Device for Hand and Keyboard Sanitization

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Abstract:

Hand hygiene is an integral part of the healthcare system. Patient vulnerability to infections is a major problem in hospitals. Hand washing frequently will help prevent the spread of bacteria from healthcare professionals to patients. The purpose of this device is to spray a disinfectant solution on keyboards and the user's hands to eliminate the vegetative bacteria and fungus present. This will reduce the amount of bacteria present in the environment and decrease the chances of the bacteria spreading to the patients. The device will take an already mass-produced disinfectant solution and spray it through a mist-spray nozzle. The fine mist will settle upon the keyboard and user's hands. The solution on the keyboard will evaporate within a few seconds due to the small droplet size while the user rubs his/her hands to ensure that the entire hand is cleansed. Since the commercial disinfectant has already passed all FDA requirements and is marketed presently, it contains emollients that will prevent the skin from drying and cracking. A microcontroller is used to run the device. When any key is pressed on the keyboard, the microcontroller will activate the circuit and cause the linear actuator to move forward and force the disinfectant through the nozzle. The keyboard and the user's hands will be sprayed with a fine mist of disinfectant for a specified amount of time before the circuit and actuator is reset to prepare for the next use.

Problem Statement:

This is a method development project, so no current model exists. Therefore, we have to design a system that will dispense a disinfectant to kill vegetative bacteria and fungus on a keyboard and user's hands. In addition to eradicating bacteria, the solution should not be harmful to the hands and should protect against drying. Dry skin may develop cracks, which provide locations for bacteria to grow and colonize. The dispensing system must cover the entire keyboard while still providing enough disinfectant to the user for him/her to completely cleanse both hands. The spraying of the disinfectant should be passive to ensure that the user will wash his/her hands every time he/she uses the keyboard, but should not falsely trigger. The solution should not spray beyond the workstation into the environment or in the user's face. Ultimately, the entire design should decrease the amount of time spent washing hands without interfering with the user's workflow. A complete list of design requirements is included in Appendix A.

Background

Hand washing is considered the single most important factor in reducing healthcare associated infections. It has been shown by many studies to be directly related to hospital related infections (Swoboda *et al.,* 2002) as well as being correlated with stopping outbreaks (Boyce and Pittet, 2002). Despite positive evidence supporting high standards for hand hygiene, compliance has been consistently low for the past quarter century. Various studies have shown a maximum compliance rate between 48-71% (Bischoff, 2000), which has widespread effects. For example, this lead to an estimated 1.7 million annual infections and 99,000 annual deaths, which is greater than the amount of deaths caused by AIDS in the United States (Haley *et al.,* 1985). One 1992 study addressed the economic burden related to nosocomial infections and estimated annual costs at 4.5 billion (Martone *et al* 1992).

Over the past century, three categories of efforts have been done to try to improve compliance with hand washing policies. Education, motivation and system change have been implemented to improve compliance (*Pittet 2000*). Although motivation and education have been shown occasionally to double adherence to hand washing standards, system change has been shown to be the most efficient long term solution – by saving time and improving work flow. The introduction of alcohol products as a disinfectant has been a revolutionizing system change in health-care. Studies have shown that nurses spend 80% less time by using alcohol products instead of soap and water to disinfect (Widmer 1997). However, even with the aid of alcohol-based disinfectants, compliance remains unacceptably low. A new device must be built to clean a health-care professional's hands while conserving workflow. In order to best achieve this, a passive device that doesn't require user input should be used.

As technology improves, the computer is being used more and more for patient charting. When HIPAA was enacted in 1996, it mandated that at some point in the near future all hospitals will be required to utilize the electronic medical records (Connecting For Health, 2004). As more and more computers are required on spot or nearby a patient, the keyboard becomes a larger pathogenic transport vector. Decontaminating the keyboard along with the hands would greatly improve cleanliness and hand-washing compliance.

Existing Prototype

The design team from fall 2007 built a prototype utilizing an ethanol-based spray. A fogging nozzle was fixed to the desk of a computer on wheels. This spray was initiated by a specific keystroke of <ENTER> or <TAB> and delivered using a 12 V linear actuator to draw up disinfectant through a syringe and a t-valve. LabVIEW was used to program delivery of spray.

