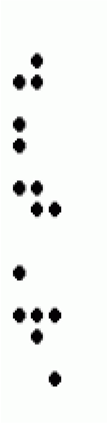

Digital Braille Watch

Alice Tang
Vidhya Raju
Alison Boumeester
Anika Lohrentz

Advisor: Professor Thomas Yen, Ph.D.
Client: Holly and Colton Albrecht

Date: March 12, 2008

Table of Contents

Abstract

There are various ways for visually impaired people to know tell time. They include verbally asking another person, using an analog Braille watch, and using a watch that voices the time. However, it is an inconvenience to always ask another person for the time, an analog Braille watch can be misread, and the audible watch can be disruptive to others. Therefore, the goal of our project is to design a digital Braille watch that does not disturb others and will be easy for the user to read accurately. The following three designs were analyzed: electrocutaneous display, vibrotactile display, and mechanical wheel. Given the results of the analysis, the vibrotactile display will be used to create the digital Braille watch.

Background

Current Method

Figure 1: One model of analog Braille watch.
http://www.geocities.com/Eureka/Concourse/3294/cortblind.jpg

Currently, visually impaired individuals have three main options for telling time: asking another person, using watches that vocalize the time, and using analog Braille watches. However, each option has its shortcomings. Having to rely on others to tell time impedes upon the autonomy of visually impaired individuals. The vocalizing watch, which the client currently uses, is loud and disruptive. It may also be difficult to use in noisy environments. The analog Braille watches, shown in Figure 1, work such that the user feels the hands of the watch to determine their placement relative to the numbers displayed in Braille. Unfortunately, it can easily be misread – there are those who are blind and have used Braille for most of their life but repeatedly misread a watch due to the fact that they have difficulty distinguishing the length of the minute and hour hands. Due to these problems, the client has suggested an alternative design – a digital Braille watch.

Figure 2: A BrailleNote© display.
http://www.humanware.com/Site/Temp/Images/41daff26bb0d57483ad43690725cfa94.jpg

One product that incorporates Braille is the Braille display, such as the BrailleNote© in Figure 2. Braille displays can connect to computers by methods such as USB and Bluetooth, and they convert the text on the computer screen to Braille. The client suggested incorporating this technology into the final design (Humanware). However, Braille displays are expensive. For example, a twenty cell display can cost $1,995.00, and an eighty cell display can cost $10,550 (Independent Living Aids).

The client reads the Braille alphabet, so creating a digital watch that incorporates this would be easy for him to use. Figure 3 shows the ten digits that would need to be used on the watch display.

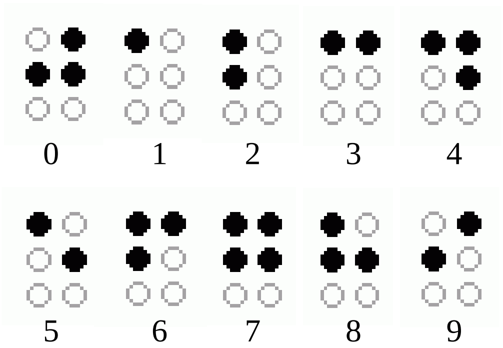

Figure 3: The Braille representation of numbers.

Our client has submitted a patent for review for a digital Braille watch with the following criteria:

- Tell time as the minutes change
- Room for five cells – four for the hour and minutes, one for the colon
- Use military time – no need for A.M. or P.M.
- Dots rise on watch face – user can slide his/her finger across the face and read current time in Braille system
- Dimensions of watch face: approximately 1 ¼” long, ½” to ¾” wide
- Worn with removable cover – protect the face from weather
- Powered with rechargeable battery – uses solar or electric charging

The following diagram (Figure 4) shows what the client envisions for the complete digital Braille watch.

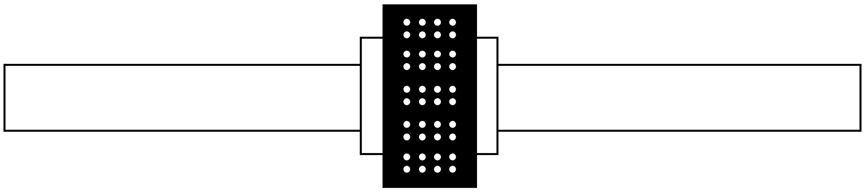

Figure 4: Depiction of client’s idea of a digital Braille watch.

