 7405 Hex Inverter. The only difference is that each output powers three LEDs instead of one. The three LEDs along with their resistors are placed in parallel. 5 volts is still connected to the positive end of each of the LEDs. The inverter still sends a low signal after receiving high signal from the PIC in order to activate the LEDs. Figure 35 depicts this set-up using only one inverter.
The resistance value can be calculated from this diagram using the following equations:

\[ V = IR \]
\[ R = \frac{V}{I} \]
\[ R = \frac{(5V - 0.4V - 2V)}{0.02A} \]
\[ R = \frac{2.6V}{0.02A} \]
\[ R = 130\Omega \]

This gives a resistance of 130 Ω.
2.2.2.5.4 Solenoid

Figure 36: Solenoid Schematic

Figure 36 depicts the Solenoid Circuit, where +Vs equals 12 volts and +Vss equals 5 volts. The two main components of the circuit are the solenoids and the L295 Dual Solenoid Driver. As mentioned, the device requires a total of six solenoids to activate the spray release mechanism on the aerosol spray cans. Although there are many different kinds of solenoids on the market, the one chosen for this device is a linear, push style, intermittent duty solenoid. The following is the list of its specifications:

<table>
<thead>
<tr>
<th>Table 6: Linear Solenoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>Max. Stroke</td>
</tr>
<tr>
<td>Input Voltage</td>
</tr>
<tr>
<td>Input Current</td>
</tr>
<tr>
<td>Power Rating</td>
</tr>
</tbody>
</table>

Since the microprocessor alone will not be able to power the 12V solenoid, the solenoid driver is necessary. The driver chosen is a monolithic integrated circuit in a 12-lead Multiwatt package, capable of direct interfacing between digital circuitry (in this case the microprocessor) and inductive loads (the solenoid). Since it is a dual driver (drives two separate solenoids), only three of these drivers will be needed because the overall
The circuit requires six solenoids. The driver has the following main features: high current capability (the solenoid requires about 1.5 A at most while the driver is rated for up to 2.5 A per channel); high voltage operation (the solenoid requires 12 V and the driver has the potential for up to 46 volts); high efficiency switch mode operation; adjustable, regulated output current; few external components; separate logic supply; and thermal protection. Its overall function is straightforward. It contains, as mentioned, two independent driver channels with individual inputs and outputs. Each channel is controlled by a total of five inputs: three digital and two analog. The three digital inputs are EN, Vin1, and Vin2. EN (lead 7 on the driver), also called chip enable, enables both channels when it is in a low state. For this reason, EN will be connected directly to ground in the device’s circuit. This ensures that it will always be in a low state and activation of each solenoid will only depend on the input from the microprocessor. Vin1 (lead 6) and Vin2 (lead 11) are the two inputs coming from the microprocessor. Vin1 controls one solenoid and Vin2 controls the other. These channels are active when in the high state. This means that the microprocessor will send a 5 volt signal to one of the channels in order to activate a particular solenoid. The two analog inputs are Vref1 and Vref2. These are used to program the peak load currents. These inputs will be left open in the device’s circuit. By leaving these open, the driver will have a default internal reference voltage of about 2.5 V and a peak current in the load fixed by the value of Rs. The peak current, Ip, can be found using the following equation:

\[
Ip = 2.5 / Rs
\]

\[
Rs = 0.5
\]

\[
Ip = 2.5 / 0.5
\]

\[
Ip = 5A
\]

Since the solenoid requires 1.5 A, a peak current for the load of 5 A is more than enough. The outputs of the driver (leads 2, 3, 14, and 15) send the appropriate signal to their associated solenoids to activate it. The remainder of the components in the schematic (resistors and capacitors) is included to manipulate the precise function of the drivers. For example, lead 9 controls the oscillator frequency. The following is a list of all the applicable electrical characteristics of the driver:

**Table 7: Electrical Characteristics**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vs</td>
<td>Supply Voltage</td>
<td>12</td>
<td>46</td>
<td>V</td>
</tr>
<tr>
<td>Vss</td>
<td>Logic Supply Voltage</td>
<td>4.75</td>
<td>10</td>
<td>V</td>
</tr>
<tr>
<td>Id</td>
<td>Quiescent Drain Current (from Vss)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iss</td>
<td>Quiescent Drain Current (from Vs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vin1, Vin2</td>
<td>Input Voltage</td>
<td>Low: -0.3</td>
<td>Low: 0.8</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High: 2.2</td>
<td>High: 7</td>
<td>V</td>
</tr>
<tr>
<td>Ven</td>
<td>Enable Input</td>
<td>Low: -0.3</td>
<td>Low: 0.8</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Voltage</td>
<td>High: 2.2</td>
<td>High: 7</td>
<td>V</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>-----------</td>
<td>---------</td>
<td>---</td>
</tr>
<tr>
<td>Ii1, Ii2</td>
<td>Input Current</td>
<td>Low: -100</td>
<td>High: 10</td>
<td>uA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>uA</td>
</tr>
<tr>
<td>Ien</td>
<td>Enable Input Current</td>
<td>Low: -100</td>
<td>High: 10</td>
<td>uA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>uA</td>
</tr>
<tr>
<td>Vref1, Vref2</td>
<td>Input Reference Voltage</td>
<td>0.2</td>
<td>2</td>
<td>V</td>
</tr>
<tr>
<td>Iref1, Iref2</td>
<td>Input Reference Current</td>
<td>-5</td>
<td>uA</td>
<td></td>
</tr>
<tr>
<td>Fosc</td>
<td>Oscillator Frequency</td>
<td>46</td>
<td>KHz</td>
<td></td>
</tr>
<tr>
<td>Ip</td>
<td>Transconductance</td>
<td>1.9</td>
<td>2.1</td>
<td>A</td>
</tr>
<tr>
<td>Vref</td>
<td>Transconductance</td>
<td>1.9</td>
<td>2.1</td>
<td>V</td>
</tr>
<tr>
<td>Vdrop</td>
<td>Total Output Voltage</td>
<td>3.6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vsens1,</td>
<td>External sensing resistors voltage drop</td>
<td>2</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vesens2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2.2.5.5 Power Supply

From the beginning, the client requested that there should not be any power cords or wires attached to the device. Therefore, the only option for providing the necessary power to the circuit would be a battery. Because one of the design characteristics is easy maintenance, it would be beneficial to have a rechargeable battery. This way the user does not have to purchase a new battery regularly. Not only does this save on user effort, but it is also more cost efficient. In addition, a rechargeable battery is more environmentally friendly. The potential waste of one battery is much less than the number of individual batteries the device would require in its lifetime.

In order to power the whole circuit efficiently, the minimum input voltage is about 12V and the current should be at least 2A. The components in the circuit that require a lot of voltage are the solenoid and the fan. The solenoid has the highest value specifications that require 12V and at least 2A inputs. The power supply must be effective, inexpensive, and rechargeable. A sealed lead acid battery is one of the top choices to power the circuit because it offers many advantages such as a wide-range of current and voltage properties available in the market and is rechargeable. A battery was found that met this criteria; it is 12 volts and has 2.3 amp-hr. It has the following features:

- Advanced absorbed glass mat technology.
- Sealed construction for operation in any position except upside down.
- Wide operating temperature range.
- High discharge rates and low self discharge rates.
- Available in VO Flame Retardant Material.
- High impact resistant plastic case.
- Each cell has a low pressure safety release valve.
• 98% recyclable. Not restricted for Surface, Maritime and Air Transport.
• Dimensions: 7.01” x 1.34” x 2.36”

A matching battery charger will be included with the device. The charger found has the following features:

• I.C. based voltage and current regulation designed for sealed (valve-regulated) lead-acid batteries.
• Useable on domestic and overseas input voltages from 110VAC - 60Hz to 240VAC - 50Hz
• Automatic, current sensing dual-rate charging for efficient, care-free and safe operation.
• LEDs indicate 'power on' and "FAST" and "FLOAT" charging modes.
• Lightweight wall mount plug-in design for 300 - 1000 mA chargers with screw type output terminals.
• Desk-top design for 4 Amp. and 24V chargers with input/output cords.
• Protected against accidental reverse polarity connection.
• U.L. and European C.E. approval.
• Dimensions: 2.05” x 1.57” x 2.64”

2.2.2.6 Switches

The user interface is composed of two interchangeable switches. These switches provide input to the Microprocessor (see following section) and enable the user to interact with and receive stimulation from Olfaction Satisfaction. The switches themselves are very simple in design providing either an open or closed circuit. This simple design however does not provide output voltages definite enough for the microprocessor to understand and interpret. Therefore, a pull up resistor set up must be used to further define the voltages representing an open and closed circuit. Figure 37 shows the circuit diagram for the pull-up resistor/switch setup used in Olfaction Satisfaction.
When the switch is open, current from the +5 Volt source goes from the source to the Microprocessor, resulting in a voltage drop across the 1K Ohm resistor causing a +5 Volt signal to be seen at the input terminal of the Microprocessor. When the switch is closed, the current from the +5 Volt source goes from the source to ground, resulting in a voltage signal close to 0 Volts (i.e. Ground) seen at the input terminal of the Microprocessor. With this setup the input to the Microprocessor is more defined, causing the user's interaction with the user interface to be easily understood by the Microprocessor.
2.2.2.7 Microprocessor

The PIC16F874 Microcontroller (PIC for short) is responsible for taking input from the switches and processing them into output that controls activation of the indicator lights, sound chips, LED’s, and the solenoids. In this regard, the PIC Microcontroller is the ‘brain’ of Olfaction Satisfaction. Therefore, it is important to understand how the PIC is programmed so that it will respond correctly to the user’s input.

The PIC Microcontroller must be programmed via assembly code in order for meaningful output, which is seen as an appropriate response from Olfaction Satisfaction, to be given. With this in mind, it is necessary to understand the behavior of the PIC microprocessor in response to the user’s inputs.

Note that the design calls for 6 solenoids. Each individual solenoid connects to an aerosol can in the fragrance chamber. Each solenoid is responsible for releasing a measured amount of fragrance from the can into the fragrance chamber. A fan in the back of the chamber allows the scent to diffuse into the room faster than it would if no fan was present (see Air Flow Calculations). The user interface allows the user to switch between these solenoids (allowing the user to change fragrances) and for activating the selected solenoid to facilitate diffusion of the scent into the fragrance chamber.

All switches of the user interface are, by necessity, active low. The first switch is responsible for activating the enabled solenoid. The second user controlled switch will be responsible for telling the device to change which solenoid will be enabled (allowing the user to switch to different fragrances). When a switch is activated or used a digital 0 (or ‘Low’, ‘false’) is sent to the PIC. When the switch is not used, a digital 1 (or ‘Hi’, ‘true’) is sent to the PIC.

For identification purposes, one signal will be designated ‘Activate’. Activate tells the circuit whether or not to turn send power to the solenoids. It is important to note that the solenoids must be activated for only a measured amount of time, otherwise too much fragrance will be sent into the chamber. From experimental observation, powering the solenoids for 2.0 seconds releases an adequate amount of fragrance into the chamber.

The second user controlled switch will be responsible for telling the device to change which solenoid will be enabled (allowing the user to switch to different fragrances). The signal coming from this switch will be designated ‘Select’. When Select is asserted (in this instance set to Low or 0 Volts), the device will disable the currently enabled solenoid and enable the next one down the line. When select is not asserted, the device will not change which solenoid is enabled.