Some recognized drawbacks were the need of an entire computer station for the use of the product. A portable system would make it more universal. The integration of LabVIEW also limited marketability of the product, which has a cost of $1199 for the basic package (NI LabVIEW 2008). LabVIEW also required a specific keystroke to initiate a spray, which reduced consistency of product performance.

Competing Products

There are currently no competitive products on the market as of April 2008 that specifically clean both a user's hands and a keyboard. However, several antimicrobial keyboards are being marketed. Products like Indukey®, Unotron® and Microban® offer an antimicrobial surface, as well as the ability to wash the keyboard surface without malfunction. In addition to these, almost all keyboard manufacturers offer protective covers which could be used to prevent contamination. Current devices that dispense alcohol-based products include Gojo®Purell® automatic soap dispenser that is designed for placement on a wall. Another is the Pure-Go® wrist worn hand sanitizer dispenser. These products do not have a passive element, and instead rely on user initiation, which could result in lower compliance.

Final Design

Mechanical Design

The existing design of the pumping system had many mechanical shortcomings. Most significantly, the syringe used with the pump was not built to withstand the pressure induced by the actuator. To reinforce the pump, the syringe was placed inside a PVC casing. Valves and connections were then fastened directly to the sides of the PVC. A second improvement was creating a mounting system for the nozzle that was independent of the workstation.

Figure 1: 6" (15.24 cm) tubular linear actuator

Linear Actuator

The linear actuator in this design moves the syringe plunger in the PVC and creates the pressure within the chamber. The liquid in the chamber is then forced through the tubing to the nozzle and is then sprayed onto the keyboard. The variables that determine the pressure/flow within the system are the force of the plunger, the speed at which it moves, the diameter of the syringe, the volume of fluid dispensed, as well as the total volume of tubing. It was determined that a 12 V, 6”(15.24 cm), 150 lb(667.2 N) tubular linear actuator would be ideal with a syringe of diameter 0.85” (2.159 cm). The actuator moves at 0.4 in/s (1.016 cm/s).

Pump

A block of solid PVC was used to hold the syringe and tube connectors. A block of PVC was constructed with dimensions 2”x 2”x 8” (5.08 cm x 5.08 cm x 20.32 cm). One hole of diameter 63/65” (2.5 cm) was drilled 6” (15.24 cm) deep to encase the syringe. Two additional holes were drilled and threaded on opposite sides of the PVC to hold the tube connectors, one for the liquid entering the PVC and one for leaving the PVC (See Figure 2 for detailed schematic). A ball check valve was also connected to the entering side of the PVC to prevent backflow into the reservoir. A water-tight sealant was used on all of the connections to ensure a tight fit (Figure 3). In order to make the design easy to incorporate on to any work station in the hospital, the linear actuator and the block of PVC were combined to a single unit.

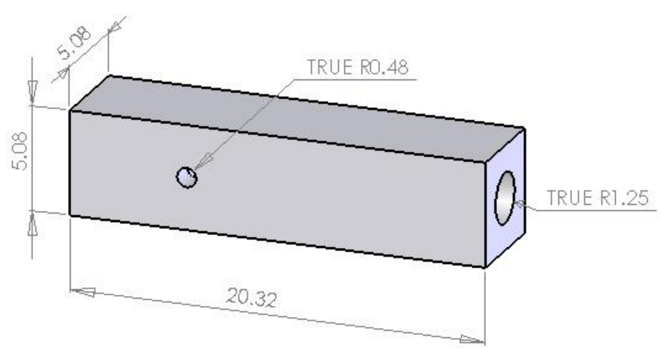

Figure 2: Schematic of PVC block (Dimensions in cm)

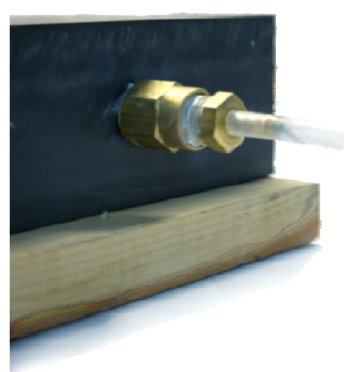

Figure 3: Connection of PVC to ball-check valve/hose connector

Final Construction

A frame was constructed to surround the keyboard and mount the nozzle. The frame was designed to fit universally around any keyboard. The pumping system was mounted to a board that could be placed anywhere on a workstation. See Figure 4 for a schematic of the final integrated design and placement of components.