Problem Statement

Due to problems with the current method of telling time for visually impaired individuals as stated in the previous section, our goal is to create a digital Braille watch that displays military time, does not cause disruptions to others, and is robust. The Braille display must be appropriately sized so that the user can accurately and reliably distinguish between the different digits displayed.

Design Requirements

The design must follow the following criteria, as well as the guidelines described in the Product Design Specification in the Appendix.

1. Must incorporate Braille, as requested by the client.
2. Displays military time, so dots indicating “A.M.” or “P.M.” are not required.
3. Braille dots must be spaced appropriately such that the user can distinguish between them and read each digit.
4. Size of a pocket watch or wristwatch.
5. Quiet.
6. Safety: Must not harm or cause discomfort to the patient.

Design Proposals

The following will describe the three proposed designs for the digital Braille watch: electrocutaneous display, vibrotactile display, and mechanical wheel.

Electrocutaneous Display

One option for displaying military time using Braille involves sending controlled electrical signals to the skin, which nerve endings can then interpret as pressure or vibration. Depending on the arrangement of electrodes used in this electrocutaneous approach, the user will interpret different sensations. For this project, four electrodes in a square arrangement can represent the four Braille dots needed to distinguish the different numbers.

An electrotactile electrode consists of several basic components. An electrode array model in Dr. Tyler’s research laboratory had an annulus located within a shallow well for each electrode, and these were arranged in a standard grid pattern; see Figure 5 for dimensions. The electrical

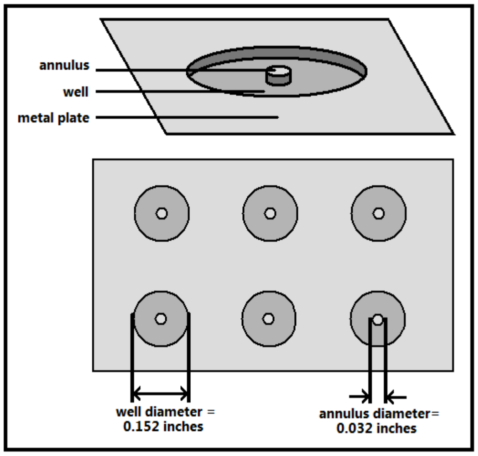

Figure 5: Electrocutaneous electrode, electrocutaneous electrode array, and dimensions as measured in Dr. Tyler's laboratory.

signal, whether it is a controlled amount of current or voltage, originates from the annulus of the electrode. The power and circuit controls to create this signal are a separate unit, far larger than the electrode itself. The well surrounding the annulus insulates it from closing the circuit with the metallic plate around it.

When the electrode is sufficiently powered and an individual presses their skin to the electrode, they close the circuit between the annulus and the plate. Human skin varies in terms of the thickness of layers, density of sweat glands, presence of hair follicles, and density of nerve endings (Saladin, *et* al, 2008). All of these factors play roles in how well a signal is conducted, and what type of sensation the individual perceives. Factors favoring the conduction of electricity include a thinner epidermal layer, increased presence of sweat glands and hair follicles, and presence of pressure and vibration sensitive nerve receptors. Contrastingly, a thick epidermal layer, lack of pores and secretions, and scarcity of proper nerve endings makes signal transmission difficult. The epidermis acts as an insulator, thereby blocking any electrical signals trying to cross into deeper tissues. The outer skin is penetrable, as sweat glands and hair follicles act as conductive passageways to cross the insulating epidermal layer. Sweat is rich with electrolytes, providing a path to the dermal tissue. Once in the dermis, the electric signal is much freer to spread through the tissue. Nerve endings are located in this layer, and are responsible for relaying information to the brain about changes like pressure, temperature, vibration, pain, and other sensations. Specialized encapsulated corpuscles and receptors associated with hair follicles are needed for pressure and vibration sensation, and can be found in various combinations and densities across the skin of the body (Saladin, *et* al, 2008).

Controlling the voltage or current of the applied electrical signal is important so that the desired nerve receptors are stimulated, and also so that the user is not endangered by higher than necessary currents or voltages. A current control system would be more ideal for skin profuse with sweat glands, because these glands act as shorts in the circuit when crossing the epidermis. Without current control in this situation, the user could receive a dangerous shock or burns because of the large amount of current crossing the skin. Voltage control is better in situations where the skin is less permeable to electricity (i.e. minimal pores, low amounts of electrolytes in solutions like sweat, etc). Thus, depending on the area of skin the electrodes will come in contact with, the circuit must either have controls in place to limit the current flowing into the skin, or the voltage applied to it.

