Hand and Keyboard Sanitizing Device

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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 two mist-spray nozzles. 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 disinfectant has already passed all FDA requirements and is marketed presently, it contains emollients that will prevent the skin from drying and cracking. The device will be automated with a microcontroller and triggered by a sensor.

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.

Background

Hand washing is considered the single most important factor in reducing healthcare associated infections. Hands are demonstrated as the number one pathogenic transport vector, with current bacterial transfer models most often involving the hands of health care personnel. Consistent compliance to hand-washing guidelines is also correlated with stopping outbreaks (Boyce and Pittet 2002). Normal human skin is colonized with anywhere from 50,000 to 1 million bacteria on different areas of the body; making it likely for a patient can get infected with his/her own flora (Selwyn 1980). The transfer of pathogens through bedside objects has been noted as a problematic path of transportation (Mackintosh and Hoffman 1984). Both of these paths to infection can be at least somewhat prevented by strict adherence to hand-washing policies; however, hand washing has been consistently low for the past few decades.

Although healthcare settings have adopted high standards for hand hygiene, compliance with these policies remains low. Various studies have shown a maximum compliance rate between 48-71% (Bischoff, 2000). In addition to taking up energy to remember, hand washing often interrupts the work flow. The introduction of a passive cleaning device on a keyboard may improve work flow and improve overall compliance. The negative effects of nosocomial infections are widespread. With an estimated 2 million affected patients and 20,000 deaths in the United States, nosocomial infections cause more annual deaths than 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 150 years, 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 to double adherence to hand washing standards, system change has been shown to be most effective with saving time and improving work flow. The introduction of alcohol products as a disinfectant has revolutionized health-care. Studies have shown that nurses can use 80% less time by using alcohol products instead of soap and water to disinfect (Widmer 1997). The introduction of a passive system to wash hand on a computer may have a similar effect. Although system change has had the most beneficial outcome over history, some education of the new product or system will always be needed.

The design team from fall 2007 built a prototype utilizing an alcoholic spray. A fogging nozzle was fixed to the desk of a computer on wheels. This spray was initiated by a keystroke 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 and vitamin E was used as an emollient.

There are currently no competitive products as of February 2008 on the market that clean both a users 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. 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.

Design Considerations

Formulation

Using an effective ethanol 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 antiseptic will leave the user’s skin dry and damaged. Although dry skin is not immediately hazardous, applying alcohol 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.

Regardless of the emollient's effectiveness, adding substances to an ethanol solution creates issues. First, the final consistency of the solution must be atomized easily so that the ethanol will still have adequate droplet sizes. If the droplet sizes are too large, it will decrease the evaporation rate and the keyboard will be wet for longer periods of time. This may disrupt the work flow and ultimately could contribute to the depreciation of the keyboard itself. In addition, keeping the consistency closer to that of water means that less residue will form on the nozzle, causing the spray to deviate from its intended path.

Though a custom formulation could be tailored to the device, many commercially available products exist that may also fulfill these spray requirements. In the interest of time and money, it would be most practical to purchase a commercially available product and focus more time on building and testing the device. However, future development may benefit from a custom formulation.

Nozzles

For this device, spray nozzles will be used to dispense the disinfectant onto the keyboard and hands. Nozzles would be the best solution because it would spray a precise amount of disinfectant on the keyboard without ruining the keyboard itself. However, there are some design constraints that had to be determined before a nozzle was chosen. The nozzles should keep the environment clean and effectively spray the user's hands and the keyboard. The number and location of nozzles must be determined.

There are many different types of nozzles available commercially, but the ones best suited for the device would be compressed air spray nozzles, fogging nozzles, or mist-spray nozzles (Figure 1). Compressed air spray nozzles are very useful in spraying because they are capable of misting billions of ultra fine droplets. This is useful for the device because the ultra fine droplets would evaporate quickly and would not damage the keyboard as much as larger droplets. Compressed air spray nozzles deliver many different shapes of mist. The spray could be cone shaped, hollow cone shaped, or a flat mist. This is an advantage because the different shapes can help spread the disinfectant uniformly over the keyboard and the hands. However, a compressed air spray nozzle would require high pressure to deliver liquid through the nozzle. The flow rate of a compressed air spray nozzle ranges from 300-4000 psi. Also, compressed air spray nozzles are the most expensive type of nozzle out of the three nozzles considered. There price range can be anywhere from 20-50 dollars per nozzle (McMaster-Carr).

Fogging nozzles are capable of producing a high percentage of 50 micron or smaller droplets at higher pressure ranges (Fog Nozzles Technical Information). Once again, these small droplets will mean that they evaporate quickly, causing a minimal amount of damage to the keyboard. Fogging nozzles require 45-250 psi, which is less pressure than compressed air spray nozzles. This would relieve the need to have a large, powerful pump. However, several disadvantages have been identified with fogging nozzles. They are only available in one kind of shape, a full cone. This could cause problems because it is more difficult to control and might deliver too broad of a spray which could be harmful to the user. Fogging nozzles are similarly priced to compressed air spray nozzles at 20-40 dollars per nozzle (McMaster-Carr).