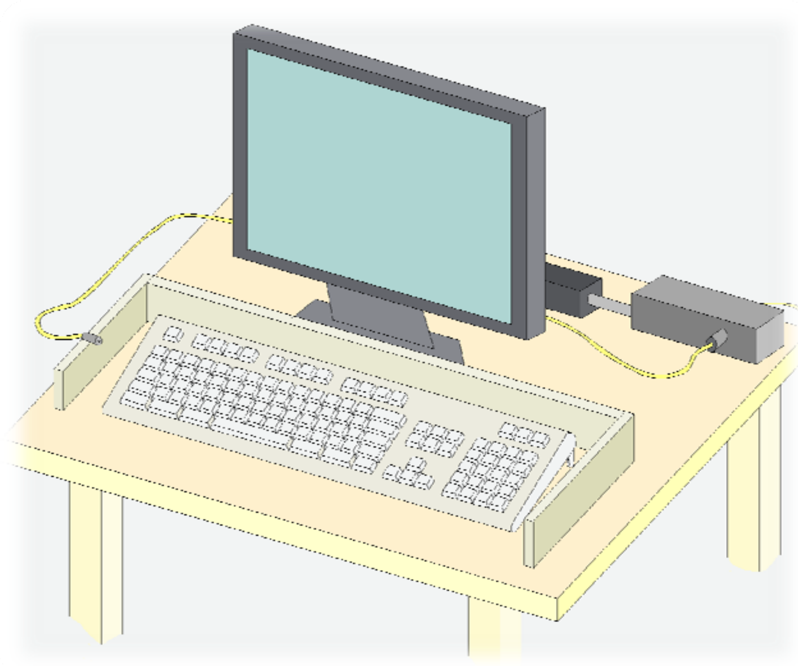

Figure 4: Final design orientation schematic.

Electrical Instrumentation

Circuitry Selection

Several methods for operating the device were identified before final construction began. The existing prototype interfaced the device with a computerized controller functioning in a LabVIEW environment operated with a DAQ board. While this method worked for demonstration purposes, it greatly limited the design by requiring a bulky interface and expensive software. LabVIEW is very specialized and not practical in a healthcare environment. Additionally, the previous design team cited that the controller did not always moderate timing accurately, compromising the functionality of the prototype.

To simplify the control device, the second option consists of several simple integrated circuits and basic electronics parts. A 555-timer chip would be central to the functioning of this device. These timers can achieve many different tasks with different orientations (555 Timer/Oscillator Tutorial). This method of triggering the device would provide a very inexpensive way to regulate disinfectant spray. However, the simplicity of this design also limits its flexibility and could be difficult for prototyping and testing the device. In order to vary different timing elements, entirely new circuit elements would have to be designed, limiting usability and adaptability.

The final control method considered, which was ultimately chosen for production of the prototype, involved the integration of a microcontroller to carry out all processes associated with the device. A microcontroller would have the ability to selectively send output signals to the device at very accurate time intervals (1 ms). The microcontroller identified to be best suited for prototyping is the Basic Stamp/Board of Education (Figure 5). This controller was selected for its flexibility and ease of use which will be especially useful when working on optimizing functional parameters. This design choice has a higher cost associated with it than a simple integrated circuit, but is still much less than a LabVIEW integrated system. In production, the circuitry could be reduced significantly, with all components interfaced into a compact circuit board.

