UNIVERSITY OF WISCONSIN MADISON: DEPARTMENT OF BIOMEDICAL ENGINEERING

Digital Braille Watch

Spring 2011

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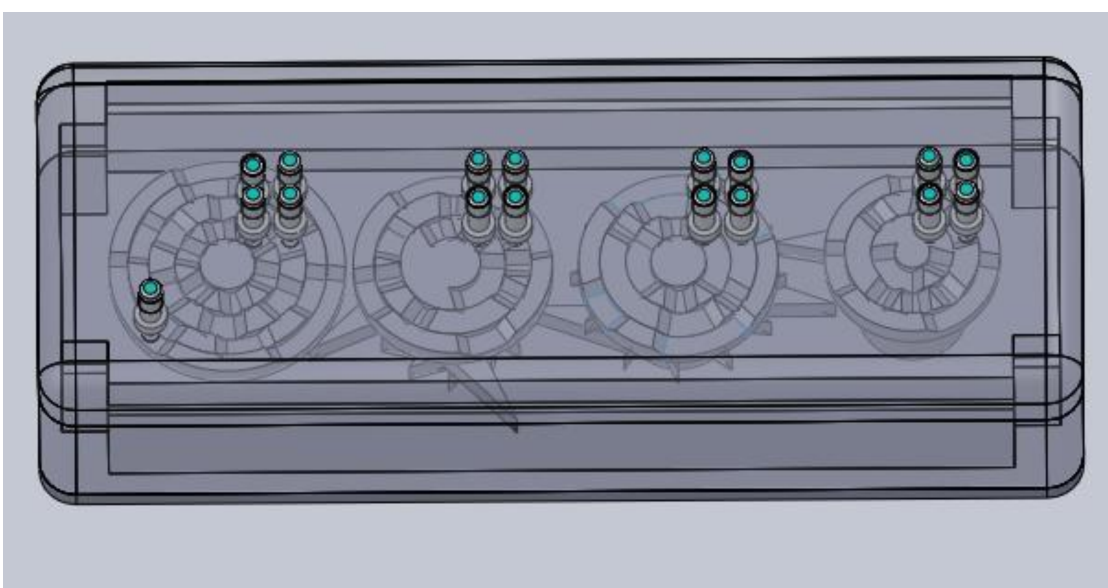

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Abstract

Worldwide, the Braille system provides 284 million visually impaired individuals with a way to read and write [1], 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. The goal for the past three semesters has been to design a watch that allows the visually impaired to read the time in standard Braille. The final prototype was developed using the Viper si2 rapid prototyping machine and 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 inner, each of which contains raised and lowered surfaces cut into the face of the disk. As the disks rotate via a gear mechanism interconnecting the four disks, the pins are raised and lowered to display the desired numbers. Testing conducted by six visually impaired individuals demonstrated necessity and market availability for the watch. The design could be improved by manufacturing the device out of metal, leading to increased durability and a better interaction between all moving parts. Future work includes patenting the design through the Wisconsin Alumni Research Foundation as well as searching for a company to aide in the development of the Braille watch.

Background

Problem Statement

In order to determine the time, the visually impaired currently depend on talking or tactile watches. However, talking watches are disruptive, while tactile watches are difficult to read and fragile. Holly and Colton desired a watch that used the standard Braille number system to display the time. The device could not be larger than a standard Smartphone, required a self-contained power supply, and needed to utilize 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. [2]

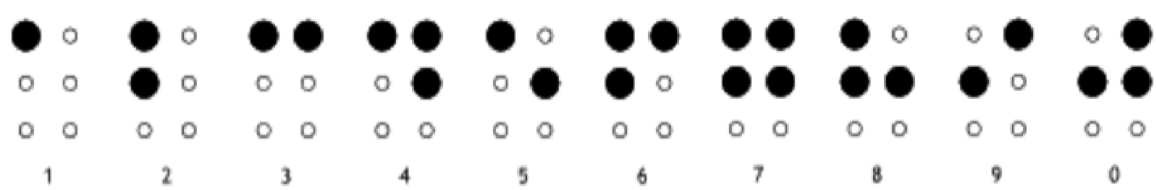

Figure 1 – Braille numerals 0-9
Image courtesy of PharmaBraille:

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. [3]

Current Methods

There are two main categories of watch products currently on the market for the visually impaired: talking watches and 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 communicating the time; however, it can be

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

disruptive and draws attention to the user. Tactile watches, on the other hand, are silent (Figure 3). They function much like traditional analog watches, except the

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

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. [4]

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

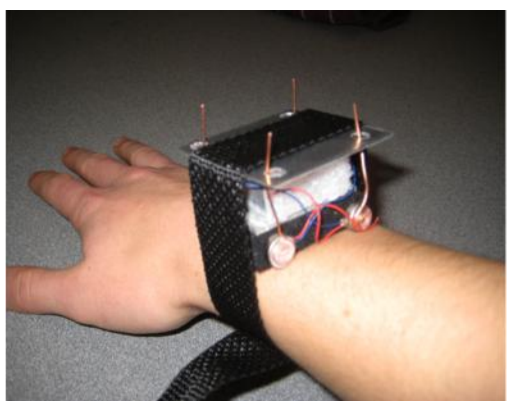

Figure 5 – Vibrating dots prototype created by past BME design team
Image courtesy of BME 200 Fall 2008 Design Team

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.