These two switches become inputs to the PIC. From this point, the PIC processes the inputs from the interface switches and sends output signals to the rest of the circuit. It is important to note, however that the PIC is capable of sending out a maximum voltage of +5V and a maximum current of 25mA. For this reason, the outputs from the PIC must
be “tweaked” in order for the corresponding component to respond (see section regarding Circuitry). Outputs controlling the indicator lights are given the designation LED Indicator # (indicating which LED the output is responsible for). Similar nomenclature is given to outputs controlling sound chips, solenoids, and LED’s. Table 11 summarizes the pin-outs for the PIC (note: LED Row # corresponds to the rows of LED’s on the faceplate that are used purely for visual stimulation):

Table 8: PIC Pin-Outs

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Connected to:</th>
<th>Type</th>
<th>Pin #</th>
<th>Connected to:</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+5V input</td>
<td></td>
<td>21</td>
<td>LED Row 3 output</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sound Chip 1 output</td>
<td></td>
<td>22</td>
<td>LED Row 4 output</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sound Chip 2 output</td>
<td></td>
<td>23</td>
<td>Solenoid 5 output</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sound Chip 3 output</td>
<td></td>
<td>24</td>
<td>Solenoid 6 output</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sound Chip 4 output</td>
<td></td>
<td>25</td>
<td>N/A output</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>N/A output</td>
<td></td>
<td>26</td>
<td>N/A output</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sound Chip 6 output</td>
<td></td>
<td>27</td>
<td>LED Row 5 output</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Select input</td>
<td></td>
<td>28</td>
<td>LED Row 6 output</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Activate input</td>
<td></td>
<td>29</td>
<td>N/A output</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>N/A output</td>
<td></td>
<td>30</td>
<td>N/A output</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>+5V input</td>
<td></td>
<td>31</td>
<td>GND input</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>GND input</td>
<td></td>
<td>32</td>
<td>+5V input</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Oscillator input</td>
<td></td>
<td>33</td>
<td>LED Indicator 1 output</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>N/A output</td>
<td></td>
<td>34</td>
<td>LED Indicator 2 output</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Solenoid 1 output</td>
<td></td>
<td>35</td>
<td>LED Indicator 3 output</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Solenoid 2 output</td>
<td></td>
<td>36</td>
<td>LED Indicator 4 output</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Solenoid 3 output</td>
<td></td>
<td>37</td>
<td>LED Indicator 5 output</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Solenoid 4 output</td>
<td></td>
<td>38</td>
<td>LED Indicator 6 output</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>LED Row 1 output</td>
<td></td>
<td>39</td>
<td>Sound Chip 5 output</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>LED Row 2 output</td>
<td></td>
<td>40</td>
<td>N/A output</td>
<td></td>
</tr>
</tbody>
</table>

Having seen how the pins are connected to the rest of the circuit, it is now important to understand how the PIC itself is programmed. The pins of the PIC are organized into ports A through E. Ports D and B have 8 pins each, Port E has 3 pins, and Port A has 6 pins. Each pin of each port can be defined as input or output. In assembly language, the variable PORTX refers to the values at the pins of Port X. When a port is initialized, which pins are inputs and which pins are outputs is defined by the variable TRISX, which is the I/O scheme for Port X. For example, if the value B”110” were stored into TRISE, then the last two pins of Port E would be defined as inputs, while the first pin would be defined as an output.

The pins that correspond to each port are shown in Table 12 below. This means that any output pin can be changed simply by changing the value of PORTX.
Note however that output pins of the PIC are not homogeneously assembled. There are some significant differences between certain pins on the PIC and the rest of the pins. For example, Port A, showed only one nonworking pin, RA4 (i.e. pin 6 of the PIC) which has a Schmitt Trigger input and an open drain output and is not capable of generating the necessary 5 V output to control the sound chips. Therefore, RA4 is ignored and its duties given to pin RB6 (i.e. pin 39 of the PIC).

The I/O scheme for all the pins of the PIC is defined right after the device is turned on during the initialization phase of the PIC's programming. Furthermore, any necessary variables used in system processing are defined during this phase. Also, since digital input and output is being used, the configuration variable ADCON1 which is integral to the PIC must be set to a specific value in order for digital input and output to be facilitated. This phase is termed the Initialization phase of the PIC startup routine. Diagram #1 shows the initialization block diagram for the PIC's programming:
Block Diagram 1:
Initialize Parts and Variables

Power On

Fix Digital I/O:
MOVLW B'000001110'
MOVWF ADCON1

Declare Variables:
B'11111111', TEMP255
B'01110110', TEMP118
B'00000101', TEMP5
B'00000110', COUNT
B'00000001', SOLARRAY

MOVLF B'00000111', TRIS E

MOULF B '00000000', TRIS A

MOULF B '00000000' TRIS B

MOULF B '00000000' TRIS C

MOULF B '00000000' TRIS D

CONTROL LOOP
Note after power has been turned on, the PIC begins to initialize all the variables and pin I/O configurations. The first 2 pins of Port E are defined as inputs, while the 3 pin is defined as an output (but is unused in our circuit). The rest of the ports are defined as outputs to the rest of the circuit. Note also that two variables are defined: COUNT and SOLARRAY (both are 6 bits in length). COUNT is a variable used for timing and coordination of the LED's (i.e. the LED's controlled by pins 19 – 22 and pins 27 and 28). SOLARRAY is a variable that is used to remember which solenoid is the currently active solenoid. When input is sent to pin 9 (i.e. the Activate input) the solenoid indicated by SOLARRAY will be activated.

TEMP255, TEMP 118, and TEMP5 are variables used in the Delay routine that causes the PIC to pause for 0.5 seconds when called in the PIC's program code. The Delay routine is used in many places to control how long to activate a certain element of Olfaction Satisfaction’s stimulatory output (i.e. LED's, sound chips, solenoids, etc.) It is also the Delay routine that allows for the specifically timed outputs seen in the Activate and Select routines.

Because a 6MHz crystal is used to give a temporal measurement to the PIC’s outputs, a nop command must be activated approximately $3 \times 10^6$ times in order for 0.5 seconds of nothing. Next considering that there is a maximum size to the register in a PIC, the largest value for a count type variable would be 255 (in decimal). Therefore, a loop must be run approximately 20,000 times. However, if 10 nop commands are placed in a second loop that loops for 118 times, the number of loop iterations reduces workable numbers. Thus, the delay loop consists of 3 nested loops, one which loops 255 times, 118 times, and another which loops 5 times. This loop structure will allow for a single nop command to be called $3 \times 10^6$ times, resulting in a 0.5 second pause.

After the initialization routine seen in Diagram #1, the PIC clears all output ports in the event that something may have inadvertently been set to Hi (a common occurrence) during initialization. After this the PIC enters a control loop, in which it looks for input from the user. This control loop is shown in Diagram #2 below. Note that the command btfss is an assembly command that looks at a specified bit of the input variable and skips the next line of code if the bit is set (i.e digital Hi), otherwise the program will process the next line of code. In function, this statement is very much like an If/Else statement seen in C++. Therefore, the btfss statements check to see if any of the inputs have been activated.

If Select is activated, then the first bit of Port E (i.e. pin 8) will be Low (a digital 0) and the program will call the subroutine seen in Diagram #3. If Select is not activated, then the first btfss statement will skip to the second btfss statement (i.e. whether or not Activate has been asserted). If Activate is enabled then the program will call the subroutine seen in Diagram #4. Otherwise, the loop will continue to check the first 2 bits of E until some input has been given to the device.
From Block Diagram 1

MOVLF B'00000000' PORTA

MOVLF B'00000000' PORTB

MOVLF B'00000000' PORTC

MOVLF B'00000000' PORTD

MOVLF B'00000000' PORTE

btfsc PORT E,1

Select Loop

Skip

btfsc PORT E,2

Activate Loop

Skip

Block Diagram #2: Control Loop
If the Select input is activated, then the PIC will change the active solenoid to the next solenoid down the line (see Diagram #3 below), change the indicator lights accordingly, and play a . This is all implemented with a series of btfsc commands and MOVLF commands. For example, if the first bit of SOLARRAY is asserted (i.e. SOLARRAY = “100000”) then the program proceeds to call the subroutine that changes the value of SOLARRAY to “010000”, activates the sound chip associated with the newly enabled solenoid (i.e. the value of PORTA is changed to “010000”), changes the indicator lights (i.e. PORTB is given the new value of “010000”, enters a do-nothing loop for 1 second (to allow the sound to finish playing), and finally disables the sound chip (i.e. changes the value of PORTA back to “000000”).

Similar processing is carried out until the value of the 6th bit of SOLARRAY is set (i.e. the last solenoid is enabled). At this point, when Select is asserted the program will always reset the value of SOLARRAY to its original value of “100000” (i.e. the state in which the first solenoid is enabled). Processing is continued as before: indicators are changed, sounds are played, etc. Block Diagram #3 shows the Select routine in a step by step layout.

If not already clear, the order of events following the activation of the Select loop are as follows: 1) Check if False Positive event occurred (if so return to Control Loop), 2) Locate currently selected solenoid given by SOLARRAY, 3) Activate currently selected solenoid, 4) wait 2.0 seconds, 5) Deactivate currently selected solenoid, 6) Flash LED’s 3 times, 7) Play sound, 8) Flash LED’s in pretty pattern.
The Activate subroutine (Block Diagram 4 below) starts off with changing the value of PORTC to the value stored in SOLARRAY. This results in a Hi value at one of the pins of Port C (see Table 12). This signal is then processed via the hardware circuitry until it connects with the solenoids. At this point, one of the solenoids is activated causing fragrance to be released. The program then does nothing (i.e. leaves the solenoid active) for 0.5 seconds. After this, the solenoid is disabled: the value of PORTC is reset to “00000000”.

Following this, the program proceeds to play a sound associated with the solenoid (i.e. the value in SOLARRAY is stored PORTA). This causes the sound to be played until the value of PORTA is cleared. From this point, the program goes into a series of loops in which the LED Rows are activated and deactivated in a series, resulting in a pretty pattern for the user’s visual stimulation. The loop activates LED rows 1-6 in series and then does so again backwards. Finally all the LED’s Flash 4 times (i.e. all bits of PORTD are set and cleared 4 times), and then the sound is stopped from playing (i.e. PORTA is cleared).

This whole loop takes up around 10-12 seconds during which time the user cannot activate the solenoid again. This enables the scent to completely dissipate from the room, allowing the user to have a fresh olfactory stimulation experience each time (See Air Flow Calculations under Analysis section).
If not already clear, the order of events following the activation of the Activate loop are as follows: 1) Check if False Positive event occurred (if so return to Control Loop), 2) Locate currently active solenoid given by SOLARRAY, 3) Set next solenoid in line as active, deactivate current solenoid, 4) Play a sound, 5) Return to Control Loop.

A block of code exists for error analysis which will cause the Indicator lights to flash in response to any error. The error routine will take over if Select or Activate loops reach the end of their respective subroutines without reaching a proper end state (i.e. the expected state for the device after running through the code). If for some reason the PIC begins to malfunction and requires reprogramming, then the Error Routine will give visual confirmation of the fact.

This block of code was written as both a debugging method and as a maintenance indicator for the client. The client will be warned in the User’s Manual when and in which instances the flashing lights are indicative of entering the Error routine. In such cases the client is advised to reprogram and/or replace the PIC. Figure 38 shows in more detail how the Error routine is entered.

![Figure 38: Error Routine Block Diagram](Image)

It is important to note that the block diagrams shown in this section are simplified (to an extent) to give the main idea of what they represent without going into specifics. As is
the case with many good programs, the bulk of the functionality is in the details of the program. Even the smallest line of code, if omitted, can have disastrous effects on the output of the program (if there is any output).

With this in mind, a copy of the actual source code for the PIC program is included in the Appendix of this report. The code is annotated with comments to facilitate understanding of each block of code (Note: code is a PDF file and must be appended to the document separately).