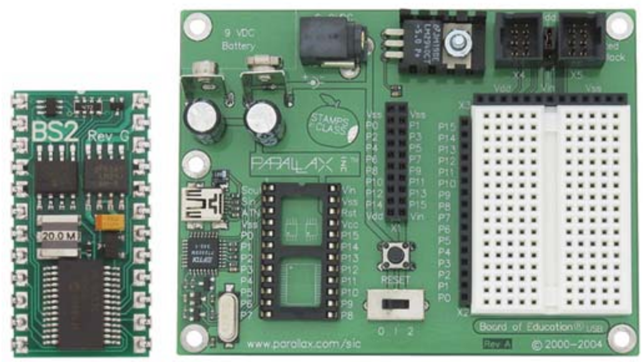

Figure 5: Image of microprocessor and interface selected for prototyping. The processor is shown enlarged at the left. The interface by which external devices are connected is shown at the Right.
Source: http://assets.devx.com/articlefigs/16841.png

The triggering of the device in the existing prototype relied on a unique keystroke (eg. Ctrl+Alt+Del) to activate the sprayer, all occurring in the LabVIEW environment. This method did not require the any additional initiation steps by the user since the keystroke is coupled to logging into the system. This method significantly complicates the design by requiring a computer interfaced controller which requires accompanying software and upper level system registry access to monitor keystrokes. Such implementations are not only difficult, but impractical in most hospital computer systems due to very securely regulated computing networks. Furthermore, not all computers require a login keystroke.

The three design options identified were analyzed using a numerical rating system based on five categories: developmental cost, mass production cost, flexibility, developmental difficulty, and implementation difficulty. Each category was rated on a scale of 1-10 with a score of 1 being the worst and 10 being the best. Numbers for each design were derived from the design considerations given above. The assessment is summarized below in Table 1. A microcontroller with a triggering device independent of the computer workstation was determined the most practical and effective in meeting the design requirements.

Table 1: Matrix of design criteria and associated ratings

Design Ratings	LabView	IC Elements	Microcontroller
Developmental Cost	8	8	5
Mass Prod. Cost	2	9	7
Flexibility	8	3	8
Developmental Challenge	4	2	6
Implementation Difficulty	2	9	9
Total	24	31	**35**

Device Triggering

One of the major focuses of development in this phase has been devising an effective and easily implemented triggering method to initiate the mechanical operation of the spray. As mentioned earlier, the existing prototype operated on a predefined keystroke and required computerized integration to initiate the device. In an effort to relieve dependency on a computer operator, three alternatives were developed. The first two functioned on similar ideology of using object detection either by infrared light or ultrasonic reflections. Each would then rely on the sensing of a user at the computer workstation by modifying the signal collection at the sensor. Each option would integrate well with the microcontroller selected, but several large limitations would be associated with these solutions. Since any interference could theoretically trigger the sensors, there is a great risk for unintentionally initiating spray which could result in any number of undesirable outcomes in a hospital workspace. Additionally, the sensors have a risk of interference with other environmental factors in the hospital which could reduce reliability of accurate triggering. Bearing in mind these limitations, the alternative of capturing a signal from the keyboard was then identified as the most desirable solution.

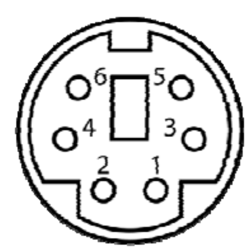

Figure 6: PS/2 Type connector interface (Female). Pin 1 corresponds to the data line. Source: http://en.wikipedia.org/wiki/Image:MiniDIN-6_Connector_Pinout.svg

The primary interface of keyboard connections in PCs is the PS/2 connection, which connects a keyboard to the motherboard of a system with a generic 6 pin plug as shown in Figure 6. Within this connection, only 4 of the pins are used, which include a +5 V source, a time varying clock signal, the keyboard signal line, and a ground. It was found that a square wave of voltage fluctuations between +/- 5V is associated with every key when pressed, though the time scale differs with each keystroke (Figure7). The BASIC Stamp 2 microcontroller has the ability to count high frequency voltage changes and store them in an internal memory bank. The limitation of this count function is a square wave width of ~8 µm, which was well within the width of key signal (~35-40 µm). In order to effectively capture the signal from the keyboard cable, the signal line was spliced to a parallel connection with the microcontroller, suspended over a 10 kΩ resistor to the ground, and a 220 Ω resistor to the microcontroller input pin. The signal was not disrupted by the microcontroller because there is an internal impedance of 1 MΩ on the microcontroller inputs. This connection is diagrammed at the bottom of Figure 8.