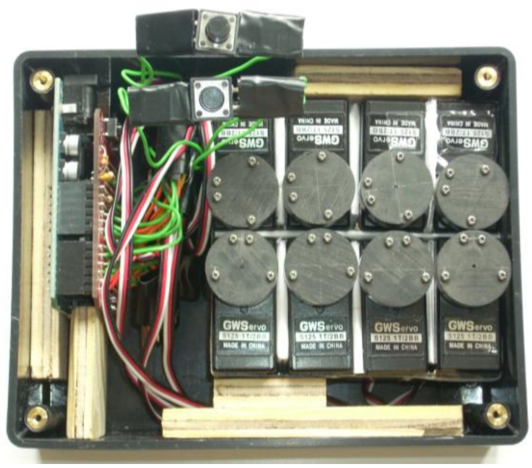

Figure 6- Internal view of rotating disk prototype
Image Courtesy of Spring 2010 Braille Watch Team

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). [5]

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.

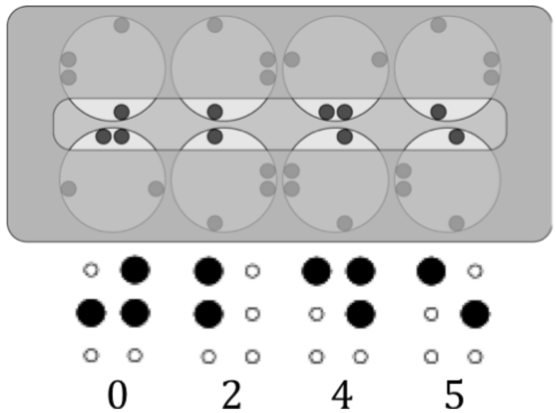

Figure 7 – By a rotation of 90º, 180º or 270º, the disks can display the correct time
Image Courtesy of Spring 2010 Braille Watch Team

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 semester: 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.

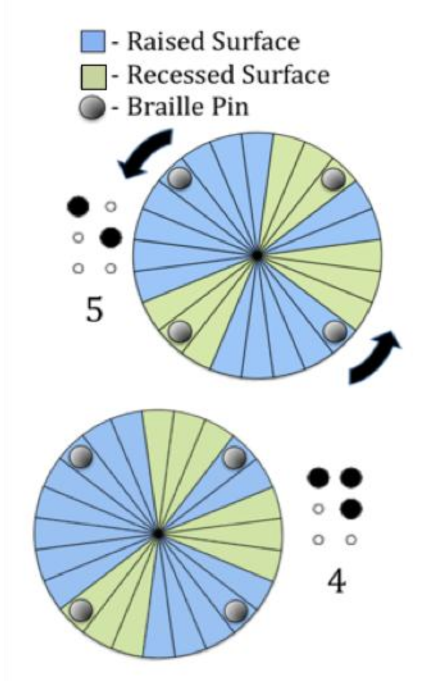

Figure 9– The raised and recessed surfaces on the disk cause different numbers to be displayed

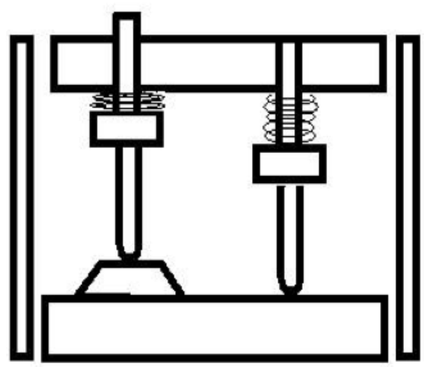

Figure 10: The raised surface on the disk pushes the Braille pin to the surface of the watch

A benefit to this design versus that of the Spring 2010 team is that 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

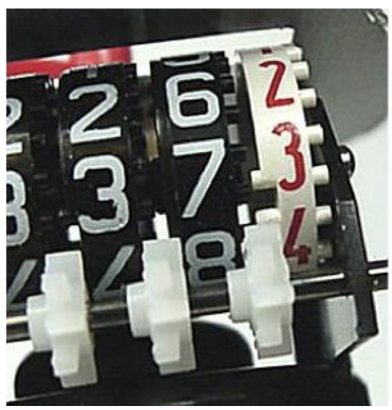

Figure 11 – The odometer gear system requires the rotation of one gear to control the display
Image courtesy of HowStuffWorks:
http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/odometer1.htm

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. [6] 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.

