UNIVERSITY OF WISCONSIN MADISON: DEPARTMENT OF BIOMEDICAL ENGINEERING

Digital Braille Watch

Spring 2011

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Client: Holly and Colton Albrecht
Advisor: John Puccinelli

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Abstract

The Braille language has provided the visually impaired with a way to read and write for many years, yet no device exists that allows the visually impaired to read the time in Braille. In order to tell time, the visually impaired currently rely on either talking or tactile watches. However, talking watches are disruptive, while tactile watches are difficult to read and fragile. Our goal is to design a watch that allows the visually impaired to read the time in standard Braille. In order to accomplish this, three preliminary Braille watch design options were proposed. The first idea is to improve upon the prototype developed by the Fall 2010 Braille watch design team. This prototype involved four disks which each rotated beneath a set of four pins. Incorporating a gear mechanism could minimize the power consumption of this design, but in its current form this would be challenging to accomplish. The second option utilizes technology found in a standard odometer. It would consist of four disks with raised and lowered surfaces cut into the rim of the disk. A set of four pins would rest above each of these disks and would be raised or lowered depending upon where they rested. A gear mechanism similar to that found in a standard odometer would be used to rotate each disk. The final design option is a hybrid of design options one and two. This design utilizes four disks which each rotate beneath a set of four pins. The surface of each disk is divided into three rings: outer, middle, and interior, in which raised or lowered surfaces are cut. As the disks rotate by way of a gear mechanism, the pins are raised and lowered to display the desired numbers. Due to the minimal size and low power consumption presented by this design, it was chosen as the design option to pursue. Future work includes finalizing the design, assembling a prototype, testing, and performing final modifications to the prototype based on the testing results and client's input.

Background

Problem Statement

In order to determine the time, the visually impaired currently depend on talking or tactile analog watches. However, talking watches are disruptive, while the tactile analog watches are difficult to read and fragile. Our client desires a device that uses the standard Braille number system to display the time. This device should be no larger than a standard Smartphone, have a self-contained power supply, and use standard Braille spacing.

Braille Basics

The Braille language is the universally accepted form of written communication for the visually impaired. It utilizes a system of dots arrayed in a three row by two column grid. Raised dots are then located in any of the six positions, displaying different letters, numbers, and symbols based on their configuration.

In order for this method of communication to be accurate and precise, universal specifications have been developed. Each dot must have a base diameter of 1.44 millimeters (0.057 in.) while being 0.48 millimeters (0.019 in.) in height. Within each individual grid, the dots must be at least 2.34 millimeters (0.092 in.) apart, measured center-to-center, and each individual character should be a minimum of 6.22 millimeters (0.245 in.) away from the neighboring character. [1]

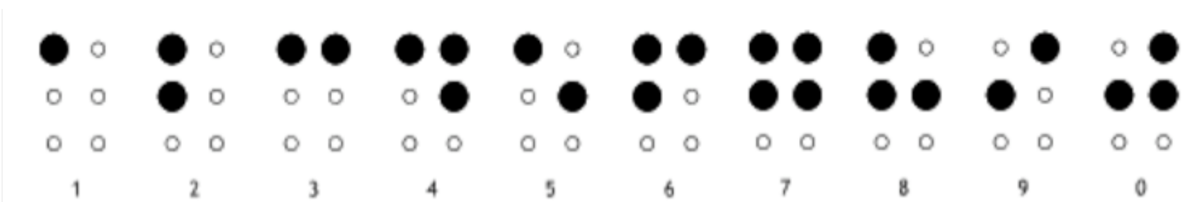

Figure 1 – Braille numerals 0-9
Image courtesy of PharmaBraille:

To simplify matters for this design, the numbers 0-9 are represented using only the top four dots of the three by two grid (Figure 1). Instead of having to manage an oblong, rectangular three by two grid, the design of the watch is much simpler and requires only a two by two grid to display any number.

The distance between two Braille pins must be at least 2.34 millimeters apart, since this is the minimal distance required to distinguish between two points with the fingertip. This minimal distance is determined by mechanoreceptors located on the skin, which are activated by the slightest deformation of the skin due to contact. In order to discriminate between two points, there must be a deactivated receptor located between two activated receptors. Without the presence of a deactivated receptor, the brain would perceive the contact of the two points as one stimulus.