Since most desktop keyboards still function on the PS/2 connection type, research and testing was isolated to these interfaces, though it should be noted that USB type keyboards are also present in the industry. With simple converters, the device becomes compatible with nearly all computer workstations.

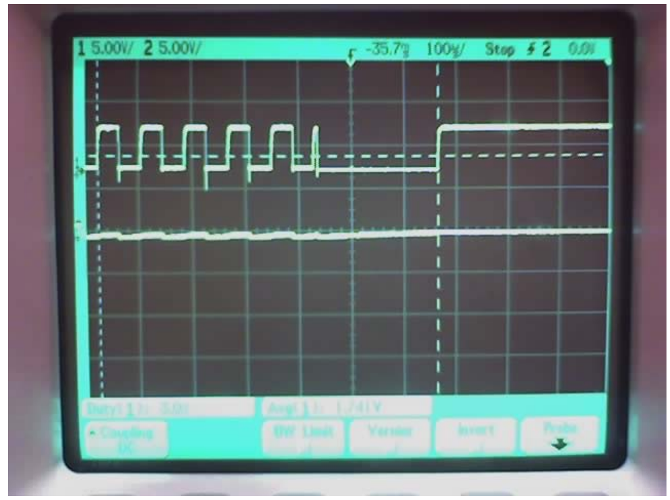

Figure 7: The top line shows output from the data line of the keyboard. The lower line is the readout from the clock signal. Voltage changes in the data line are +/- 5 V at an average frequency of ~26 kHz

A circuit was designed to moderate power output to the actuator (Figure 8). The power supply for the actuator functions on a 12 V DC current with a maximum current draw of 5 A, while the microcontroller delivers only 5 V and 300 mA. In order to isolate this relatively high power source from interfering with the other electronic elements of the device, two single-pole-double-throw micro-relays were used to both activate and control polarity of output power driven to the device. However, the nominal current to activate these relays exceeded the current released from the I/O pins of the microcontroller. To solve this problem, an independent 12 V power supply was driven through a 2N3904 Transistor, switched by the 5 V output of the I/O pins on the microcontroller. The output from the microcontroller was operated by the source code included in Appendix B. The program language used is PBASIC. Essentially, a function is encoded first scan for a keystroke with the count function. Once a keystroke is found, a series of high and low outputs moderate the polarity of the leads connected to the actuator. Then, at the end of the code, a pause is placed in the script during which there is no activity of the device to allow typing without repeat spraying.