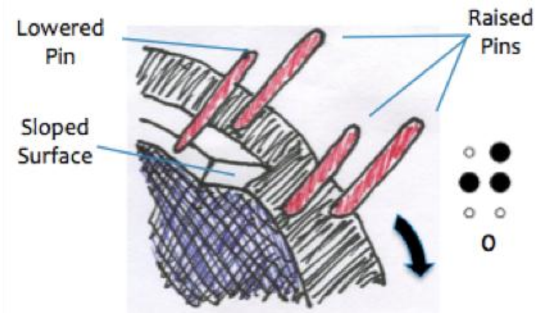

Figure 12: The raised and lowered surfaces along the circumference of the disks could be designed to raise and lower pins in the configuration of any Braille number

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.

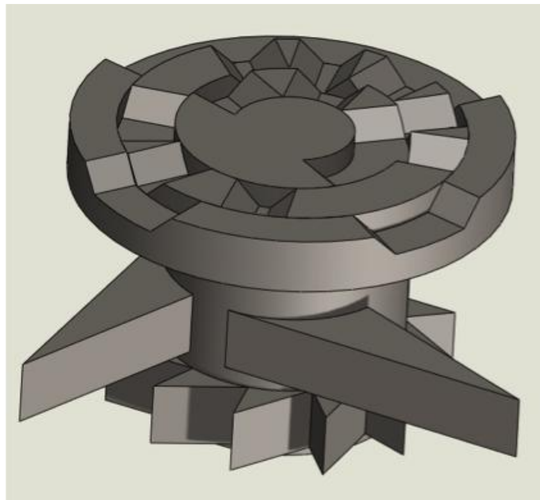

Figure 13: A disk with different combinations of raised and lowered segments can display a desired range of numbers

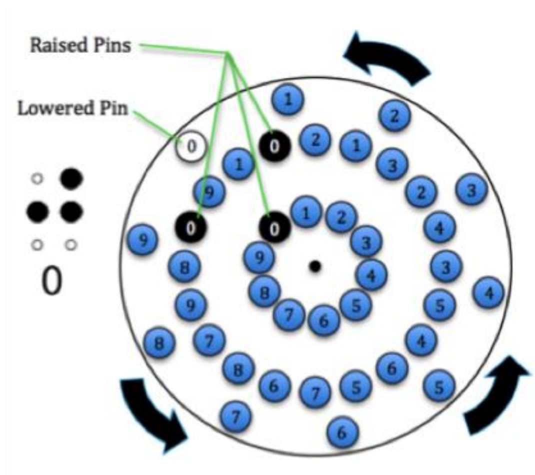

Figure 14: Number layout of a Gear and Pins disk, which can display the numbers 0-9 as it completes its rotation

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

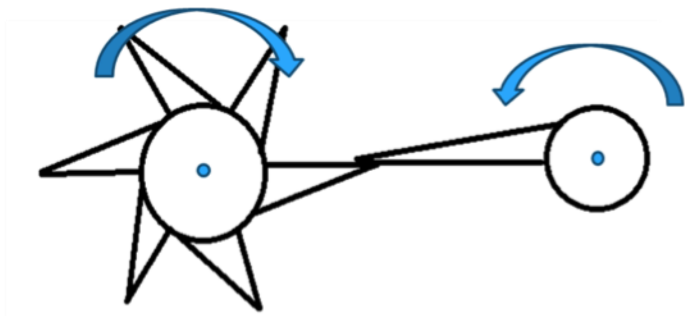

Figure 15: The full rotation of the gear on the right leads to a 60° partial rotation of the gear on the left, creating a gear system similar to that of the odometer

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.

Prototype

Disks

The four disks with raised and lowered surfaces (Figure 13) had to be designed and manufactured with extreme precision. With this in mind, we decided to use the Viper si2 SLA printer made available to us by the Wisconsin Institutes of Discovery. In order to gain access to this printer, a short proposal was written to describe what the printer would be used for (Appendix B). Each disk surface is unique (Figure 16), as each disk displays a different set of numbers. Disk one displays numbers 0-9, disk two numbers 0-5, disk three numbers 1-9 and 0-2, and disk four numbers 0-1. Disk four also contains an extra track for an included AM/PM pin. It is meant to signify PM when this pin is raised above the watch surface.