The sensation created by the electrode depends on the density and type of nerve endings present in the dermis. The electrode does not stimulate a specific point on the skin, rather a small field, with intensity diminishing when moving away from the annulus. Therefore two electrodes placed closely together could potentially be mistaken as a single electrode. This means that the electrodes must be spaced sufficiently so the user can distinguish two signals versus a single signal. Fingertips contain a very large number of nerve endings, making them very acute in distinguishing one point from two. Other parts of the body, such as the abdomen or back have a much lower nerve density (Strang, *et al*, 2006). On these less sensitive parts of the body, electrodes or stimuli must be much farther apart in order for the individual to distinguish a single point from two. When considering the size of the electrocutaneous Braille display, this two point discrimination factor must be considered; otherwise if the individual cannot distinguish the Braille numbers, then the watch is useless to him or her.

The skin of the fingertip is a possible display site for the Braille configured electrocutaneous electrodes. If designed for use by the fingertips, the display could be made very small, but electrode spacing would be limited by the size of the field created by each signal. The thick epidermal layer would require a large amount of voltage to reach the nerve endings beneath the insulating stratum corneum. Such a voltage could be 240V, which requires custom designed circuitry, as it is not readily available for purchase.

Another viable site for Braille display is on the back of the wrist, similar to where a wristwatch is normally in contact with the skin. Instead of an outward display, the electrodes would be on the underside of the band, applied to the skin of the back of the wrist. The advantage of this site is that the stratum corneum is much thinner, thus possibly requiring as little as 30V. In addition to the thinner epidermal layer, the presence of hair follicles and sweat glands makes this skin more conductive and better able to receive the signal. This could become problematic if the user began to sweat profusely and greatly increase their conductivity, putting them at risk for shock. The two-point discrimination on the back of the wrist is poorer than the fingertip, and a larger display would become necessary. This concept can be adopted into displays elsewhere on the body, such as the abdomen, forearm, and so forth. While the voltage requirements would drop, the spacing would increase.

Common to all of the electrocutaneous design possibilities is a need for a power supply to generate the electrical signal to the skin. For better efficiency, the time display should only be on and signaling when cued by the user or at regular intervals such as at the new hour. The physical size of the circuit components for creating a sustainable 240V supply is rather large. In Dr. Tyler's laboratory, the components were kept on a shelving unit, nowhere near the size of a wrist or pocket watch. Also, his laboratory was using AC power, but our portable device would not have that luxury. In order for our product to be useful and worthwhile for the user, the power supply should not be a burdensome load, nor should it have such a short lifespan that it requires constant recharging or replacement of batteries. Modification or alteration of Dr. Tyler's approach would require researching and testing before integration with this project.

Pros

There are several benefits to this electrocutaneous approach for displaying Braille. The versatility of displaying anywhere on the body certainly has its appeal. There are other research groups working on technology for sensory substitution, and using electrocutaneous technologies to convey information to the user. In the future, this project could be integrated with such a system, and improve an individual's ability to interact with the world around them using this alternative sensory display. Before any of this could be achieved, a great deal of research is still necessary, as well as prototyping and other studies.

Cons

Although there is significant potential with this type of technology, there are downsides to be considered. The scope of the research necessary before a finished product can be reached will require extensive technical and human testing, purchasing of custom equipment, and attention to detail. Given the budget constraints of this project, as well as the desire to create a product as soon as possible for our client, this makes an electrocutaneous display unfavorable. In addition, some aspects of this design may not be feasible regardless of the availability of time and money. The challenge would be creating a power supply capable of delivering the necessary voltage, with a reasonable amount of time between charges and/or battery replacements, and being ergonomically practical for an individual to carry around with them. Associated with such a power supply is the risk of electrical shock due to malfunction, damage, or misuse. If the electrodes were applied to the wrist when intended for the finger, the voltage applied would be quite excessive, and could harm the user or damage the watch itself. The user should feel completely safe using this product and not hold the lingering fear that it could cause them harm.

Several aspects of this design detract from the usability and cohesiveness with the user's daily activities and life style, making it a less desirable option.