2.2.3 Analysis

2.2.3.1 Experimental Analysis

In order to analyze the time delay before the user can select another scent, a quantitative experiment was performed. The experiment consisted of a stopwatch, a scented Glade aerosol spray, and a few participants. One person diffused the scent, while another sniffed the scent and used a stop watch to time himself from the point of smelling the scent till he no longer smelled the scent. In order to cleanse an individual’s olfactory sense, each trial was conducted in a slightly different area of the room. Ten trials were sufficiently taken, which can be seen in Table 13. The median of the results was 7.50 seconds while the mean time before the scent dissipates was about 9.59 seconds.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.63</td>
</tr>
<tr>
<td>2</td>
<td>7.53</td>
</tr>
<tr>
<td>3</td>
<td>14.2</td>
</tr>
<tr>
<td>4</td>
<td>6.8</td>
</tr>
<tr>
<td>5</td>
<td>12.88</td>
</tr>
<tr>
<td>6</td>
<td>7.56</td>
</tr>
<tr>
<td>7</td>
<td>7.48</td>
</tr>
<tr>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>9</td>
<td>12.38</td>
</tr>
<tr>
<td>10</td>
<td>11.96</td>
</tr>
<tr>
<td>AVG.</td>
<td>9.59</td>
</tr>
</tbody>
</table>

Throughout the experiment there were many experimental errors associated in the data. As one can see, the data ranges from 6.8 – 14.2 seconds with a high standard deviation of 2.87. This signifies that errors occurred in the experiment. These include effects of the surroundings or the sensitivity of one’s nose. Such environmental effects are the room ventilation systems, the dimensions of the room and if the room contains any odor neutralizers. With these results, the time delay set for this design was 12 seconds. This time provides enough time delay for the diffused scent to neutralize. The user will not be
able to activate the activator switch before 12 seconds. After 12 seconds they will be able to stimulate their olfactory senses with other scents.

### 2.2.3.2 Air Flow Calculations

There are many ways of describing the characteristics of a fan such as power, torque, electrical impedance, etc. But when studying airflow, the characteristics of the fan that one is most interested in are Fan Cross Sectional Area, Outlet Velocity, and the CFM (Cubic Feet per Minute) rating. Each of these characteristics has an effect on the strength and quality of airflow. For this design, air flow through the fragrance chambers is especially important. If airflow is bad, then the fragrance will take longer to reach the user, resulting in inadequate stimulation of the olfactory senses. Furthermore, if airflow is not good, then it will take a longer amount of time for one fragrance to clear the user’s peripheral atmosphere (i.e. it will take longer for one scent to become unnoticeable enabling the user to smell the next scent without interference from the first). For this reason, it is worth some time to consider what type of fan to use to diffuse the scents from the fragrance chamber to the user’s atmosphere.

CFM is a measure of the volume of air that passes through the fan. For this reason, the units of CFM are, as the name implies, cubic feet per minute. For example a fan with a CFM rating of 24 will move 24 cubic feet of air through itself every minute. This measure is an important characteristic when looking at a fan because it reveals the amount of fragrant air that will be pushed into a room. For this design, it is important for a fan with an adequate CFM rating to be used; otherwise it will take an inordinate amount of time for fragrances to reach the user, and also an inordinate amount of time to clear out the scent from the room.

The next important characteristic of the fan is its Cross Sectional Area. Cross Sectional Area is the measure of the area about which air flows through the fan. Fans with a large Cross Sectional Area can move more air with less rotational velocity from the fan blades. Therefore, if Cross Sectional Area remains constant, then if CFM increases, the speed at which the air flows through the fan must also increase.

The speed of the air at the outlet of the fan is referred to as the Outlet Velocity. This quantity is usually given in units of meters per second. Outlet Velocity can be calculated by dividing the CFM rating by the fan’s Cross Sectional Area (in square feet). This quotient, however, will yield a value having units of feet per minute, not the usual meters per second. Therefore, unit conversion is necessary to convert feet into meters (3.28 ft = 1 m) and minutes into seconds (1 min = 60 s). This process yields the following equation for Outlet Velocity from CFM and Cross Sectional Area:

\[
\text{Outlet Velocity} = \frac{\text{CFM}}{(\text{Cross Sectional Area} \times 3.28 \times 60)}
\]

With these characteristics in mind, it is important to consider what characteristics are necessary for a fan in the Olfaction Satisfaction device. A Fan with a CFM rating of 3.5 will, as stated earlier, move 3.5 cubic feet of air through the chamber every minute. This is equivalent to moving 0.0583 cubic feet of air every second. As determined in the
experiment, it took approximately 10 seconds for the fragrance to clear the room. This corresponds to 0.583 cubic feet of air moving through the fan. Therefore, it is a good idea to program around 12 seconds of time for the fan to adequately clear scent from the chamber after activation of the device’s scent release protocol.

However, it is also important to note that the experimental data does not factor into account the changes that occur when a fan is present. The fan that will be used in the device has a cross sectional area of 5.76 square inches (0.04 sq. ft.) and a CFM of 3.5 ft³/min, corresponding to an Outlet Velocity of 0.44 m/sec. The speed at which the air flows through the chamber may quicken the rate at which the fragrance diffuses through the room. In this case, it is even more likely that the fragrance will have completely come and gone in the span of 10 – 12 seconds. Therefore, as long as some protocol exists in the device that inhibits any further fragrance release for 12 seconds after the first fragrance release, the air both in the chamber and in the room should be clear of the first fragrance, enabling for an olfactory stimulation that is free from the previous scents.

2.3 Prototype

2.3.1 General Description

This device (See Figure 39) is designed for use by adults with severe cognitive and motor disabilities. It will be incorporated into a multisensory stimulation room located in the Passion Works facility. Its main goal is to provide olfactory stimulation in an entertaining form in effort to increase the quality of life for the aforementioned adults. In order to achieve this goal, the device operates in the following manner. The user can operate the device with two user-friendly switches, termed the selector and activator switch. To maximize user accessibility, two types of switches are available for use. These will easily be interchangeable. Using the selector switch, the user can relay among six different fragrance choices. For clarity and additional stimulation purposes, selection of a fragrance choice is indicated by the activation of a corresponding red LED. Once the user has decided upon the desired scent, the user can then use the activator switch to activate the fragrance. Upon activation, the desired scent is released into the surrounding atmosphere via holes on the front exterior of the device. After activation, the selector switch can be used once again to choose a different scent or the activator switch can be used to activate the same fragrance again. This process of selection and activation can potentially continue indefinitely.
Figure 39: Olfaction Satisfaction

From this operation, the device can be broken into five subunits. These subunits are structure, user interface, display, fragrance dispersion system, and circuitry.

The structure can be broken into two portions: the base and the device casing. Although the base is simple in design, it provides essential stability and protection for the device. It was designed to rest directly on the floor to provide easy access to the user. Most of the projected users are most comfortable lying/sitting on the floor with a bean bag or pillow for comfort. In addition, both the base and device casing is constructed in such a manner to minimize user damage resulting from any mishandling of the device. The weight of the structure is also such that mobility of the device is possible while still maintaining stability. In other words, supervisors will be able to move the device but the user will not be able to tip or slide it during use.

The base and device casing is constructed out of Gray PVC sheeting. PVC was chosen due to its toughness, strength, durability, impact strength, excellent electrical insulation properties, corrosion resistance, ease of bending/processing, and affordability. To prevent user injury, all edges were smoothed and rounded using a filer and a deburred tool.
The 16” (L) x 13” (W) x 5” (H) rectangular base (See Fig. 40) will be composed of six individual sheets of PVC sheeting with the following dimensions:

<table>
<thead>
<tr>
<th>Piece Description</th>
<th>Length</th>
<th>Width/Height</th>
<th>Number of Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top and Bottom</td>
<td>16 in</td>
<td>13 in (W)</td>
<td>2</td>
</tr>
<tr>
<td>Front and Back</td>
<td>16 in</td>
<td>5 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>Sides</td>
<td>12.25 in</td>
<td>5 in (H)</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 10: Dimensions of Base PVC Sheets

Some of the components available within the base are storage space for the switches, and electrical components such as the sound chips, PCB board, and the battery. The storage space is separated with a divider plate from the electrical components. The exterior features of the base are the access panel and the user interface. The access panel contains a specific cam-lock to lock users from accessing electrical components within the base. The access panel provides easy accessibility to the storage space for the two switches and the battery compartment. Individuals will have no problems removing the battery from the base for recharging because it’ll be Velcro to the base. In addition, the box containing the sounds chips, and the PCB box will also be safely Velcro on the base. The Velcro strongly holds these components onto the base and allows personnel to easily remove them without the hassle of screws.

The user interface is located adjacent to the access panel that includes the jack inputs for the activator, selector and on/off key switches (See Fig. 41). These components are located on the side of the device in order to safely keep users from contacting with the components. Three screws are used to support and hold the user interface with the base, where two screws are use to hold the interface with the bottom panel of the base and another screw on the side of the base.

Figure 40: Base
The main 14” (L) x 10” (W) x 18.5” (H) device casing with a thickness of 0.25” will be composed of eight individual panels with the following dimensions:

<table>
<thead>
<tr>
<th>Piece Description</th>
<th>Length</th>
<th>Width/Height</th>
<th>Number of Pieces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top/Bottom</td>
<td>14 in.</td>
<td>10 in. (W)</td>
<td>2</td>
</tr>
<tr>
<td>Exterior Sides</td>
<td>10 in</td>
<td>10 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>(Access Panels)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front/Back</td>
<td>13.5 in</td>
<td>18 in (H)</td>
<td>2</td>
</tr>
<tr>
<td>Interior Chamber Sides</td>
<td>10 in</td>
<td>8 in (H)</td>
<td>2</td>
</tr>
</tbody>
</table>

The top and bottom panel is a flat sheet (See Fig. 42). To assemble the top lid onto the case, there are four screws on each corner to hold two corners of the interior chamber sides. For the bottom panel, the two longer sides (14 in) hold the front and back panels with nine screws on each side. On the two short sides (10 in) of the panel, it holds each one side of two access panel hinge with five screws. In addition four screws are used to hold the bottom panel of the casing with the top panel of the base. Therefore to secure and tighten the screws onto the top panel of the base, nuts are used.
The exterior casing (See Fig. 43) has two interior chamber sides, two access doors to the fragrance source, and the front and back panel. On each of the interior chamber sides there are eight flat-head metal screws to hold the front and back panels of the casing. These sides are detachable for maintenance in the fragrance chamber.

The front panel contains several important features: six fragrance indicator lights, four speakers, 18 LEDs light display, two fragrance dispersion holes, and two clear protective PVC front panels to protect individuals from the LEDs.

As mentioned previously, the main concern of the design is to provide users a safe and reliable device to operate. Therefore, to protect the device and to prevent user injury, the
front panel is incased in two 0.125” thick clear PVC. The dimension of each protective PVC panel is 5.5 in (L) x 12 in (H) with two side pieces (0.9375 in (L) x 12 in (H)) and a top piece (5.5 in (L) x 0.9375 (W)). These pieces were assembled together and attached to the front panel with clear PVC cement glue (See Figure 45).

For the speakers and fragrance dispersion holes, a simply pattern of holes was created (See Fig. 46).
The back panel includes two fragrance dispersing fans opening for ventilation. As seen in Fig. 47, the two fan grids cover the fan openings with four screws used to secure the grids on the panel. The four screws are also used to hold and support the fan.
The access door are attached using a surface mount hinge with a total of 10 metal screws on each hinge and, as mentioned, kept in place using a cam lock. There are two access panels on the side of the casing and as seen in Fig. 48, both panels contain a cam-lock and three aerosol sprays can holders. In order to identify which keys belong to which lock, the keys and locks are color-coordinated with two different colors; dark and light pink. The hinge is attached on the outside bottom portion of the panel with five metal screws. The aerosol spray can holders provide stability and position on which the lever activators and solenoids will activate the cans. Once the aerosol spray cans are loaded, users are able to subsequently lock the aerosol spray cans in place secure with the cam-lock.
The user interface consists of essentially three components. The first of these components is the already mentioned selector and activator switches. These will interface with the device through plugs located on the exterior of the base. Because the switches come with cords, the user is not limited position wise during use of this device. The two discussed switches requested by the client are a squish switch (See Figure 49) and a large touch pad (See Figure 50).
The second component of the device is an on/off switch. The on/off key switch is next to the stereo jacks on the exterior of the base as explained previously. In addition, the exterior of the base contains two \(\frac{1}{4}\) inch stereo jacks for the switches to interchange as the selector or the activator. In order to prevent the user from shutting the device off or turning the device on, the on/off switch will be a key switch only accessible to Passion Works supervisors. This SPDT single pole switch (See Figure 13) has three positions (on-off-on) with position two as the key removable position.