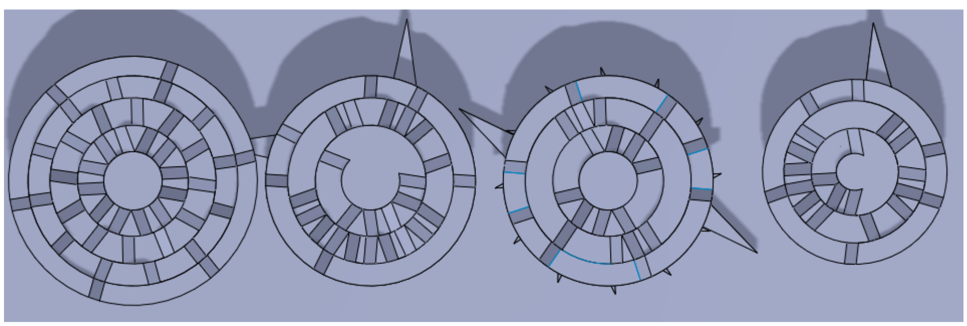

Figure 16-Disks 1-4 (from left to right) aligned on the base of the watch.

Gears

Incorporated into the bottom of each disk is a series of gears. The gears are uniquely designed for each individual disk (Figure 16+17). This gear system allows for the propagation of the first disks rotation down the line to all four disks. When disk one rotates 360 degrees, it catches gear number two, causing it to spin. When the second disk spins 180 degrees it catches disk number three, and after disk three spins 90 degrees, it catches the final disk. The calculations for this gear mechanism can be seen in Appendix C.

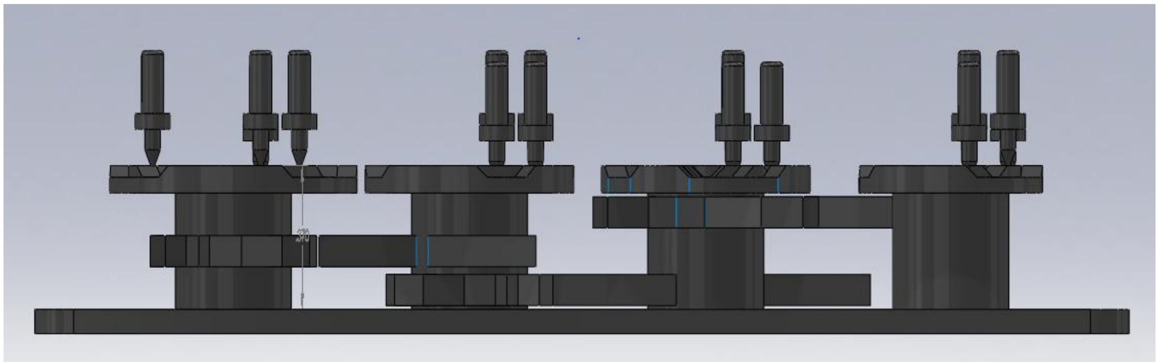

Figure 17-A side view of the disk interactions and the pins being raised or lowered.

Pins

The sixteen pins used were also manufactured using the Viper si2 SLA printer (Figure 18). In order for the pins to be held in place and to support a spring that will push against the underside of the top of the watch, the pins were designed with a circular platform. This platform provides a surface for the spring to rest on while also preventing the pin from falling out if the watch is overturned. The pins were designed with a rounded bottom in order to easily slide over the surface of the disk and the top also rounded to provide a user-friendly interface.

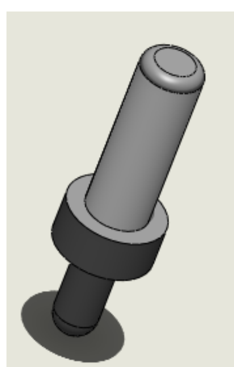

Figure 18-The CAD drawing of the pins used in our prototype.

Springs

In order to hold the pins inside the casing, springs were placed on the pins, keeping the pins from rising when in the recessed position. Springs that were 0.070 inches in diameter and .113 inches in length were selected. These springs had a spring constant, *k*, of 0.9 pounds per inch, meaning they exerted a force of 7.96 pounds on the top of the casing. This amount of force cased the middle of the casing to bulge slightly after final assembly. However, this had a minimal affect on the operation of the watch and caused no difficulty in reading the time.

Casing

The casing of our watch, which housed the disks with incorporated gears and the pins, was also made using the Viper si2 printer (Figure 19). It involves three separate pieces that are screwed together to form the final casing. The bottom portion contains four axles .28 inches in height for the gear disks to fit on. This allows the gear disks to be locked in place and yet still have freedom of rotation with minimal friction. The middle portion of the casing covers the gear disks and has four grids of two by two holes, as well as a hole for the AM/PM pin, for the bottom portion of the pins to fit in. The top of the case, which serves to contain the pins, has similar sets of holes, as well as the hole for the AM/PM pin, for the top portion of the pins. Overall, the casing measures 2.826 inches by 1.025 inches by .7 inches.