Vibrotactile Display

A more traditional approach to displaying Braille involves mechanical components that raise and lower pins to activate the dots in a Braille cell. This is referred to as a "pin" mechanism, and is common to many existing Braille display products, such as the Braille Note ©. There are several mechanisms for creating a dynamic vibrotactile display, including microsolenoids, smart metal alloys, and vibration. The pins are arranged in a grid pattern, using six or eight pins for a full Braille cell.

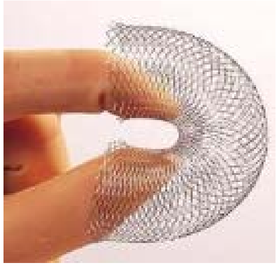

Figure 6: Smart metal alloy, shown as a deformable stent. It has many other applications in medical technology for its flexibility and "memory" abilities.
http://www-civil.eng.ox.ac.uk/people/zy/research/stent.jpg

Smart metals, such as Nitinol, are capable of forming a new shape when heated externally or by applying sufficient currents to it; an example of a smart metal can be seen in Figure 6. Stents and other medical technologies commonly make use of these properties. There are patents that incorporate smart metals into the mechanism of a mechanical Braille cell (Decker, 1997), but there are many factors to be considered. The strength of the wire when taking a new form varies, depending on thickness and the ratio of metals within the alloy. This approach would not require a motor or otherwise bulky mechanical device, and could theoretically be achieved using springs and cantilevers. The two other requirements would be an efficient cooling system so the wire could return to its resting form, as well as a power supply to generate the current or heat. These secondary components could become bulky and expensive, as research and development would require extensive prototyping and modeling before a safe and reliable product could be made.

Many existing Braille devices incorporate microsolenoids. This availability in other products creates the option of harvesting components for the purposes of constructing a digital Braille watch. By not spending time and resources on developing a new display mechanism, other aspects of the project could be focused on, such as aesthetics and ergonomics. The dimensions of a standard microsolenoid Braille cell as available commercially are at least a couple inches in length, and have a cross-sectional area of at least that of a standard Braille cell, not considering any auxiliary components for control or computer integration. One version can be seen in Figure 7, used in research projects at MIT. Constantly displaying the time would consume excessive amounts of power and require the user to recharge more frequently. Thus an "on" button would be advisable for this model, so the time is only displayed when called for by the user. As another space saving method, displaying a single digit at a time and "scrolling" through the four digits would reduce the bulkiness of the watch, as well as the cost for mechanical parts. To acquire these parts from a Braille display would cost at least several hundred dollars, based on research of commercial vendors. From a practical standpoint, spending several hundred dollars, or even several thousand dollars in some cases, is beyond the desired costs for fabricating a wrist or pocket watch. A more inexpensive product still capable of being manipulated into a vibrotactile display would be more desired by potential users.

Figure 7: Microsolenoid driven Braille cell, used by researchers at MIT.
http://web.mit.edu/erblan/www/Graphics/solenoid-big.jpg

An alternative pathway within the vibrotactile category is a vibration approach. Instead of physically raising and lowering a pin for each of the dots within a Braille cell, a pin or small panel could be motionless while "off" and vibrate when "activated". The vibration can be generated using a shaftless vibro-motor, one for each of the dots of the Braille cell. These motors have rather small dimensions, at ten millimeters in diameter and only three millimeters in thickness, and a mass of only one gram. A comparison of size with a quarter can be seen in Figure 8. Even while running on the upper limits of the acceptable voltage range, this device does not vibrate audibly. Their voltage requirements are at most three volts, while still capable of strong vibration with as little as one volt. The power drawn by each of these vibro-motors is also low, as it only draws at most 85 milliamps of current. This is excellent for users concerned about not disrupting a quiet room while checking the time. The overall power needs of this design are very minimal, and can be even more so by letting the user cue the display to turn on, so that the majority of the time the watch is in a resting mode, i.e.

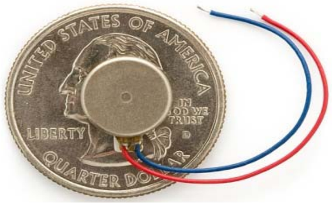

Figure 8: A shaftless vibro-motor cell, capable of moderate vibration while drawing a small amount of power.
http://www.sparkfun.com/commerce/product_info.php?products_id=8449

motionless. Rechargeable batteries are a reasonable option for powering a vibro-motor cell display.