These receptors are distributed all over the body; however, they exist in some areas in higher concentration. The distribution of these touch receptors is represented by a homunculus diagram, which shows that these receptors are present in high concentration in the fingertips, making them more sensitive to touch. It was important to consider these sensory limitations when designing the watch. [2]

Current Methods

There are two main categories of watch products currently on the market for the visually impaired: talking watches and analog tactile watches. Talking watches function by verbally relaying the time to the user whenever the user presses a button (Figure 2). This method is effective in

Figure 2 – Talking watches verbally communicate the time
Image courtesy of Independent Living Aids, LLC:
http://www.independentliving.com/prodinfo.asp?number=756480

communicating the time; however, it can be disruptive and draws attention to the user. Analog tactile watches, on the other hand, are silent (Figure 3). They function

Figure 3 – Visually impaired touch the hands of the tactile analog watch to tell the time
Image courtesy of Auguste Reyond: http://watchluxus.com/braille-watches-by-auguste-reyond

much like traditional analog watches, except in this case in order to tell the time the user must touch the face of the watch to feel where the hands are located. There are also raised markings on the watch that indicate the positions of the numbers; however, there is no standard format for these markings and they vary from product to product. Our client has informed us that these watches can be difficult to read and come with a learning curve when first used. Also, the hands of these watches are exposed while the user is telling the time, and therefore they can be easily broken or damaged.

In addition to these currently available watch products, there is a watch that has recently been designed called the Haptica Braille Watch (Figure 4). This design features a set of 16 rotating disks that circulate Braille dots in and out of the display to assemble the desired Braille numerals. Each disk contains a single Braille dot that is moved in concert with the other disks to display the time in Braille. This concept was created by David Chavez in 2008. Chavez is not an engineer and has not created a prototype for his design. [3]

Figure 4 – Haptica Braille Watch design by David Chavez
Image courtesy of Tuvie Design of the Future:
http://www.tuvie.com/haptica-braille-watch-concept/

Past Designs

This is the fifth semester that a team has worked on this project. The first two teams developed a vibrating dots design. It features four vibrating motors that vibrate in sequence to communicate the time (Figure 5). When the user presses a

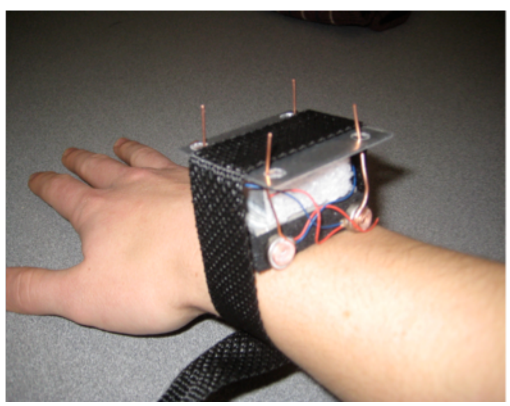

Figure 5 – Vibrating dots prototype created by past BME design team
Image courtesy of BME 200 Fall 2008 Design Team

button on the watch, the four motors vibrate to signify one Braille numeral, and, after a short pause, they vibrate again to denote the second numeral. This process is repeated until all four numerals have been relayed to the user.

The fall of 2008 team that worked on this project was able to construct a working prototype of this design; however, it had some major drawbacks. After testing the device, Colton informed the team that many visually impaired people have increased sensitivity to touch in their hands. This is due to the fact that many use their fingers to detect subtle tactile differences, including those encountered while reading Braille. As a result, the vibrations of this prototype had an over-stimulating effect. Also, because of the size of the watch, the user must use their entire hand to read the device. This ends up creating an experience that is very different from actual Braille reading, which only requires one fingertip. In addition, the design had high power consumption.

The design shown in Figure 6 was designed by last spring's design team.