The final component is the fragrance and battery access located on either side of the device and the base, respectively. To prevent undesired openings of these panels, a cam lock (See Figure 52) will be used to hold each in place during operation of the device. The fragrance/battery access provides a simple and effective manner for removing and loading the fragrance sources and batteries. Battery-operation was chosen to eliminate safety-hazards involved with electric cords. Because of the simplicity and safety incorporated into these components, minimal supervision is necessary during use.

---

In addition to the olfactory stimulation, auditory and visual stimulation was added to enhance the entertaining experience of the user. The visual portion consists of two light displays (See Fig. 53). As discussed previously, the front panel contains six indicator LED’s that correspond to the six fragrances within the device. When the selector switch is triggered, a new indicator is activated while the previously activated LED is deactivated indicating a new fragrance was selected. In addition to these six, a series of 18 LED’s are used to create a pattern on either side of the front panel. When the activator switch is activated, the LED pattern is activated. All 18 LEDs blink three times in unison, then light up from bottom to top, then blink three times in unison and then light up from top to bottom.
The auditory portion consists of four sound chips and associated speakers. The speakers are arranged vertically on the front of the device. The top speaker corresponds to a “ping” sound chip. This chip is activated each time a new fragrance is selected. This creates the combination effect of a new LED indicator being activated simultaneously with an audible sound. The other three speakers correspond to a Frog, Lion, and Dinosaur Voice sound effect. When the user activates a particular fragrance, one of these three sounds is activated in addition to the LED pattern. In general these effects greatly enhance the amusement of the device. Not only will the user experience olfactory stimulation from the scent, but be witness to an enjoyable light display in addition to sound effects.

The only compatible aerosol spray cans use in the device is aerosol cans from Glade. The Glade Aerosol Spray product comes in a variety of scents including: apple cinnamon, butterfly garden, cinnamon sticks, clean linen, country garden, French vanilla, Hawaiian Breeze, lavender meadow, lilac spring, melon burst, powder fresh, Rainshower, refreshing spa, strawberries and cream, suddenly spring, and tropical mist.

As mentioned before, a fragrance access door is located on both sides of the casing that facilitates removal and loading of these aerosol spray cans. Once the door is unlocked and opened, the aerosol spray cans can easily be removed or loaded into a fixed holder. This holder was constructed out of five individual pieces of gray PVC sheets (see Fig. 54).

![Figure 54: Aerosol Spray Can Holders](image)

The design of the holder is perfectly constructed to fit the 2” diameter and 9” height glade aerosol spray can. The holders will apply a good amount of tightness to secure the cans but also allow slight movement for the user to easily remove the cans. The only difficulties on loading the aerosol can perfectly is the scent release button on the can must be facing the interior casing in order for the lever activators to have direct contact with the button (see Fig. 55).
The interior fabrication of the fragrance dispersion system can be seen in Fig. 56. Figure 56 displays the top view of the system with six individual compartments for the six aerosol cans. There are three separate scent releasing mechanism on each side of the casing. Each compartment contains an aerosol spray can holder, lever activator, solenoid, and solenoid holder. In order to separate these compartments there are six dividers within the casing. Four small dividers are used to separate each fragrance from interacting with each other and provide support for the threaded rod. There are two large dividers in the center of the device to provide separation from each side and hold the solenoids as they are activated. Support is one of the crucial factors in having a working fragrance spray mechanism. These dividers provide support for the solenoids and the threaded rod because the force of the solenoid can easily move the threaded rod without the two small dividers for stability.
There are two 0.25” diameter threaded aluminum rods used to hold the three lever activator and two compartment dividers on each side. The two compartment dividers provide stability for the rod and levers as they are activated by the solenoid. In addition, it supports and securely holds the lever activators in place and provides the solenoid to freely release the desired scent.

The shape and dimensions of each lever activators can be seen in Fig. 57. An ‘L’ shape was chosen to activate the scent due to its simplicity and its ability to directly contact the release button on the tip of the activator. The tip of the activators contains teeth for better contact with the can. The location of the threaded rod insertion must be precisely made in order to provide direct contact with the release button. The position of the hole was determined to be 2 in. from the tip of the activator.

Linear push solenoids were used to activate the spraying mechanism on each of the aerosol spray can compartment (see Fig. 58). A solenoid converts electrical energy into linear mechanical work. When the activator switch is pushed, an electrical signal will be sent through the microprocessor to the appropriate solenoid determined from the
selector switch. Once the solenoid is activated, the plunger will push on the lever activators to release the scent into the interior fragrance chamber. Once the spray mechanism is activated, the fragrance will be released into the interior chamber, where it is sent out through the two air dispersion holes on the front panel into the outside atmosphere via fans.

There will be a time delay of 12 seconds before the next fragrance is release in order to clear any previous scents before activating the next scent. During the time delay, the users won’t be able to operate any of the switches and the LEDs light display pattern and the sound chips will activate.

![Figure 58: Side View of a Compartment](image)

Interiorly, a divider plate was installed to separate the fragrance chamber on the top portion of the casing to the central fragrance dispersion system (see Fig. 59). The top portion of the casing is where fragrances are dispensed and two fans are used to diffuse the scents out of the chamber into the atmosphere. The divider plate provides a pathway for the fragrance to diffuse into a fragrance chamber and protect any fragrance debris from getting on the solenoids or the wires in the center of the casing. On the divider plates there are three 2.5” diameter holes on each side with a total of six holes for each aerosol spray cans to diffuse into the chamber.
As mentioned, two fans are used to direct the fragrance as well as blow fresh air. These fans are known as DC brushless fan or equipment cooling fans. It is compact, cost-effective and easy for installation. Although many types of fans exist, the design of the fan use is a square fan that is easily mountable with four screws on each corner to the back of the device.
Figure 60 depicts the main body of the device's circuit. The main body of the circuit is mainly responsible for supplying power and control to the remainder of the circuitry. Overall power is drawn from a 12 Volt battery controlled by a simple switch. When the circuit is receiving the power, it sends 12 volts to the solenoid circuitry, two fans, and two LM7805 voltage regulators. One regulator supplies the sound chips, the LED Indicators circuit, and PIC and the other supplies the LED Pattern circuit. The PIC is also grounded at pin 12 and 31. In order for the PIC to function properly, it must be connected to an oscillator at pins 13 and 14. The oscillator must also be grounded. The remainder of the pins are designated as either an input or an output. The PIC contains 40 pins altogether. The two input pins are 8 and 9. They are attached to the selector and activator switch, respectively. Based on the input from these two pins, the PIC will send output to the other pins accordingly. These pins control the sound chips, solenoids, pattern LEDs, and indicator LEDs.

Figure 61: Sound Chips and Speaker Schematic

Figure 61 depicts the sound chip circuit complete with the associated speakers. As mentioned previously, there will be four sound chips: Lion, Frog, Dinosaur, and Ping. The upper schematic in Fig. 20 represents the Lion, Frog, and Dinosaur Sound Chip.
Each of the chips is grounded and connected to the 5 volt supply. When the user triggers the activator switch the PIC will send a signal to the Lion, Frog, or Dinosaur depending on the scent selected and activate that sound chip. The Ping Sound Chip, on the other hand, is directly connected to pin 39 of the PIC and grounded. When the user triggers the selector switch, the PIC will send a signal to the Ping chip causing it to activate.

Figure 62 depicts the LED Indicator circuit. Its purpose is to activate six red LEDs based on input from the user as described above. When the device is initially turned on, the PIC automatically activates the first LED. This indicates that the first scent is chosen or ready for activation. When the user triggers the selector switch, the PIC will activate the second LED and stop activating the first simultaneously and so forth.
Figure 63: LED Pattern Schematic on Interface

Figure 63 depicts the LED Pattern circuit. Its purpose is to activate 18 LEDs: 6 red, 6 green, and 6 yellow. As mentioned earlier, activation of a particular scent will also result in the activation of a light display consisting of these 18 LEDs.
Figure 64: Solenoid Schematic

Figure 64 depicts the Solenoid Circuit, where +Vs equals 12 volts and +Vss equals 5 volts. The two main components of the circuit are the solenoids and the L295 Dual Solenoid Driver. As mentioned, the device requires a total of six solenoids to activate the spray release mechanism on the aerosol spray cans. Since the microprocessor alone will not be able to power the 12V solenoid, the solenoid driver is necessary. The drivers used are able to power two solenoids.

A sealed lead acid, rechargeable battery was chosen for the power supply (See Fig. #). It is 12 volts and has 2.3 amp-hrs. A corresponding charger will be included with the device.
The PIC16F874 Microcontroller (PIC for short) is responsible for taking input from the switches and processing them into output that controls activation of the indicator lights, sound chips, LED’s, and the solenoids. In this regard, the PIC Microcontroller is the ‘brain’ of Olfaction Satisfaction. Therefore, it is important to understand how the PIC is programmed so that it will respond correctly to the user’s input.

All switches of the user interface are, by necessity, active low. The first switch is responsible for activating the enabled solenoid. For identification purposes, this switch (and the signal that it sends out) will be designated ‘Activate’. The second user controlled switch will be responsible for telling the device to change which solenoid will be enabled (allowing the user to switch to different fragrances). The signal coming from this switch will be designated ‘Select’. When either switch is activated or used a digital 0 (or ‘Low’, ‘false’) is sent to the PIC. When the switch is not used, a digital 1 (or ‘Hi’, ‘true’) is sent to the PIC.

Outputs controlling the indicator lights are given the designation LED Indicator # (indicating which LED the output is responsible for). Similar nomenclature is given to outputs controlling sound chips, solenoids, and LED’s. Table 11 summarizes the pin-outs for the PIC (note: LED Row # corresponds to the rows of LED’s on the faceplate that are used purely for visual stimulation):

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Connected to:</th>
<th>Type</th>
<th>Pin #</th>
<th>Connected to:</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+5V</td>
<td>input</td>
<td>21</td>
<td>LED Row 3</td>
<td>output</td>
</tr>
<tr>
<td>2</td>
<td>Sound Chip 1</td>
<td>output</td>
<td>22</td>
<td>LED Row 4</td>
<td>output</td>
</tr>
<tr>
<td>3</td>
<td>Sound Chip 2</td>
<td>output</td>
<td>23</td>
<td>Solenoid 5</td>
<td>output</td>
</tr>
<tr>
<td>4</td>
<td>Sound Chip 3</td>
<td>output</td>
<td>24</td>
<td>Solenoid 6</td>
<td>output</td>
</tr>
<tr>
<td>5</td>
<td>Sound Chip 4</td>
<td>output</td>
<td>25</td>
<td>N/A</td>
<td>output</td>
</tr>
<tr>
<td>6</td>
<td>N/A</td>
<td>output</td>
<td>26</td>
<td>N/A</td>
<td>output</td>
</tr>
<tr>
<td>7</td>
<td>Sound Chip 6</td>
<td>output</td>
<td>27</td>
<td>LED Row 5</td>
<td>output</td>
</tr>
<tr>
<td>8</td>
<td>Select</td>
<td>input</td>
<td>28</td>
<td>LED Row 6</td>
<td>output</td>
</tr>
<tr>
<td>9</td>
<td>Activate</td>
<td>input</td>
<td>29</td>
<td>N/A</td>
<td>output</td>
</tr>
<tr>
<td>10</td>
<td>N/A</td>
<td>output</td>
<td>30</td>
<td>N/A</td>
<td>output</td>
</tr>
<tr>
<td>11</td>
<td>+5V</td>
<td>input</td>
<td>31</td>
<td>GND</td>
<td>input</td>
</tr>
<tr>
<td>12</td>
<td>GND</td>
<td>input</td>
<td>32</td>
<td>+5V</td>
<td>input</td>
</tr>
<tr>
<td>13</td>
<td>Oscillator</td>
<td>input</td>
<td>33</td>
<td>LED Indicator 1</td>
<td>output</td>
</tr>
<tr>
<td>Port</td>
<td>Pin</td>
<td>Description</td>
<td>Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>-------------</td>
<td>--------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Solenoid 1</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Solenoid 2</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Solenoid 3</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Solenoid 4</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>LED Row 1</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>LED Row 2</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>LED Indicator 2</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>LED Indicator 3</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>LED Indicator 4</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>LED Indicator 5</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>LED Indicator 6</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Sound Chip 5</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>N/A</td>
<td>output</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Having seen how the pins are connected to the rest of the circuit, it is now important to understand how the PIC itself is programmed. The pins of the PIC are organized into ports A through E. Ports D and B have 8 pins each, Port E has 3 pins, and Port A has 6 pins. Each pin of each port can be defined as input or output.