This is also practical because a user would lose sensitivity after prolonged exposure to a vibrating surface. While these cells are small and potentially four digits could be simultaneously displayed, the combined vibration of that many vibro-motors could overload the senses making interpretation near impossible. For this design displaying a single digit at a time and scrolling through is the most practical approach.

The vibration display approach has versatility in that it could be created on a large scale or small scale to be read by different parts of the hand or body. This would likely require packaging this as a pocket watch rather than a wristwatch. As shown in Figure 9 to the right, four panels could be arranged in a square formation, allowing the user to read the vibrations using their palm. If these four panels were scaled down, or reshaped to a finer pin type heading, then it could be read with the fingertip. The spacing of these panels is not yet known, and would require field research on the human ability to use two-point discrimination of vibrating stimuli. There are other aspects of vibration stimuli and interpretation that would need to be researched as well, such as threshold sensitivity levels, desensitization due to over exposure, and time needed between displaying each digit.

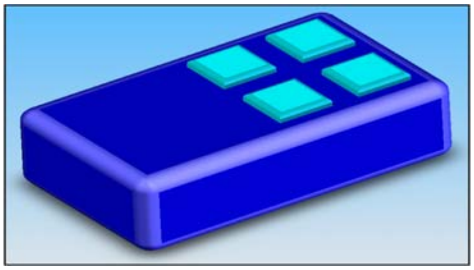

Figure 9: A Solidworks model of a vibration driven display for Braille numbers using just four panels, analogous to traditional dots.

Pros

There are several advantages to a vibrotactile approach to displaying Braille numbers for telling time. First, it is a system already used in many Braille technologies, so users would be accustomed to the style and interface of the display. The vibration system does alter this, but fundamentally the refreshable tactile display remains the same. From the perspective of ergonomics and human factors, this watch is very cohesive with the user’s lifestyle because it can realistically be scaled to the size of a pocket watch, and possibly with further refinement as small as a wristwatch. Another positive factor is the low power consumption by easily acquired components. This saves time that would have been spent fabricating a complex power supply system or a new mechanism or raising pins. Saving time is desired so that a usable product can be delivered to the client as soon as possible. Safety is very high with this approach, as all components, electrical and mechanical, stay within the housing. Compared to the electrocutaneous approach, this model poses practically no safety risk to the user.

Cons

The downside to a vibration driven display is that it can only be so small, as it must house mechanical components. The vibro-motors are relatively small, but still would likely work better as a pocket watch than as a wrist watch. The other downside to this approach is that some users may not like the vibration approach compared to the pin models used in other products. This is dependent on the users flexibility and willingness to try a new technology. The other vibrotactile options (smart metal alloys and microsolenoids) are costly either for research or for obtaining components. This would drive up the cost of the final product, making it less desirable when cheaper audible or analog Braille watches are available for much less money. Ideally, the final digital Braille watch will have low labor and parts costs so it can compete with other alternative display time telling technologies currently available on the market.

Mechanical Wheel

The design for a mechanical wheel watch is based on that of a flip clock, which was quite popular before the development of digital watches (as shown in Figure 10). The clock itself consists of four bands, with each band containing the numbers required to display the time. For example, in military display configuration, the first hour band would contain the numbers 0, 1 and 2; the second hour band would contain the numbers between 0 and 9; the first minute band would contain the numbers between 0 and 5; the second minute band would contain the numbers between 0 and 9.

Figure 10: Standard flip clock
http://jacklambert.files.wordpress.com/2006/06/flipclock.jpg

The mechanism powering the flipping of the numbers in the clock is a counter (such as a quartz crystal). For this design, using an integrated circuit, as seen in standard digital watches, would provide the mechanism behind changing the display.

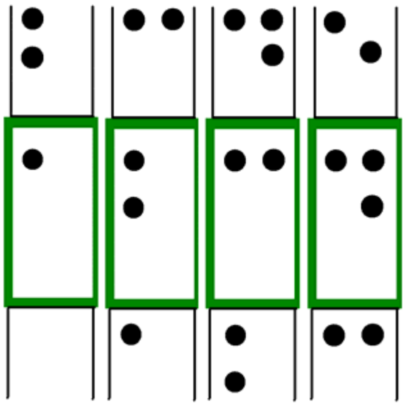

Figure 11: Depiction of the mechanical wheel display.