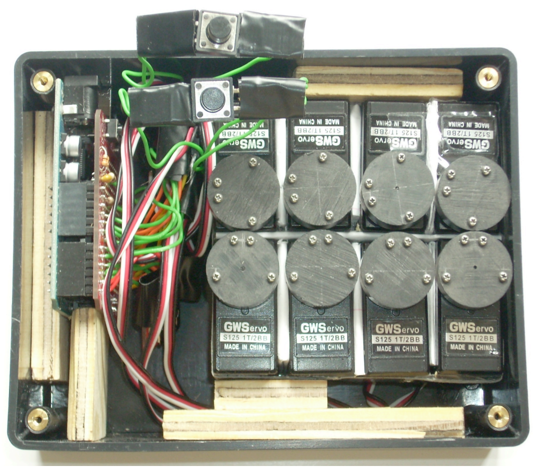

Figure 6- Internal view of rotating disk prototype
Image Courtesy of Spring 2010 Braille Watch Team

Their design uses eight rotating disks to form the required Braille numerals. Each disk has four raised dots, which can be configured to form the top or bottom half of the character cell (Figure 7). [4]

This design met the client's requirements and was the first existing Braille time-keeping device. However, many downfalls exist with this design. As can be seen in Figure 7, the prototype is too large to fit on the wrist of a user, thus, the size must be cut down significantly. Also, this device uses eight moving parts, leading to high power consumption. With this design, there was not much opportunity to significantly cut size and power use. Finally, due to the mechanical nature of this design, the Braille numbers were often difficult to read. The Braille display relied heavily on the accuracy of the servo motors used to rotate the disks.

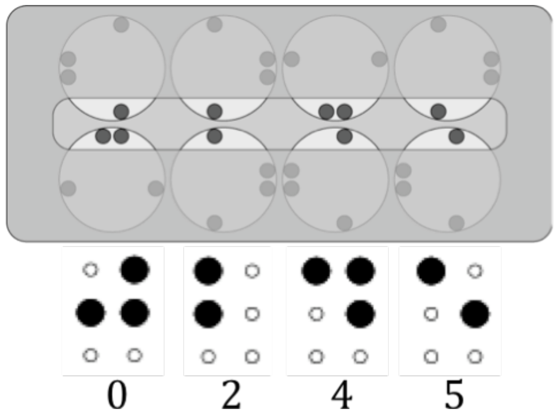

Figure 7 – By a rotation of 90º, 180º or 270º, the disks can display the correct time
Image Courtesy of Spring 2010 Braille Watch Team

Design Criteria and Considerations

Design Specifications

The clients for this project are Holly and her visually impaired son Colton Albrecht. Together, they came up with the idea for the Digital Braille Watch. As such, the project will be created in accordance to their wishes and specifications. Their main requirements are that the design is able to correctly display the current time in standard Braille and operate without any noise. The watch must not be dangerous to the user, so moving parts and electronic components must be contained properly. It has to be accurate within the minute whenever it is connected to a power source. Holly and Colton did not request that the prototype is any particular size; rather, they are looking for a proof of concept. However, the prototype should be designed so that it would be possible to scale down to watch-size in the future. For more information on the product design specifications, see Appendix A.

Funding

Since caring for a visually impaired child can be financially taxing, it is difficult for our client to provide funding for this project. As a result, we turned to outside sources to try to offset the financial burden on our client. Based on advice from our advisor, John Puccinelli, we will be consulting with the University of Wisconsin Madison Department of Biomedical Engineering (BME) to fund our project. A budget proposal is not needed for this project since expenses should not exceed $50.

Disk and Pins

The first design option was that which was developed by this team last semster: the disk and pins design (Figure 8). The basis of this design was four disks located beneath the watch surface, one for each Braille numeral. Above each

Figure 8: Disk and pins prototype developed by last semester's team

disk four pins were positioned so that they rest on the disks' surface. The portion of the disk against which the pins rest has both raised and recessed sections (Figure 9). If a pin is on the raised surface, it will be pushed slightly above the watch plane, and if not, the top of the pin will remain flush with the surface of the watch (Figure 10). When the disk rotates to different positions different combinations of pins are raised. In this way all necessary numbers can be displayed.