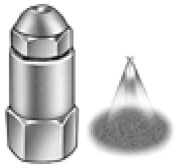
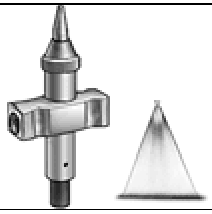
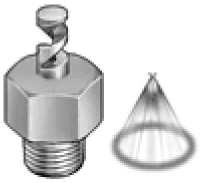
Mist Spray Nozzle	Compressed Air Spray Nozzle	Fogging Nozzle
		

Figure 1: Nozzle options and corresponding spray shapes (From left to right: full cone, flat, hollow cone)

Mist spray nozzles are the most commonly used nozzles in the commercial world. They do not require as much pressure to use as the other types of nozzles and can be cheaper. They produce small droplets like the other types of nozzles, although these droplets are not always as small. The spray shape can range from a cone to a straight stream of spray. The area of the spray is much smaller than the other types of nozzles, making it easier to control. However, the smaller spray area may require a second nozzle to effectively spray the entire keyboard and the user's hands. Mist spray nozzles prices range from 13-22 dollars (McMaster-Carr).

Two 1/8" no-drip misting spray nozzles with orifice diameter 0.009" from McMaster-Carr (P/N 32215K11) were decided to be used. This nozzle is designed to deliver 0.59 gallons per hour (GPH) at 100 PSI, which produces droplets 39 µm in diameter. This nozzle is able to spray enough disinfectant to cover the hands and keyboard while still maintaining a clean environment around the work station. The only major drawback is that a high pressure source will be required. Testing will be performed to determine optimal placement of the nozzles. A possible configuration of the design is shown in Figure 2.

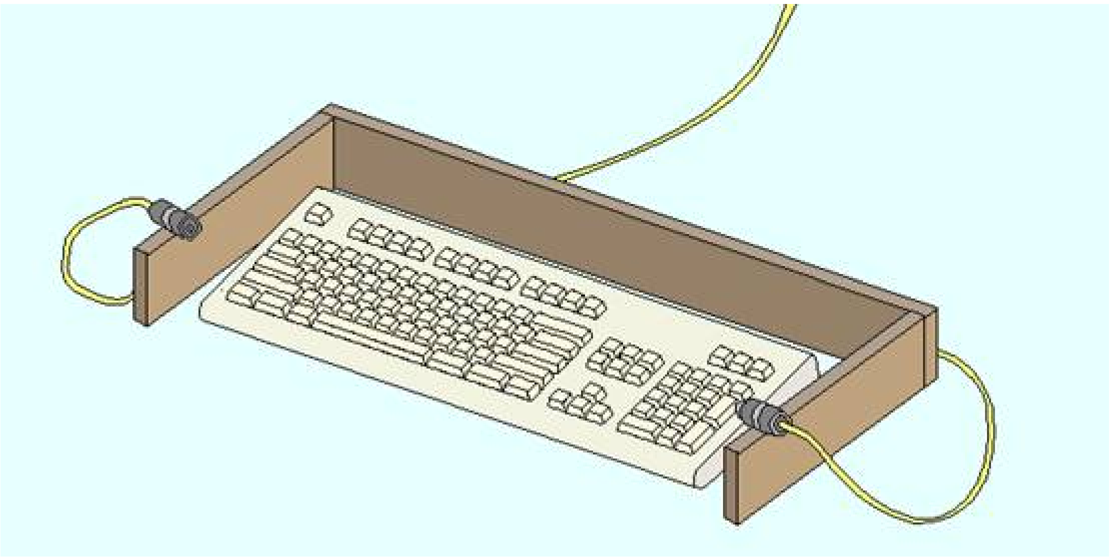


Figure 2: Illustration of Proposed Design with Nozzles

Electrical Instrumentation

Several methods of triggering the device have been identified. 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 limits 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. A diagram of a circuit is shown in Figure 3 which would result in an output signal equivalent to the source voltage for a time determined by $1.1R_1C_1$ after being triggered by an external signal (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.

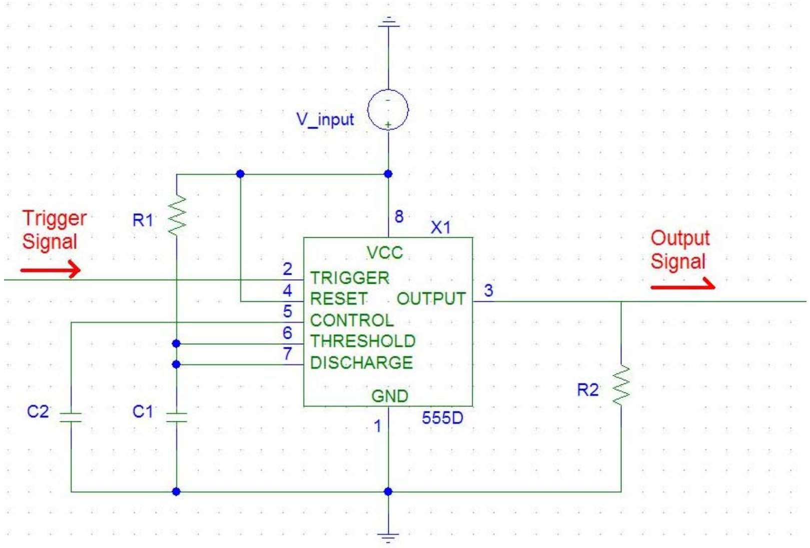


Figure 3: Diagram of 555 Timer Circuit proposed for use in triggering pump action. The time of the output signal is defined by 1.6(R1)(C1). Made with PSpice Schematics V9.1