Designing the rest of the circuit would involve replacing the digits by Braille cells, as shown in Figure 11. There are four slots for the watch to display the time (two showing hours and two showing minutes; the figure is displaying the time 12:34). The Braille bands containing the numbers are wound around the wrist.

Pros

The main advantage of this design is the fact that it is one that has already been implemented in clocks, as shown. Constructing the interface between the circuit and the mechanical components, therefore, is not as much of an issue as it is with the electrocutaneous and vibrotactile displays. In addition, a design using mechanical components will require a smaller power supply (as opposed to the electrocutaneous and vibrotactile displays, which may require rather large power inputs to drive their circuits). The components involved, in addition, are easily obtainable (example parts include gears) and cheap. The other designs require specialized parts, such as vibrotactile motors, and may prove more costly to build.

Since the mechanical display is constructed form currently used parts (strips of Braille paper, for example), the device does not require the user to change his or her sensory recognition patterns, and this is a major contribution to the human factor aspect of the design. The display on this design is the most familiar to the user and would provide the adequate two-point discrimination threshold (which has been researched extensively). This design, in other words, would not require construction of a new type of Braille display cell.

From the safety perspective, this design does not require excessive amounts of current or voltage. It functions autonomously, and would most resemble the current design watches are built from.

Cons

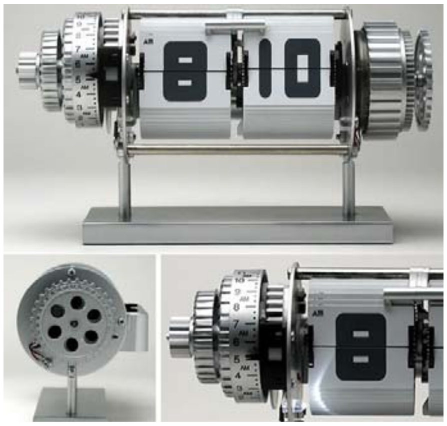

Figure 12: Gear mechanism, standard flip clock
http://technabob.com/

The difficulty in adapting the flip clock circuitry to the concept of a digital Braille watch lies in the large size difference between the basic design and the ideal size of a wristwatch. As shown in Figure 12, the gear mechanisms powering the flip clock are quite bulky and may not be suitable for a portable device. Also, flip clock circuitry relies heavily on 60 Hz AC input from the wall outlet in order to power its counting abilities. However, alternating current is not available to power this portable circuit.

Adding mechanical parts to the design (in this case, the Braille bands and the gears powering their movement) increases the probability of mechanical failure. The gears and other components also will increase the size of the device, especially the thickness of the display. In addition, extra components may also pose a safety risk. In the long term, the complexity of the watch may mean that additional labor is required to assemble it, which would drive the cost of manufacturing up.

Since the Braille strips are wound around the wrist, a constant length of the strap must be maintained. However, the strap length of the watch needs to change every time it is put on or taken off. Working around this constraint may further complicate the design.

Design Evaluation

Table 1: Design matrix showing criteria that are important to choosing the final design.

Criteria	**Weight**	**Electrocutaneous**	**Vibrotactile**	**Mech Wheel**
Ergonomics/Human factors	20	13.75	18.25	16.5
Achievability	20	9.5	17.5	14.5
Safety	20	9.75	18	18
Cost	15	7.5	13	11.75
Power supply	15	5.25	11.25	10.5
Durability	10	8.5	9	7.75
	100	54.25	**87**	79

We evaluated our design alternatives against the criteria listed in the design matrix shown above (Table 1). Some of the most important criteria listed involve safety, ergonomics and human factors. A digital watch is a tool that is used daily, and is in close contact with the user. Therefore, it is important for the watch not to cause obstruction during daily life activities and to be safe to wear daily. The mechanical wheel design received intermediate marks for these criteria; since it consists of many mechanical components; mechanical failure is more likely to occur. If the watch should break, the user may be hurt by the small gear components. The electrocutaneous design received the lowest grade out of all three designs; it involved directly applying either a current or a voltage to the skin. If the circuit malfunctions, the watch may shock the user. The vibrotactile device received the highest score in this category. Existing designs using vibrotactile cells (such as Braille displays) have already been evaluated for safety and ergonomics.