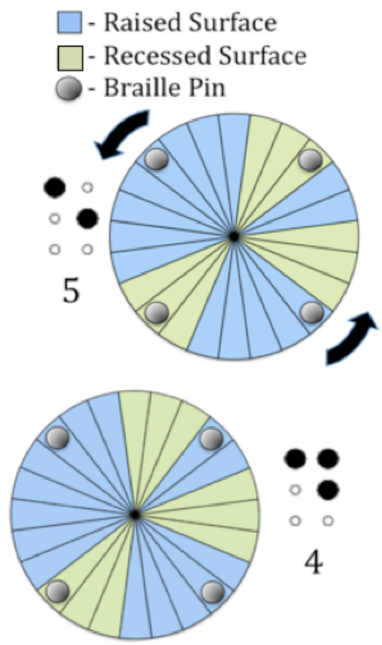

Figure 9– The raised and recessed surfaces on the disk cause different numbers to be displayed

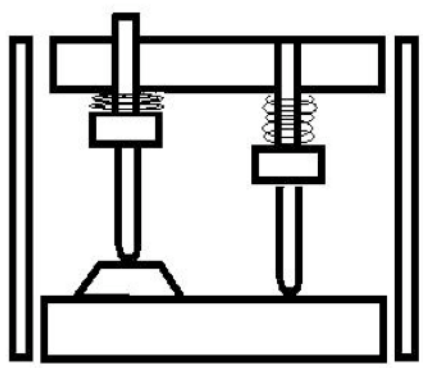

Figure 10: The raised surface on the disk pushes the Braille pin to the surface of the watch

A benefit to this design over that of the previous team is that only four moving parts are needed. This cut down on the energy necessary to run the watch. Also smaller servos were used since only 165° of rotation was needed to rotate the disks opposed to the 270° previously needed. This design also removed the ambiguity of the Braille number display. The pins remained in place, causing the Braille dots to remain aligned. However, upon completion of a prototype, several shortfalls of this design were apparent. The design still consumed too much energy, as a USB cord was needed to power the watch. In addition, the spacing of the Braille characters and dots within the Braille characters was much larger than standard. These two major concerns made it difficult to work with this design in its current form. A design that could optimize power consumption and spacing of the characters would be preferred.

Odometer Concept

Inspired by the previous design concept, this design entails setting up a system of gears in a way that only one gear needs to be rotated in order to control the entire watch. A gear system of this exact type is shown in the design of an odometer in Figure 11. Looking at the white gear in the figure, it can be seen that there are only two pegs on its left side. This is the key to the proper function of an

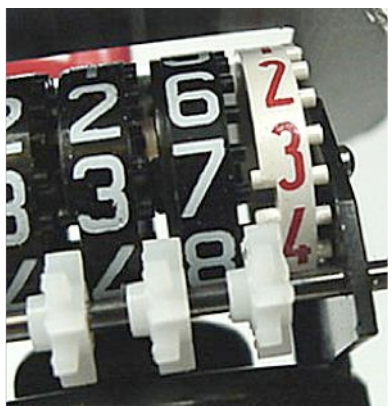

Figure 11 – The odometer gear system requires the rotation of one gear to control the display
Image courtesy of HowStuffWorks:
http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/odometer1.htm

odometer. Due to this design, the white gear only briefly comes in contact with the intermediate opaque gear for every rotation. This contact is enough to rotate the first black gear from one number to the next. Each gear is connected to its adjacent gear in this way. [5] By using this gear system combined with the raised and lowered disk surface idea introduced previously, a functional Braille watch could be created.

Figure 12 shows how raised and lowered surfaces along the circumference of each disk could be used to display each number.

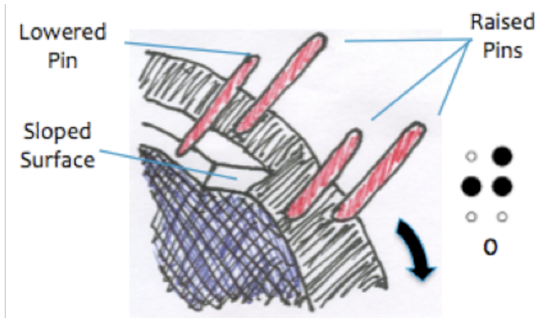

Figure 12: The raised and lowered surfaces along the cirucumference of the disks could be designed to raise and lower pins in the configuration of any Braille number

This design could easily achieve standard Braille spacing. In addition, due to the gear system, a constant angular velocity would need to be applied to only one disk in order to operate the entire watch. This would lead to a significant decrease in power consumption and also allow for the elimination of any servo motors or microcontrollers, further optimizing space. The largest downfall to this design regards the final dimensions of a prototype. The height of the final design would be based on the diameter of the disks, since each is standing on its side to raise and lower the pins. Some preliminary calculations suggested that this height may be as large as one inch, a thickness too large for a watch. A compact design that functions similar to this one would be ideal.