Note however that output pins of the PIC are not homogeneously assembled. There are some significant differences between certain pins on the PIC and the rest of the pins. For example, Port A, showed only one nonworking pin, RA4 (i.e. pin 6 of the PIC) which has a Schmitt Trigger input and an open drain output and is not capable of generating the necessary 5 V output to control the sound chips. Therefore, RA4 is ignored and its duties given to pin RB6 (i.e. pin 39 of the PIC).

The I/O scheme for all the pins of the PIC is defined right after the device is turned on during the initialization phase of the PIC’s programming. Furthermore, any necessary variables used in system processing are defined during this phase. Also, since digital input and output is being used, the configuration variable ADCON1 which is integral to the PIC must be set to a specific value in order for digital input and output to be facilitated. This phase is termed the Initialization phase of the PIC startup routine.

Note after power has been turned on, the PIC begins to initialize all the variables and pin I/O configurations. The first 2 pins of Port E are defined as inputs. The rest of the ports are defined as outputs to the rest of the circuit. Note also that two variables are defined: COUNT and SOLARRAY (both are 6 bits in length). COUNT is a variable used for timing and coordination of the LED’s (i.e. the LED’s controlled by pins 19 – 22 and pins 27 and 28). SOLARRAY is a variable that is used to remember which solenoid is the currently active solenoid. When input is sent to pin 9 (i.e. the Activate input) the solenoid indicated by SOLARRAY will be activated.

TEMP255, TEMP 118, and TEMP5 are variables used in the Delay routine that causes the PIC to pause for 0.5 seconds when called in the PIC’s program code. The Delay routine is used in many places to control how long to activate a certain element of Olfaction Satisfaction’s stimulatory output (i.e. LED’s, sound chips, solenoids, etc.) It is also the Delay routine that allows for the specifically timed outputs seen in the Activate and Select routines.

After the initialization routine, the PIC enters a control loop, in which it looks for input from the user. This control loop is shown in Diagram #2 below. Note that the command btfss is an assembly command that looks at a specified bit of the input variable and skips
the next line of code if the bit is set (i.e digital Hi), otherwise the program will process
the next line of code.

If the Select input is activated, then the first bit of Port E (i.e. pin 8) will be Low (a
digital o) and the program will call the Select subroutine. Then the PIC will change the
active solenoid to the next solenoid down the line, change the indicator lights
accordingly, and play a sound. This is all implemented with a series of btfsc commands
and MOVLF commands. Similar processing is carried out until the value of the 6th bit of
SOLARRAY is set (i.e. the last solenoid is enabled). At this point, when Select is asserted
the program will always reset the value of SOLARRAY to its original value of “100000”
(i.e. the state in which the first solenoid is enabled).

If not already clear, the order of events following the activation of the Select loop are as
follows: 1) Check if False Positive event occurred (if so return to Control Loop), 2)
Locate currently selected solenoid given by SOLARRAY, 3) Activate currently selected
solenoid, 4) wait 2.0 seconds, 5) Deactivate currently selected solenoid, 6) Flash LED’s 3
times, 7) Play sound, 8) Flash LED’s in pretty pattern.

If Select is not activated, then the first btfss statement will skip to the second btfss
statement (i.e. whether or not Activate has been asserted). If Activate is enabled then the
program will call the Activate subroutine. The Activate subroutine (Block Diagram 4
below) starts off with changing the value of PORTC to the value stored in SOLARRAY.
This results in a Hi value at one of the pins of Port C. At this point, one of the solenoids
is activated causing fragrance to be released. The program then does nothing (i.e. leaves
the solenoid active) for 0.5 seconds. After this, the solenoid is disabled: the value of
PORTC is reset to “00000000”.

If not already clear, the order of events following the activation of the Activate loop are
as follows: 1) Check if False Positive event occurred (if so return to Control Loop), 2)
Locate currently active solenoid given by SOLARRAY, 3) Set next solenoid in line as
active, deactivate current solenoid, 4) Play a sound, 5) Return to Control Loop.

The circuit schematics shown above were used to design the layout for the device’s PCB
(See Fig. 66).
This layout was used to create the actual PCB. All of the electrical components discussed above were installed onto the PCB and incorporated into the device. Both the PCB and sound chips were contained in individual black, plastic containers (See Figure 67 & 68). Holes were drilled in each to provide exit/entry for the necessary wires going to other components. As mentioned above, these boxes were secured to the base using Velcro to facilitate removal if necessary.
2.3.2 Testing

After the device was complete, the client was contacted. Autumn appeared to be extremely satisfied with the device. She stated that “it will be a welcome addition to the multi-sensory stimulation room.” She also discussed how previous market search found no applicable devices. The only product found was aroma therapy kits which require outside assistance for operation. This device however will provide the necessary olfactory stimulation with only minimal supervision. Overall, she looks forward to incorporating this device with their facility.

In addition to correspondence with the client, two individuals were able to do a short pilot test of the device: Crystal Yeung and Christen Thomsen. Crystal Yeung is an 8th semester nursing major attending University of Connecticut. As a nursing major, she’s been working with many disable individuals. Therefore, she was very helpful to understand how a disabled individual would respond to using the olfactory stimulation device. As she tested the device, there are many beneficial features a disabled individual will gain such as the LED display pattern, easy handling and usage of the switches, and the smell, sound and sight stimulation. She stated “I love the LED display patterns. It is easy to use and very stimulating!” She also noticed this device would be excellent in hospital setting such as a patient requires stimulation during post-op. Once the device was on, Crystal was able to open the access panel easily. As seen in Fig. 69, she was able to load and unload the aerosol cans.

Figure 69: Removing and Loading Aerosol Spray Cans
Once everything was setup, she was able to begin testing the device. In Fig. 70, she was able to use two switches for selecting and activating the scent and complemented “The switches are **excellent** for motor disable individuals to use”.

![Crystal Testing the Device](image1.png)

**Figure 70: Crystal Testing the Device**

Overall, she was very delighted to see how simple it is to operate the device and having an olfactory stimulation device available in the market.

Christen Thomsen is a fellow 8th semester Biomedical Engineering Major attending the University of Connecticut. During the testing, Christen was able to proficiently use the device after given a few, simple directions (See Fig. 71).

![Christen Testing the Device](image2.png)

**Figure 71: Christen Testing the Device**
He also verified the ease of accessing and removing the battery for maintenance purposes (See Fig. 72).

Figure 72: Assessing the Battery

In addition to easy maintenance, Christen also commented on the device’s ease of use. He also said the device possessed excellent safety features such as keyed entry, as well as, stability and durability. His favorite part of the device was the fact that it was a stand alone unit. All of the exterior components (user switches and battery charger) could be neatly stored in the base of the device when not in use. He also thought that the future users would enjoy the LED patterned display and the entertaining sound effects. Finally, he stated that “the scents are ‘satisfying’ but not over-bearing.”

3 Realistic Constraints

In order to satisfy the individuals’ needs, design limitations are assigned. The device should be safe for any individuals to use without any hazardous factors such as rough edges, potential of electric shock, and possible spillage. The weight of the device should not be exceedingly heavy as to hinder portability or endanger the user in case accidental mishandling.

3.1 Engineering Standards

According to the Americans with Disabilities Act (ADA) the following requirements should be met: 1) the device should sit on a table with clear floor space of 30 by 48 inches, 2) the user should be able to access the device by facing forward or sideways, 3) when the user is facing forward, he or she should be able to reach the device from 48 inches off the ground or be able to reach the device if placed within 15 inches from the ground, 4) when the user is sideways, the maximum height that he or she should reach is 54 inches and the minimum low side reach should be no less than 9 inches above the floor, 5) the device must be placed within visual range, and 6) Character limitations on the device (i.e. for labeling, etc.): the height to width ratio has to be between 3:5 and 1:1 and the stroke width-to-height ratio is between 1:5 and 1:10. Each of these requirements is observed in the final design and the assembled prototype.
The first requirement from the ADA is that the device must be able to be used on a table with a clear space of at least 30 by 48 inches. Olfaction Satisfaction was designed to accommodate this requirement by having a base that is large enough to provide adequate stability for the device but also small enough to fit on a table with enough clear space to maintain the 30 by 48 inches required by the ADA. Furthermore, the Olfaction Satisfaction User’s manual recommends just this amount of clear space for optimal device usage as the user’s interface requires clear space for ease of accessibility.

The second requirement from the ADA is that the user must be able to use the device facing forward or sideways. This requirement is geared mainly for those users who require the use of a wheelchair or are otherwise confined to a sitting position when using the device. Olfaction Satisfaction’s easily moveable and accessible user’s interface provides for just such a requirement because the interchangeable switches can be moved to the user’s preference so as to provide optimal interaction with the device. Furthermore, Olfaction Satisfaction’s large display face ensures that the user will receive adequate stimulation from the device in both forward and side viewing angles.

The third and fourth requirements from the ADA are met in the final design by Olfaction Satisfaction’s mobile user’s interface. Regardless of where the device is placed (i.e. on the floor or on a table), the location of the user’s interface can be modified to meet the user’s needs. This ensures that the controls for the device will always be within reach. Personnel need only move the user’s interface to an appropriate location before the device is used.

The fifth and sixth requirements from the ADA are observed in the final design of Olfaction Satisfaction by its large viewing face and the large characters that mark out the important switches and key locks of the device. Firstly, the nature of the device requires that it should be placed within viewing range as the user’s interface cannot reach to a distance at which the device cannot be adequately seen. Secondly, the user’s interface is extremely simple, possessing only two switches, and therefore requires no labeling. For ease of maintenance, however, all important key locks and plugs are labeled with legible signs indicating their function to maintenance personnel or caretakers.

3.2 Realistic Constraints

As mentioned, the choice of the final design was also based on several special considerations. These include: economic, manufacturability, sustainability, environment, health and safety, social, political, and ethical. Looking at the device from an economic point of view, it achieves a compromise between quality and quantity. While keeping costs at a minimum, the device was still able to meet the client’s need in an effective and valuable manner. The device was even able to incorporate additional features and still maintain total costs comparable to the other devices currently offered that lack all desired characteristics. In accordance with economic considerations, The device also maintained the best manufacturability potential. The majority of the device is composed of PVC sheeting, a material known for its ease of processing and
machining. The remainder of the device build simply consists of electrical component assembly involving mostly soldering. It is important to note, however, that despite the apparent straightforwardness of the device’s manufacture process quality assurance will still need to be rigorously ensured. In addition to these considerations, it is anticipated that this device will sustain its usefulness for its entire lifetime. The device offers a quality, versatile product that cannot easily be outmoded both economically and functionally without replication.