The second most important criteria considered is the feasibility of the designs in terms of achievability during the time frame of a semester. The mechanical wheel design received intermediate marks for this section because we would have to individually interface the clock circuit with the mechanical flip design, a time-consuming process. The electrocutaneous design received the lowest score. Most electrocutaneous circuits require custom-built electronics (cascaded and staged amplifiers in order to control the voltage or current, as the situation requires), which is beyond our scope in terms of the available budget and time frame. The vibrotactile device received the highest score in this section because small vibration motors are already available at low costs.

We evaluated the designs in terms of how much power each one would use. The mechanical wheel device is difficult to evaluate in terms of power consumption from a battery, since most flip clocks run on AC power. Current electrocutaneous circuits require large sources of voltage to drive the circuit. The vibrotactile motor that we are considering, however, has an operating range roughly between 2-4 V, a range feasible to supply from a battery. Cost is somewhat correlated with power consumption; the more the energy consumption of the device, the more it costs to build it. The vibrotactile device is the cheapest to construct (small vibrotactile motors are available at about $7 each).

The last factor used to evaluate the designs was durability. Most digital watches can last for years. Provided that we are able to power the watch, it is important that the circuitry within last long enough so that the client is able to use it for a long time, especially because this design will be custom-made for our client.

Future Work

The rest of the semester will be devoted to testing and building our vibrotactile design. There are several things we must accomplish by the end of the semester. One task is to test different arrangements to use as an interface for a Braille display. We have obtained several shaftless vibration motors and will be experimenting to see what voltage will be needed to power the motors. With the motors, we will run tests to ensure that the user can distinguish between the Braille dots. Another important task is to create a circuit that will convert a digital signal from an integrated circuit chip from a digital watch to a Braille display. The last goal is to ensure that the whole design is fully functional so our client can use it in his daily life. Beyond the timeframe of this semester, continuous improvements may be made to enhance the product’s size, features, and aesthetics.

References

HumanWare. http://www.humanware.com/en-new-zealand/home. Retrieved Jan 29, 2008

Decker, Lawrence H. November 11th, 1997. Refreshable Braille- Cell Display Implemented with Shape Memory Alloys. US Patent Number 5,685,721.

Independent Living Aids, Inc. http://www.independentliving.com. Retrieved Jan 31, 2008

Saladin, K. (2008). Human Anatomy (2nd ed.) McGraw- Hill.

Strang, K, Raff, H., and Widmaier, E. 2006. Human Physiology: The Mechanisms of Body Function.10th edition. New York: McGraw- Hill.

Project Design Specification

March 12, 2008

Team Members: Alice Tang, Vidhya Raju, Alison Boumeester, Anika Lohrentz

Problem Statement:
Currently, visually impaired individuals rely on speaking watches, or tactile analog watches that must be carefully examined to tell time. These technologies can be disruptively noisy or prone to misreading. Our goal is to create a digital Braille watch that displays military time, does not cause disruptions to others, and is robust. The Braille display must be appropriately sized so the user can accurately and reliably distinguish between the different digits displayed.

Client Requirements:

- Digital military time watch
- Wristwatch or pocket watch size
- Silent
- Time displayed in Braille

1. Physical and Operational Characteristics

a. *Performance requirements*: The watch must not make any audible sounds.

b. *Safety*: The watch must contain non-toxic materials. Wires must not be exposed.

c. *Accuracy and Reliability*: The device must incorporate a counter to tell time within one minute of accuracy.

d. *Life in Service*: Must have a lifespan of 10 years.

e. *Shelf Life*: Dry environment between -30 to 50 degrees Celsius.

f. *Operating Environment*: The device will be used daily. Therefore, it must be able to withstand abrasion, water, and other types of weather such as humidity and temperature.

g. *Ergonomics*: Cannot shock the user. May be worn as a wristwatch or carried as a pocket watch.

h. *Size*: Small enough to fit into a pocket (2 inches x 2 inches x 1 inch).

i. *Weight*: Within 0.2 kilograms.

j. *Materials*: Non-toxic materials.

k. *Aesthetics, Appearance, and Finish*: Sleek, streamlined.

2. Production Characteristics

a. *Quantity*: One.

b. *Target Product Cost*: To be determined, based on final design and long-term plan.

3. Miscellaneous

a. *Standards and Specifications*: The client has a patent pending.

b. *Customer*: The client would like to physically feel the time using Braille. A power-saving function is preferable. Flip cover to protect from environmental damage.

c. *Patient-related concerns*: Criterion listed above must be met for patient comfort.

d. *Competition*: There are watches available commercially for visually impaired people: audible watches and analog Braille watches.