The final control method considered involves 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 (<1ms). The microcontroller identified to be best suited for prototyping is the Basic Stamp/Board of Education (Figure 4). 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. (See Appendix A for approximate pricing of all options).

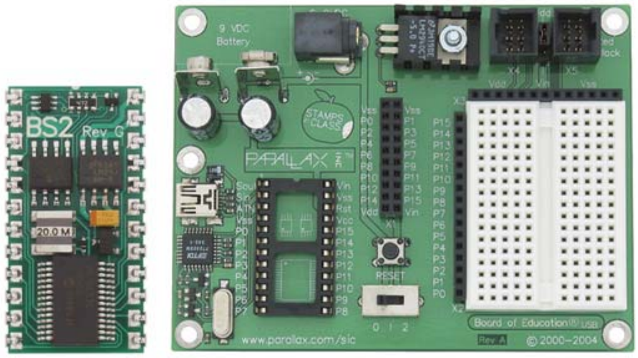


Figure 4: Image of microprocessor and interface selected for prototyping. The processor is shown enlarged at the right. The interface by which external devices are connected is shown at the Right.
Source: http://assets.devx.com/articlefigs/16841.png

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.

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**

A microcontroller with a triggering device independent of the computer workstation would be most desirable. Though a button would be a simple trigger, this circumvents the key goal of this design project to provide a passive control that happens every time a healthcare provider accesses the workstation. It has already been cited that despite many opportunities for hand sanitization compliance, healthcare providers still do not practice proper hygiene. In order to automatically trigger the sanitization device to run at every use, a user sensor needs to be developed. There are many different sensor techniques available like pressure, movement, or sound. It was decided that a light sensor would provide an inexpensive and efficient way to monitor the presence of someone at the workstation. This triggering could be easily integrated into a microcontroller. Logic of trigger timing would need to be developed based on behavioral considerations, while also avoiding false signaling. An infrared light emitter and sensor could be attached to the spraying device and oriented in such a way that in the presence of a healthcare worker, a broken light signal would trigger the device to run. This reinforces the benefit of having a microcontroller to run the device, since it would be the easiest to maintain and monitor signals and delays.

The proposed design calls for a microcontroller circuit to manage all signaling and operation of the prototype. The device will be triggered by a positive signal from an infrared light signal. This will activate the delivery of an operational current to the pumping mechanism to release the sanitizing spray. In this method, spray volumes, triggering sensitivities, and operational delays can be flexibly selected and easily modified to fit user needs, since the microcontroller can be easily adjusted through a computer interface included with the chosen device.

Future Work

Once the microcontroller, nozzles, and disinfecting agent have arrived, the rest of the semester will be devoted to building and then testing the efficiency of the device’s spraying nozzle and disinfectant solution. The microcontroller will be programmed using BASIC to run the device. The infrared trigger device will also have to be purchased and tested to ensure that the nozzles spray the disinfectant solution at the appropriate time. A simple pumping mechanism also needs to be designed which will be similar to the previous prototype. Once the whole device has been assembled, various tests can be conducted. Bacteria can be placed on a keyboard and then sprayed with the disinfectant solution. With the use of a microbiology lab, the sprayed keyboard can be sampled to determine if all of the bacteria have been killed. This will demonstrate the effectiveness of the disinfectant solution to kill vegetative bacteria and fungus. Another test will be done to determine the range of the keyboard to ensure that the spray completely cleans all parts of the keyboard. Lastly, using the results of the tests, the final device will be modified and finalized.

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Appendix A:

Costs Associated with Electronics Designs

Option 1: Computer Based Controller

LabView Base Package (Software):	$1199
DAQ Data Acquisition Hardware:	$999+
Total:	**$2198** (Minimum)

Prices from: http://www.ni.com/products/

Option 2: IC Elements

555 Timer:	$2.00 (2+)
Resistors and Capacitors:	~$0.20 (~10)
Sensors (e.g. IR, Button):	~$6.00
DC Power Suppy:	$8.95
Total:	**~$25.00**

Prices from: http://www.parallax.com

Option 3: Microcontroller

Development Kit:	$159.95
DC Power Supply	$8.95
Sensors(e.g. IR, Button):	~$6.00
Total:	**~$175.00**

Appendix B:

Project Design Specification—Hand Hygiene

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March 12, 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.

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 alcohol-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

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.
   - 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.