As with any device, it is extremely important to consider the environmental impact of its manufacturing procedure and use. The major source of environmental concern with device is the disposal of the PVC, empty air freshener cans, and electrical components at the end of the device’s useful life. One of the biggest downfalls associated with the use of PVC entails its disposal procedure since it does not biodegrade at a significant rate. Large scale recycling is nearly impossible due to the extent of additives present in the PVC. These additives also interfere with the recycling process of other plastics (“PVC Plastics”). It has been stated, however, that when compared to other material choices PVC is actually favorable recycling wise. Special facilities now exist with the capability to deal with the complex process of properly recycling PVC (“PVC in Building & Construction”). The recycling of aerosol cans is also not straightforward. In addition to this difficulty, studies claim that substances contained in items such as air fresheners contribute to both indoor and outdoor air pollution (Bridges). These studies have yet to be accepted universally, however. The device reduces some electrical waste by using permanent LEDs and a rechargeable battery. It is also extremely important to consider the impact of the device on the health and safety of the individuals connected with the device including the user. The two biggest health and safety concerns associated with this device involve the PVC sheeting and the aerosol air fresheners. Many toxic byproducts result from the production of PVC including dioxin, ethylene dichloride, and vinyl chloride. These have the potential to cause cancer, endocrine disruption, endometriosis, neurological damage, birth defects, and immune system damage if not properly dealt with. Chemical stabilizers remaining in the PVC such as lead or cadmium can potentially increase the risk of asthma, lead poisoning, and cancer if they leach, flake, or outgas overtime from the PVC (“PVC Plastics”). Although the production of PVC is uncontrollable, warranting a specific life span for the device after which risks become significant should be considered. Evidence also exists linking substances found in aerosol air fresheners to a multitude of medical conditions. For instance, it has been shown that excessive exposure may cause headaches, nausea, shortness of breath, eye, throat and lung irritation, skin rashes, burns and liver damage (“Indoor Air Pollution”). It might be necessary to set a daily time limit for device use per individual based on these observations. Additionally, aerosol air fresheners have the potential to explode when exposed to excessive heat. Explosions could result in serious injuries to nearby individuals (“Indoor Air Pollution”). Because of this, it will important to maintain an operating temperature below 120 °F.

One of the most positive aspects of this device is its social contribution. By providing acceptable stimulation to adults with severe disabilities, the device aims to improve the quality of life for these individuals. Because of this, it is unlikely to detriment society in any manner. From a political perspective, the device does not have a significant impact.
Its design and use does not impinge upon the American with Disabilities Act or any other pertinent legislation. From an ethical perspective, the device does not raise any issues excluding those involved with its safety and environmental impact.

4 Safety Issues

Olfaction Satisfaction was designed with safety in mind. Various features of the design serve to protect the user from accidental harm. In particular, the device is designed to protect the user from 3 types of hazards: 1) Electrical Hazards, 2) Mechanical/Physical Hazards, and 3) Chemical Hazards. These types of hazards are the most likely given the intended use of the device; hence it is specially designed to guard against them. The combination of all these safety factors results in a device that is completely user friendly, requiring little to no supervision while in use.

Firstly, Olfaction Satisfaction is designed to protect the user from Electrical Hazards. To do so, the device was designed to be battery operated to eliminate any unnecessary power cords that can be tripped over, entangled in, or exposed to electric shock. Furthermore, the device’s housing is designed to be electrically neutral, protecting both the user and Olfaction Satisfaction’s circuitry from electric shock. Finally, the device is designed to protect the user from coming into contact with any electrical component of the device by having access to the circuit housing restricted by key locks that only authorized personnel can open.

Secondly, Olfaction Satisfaction is designed to protect the user from Mechanical and Physical Hazards. To do so, the device was designed to have a smooth exterior devoid of sharp edges to protect the user from harming him or herself in case of mishandling of Olfaction Satisfaction. Also, protective grills were installed to prevent the user from sticking fingers or other appendages into the intake of the device’s fragrance fans. Furthermore, a protective clear PVC cover was placed over the devices LED’s to prevent the user from pulling on them, causing physical damage to the device resulting in sharp edges and possible electrical shock. In addition to this, Olfaction Satisfaction features a wide base to prevent accidental tipping of the device. Finally, the choice of PVC to fabricate Olfaction Satisfaction’s outer casing was made due to the material’s excellent durability. This component of the design ensures that the device will stand up to mishandling by the user while still maintaining all the safety factors mentioned earlier.

Finally, Olfaction Satisfaction is designed to protect the user from Chemical Hazards. This is accomplished by the design of Olfaction Satisfaction’s fragrance chamber. When the solenoids are activated, the corresponding release of a fragrant chemical spray from the interchangeable aerosol cans could potentially harm the user were it not for the fragrance chamber. The fragrance chamber takes this potentially harmful chemical spray and allows it to further disburse in the air before it is gently blown from the fragrance outlets. As a result, the chemical spray from the aerosol cans is converted to a fragrant breeze from Olfaction Satisfaction’s fragrance outlet vents.
In summary, Olfaction Satisfaction was designed to protect the user above all else from Electrical, Mechanical, and Chemical Hazards. Also, the device was designed to retain these safety features even in cases of extreme mishandling or misuse. Only in severe cases of mishandling will the safety features of the device begin to break down, as would happen with any device. However, if properly maintained and used, Olfaction Satisfaction will serve as an excellent and safe addition to any device collection.

5 Impact of Engineering Solutions

In the foreseeable future, Olfaction Satisfaction may have three types or areas of impact: 1) Economic Impact, 2) Societal Impact, and 3) Global Impact. In each of these areas, it is clear that the technology of Olfaction Satisfaction will have a positive impact. The smallest impact is the improvement of the quality of life of a small niche of clients in the US. The greatest impact is the global improvement in the quality and quantity of similar devices throughout the world.

5.1 Economic Impact

Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the Olfaction Satisfaction’s main purpose is to provide a pure and simple stimulation of the individual’s senses. The device not only delivers quality sensory stimulation, but also goes further and improves on deficiencies seen in products with olfactory stimulation technology on the market today.

Designed with the purpose of meeting the client’s needs, Olfaction Satisfaction not only does so, but also addresses issues that are found in current devices on the market today. Analysis of existing designs shows that there is a real lack of devices possessing olfactory stimulation technology designed to meet the needs of disabled adults. Although the need exists for designs geared towards disabled children, the needs of disabled adults cannot be ignored. Designed with disabled adults in mind, Olfaction Satisfaction meets a market demand that has been previously overlooked.

With these points in mind it is clear that the economic impact of Olfaction Satisfaction’s technology on the market for biomedical devices geared towards improving the quality of life for disabled adults. Up to this point in time, there is a real deficiency in both the quality and the quantity of such devices on the market today. In many cases, devices are designed with children in mind and are geared towards teaching or hand eye coordination. Furthermore, many of these toys lack the capacity to stimulate the olfactory sense and the few that do are again geared towards children.

This being the case, Olfaction Satisfaction represents a new breed of biomedical device: a purely entertainment focused device for disabled adults. During the design phase of the project it was made clear that any device geared toward learning or teaching would not be appreciated by the intended users (indeed, a device geared to do so may in fact
frustrate or anger the user). Considering the current market for devices and what they are geared towards, Olfaction Satisfaction will satisfy a niche in the market that has been completely ignored.

Economically, the presence of this device may cause biomedical companies to re-evaluate their current marketing strategy and begin developing similar devices for disabled adults. At best this trend may result in a market shift into more devices like Olfaction Satisfaction. At least this trend will result in the increased presence of more biomedical entertainment/stimulation devices for disabled adults. In either event, the consumer (and in turn the client) will benefit greatly from the improved quality of life such devices afford.

5.2 Societal Impact

The end of the result of the increased presence of devices like Olfaction Satisfaction in the market and the increased competition between biomedical companies to sell such devices is a decrease in retail price. This will cause a decrease in the financial burden of incorporating these devices into modern disabled adult care facilities resulting in increased quality of living at a reduced cost. Eventually such an impact will ripple through the economic chain of the health care industry. If such a thing were to happen, the best possible outcome would be a decreased financial weight associated with governmental programs such as Medicare, freeing more tax money to go into other programs.

This being so, the end result is a more competitive biomedical sector of the market and a decreased dependency on government funding to provide health care to disabled adults. If this is the case, then an increasingly competitive health care market makes a vision of the privatization of the health care industry more plausible. Financial conservatives, in this regard may come out as the winner of the Public versus Private health care debate. In this case the quality of life of both the patient and the tax payer is improved.

On the other hand, a decrease in the cost of devices like Olfaction Satisfaction may leave more funds to be spent on other health care items, in which case the size of the Federal budget for health care programs such as Medicare may stay the same. This being the case, things stay the same financially and politically (patient's quality of life, however, will continue to rise).

5.3 Global Impact

On a global scale, the effect of Olfaction Satisfaction and similarly geared devices will be the increased presence of such devices in disabled adult care facilities. Improving the quality of life of disabled adults is a global problem and Olfaction Satisfaction is, in part, a solution. By answering the demand for devices aimed at entertainment and sensory stimulation, the quality of life of disabled adults all over the globe will be improved.
Olfaction Satisfaction’s versatile and easy to use user interface, battery powered operation, and ease of maintenance represent a device that can be used anywhere in the world with anyone. As a result, it can improve the quality of life of clients anywhere in the world, regardless of language, race, religion, or culture. The sensory stimuli (auditory, visual, tactile, and olfactory) represent universal constants that are alien to no one, thus giving the technology a wide range of clients which will appreciate its design and function.

6 Life-long Learning

Through the course of Senior Design, the team acquired valuable knowledge and experience. To begin with, the team gained familiarity with several skills that will be helpful no matter what area of Biomedical Engineering their career takes them. These skills include searching for parts online/in catalogues, interacting with distributors of these parts, generating a purchase order, and keeping track of a budget. In addition to these skills, the team was also exposed to several important computer programs including Microsoft Visio, Microsoft Project, Dreamweaver, MPLab, and PCBExpress.

The team also expanded their understanding of electric circuits and their components. In additional to general knowledge of current and voltages, they also learned about various unknown electrical parts. These include voltage regulators, hex inverters, LEDs, solenoid, solenoid drivers and sound chips. Their troubleshooting electrical circuit skills were also improved. Along with this knowledge, the team also greatly enhanced their circuit assembly skills. These skills include soldering (including surface mount), tinning, and shrink wrapping.

The team was also exposed to the process of designing a PCB (Printed Circuit Board) using a program provided by PCBExpress and programming a PIC Microprocessor using MPLab. The process of designing the PCB consisted of generating a schematic based on a protoboard circuit, laying out the necessary parts and pins, and making all the necessary connections with traces. Also the process of programming the PIC Microprocessor involved learning Assembly language and syntax, debugging skills, and learning from component data sheets. Such skills will become invaluable in the future.

Before structure fabrication, one of our team members had the opportunity to take the machine shop course over a week span and acquired many techniques for structural fabrications. Such techniques were making an aluminum T-nut and a copper based drill punch. In addition, other techniques acquired are as following:

- Measuring and determining threads on a screw.
- Using drill bits, taps, and countersink.
- Measuring techniques.
- Using different measuring tools such as calipers and micrometer.
- Setup and operate on a miller, band saw, drill press, and a lathe.
- Manually shear different types of materials (PVC, galvanic steel, sheet metal).
Once structural fabrication began, the band-saw was used to quickly cut and modified any PVC pieces with a thickness greater than 1/16” into any shape. In order to operate the band saw efficiently, it was operated at high speed and the saw blade was placed closer to the piece for precise and smooth cutting. Another device frequently used on the project to fabricate complex shapes and areas is the miller. The miller is one of the most accurate machines in the shop due to its simple programmable features to make circular pockets, holes, and frame. Besides being automatic, it is also compatible for manually cutting a piece. The drill press machine was also frequently used to make hinges and assemble the device together. In order to assemble pieces together, it requires three steps; drilling, tapping, and countersinking. The drill press professionally makes the screw holes vertically straight into the piece. Once the holes were made, tapping the holes provides screws to easily tighten and secure the pieces together. However, to provide a better fit for the flat head screws used, a counter sink was applied to each surface of the holes. One of the most important factors in operating these machines is to determine its appropriate operating speed. The speed rates can be determined on a drill press speed rate. To operate the miller and drill press machine, the nominal operating speed is around 200 – 360 rpm, depending on the thickness and the size of the drill bit. Overall the machine shop had taught much about machining techniques on different types of materials in the project.