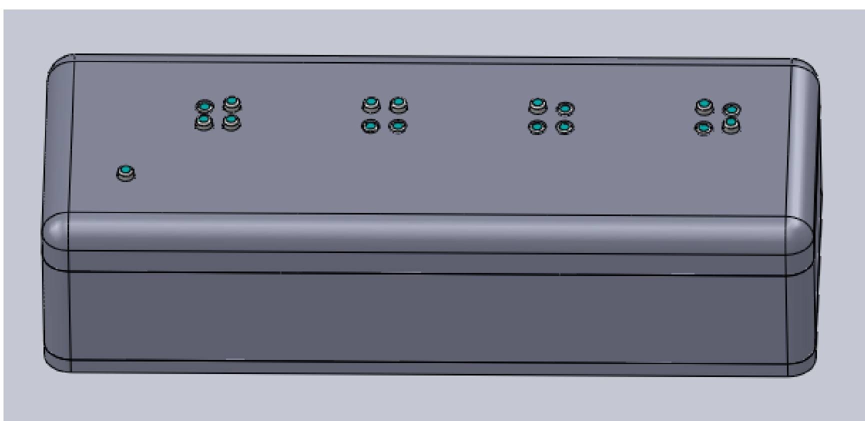

Figure 19-The completed casing.

Assembly

Aided by the casing design, the assembly of the prototype was straightforward. For presentation purposes the casing and first disk were modified slightly. An opening was cut into the casing to allow for the viewing of the mechanism and the pins raising and lowering. In addition, instead of resting on an axle, the first disk was modified to contain a cylindrical tube that extended out of the bottom of the casing. This addition allowed us to rotate the first disk by spinning the portion of the tube extruding out of the bottom of the casing and thus change the displayed time.

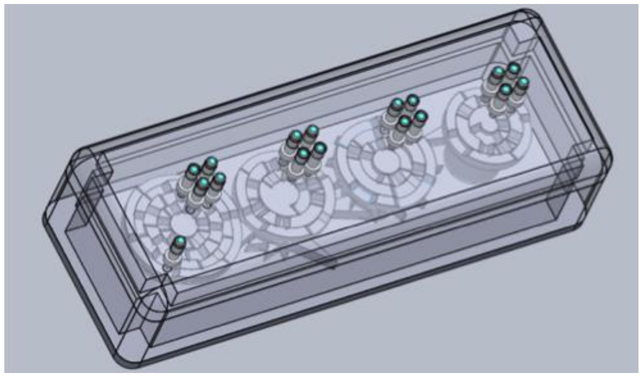

Figure 20- Final assembly of Digital Braille Watch

Despite the fact that the Viper si2 printer offered a resolution of 0.002 inches, there were still noticeable "steps" on the transitional surfaces of the disks, the surfaces between the raised and lowered portions. Because of these steps, the interaction between the base of the pins and the surface of the disks was not smooth enough to allow for easy rotation. In order to counteract this friction, white lithium grease was applied to the surfaces of each disk. This sufficiently lubricated the surfaces, making rotation of all four disks possible.

Further assembly involved placing the base of each pin into the middle casing, sliding on the springs, and placing the top third of the casing over the top. This assembly was then placed on top of the disk and bottom casing assembly and screwed into place. The final assembly can be seen in figure 20.

For the design competition, an executive summary was written to aid in the description of our final prototype (Appendix D). This summary will also be elaborated on to use during the patenting process.

Testing and Results

In order to gain feedback on the functionality, practicality and necessity of the Braille watch, six students, including Colton, and a teacher from the Wisconsin School for the Visually Handicapped were brought to campus to test the prototype. Initially, they were shown the prototype developed during the Fall 2010 semester. This device proved hard for them to read, as the display does not utilize standard Braille spacing. After they had critiqued the fall semester prototype, they were given the prototype developed this semester. Due to the standard Braille spacing, all of the testers were able to read the correct time after one swipe of their finger. Colton was extremely pleased with the prototype, saying, "This is exactly what I wanted."

When asked if any of them would be willing to buy a device with the functionality and size of the prototype, the answer was a unanimous yes. The students, who all used the talking watch desired a product that was not as disruptive in public; while the teacher, who used the analog watch, wanted a watch that was easier to use and read. Based on these results, it was concluded that the design sufficiently met Holly and Colton's needs and that if the prototype were to be developed into a fully functional watch, a significant market potential would exist.