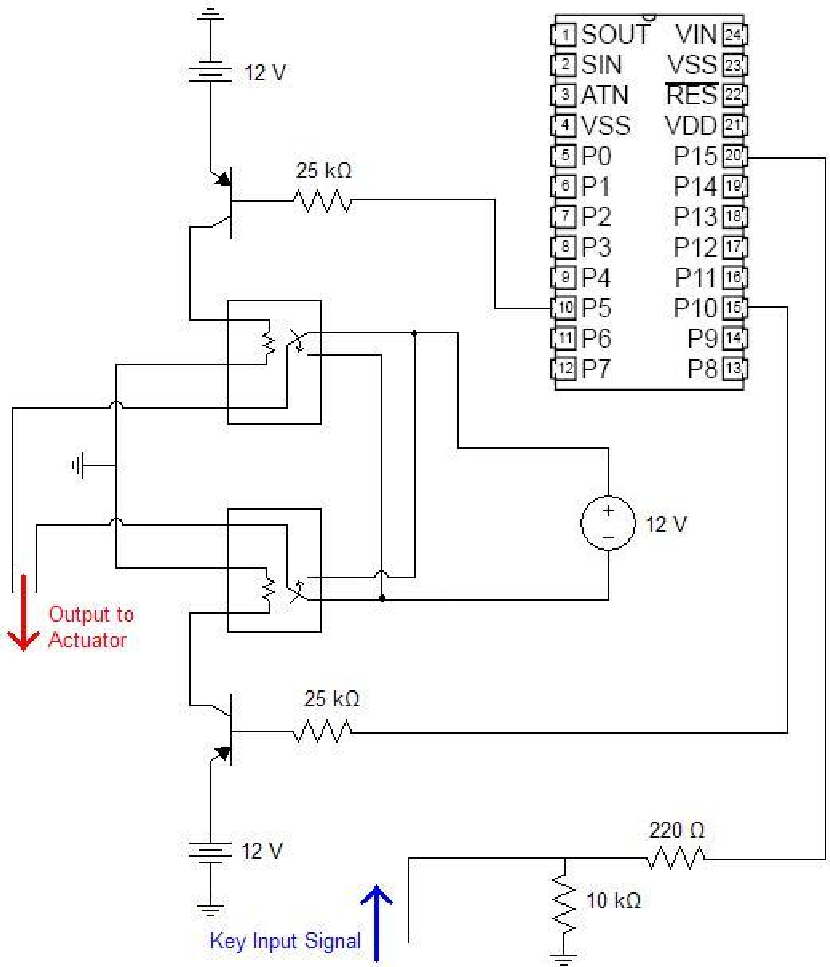

Figure: Final schematic of operational circuitry

Formulation

Using an effective ethanol-based formula for the prototype is an essential aspect of the design. There are two main requirements the spray must fulfill. First, it must have a high percentage of ethanol by weight in order to eliminate as much infectious material as possible. Second, it must protect the skin from the dehydrating properties of ethanol.

Ethanol (C_2H_5OH)is a simple hydrocarbon that can be used quite effectively as disinfecting agent. It will kill bacteria when it's mixed with water at a concentration level between 60% and 90%, but performs most effectively at around 70% (Boyce and Pittet 2002). One key quality of ethanol is that it is miscible with water; that is, it will mix with water in all proportions. Both water and ethanol have hydroxyl groups, –OH, which means there are significant amounts of hydrogen bonding between them. This is an important feature, because when the two liquids are mixed at 70% ethanol, the ethanol will be absorbed into the cells of bacteria more readily than if it were at a higher or lower concentration.

Ethanol evaporates quickly, which makes it ideal as an antiseptic. However, because of its strong hydrogen bonding with water, much of the water is vaporized along with the ethanol (Shakhashiri, 2008). Losing the water from one's hands after using an ethanol-based antiseptic will leave the user's skin dry and damaged. Although dry skin is not immediately hazardous, applying ethanol many times may crack the skin and allow bacteria to enter the body.

In order to reduce the effects of this problem, emollients are introduced to the solution to prevent the dehydrating effects of ethanol. Emollients are agents that are used to soften the skin or to help keep the moisture on the skin before it evaporates. Some common emollients include Aloe Vera extract, Vitamin A and glycerin, yet there are hundreds of other compounds that have been claimed to work just as effectively. Aloe Vera is probably one of the more prevalent emollients used in a wide variety of commercial products since it forms naturally and is readily available. Vitamin A has been shown to be effective in keeping the skin moist and elastic by increasing the amount of collagen in the skin (Bastyr Center, 2004). These examples are part of the many natural forms of emollients, but other artificial types exist as well. For instance glycerin, or glycerol, keeps moisturizes and lubricates the hands, making them feel more natural.

A commercial product was identified as a possible disinfecting agent that would integrate well with the device. The VioNexus™ sanitizing spray produced by MetRex® has a low viscosity which would be ideal for the pumping apparatus. The product also is FDA approved for effectiveness against bacteria and also contains emollients to ensure safety. Further testing of the effectiveness of the solution still must be conducted.

Future Work

While the prototype constructed this semester meets the client's needs and specifications, several areas have been identified that will improve the effectiveness of the design.

First, a new nozzle that requires less pressure and delivers the same amount of liquid as the current nozzle would be ideal. The current nozzle needs approximately 100 psi (689.7 kPa) of pressure before any of the solution will be dispersed, which may be impractical. Once a new, satisfactory nozzle has been found, the actuator could also be replaced. Changing the combination of nozzle and actuator would make the entire device smaller and more efficient, since less power would be drawn to create high pressures. Eliminating the need for high pressure also alleviates the leakage risk in the syringe and the ball-check valves.