Gear and Pins

The Gear and Pins design utilizes the raised and lowered surfaces introduced with the Disk and Pins design. There are once again four disks, one for each Braille digit displayed, which have raised and lowered portions (Figure 13). Four pins set with standard Braille spacing rest on a section of the disk aligned over three separated tracks, with the two diagonal pins functioning off of the same track (Figure 14). As the disk rotates, combinations of raised and recessed sections beneath the pins change, subsequently altering the number being displayed.

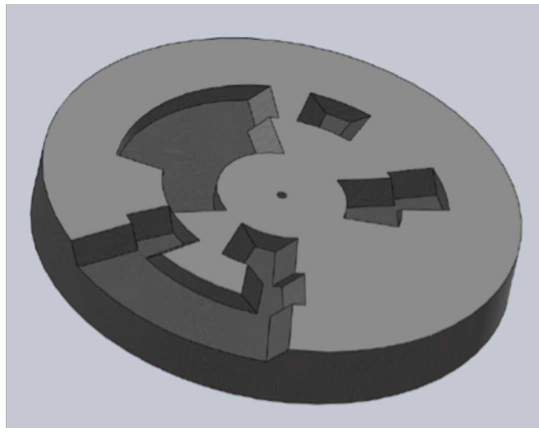

Figure 13: A disk with different combinations of raised and lowered segments can display a desired range of numbers

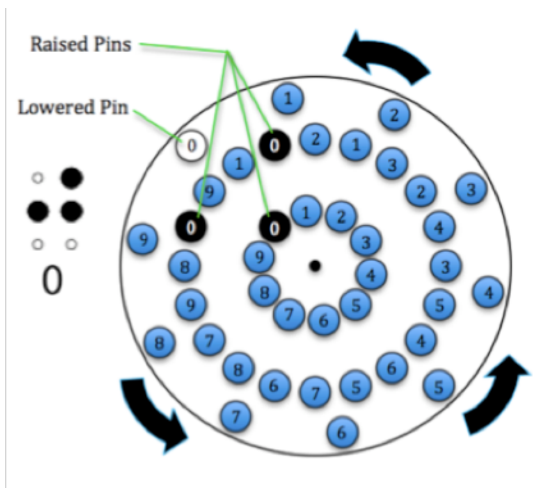

Figure 14: Number layout of a Gear and Pins disk, which can display the numbers 0-9 as it completes its rotation

Another important aspect of this design is the gear system that exists between the disks. This system allows for the full rotation of one disk to be translated into a partial rotation of the following disk. Each disk has teeth around its edge, with number and length varying from disk to disk. As can be seen in Figure 15, a full rotation of the one tooth gear will lead to a partial rotation of the multi-tooth gear. The number of degrees the disk is turned is determined by the peg length and number of pegs present on the disk. This gear mechanism allows for the continuous motion described in the odometer concept design to be utilized. The disks are

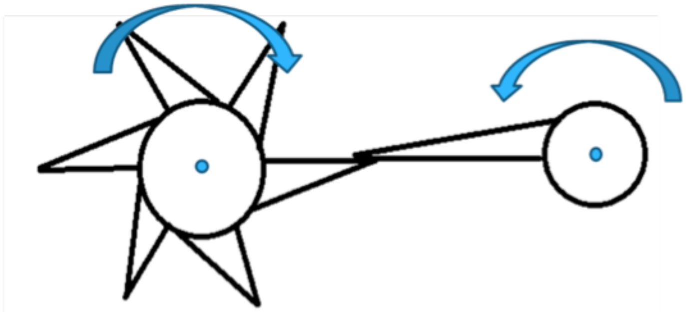

Figure 15: The full rotation of the gear on the right leads to a 60° partial rotation of the gear on the left, creating a gear system similar to that of the odometer

connected to a constantly moving "dummy disk", which has constant rotation and drives the rest of the number displaying disks. In this way, only one motor is needed in order for this model to function.