Finally, the team learned a very important lesson: Problems, no matter how impossible they may seem, are always solved through teamwork and persistence. During the design and assembly of the project many issues and problems were encountered: Circuit Design issues, Microprocessor problems, Fabrication setbacks, and shipping delays. In each case, it seemed like an insurmountable obstacle to the completion of the project within its timeline has been suddenly thrown at the team. However, though perseverance and maintaining a cool head the team was able to devise solutions to all of these problems. Good Teamwork is the backbone of any successful project.

7 Budget

The following is a list of the components and corresponding costs purchased during the build the device:

Table 13: Budget by Components

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Switch</td>
<td>1</td>
<td>$11.96</td>
<td>$11.96</td>
</tr>
<tr>
<td>1/4&quot; Black Plastic Stereo Jack</td>
<td>2</td>
<td>$2.12</td>
<td>$4.24</td>
</tr>
<tr>
<td>PVC Glue</td>
<td>1</td>
<td>$4.02</td>
<td>$4.02</td>
</tr>
<tr>
<td>PCV Type I Sheet 1/8&quot; thick, 12” x 24”, Gray</td>
<td>3</td>
<td>$7.52</td>
<td>$22.56</td>
</tr>
<tr>
<td>Unfinished Steel Piano Hinge without holes .025&quot; thick, 3/4&quot; open width, 3 ft length</td>
<td>2</td>
<td>$1.36</td>
<td>$2.72</td>
</tr>
<tr>
<td>Standard Camlock w/ Polished Nickel Finish, Key Different, 3/4&quot; Dia hole, 7/64&quot; material thk</td>
<td>2</td>
<td>$4.31</td>
<td>$8.62</td>
</tr>
<tr>
<td>Clear PVC Type I Sheet, 1/16&quot; thick, 12&quot; x 24&quot;</td>
<td>2</td>
<td>$6.71</td>
<td>$13.42</td>
</tr>
<tr>
<td>DC Equipment Cooling Fan, 3.5 cfm, 1.75 in sq. x 0.39&quot; depth, 12 VDC</td>
<td>1</td>
<td>$13.50</td>
<td>$13.50</td>
</tr>
<tr>
<td>Linear Solenoid Push, Intermittent, 12 VDC, 1/2&quot; stroke, 43 oz force</td>
<td>1</td>
<td>$13.02</td>
<td>$13.02</td>
</tr>
<tr>
<td>Item Description</td>
<td>Quantity</td>
<td>Unit Price</td>
<td>Total Price</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>----------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Microchip PICmicro - PIC16Fxxx Flash MCU's</td>
<td>2</td>
<td>$ 7.80</td>
<td>$ 15.60</td>
</tr>
<tr>
<td>Monkey Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Bird Voices Kit</td>
<td>1</td>
<td>$ 3.95</td>
<td>$ 3.95</td>
</tr>
<tr>
<td>Lion Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Pig Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Frog Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Mini Siren Kit</td>
<td>1</td>
<td>$ 3.95</td>
<td>$ 3.95</td>
</tr>
<tr>
<td>Squish Switch</td>
<td>1</td>
<td>$ 49.00</td>
<td>$ 49.00</td>
</tr>
<tr>
<td>Large Touch Pad</td>
<td>1</td>
<td>$ 69.00</td>
<td>$ 69.00</td>
</tr>
<tr>
<td>Voltage Regulator, 7805T</td>
<td>2</td>
<td>$ 0.35</td>
<td>$ 0.70</td>
</tr>
<tr>
<td>Red LED, 5 mm</td>
<td>10</td>
<td>$ 0.10</td>
<td>$ 1.00</td>
</tr>
<tr>
<td>Yellow LED, 3 mm</td>
<td>20</td>
<td>$ 0.08</td>
<td>$ 1.60</td>
</tr>
<tr>
<td>Red LED, 3 mm</td>
<td>30</td>
<td>$ 0.10</td>
<td>$ 3.00</td>
</tr>
<tr>
<td>Green LED, 3 mm</td>
<td>20</td>
<td>$ 0.08</td>
<td>$ 1.60</td>
</tr>
<tr>
<td>Adhesive Sandpaper</td>
<td>1</td>
<td>$ 1.69</td>
<td>$ 1.69</td>
</tr>
<tr>
<td>Glade Aerosol Spray Cans</td>
<td>6</td>
<td>$ 1.50</td>
<td>$ 9.00</td>
</tr>
<tr>
<td>Fan Guard</td>
<td>2</td>
<td>$ 0.79</td>
<td>$ 1.58</td>
</tr>
<tr>
<td>Fan, 12 VDC, 2x2x0.6</td>
<td>2</td>
<td>$ 3.55</td>
<td>$ 7.10</td>
</tr>
<tr>
<td>.25 Type I PVC Sheet</td>
<td>3</td>
<td>$ 18.32</td>
<td>$ 54.96</td>
</tr>
<tr>
<td>.375 Type I PVC Sheet</td>
<td>1</td>
<td>$ 54.96</td>
<td>$ 54.96</td>
</tr>
<tr>
<td>.25 Diam. PVC Type 1 Rod</td>
<td>1</td>
<td>$ 2.45</td>
<td>$ 2.45</td>
</tr>
<tr>
<td>Linear Solenoid Push, Intermittent, 12 VDC, 1/2&quot; stroke, 43 oz force</td>
<td>6</td>
<td>$ 13.02</td>
<td>$ 78.12</td>
</tr>
<tr>
<td>Standard Camlock w/ Polished Nickel Finish, Key Different, 3/4&quot;Dia hole, 7/64&quot; material thk</td>
<td>1</td>
<td>$ 4.31</td>
<td>$ 4.31</td>
</tr>
<tr>
<td>Indicator, 8 mm LED Panel Mount, 2V, Red</td>
<td>6</td>
<td>$ 1.61</td>
<td>$ 9.66</td>
</tr>
<tr>
<td>Indicator, 1/4&quot; Snap Mount LED, 6&quot; leads, 2V, Yellow</td>
<td>6</td>
<td>$ 1.34</td>
<td>$ 8.04</td>
</tr>
<tr>
<td>Indicator, 1/4&quot; Snap Mount LED, 6&quot; leads, 2V, Red</td>
<td>6</td>
<td>$ 2.55</td>
<td>$ 15.30</td>
</tr>
<tr>
<td>Indicator, 1/4&quot; Snap Mount LED, 6&quot; leads, 2V, Green</td>
<td>6</td>
<td>$ 2.55</td>
<td>$ 15.30</td>
</tr>
<tr>
<td>Melody Generator Kit</td>
<td>1</td>
<td>$ 3.95</td>
<td>$ 3.95</td>
</tr>
<tr>
<td>Frog Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Lion Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Dinosaur Voice Kit</td>
<td>1</td>
<td>$ 4.95</td>
<td>$ 4.95</td>
</tr>
<tr>
<td>Gray Box</td>
<td>1</td>
<td>$ 5.07</td>
<td>$ 5.07</td>
</tr>
<tr>
<td>Mounting Screws</td>
<td>1</td>
<td>$ 2.50</td>
<td>$ 2.50</td>
</tr>
<tr>
<td>Sealed Lead Acid Battery</td>
<td>1</td>
<td>$ 20.99</td>
<td>$ 20.99</td>
</tr>
<tr>
<td>Lead Acid Battery Charger</td>
<td>1</td>
<td>$ 39.99</td>
<td>$ 39.99</td>
</tr>
<tr>
<td>PCB</td>
<td>1</td>
<td>$ 51.00</td>
<td>$ 51.00</td>
</tr>
<tr>
<td>Dual Solenoid Driver</td>
<td>7</td>
<td>5.73</td>
<td>40.11</td>
</tr>
<tr>
<td>IC Socket ST 40POS</td>
<td>1</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>RES 130 1/4W 5% 1206 SMD</td>
<td>30</td>
<td>0.09</td>
<td>2.82</td>
</tr>
<tr>
<td>RES 160 1/4W 5% 1206 SMD</td>
<td>20</td>
<td>0.09</td>
<td>1.88</td>
</tr>
<tr>
<td>RES 100k 1/4W 5% 1206 SMD</td>
<td>10</td>
<td>0.09</td>
<td>0.94</td>
</tr>
<tr>
<td>CAP CERAMIC 1uF 25V 0603</td>
<td>10</td>
<td>0.06</td>
<td>0.59</td>
</tr>
<tr>
<td>RES 10k 1/4W 5% 1206 SMD</td>
<td>10</td>
<td>0.09</td>
<td>0.94</td>
</tr>
<tr>
<td>IC REG 1A POS 0-125DEGC</td>
<td>2</td>
<td>0.48</td>
<td>0.96</td>
</tr>
<tr>
<td>IC PWM LO-SIDE DRV 8-SOP</td>
<td>3</td>
<td>4.16</td>
<td>12.48</td>
</tr>
<tr>
<td>RES .47 OHM 1/4 W 1206 SMD</td>
<td>20</td>
<td>0.27</td>
<td>5.40</td>
</tr>
<tr>
<td>CAP 3900pF 50V Ceramic</td>
<td>20</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td>Cap .1uF 50V Ceramic</td>
<td>20</td>
<td>0.10</td>
<td>1.96</td>
</tr>
<tr>
<td>RES 130 1/4W Carbon Film</td>
<td>40</td>
<td>0.05</td>
<td>2.16</td>
</tr>
<tr>
<td>RES 160 1/4W Carbon Film</td>
<td>20</td>
<td>0.05</td>
<td>1.08</td>
</tr>
<tr>
<td>Cap 220uF 25V Elect. Radial</td>
<td>10</td>
<td>0.38</td>
<td>3.80</td>
</tr>
<tr>
<td>Rectifier GPP 1000V 1A</td>
<td>30</td>
<td>0.09</td>
<td>2.82</td>
</tr>
<tr>
<td>RES 10K 1/4W 1206 SMD</td>
<td>20</td>
<td>0.09</td>
<td>1.88</td>
</tr>
</tbody>
</table>
The following is a list of the same budget broken down by company and including shipping:

**Table 14: Budget by Company**

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Cost</th>
<th>Shipping</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFH Special Needs Toys</td>
<td>$118.00</td>
<td>$7.08</td>
<td>$125.08</td>
</tr>
<tr>
<td>McMaster-Carr</td>
<td>$156.27</td>
<td>$29.84</td>
<td>$186.11</td>
</tr>
<tr>
<td>Quality Kits</td>
<td>$46.50</td>
<td>$20.91</td>
<td>$67.41</td>
</tr>
<tr>
<td>Digi-Key</td>
<td>$61.97</td>
<td>$2.63</td>
<td>$64.60</td>
</tr>
<tr>
<td>Allied Electronics</td>
<td>$60.26</td>
<td>$17.68</td>
<td>$77.94</td>
</tr>
<tr>
<td>Jameco</td>
<td>$16.58</td>
<td>$9.73</td>
<td>$26.31</td>
</tr>
<tr>
<td>Pearl Yeung</td>
<td>$14.71</td>
<td></td>
<td>$14.71</td>
</tr>
<tr>
<td>Modern Plastics</td>
<td>$112.37</td>
<td>$19.64</td>
<td>$132.01</td>
</tr>
<tr>
<td>Polycase</td>
<td>$7.57</td>
<td></td>
<td>$7.57</td>
</tr>
<tr>
<td>Planet Battery</td>
<td>$60.98</td>
<td></td>
<td>$60.98</td>
</tr>
<tr>
<td>ExpressPCB</td>
<td>$271.66</td>
<td></td>
<td>$271.66</td>
</tr>
<tr>
<td>Arrow</td>
<td>$40.11</td>
<td></td>
<td>$40.11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$1,074.49</strong></td>
</tr>
</tbody>
</table>