The circuitry for reading the signal and supplying current to the actuator is simple and the possibility of using purely integrated circuit elements was considered. It would make the electrical aspect of the design extremely affordable and small. However, the flexibility that microcontrollers offer is quintessential for the customer. The device should make health-care workers feel comfortable in their workplace and the timing settings should be adjustable to suit those needs.

The Parallax microcontroller that we used was both expensive and bulky. Other microcontrollers exist that are faster, less expensive, and smaller. Atmel's AVR and Microchip's PIC microcontrollers are two possible types that could be used in future designs. Both are 8-bit microcontrollers and can operate with multiple programming languages. The microcontroller was one of the most expensive pieces of the design and lowering that cost would significantly increase the device's marketability.

The disinfecting solution must kill 99.99% of bacteria without harming the user or clogging the nozzle. Finding a formula which maximizes comfort and integrates seamlessly with this system requires extensive chemical knowledge. Some research had been conducted already (see Formulation), and many natural emollients were found that could potentially work in the ethanol-based solution. In order to maximize the effectiveness of the solution, further testing with commercial products or custom solutions needs to be done.

Two distinct nozzle placements could be used if this device were to go into manufacturing. One option would include a nozzle built into a keyboard. This would decrease the amount of hardware, minimize desk space usage, and eliminate the need to adjust the position of the nozzle separately from the position of the keyboard. The alternative option is to have the nozzle attached to a separate stand as it is in the current prototype. The benefit of the stand is that it can be retrofitted to all existing keyboards and requires less new hardware. Also, the stand allows for more directional control of the nozzle and helps contain the spray within the keyboard area. Both options are equally employable.

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Appendix A: PDS

Project Design Specification—Hand Hygiene

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May 4, 2008

Function:

The purpose of the device is to eliminate the spread of vegetative bacteria and fungus from computers to healthcare professionals since it may transfer to patients and cause infections. This device will minimize the amount of time that healthcare professionals spend washing their hands and also help prevent hospital-acquired infections in patients. This will be a passive device in order to ensure 100% compliance with hand washing protocol.

Client Requirements:

- Eliminate vegetative bacteria and fungus on keyboards and healthcare professional's hands
- Easily retro-fitted to a variety of keyboards
- Minimize environmental mess created by atomized ethanol-based solution
- Protect user's skin to prevent spread of bacteria
- Passive system so the user does not need to remember to trigger the device
- Does not disrupt the user's work flow

Design Requirements:

1) Physical and Operational Characteristics
   a) *Performance requirements* The device will decontaminate a computer keyboard and the user's hands at the same time. The device will be used every time the computer if used, up to 40 times per clinician per day.
   b) *Safety* The disinfectant solution used will not harm the user's hand. It must protect against dry skin, which cracks and allows bacteria to colonize and spread. The solution may have to conform to FDA requirements. The electronic parts must be protected to ensure that short circuits do not result in fires. If the disinfectant is flammable it should be protected from potential sparks or other fire hazards
   c) *Accuracy and Reliability* The disinfecting solution should be spread evenly over the keyboard and user's hands and be able to kill vegetative bacteria and fungus.
   d) *Life in Service* The device must be able to withstand repeated use by multiple users. The entire device must be able to be moved without affecting its performance. It should be designed to be in use for a maximum of five years.

e) *Shelf Life* The device may be stored in warehouses prior to shipment to hospitals and clinics. These conditions may be dark, dusty or slightly damp. The device should be able to withstand these conditions without degrading. Additionally, the electronic parts should be protected. The disinfectant solution will have a shorter shelf life.

f) *Operating Environment* This device will be mostly used in healthcare settings, such as clinics and hospitals. It may also be used in laboratories. The device must be able to withstand normal levels of heat, humidity, dust, and air conditions. The device will be mounted onto a computer on wheels. Therefore, it must function with small shocks and movements associated with moving the whole device.

g) *Ergonomics* The device must not impede the workflow in anyway, either by taking up too much space or preventing users from using a keyboard normally. Also, the device should not interfere with hand washing procedure.

h) *Size* The device must be able to fit on a computer on wheels without affecting the performance of the user.

i) *Weight* The product should be as lightweight as possible, to ensure that the computer on wheels will be able to hold its weight in addition to the computer.

j) *Materials* The device should be constructed with cost-efficient material that will not be damaged or degraded over the product's lifetime. All materials should comply with FDA regulations if needed, and should not contain any hazardous materials.

k) *Aesthetics* The device should be as compact as possible to reduce the amount of space it takes up. All electronic parts should be safely covered.