Due to only needing one motor, this design requires considerably less power. This is a significant benefit, as the watch must have a portable power source. This design also allows for smaller size and actual Braille spacing for the numbers being displayed. Not only does this make the design more portable, but also easier to read. The primary difficulty in this design has to do with the accuracy of all design measurements, as there is little room for error with its smaller size. Many of the parts of this semester’s design will be printed using a three-dimensional printer, which has a limitation as to how accurate of parts it can print.

Design Evaluation

The disk and pins design, the odometer concept, and the gear and pins design were evaluated on a weighted scale ranging from zero to one hundred over a variety of design criteria (Table 1). The most important criteria were given more weight in the matrix and include ergonomics, aesthetics, accuracy, and design simplicity. These aspects were determined to be the most important design characteristics since they are critical in terms of the ease of use and effective functionality of the final product.

Table 1: The Design Matrix displays the design evaluation on a scale of zero to one hundred (zero=very poor, one hundred=excellent) and is weighted on a variety of criteria.

Weight	Design Aspects	Disk and Pins	Odometer Concept	**Gear and Pins**
0.25	Ergonomics	70	80	**90**
0.15	Aesthetics	60	70	**90**
0.15	Accuracy	90	90	**100**
0.15	Design Simplicity	80	90	**70**
0.1	Scalability	60	80	**80**
0.1	Durability	60	70	**80**
0.05	Safety	80	80	**80**
0.05	Prototype Cost	70	80	**90**
	Total	71.5	80.5	**86**

A priority in this semester's design is to achieve standard Braille spacing on the face of the watch, so ergonomics was given the highest weight of 0.25. Although the Disk and Pins design was fairly accurate and a significant improvement over the Rotating Disks design, it lacks potential to be scaled down to a typical watch size. The Odometer Concept and the Gears and Pins design are a better alternative; however, the Gears and Pins Design allows for a shorter height when compared to the Odometer Concept. Aesthetics was also weighted heavily since the watch should not draw attention to the user. Given the same weight as aesthetics, accuracy is a key component to any watch, as a watch must keep the correct time to fulfill its purpose. The design must also be simple in order to minimize cost, increase durability, and ease assembly. Although the cost of the design was not weighted heavily, the Gears and Pins design will be significantly cost-effective when being compared to the Disk and Pins design. This is due largely in part to not requiring four servo motors and the power necessary to supply them. After evaluating the designs' pros and cons, it was determined that the Gear and Pins design scored the highest and, therefore, was selected as the design to pursue.

Future Work

The Gear and Pins design offers a greater reduction in size while allowing the implementation of the standard Braille spacing and a decrease in power consumption. A downfall to this is that there is less room for error due to the reduction in size of the design, meaning that the manufactured parts have to be extremely precise. To counter the higher precision needed in this design, the Viper SI2 prototyping machine will be used to print all parts. This offers resolution of up to 0.002 inches, significantly higher than the 0.007 offered by the printer used last semester. The Viper will be used to manufacture the casing, pins, and disks needed for this design. In order to spin the disks, a clockworks device (Figure 16) will be modified and incorporated into our prototype. This device is powered by a small

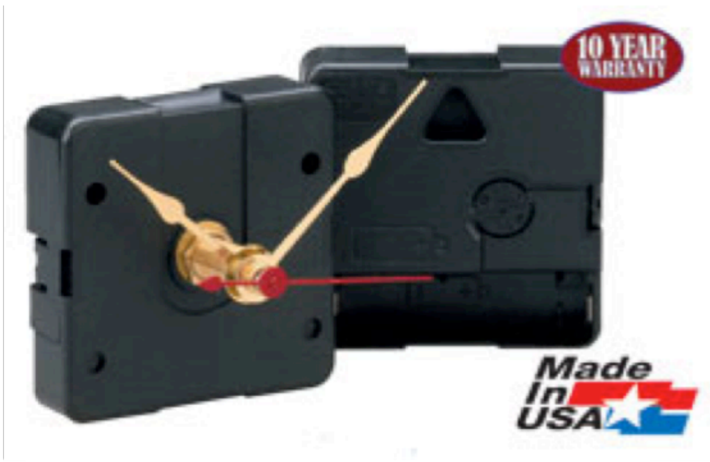

Figure 16 – The clockworks time keeping device contains a gear that completes exactly one rotation per minute, providing the desired rotation to control the Gear and Pins watch
Image courtesy of Klockit:
http://www.klockit.com/depts/ClockMovementsfeaturingQuartexBrand/dept-355.html