8 Team Members Contributions to the Project

8.1 Pearl Yeung

Since attending the machine shop certification course, Pearl was able to contribute to the design, mechanics and structural fabrications of the project. She was able to measure and cut all the require PVC pieces to assemble the casing and the base. Exteriorly, Pearl was able to assemble all the structures with screws and PVC glue, fabricated hinges for the three access panels, installed fan, fan accessories and LEDs, place two clear PVC front panels, and make dispersion and speaker holes on the front panel. On the two access panels, Pearl was able to design and fabricate three aerosol can holders that easily allow individuals to switch or replace cans by opening the panels and sliding new aerosol cans into the holders. For the interior fabrication, Pearl was able to design the fragrance dispersion system, which is the heart of the project. The location and shape of the lever activators and solenoid must be precisely fabricated and place in order to successfully activate the aerosol cans. These fabrications were important and Pearl dedicated most of her time working on the fragrance dispersion system. For each solenoid, she also created solenoid holders that provided stability and lock the solenoids in place. For each of the six fragrance dispersion components, they were separated into three compartments on each side of the casing. Pearl came up with the idea to have a portion of the base dedicated as the storage space for the two switches, while a small portion of the base will incorporate all the electrical circuitry such as excessive wires, PCB board and the battery.
8.2 Chris Ambler

Chris Ambler contributed to the project was in the form of programming, testing, debugging, and re-programming the PIC microcontroller. This task, though it sounds simple, turned out to be rather arduous requiring help from several sources and a lot of man hours before a completely functioning PIC was produced. Assembly language syntax and diction needed to be learned before anything could be programmed. Also, learning how to operate with MPLab software to program the PIC was an obstacle that needed to be overcome. Once he gained a confident level of understanding in assembly program architecture, he began to write the program code from block diagrams that were designed earlier with the help of his fellow teammantes. Once the code was written, the program needed to be debugged. As it turned out, this phase of the process resulted in the most improvement to the original program. Also during this phase, several changes needed to be made to the original program code and also to the connectivity to the PIC. Completion of this task was a significant contribution to the project as without the PIC, the components of the device would not mesh together into a functional whole.

8.3 Emily Heuer

The majority of Emily’s contribution to the project involved the device’s electrical system. Using last semester’s theoretical circuit diagrams as a jumping off point, Emily began constructing actual circuits using a protoboard. It soon became clear that considerable changes needed to be made. An entirely new circuit for the LED indicators and patterns had to be developed. Although the operation of the sound chips was straightforward, a working interface with the PIC proved to be difficult. She also devised an appropriate circuit using a solenoid driver chip to control/power each of the solenoids. The circuit planned for the battery, key switch, voltage regulator, and fan worked as desired. Before using any electrical component, Emily determined the workings of each part (i.e. which pin did what) and then tested to ensure proper functioning. Emily also tinned or soldered wire to several components in order to interface them with the protoboard. In addition, Emily also assembled the sound kits. After ensuring that each part worked and was understood, Emily set-up the complete circuit. Once the completed, working circuit was demonstrated on protoboards, Emily began designing the PCB. Using the programs provided by PCBExpress, she first devised the circuit schematics and then using these schematics she created the PCB layout. Upon arrival of the ordered circuit board and components, Emily assembled the PCB.

9 Conclusion

The *Olfaction Satisfaction* device meets all of the client’s demands. It will provide a complete olfactory stimulation experience for the user. The user interface will be simple and easy to use, so that frustration does not result from interaction with the device. Furthermore, a versatile interface consisting of interchangeable switches ensures that the device can be used by any user regardless motor skill or disability.
The *Olfaction Satisfaction* device is also durable enough to withstand rough handling and mistreatment. A wide base provides adequate stability when in use but does not hinder mobility, making it a very functional and adequately portable device. The smooth exterior also provides for the safety of the user, making it able to be used without risk of injury. This fact, combined with the easy to use interface, makes *Olfaction Satisfaction* a supervision free device. Caretakers can simply turn the device on and let users interact with the device at will.

Also, the removable aerosol canisters make it easy to clean and allows for the placing of new fragrances in the device. This allows for stimulation with a wide variety of scents and odors, giving the *Olfaction Satisfaction* device the ability to offer a constantly changing and engaging sensory experience. Able to be renewed with new and different scents, the *Olfaction Satisfaction* device becomes a new sensory experience every time the scents are changed.

Designed with the purpose of meeting the client’s needs, the *Olfaction Satisfaction* device not only does so, but also addresses issues that are found in current devices on the market today. Analysis of existing designs shows that there is a real lack of devices possessing olfactory stimulation technology designed to meet the needs of disabled adults. Therefore, the *Olfaction Satisfaction* device meets a market demand that has been previously overlooked. Most importantly, however, is the fact that the *Olfaction Satisfaction* device will improve the quality of life the disabled adults who use it.

Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide a pure and simple stimulation of the individual’s senses. In this regard, Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide stimulation of the individual’s senses. The *Olfaction Satisfaction* device not only delivers quality sensory stimulation, but also goes further and improves on deficiencies seen in products with olfactory stimulation technology on the market today.

10 References
11 Acknowledgements

Special thanks to the following individuals who contributed to this design:
- Dr. John Enderle
- Chris Liebler
- Dave Kaputa
- Professor Monty A. Escabi, Department of Electrical and Computer Engineering
- Professor Mei Wei, Department of Material Sciences and Engineering
- Professor Yunsi Fei, Department of Electrical and Computer Engineering
- Dr. Robert Northrop, Department of Electrical and Computer Engineering
- Dr. Martin Fox, Department of Electrical and Computer Engineering
- Richard D. Bonazza, Senior Machine Shop Engineer
- Serge Doyon, Senior Machine Shop Engineer
- Maureen Gay, 8th Semester Graphic Design Major

12 Appendix

12.1 Additional Information

12.1.1 Existing Market

Several manufacturers currently offer some type of sensory stimulation products. In addition to these products, several sensory stimulation devices have been fabricated in past years by the National Science Foundation Engineering Senior Design Projects to Aid Persons with Disabilities. The following is a summary of these devices and their associated descriptions and shortcomings:

**Dragonfly Toy Company**
*Sensory Stimulation Kit - $277.50*
General Description:
- Designed for children with neurological, cognitive, or sensory disabilities
- Offers more than ninety activities involving auditory, visual, olfactory, gustatory, and tactile stimuli
Limitations:
- Sensory integration evaluation instead of pure stimulation and enjoyment
- Geared toward children
- Requires involvement of an outside party to setup and monitor the activities.

**Maddack Incorporated**
*Baby Booster Infant Simulation Kit - $55.00*
General Description:
- Designed for children with neurological or sensory disabilities
- Includes activities that promote preceptor stimulation, tactile stimulation, auditory stimulation, olfactory/gustatory stimulation, and vocalization.
Limitations:
♦ Aims to provide sensory integration rather than entertainment
♦ Requires involvement of an outside party to setup and monitor activities

Enabling Devices

Multisensory Motivational Center - $159.95
General Description:
♦ Includes three different toys providing auditory, visual, and somatosensory stimulation that are activated by interchangeable switch pads
Limitations:
♦ Designed for the development of eye-hand coordination and fine/gross motor skills instead of diversion.

Wright State University

Sensory Stimulation Station
General Description:
♦ Encourage interaction, increase attention span, and provide entertainment for individuals with disabilities
Positive Aspects:
♦ Ease of mobility
♦ Durable; prevents disruption or damage by the user
Limitations:
♦ Geared toward children
♦ Device too large
♦ Atomizers used to dispense fragrance
  ♦ Present possibility for eye injury
  ♦ Build up of fragrance in and around the device
♦ Although user friendly switch, does not offer interchangeable switches with tailoring capabilities to the user

Wright State University

Sensory Feedback Stimulus Response Board and Vibration Board
General Description:
♦ Provides individuals with disabilities increased environmental interaction
Positive Aspects:
♦ 24-volt DC fan used to disperse fragrance from aroma source (Glad Plug-In cartridge)
♦ Easily interchangeable scents
Limitations:
♦ Geared toward children
♦ Offers limited number of scents

Duke University

Stimulation Activity Center
General Description:
♦ Created for children under three with Down’s syndrome or closed head injury
Contains an olfactory stimulation portion

Positive Aspects:
- Isolated fragrance chamber
- Removable air freshener cartridge

Limitations:
- Geared toward children
- Lack of interchangeable user switches
- Offers limited possible fragrance selections

12.1.2 Patents

The following are patent results that are vaguely related to the function of the Olfaction Satisfaction device. Note however, that these all involve medical application or are designed for children or animals:

**Inventor: Nelson R. Douglas** (151 N. Alvardo Ave., Ojai, CA 93023)
**Patent #:** 6,783,084
**Date:** Aug. 31, 2004
**Purpose:** “A method and apparatus for delivering aromatic substances for olfactory stimulation, treatment and/or therapy which includes a delivery assembly including a chamber into which air is introduced and subsequently delivered under even pressure through a mixing venture.”

**Inventor: Ritchey; Sharon A.** (20817 N. 20th Ave., Suite A, Phoenix, AZ 85027)
**Patent #:** 6,786,792
**Date:** September 7, 2004
**Purpose:** “A stuffed toy for play by an animal is taught. The stuffed toy has an outer pliable shell formed of a first fur, an inner pliable shell formed of a second fur located within the outer pliable shell, a pouch formed of a third fur located within the inner pliable shell and a play-stimulation item located within the pouch to provide stimulation for play by the animal.... The play-stimulation item may be an olfactory-excitation material (catnip) or a sound-producing device (squeaker).”

**Inventor: Ritchey Spector; Donald** (380 Mountain Rd., Union City, NJ 07087)
**Patent #:** 4,243,224
**Date:** January 6, 1981
**Purpose:** “A game or puzzle for pre-school children which exploits both the olfactory and visual senses.”

---

5 Taken from patent’s abstract filed with the US Patent Office.
6 Taken from patent’s abstract filed with the US Patent Office.
7 Taken from patent’s abstract filed with the US Patent Office.
12.2 Specifications

12.2.1 Electrical Parameters

Battery
- Type: Rechargeable - (1 Year Warranty)
- Chemistry: Sealed Lead Acid
- Dimension: 7.01” (L) x 1.34” (W) x 2.36” (H)
- Voltage: 12V
- Current: 2.3AH
- Temperature: -65°C to + 80°C

Voltages
- Power
  - Input: 12V
- Current
  - Input: 1.5A

Fan
- Voltage: 12V
- Current: 0.5mA

12.2.2 Mechanical Parameters

Input
- Squish Switch
  - Dimensions: 2” x 2”
  - Actuation Pressure: 0.001 NT max
- Large Touch Pad
  - Dimensions: 6” x 4”
  - Actuation Pressure: 0.001 NT max

Size
- Casing: 14” (L) x 10” (W) x 18” (H)
- Base: 16” (L) x 13” (W) x 5” (H)
- Weight: ~ 15lb - 30lb
- Durability: operate nominally after 10 squeeze

12.2.3 Environmental Parameters

Location: Floor Level
Operating Temperature: 40° F - 80° F
Storage Temperature: 40° F - 80° F

Location: Floor Level