2) Production Characteristics

a) *Quantity* Only one unit is currently needed. However, it is designed with the intent of mass-production in the future.

b) *Target Product Cost* The price of production of the prototype should be less than $1000. However, if the device is mass-produced, it should be affordable for all hospitals and low enough to encourage the use of this passive system of hand hygiene.

3) Miscellaneous

a) *Standards and Specifications* The device may have to follow FDA standards. It should also meet ergonomic standards for use with keyboards. It should be designed with the purpose of mass-production.

b) *Customer* The device will be used in hospitals and clinics by healthcare professionals. It should have precautions to prevent accidental sprayings, which may harm users.

c) *Patient-related concerns* It should not interfere with the computer, which contains patient's medical data. The device may have an indicator to facilitate refilling when the disinfectant solution is finished. The device should not interfere with the user's workflow. The disinfectant solution should be shielded to prevent the possibility of spraying the user's face.

d) *Competition* There are currently no similar products that exist. While FDA approved disinfectants may be competition, they do not have the same function as this device (to also disinfect the keyboard). These disinfectant solutions will be incorporated into the device.

Appendix B: Microcontroller Code

```
' {$STAMP BS2}
' {$PBASIC 2.5}

' COUNT.bs2

Keyinput PIN 0          ' Attach Red line to on P0

LOW 11
LOW 5

DurAdj CON $100         ' / 1
Capture CON 1000        ' captures for periods of .5 seconds
cycles VAR Word         ' counted cycles
KeyTrig VAR Bit

KeyTrig = 0

Main:

cycles = 0

DEBUG CLS,
"Reading Keystroke...", CR
COUNT Keyinput, (Capture */ DurAdj), cycles
DEBUG CR, "Number of Peaks: ", DEC cycles, CR
IF (cycles < 1) THEN Main

DEBUG CR, "Keystroke Found!"


HIGH 5
LOW 11

PAUSE 2000

LOW 5
HIGH 11

PAUSE 1500

LOW 11

PAUSE 10000

cycles=0

GOTO Main
```

Appendix C: Expenses

Date	Item	Product Number	Supplier	Price
2/29/2008	BASIC Stamp Discovery Kit (USB)	27807	Parallax Inc.	159.95
	9 Volt DC 300ma Wall Pack Power Supply	750-00008	Parallax Inc.	8.95
	No-Drip Misting Nozzle	32215K11	McMaster-Carr Supply Company	13.21
	No-Drip Misting Nozzle	32215K11	McMaster-Carr Supply Company	13.21
3/29/2008	Barbed Brass Hose Connector (2)	749879	Dorn Hardware	2.09
	1/4" Tube QC Tee	637355	Dorn Hardware	5.58
	Clear 1/4" Tubing, 25' Length	19643025417	Home Depot	2.63
4/2/2008	Bulk PVC (2"x2"x1.5')	8740K43	McMaster-Carr Supply Company	51.66
4/16/2008	Teflon Paste	6931513	Menards	1.78
	Electrical Tape (3/4"x 60')	3648003	Menards	0.58
4/27/2008	1/8" BRS Hex Nipple	255452	Dorn Hardware	1.04
	1/4x1/8 BRS Bushing	239731	Dorn Hardware	1.04
	Threading Coupling		Dorn Hardware	1.79
4/29/2008	Final Poster		College Library Poster Printing	28.12
4/30/2008	SPDT 5V 1Amp RLY	2750240	RadioShack	4.95
	USB Male to 2 PS/2 Female Connectors	41665	DoIT Tech Store	21.09
			Total	**317.67**