battery, the only power requirement of the entire design, and is small enough to fit the size requirements set forth by Holly and Colton. In addition to ordering the clockworks device, sixteen springs will be ordered as well. These springs will hold the pins in place and prevent them from breaking the surface of the watch if it is overturned.

After ordering and manufacturing the necessary parts, the prototype will be assembled. Based on preliminary numbers, the prototype should be near the size of a standard Smartphone, adding a few tenths of an inch in thickness but taking away an inch or two in length. This prototype will be subjected to a series of tests to determine its accuracy and durability, as well as shown to a number of visually impaired students to gather their feedback. If the prototype is successful, the team will apply for a patent through WARF. In addition to patenting the device, the team will consider working with ViewPlus Technologies, a company which specializes in Braille technology and has shown interest in the digital Braille watch project.

References

[1] "Size and Spacing of Braille Characters." Braille Authority of North America. n.d. 31 Jan. 2011. <http://www.Brailleauthority.org/sizespacingofBraille/>.

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[3] "Haptica Braille Watch Concept." Tuvie Design of the Future. 2009. 24 Sep. 2010. <http://www.tuvie.com/haptica-Braille-watch-concept/>.

[4] "Braille Watch." UW-Madison Biomedical Engineering Design Courses – Project Pages. 2010. 22 Sep. 2010.

[5] "How Odometers Work." How Stuff Works. n.d. 11 Feb. 2011. <http://auto.how stuffworks.com/car-driving-safety/safety-regulatory-devices/odometer1.htm>.

Appendix A: Product Design Specifications

Product Design Specifications—Digital Braille Watch

February 2, 2011

Team: Nick Anderson, Taylor Milne, Kyle Jamar, Chandresh Singh
Client: Holly and Colton Albrecht
Advisor: John Puccinelli

Problem Statement:

In order to determine the time, the visually impaired currently depend on talking or tactile analog watches. However, talking watches are disruptive, while the tactile analog watches are difficult to read and fragile. Our *client* desires a device that uses the standard Braille number system to display the time. This device should be no larger than a standard Smartphone, have a self-contained power supply, use standard Braille spacing, and display military time.

Client Requirements:

- Digital military time display
- Silent and without vibrations
- Time in standard Braille

Design Requirements:

1) Design Requirements

a) *Performance requirements:* See Client Requirements above, in addition to being self-contained, using standard Braille spacing, and meet the size requirements below
b) *Safety:* All electronics must be contained and the watch must not contain hazardous materials
c) *Accuracy and Reliability*: The watch must accurately display military time within the minute
d) *Life in Service*: The watch must be able function continuously using a self-contained power source capable of powering it without charging for 24 hours
e) *Shelf Life*: Not specified for prototype
f) *Operating Environment*: The device must be able to operate reliably in a dry environment
g) *Ergonomics*: The watch should not contain rough edges or loose components and the display surface should be easy to read
h) *Size*: The prototype should be similar in size to a cellular phone with thickness being the most important dimension to minimize

i) *Weight*: No quantitative limit, but must be able to be carried comfortably over the course of a day
j) *Materials*: The device must comprise of non-toxic components
k) *Aesthetics, Appearance, and Finish*: The watch should be aesthetically pleasing

2) Product Characteristics
   a) *Quantity*: One working prototype
   b) *Target Product Cost*: $100 or less when mass-produced

3) Miscellaneous
   a) *Standards and Specifications*: Must display time according to the standard Braille language
   b) *Customer*: The customer would like a device that physically displays the time using Braille digits
   c) *Patient Related Concerns*: None
   d) *Competition*: Audible and tactile analog watches are commercially available for the visually-impaired