Management and Planning

At the beginning of the semester, the Gantt chart found in Appendix E was created as a work and time management tool. It was roughly followed throughout the semester to ensure that the project was on track and deliverables were finished on time. All expenses were recorded throughout the semester as well. The project's total cost was $104.24, although the final prototype only cost $17.00 since all printing done on the Viper si2 rapid prototyping machine was free, and a motor was never integrated into the final prototype. The $17.00 cost is solely the expense of the 17 springs within the prototype. A detailed list of expenses can be found in Appendix F.

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. The current prototype is considered a success, but manufacturing the watch out of metal parts would lead to even a further reduction in size. These parts would allow for reduction in the thickness of the gears and the cost of production. Metal parts would also make the interaction of gears smoother and decrease the force needed to rotate them. Overlapping the gears will decrease the lateral size of the watch and assist in achieving standard Braille spacing as well. A rotating motor needs to be integrated into the device as well. For this design, a motor similar to that found within an analog watch would provide the desired functionality needed to control the entire watch. Finally, the team will apply for a patent through the Wisconsin Alumni Research Foundation for the disk and gear concept used within the design. In addition to patenting the device, the team will try to find an interested company who would be willing to market the product.

Conclusion

A fully functional Digital Braille Watch was successfully created using a rotating disk and gear design. The final prototype met all of the major design specifications, with the exception of having a self-contained power supply. However, the type of motor needed is similar to that contained within any analog watch. Based on the results of the testing, it was determined that the watch would be well received by the visually impaired public. After patenting the product through the Wisconsin Alumni Research Foundation, the team will search for a company that would be willing to make the necessary improvements to the watch to make it marketable. These include manufacturing the prototype out of aluminum or a similar metal and developing a custom rotating mechanism. This would allow the size of the watch to be further minimized and yield a product with substantial market potential. This innovative prototype demonstrates that it is possible to create a Digital Braille Watch that is silent, is easy to read and improves the daily life of the visually impaired.

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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

Appendix B: Printer Proposal

Team #21 Digital Braille Watch

Wisconsin Institutes of Discovery Printer Paper

For our design we are printing four gear-disks, sixteen pins, and a case to house the mechanisms. These will be assembled along with springs and a rotating motor to make a Digital Braille Watch. This motor will drive one of the interconnected gear-disks at a constant rate, propagating movement of the rest of the gear-disks. The top of each gear-disk will have raised and lowered surfaces specific to each disk. Above each disk, four pins are arranged in a square and set in a particular location on the raised or lowered surface. As the gear-disk turns, the pins are subsequently raised or lowered depending upon the orientation of the gear-disk. All of this will be contained inside the compartmentalized casing.

In order for our design to function accurately, we need an extremely high degree of precision in machining our parts. This printer allows us to achieve this necessary degree of precision while at the same time minimizing our production cost. Having this printer available to us is what made our design possible. Without it, the gear-disks that we printed would not have been possible to manufacture with the degree of accuracy the mechanism requires.

Appendix C: Calculations

The calculations that were done to determine the radius of the disks:

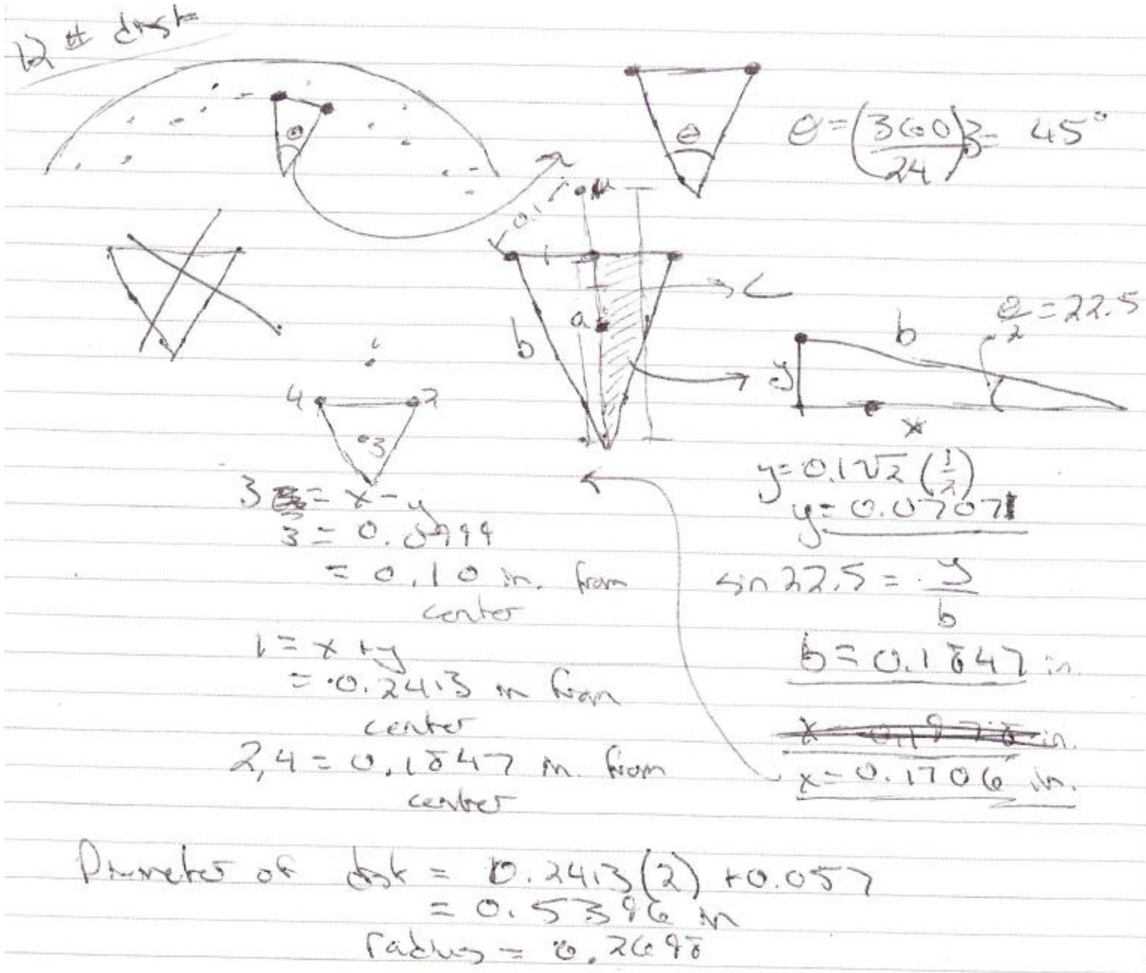


Table of the final disk dimensions:

Summary of Disk Dimensions (all in inches)

Disk	a	b	c	[illegible]	Diameter
#1	0.068	0.156	0.209	0.237	0.474
#2	0.100	0.184	0.241	0.2698	0.5396
#3	0.100	0.184	0.241	0.2698	0.5396
#4	0.100	0.184	0.241	~~0.2698~~ 0.320	~~0.5396~~ 0.640

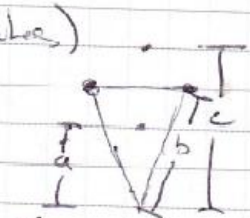


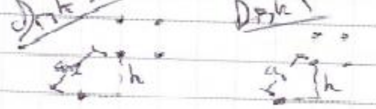
Figure 1

Table 1: Disk measurements. A, B, C correspond to Figure 1.

Location of the centers of each disk:

- centers for Disks 1, 2, 3, and 4 will all be at the same height since a, b, c are all the same for disks 2-4. Disk 1 will be moved to accommodated for its measurements being slightly different.

Disk 2 Disk 1

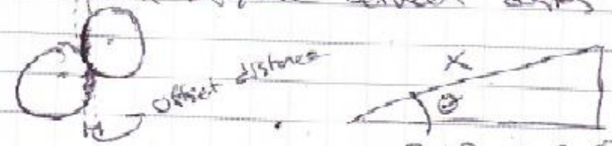


$a_1 < a_2$ $\quad \frac{a_2}{\sqrt{2}} = h_2 \quad \frac{a_1}{\sqrt{2}} = h_1$

$\left(\frac{a_2}{\sqrt{2}} - \frac{a_1}{\sqrt{2}}\right)$ = height difference between centers

$= 0.023$ inches offset

Horizontal Distance between disks 1 and 2



$a^2 + b^2 = x^2$

$x = 0.5073$

$r_1 + r_2 = 0.5068$

Offset distance $= 0.5073 - 0.5068$

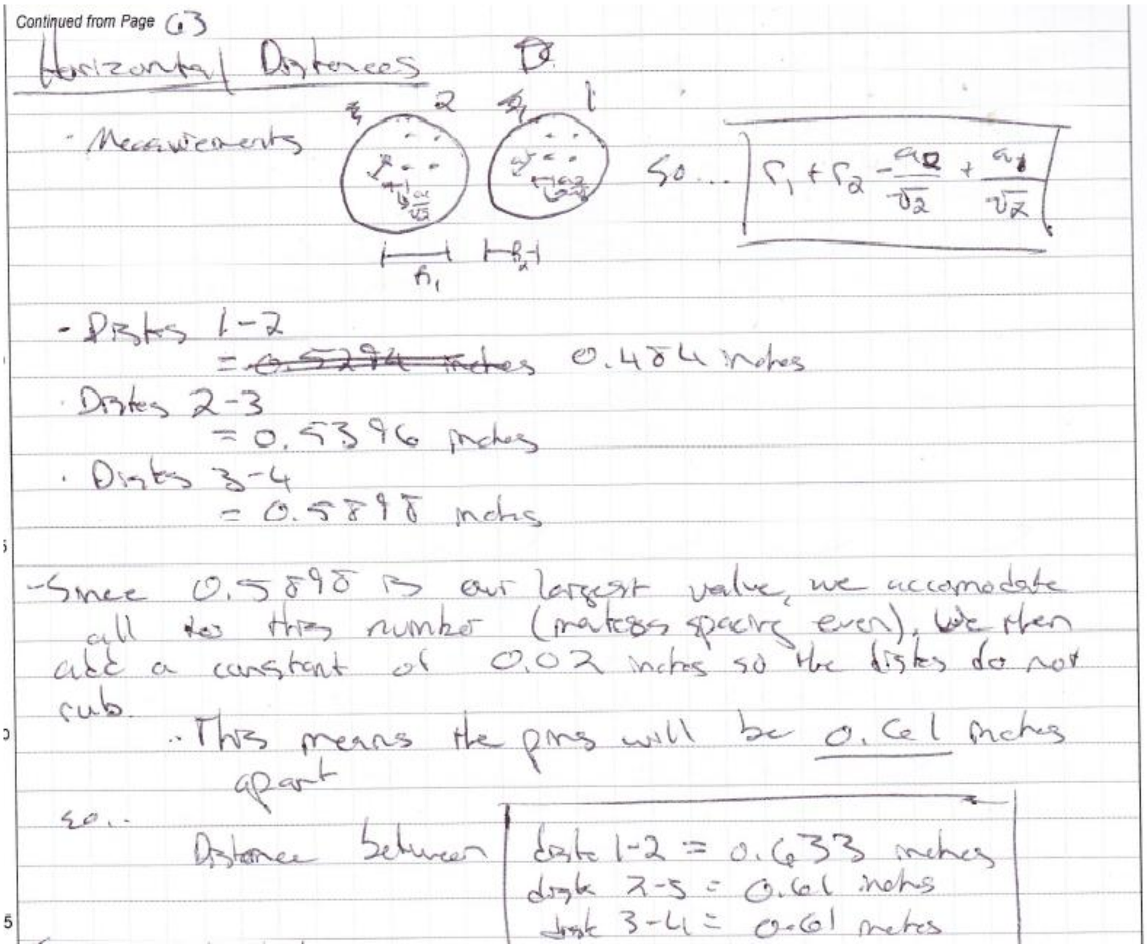
$= 5.21 \times 10^{-4} = .000521$ (negligible)

$\theta = 2.598$

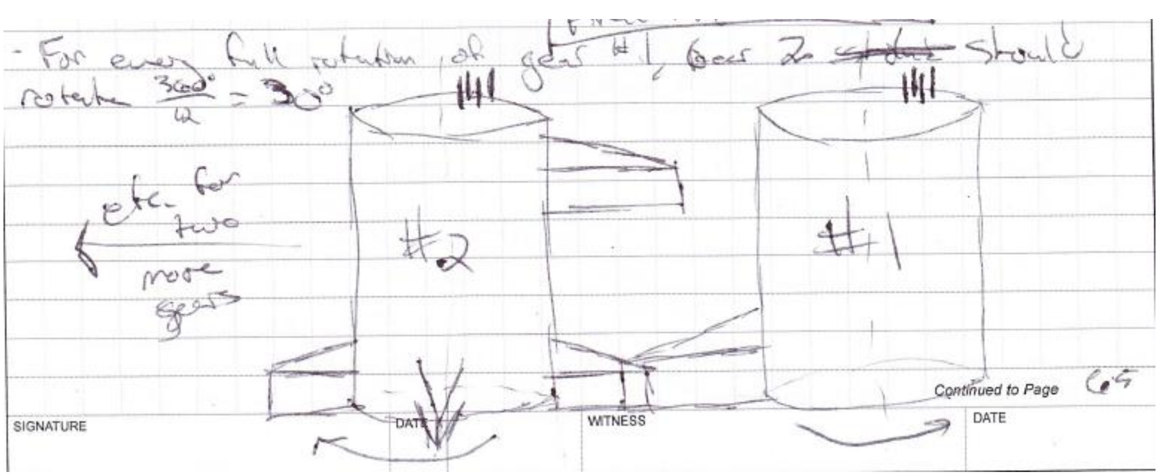
SIGNATURE DATE WITNESS DATE

Continued to Page Co 4

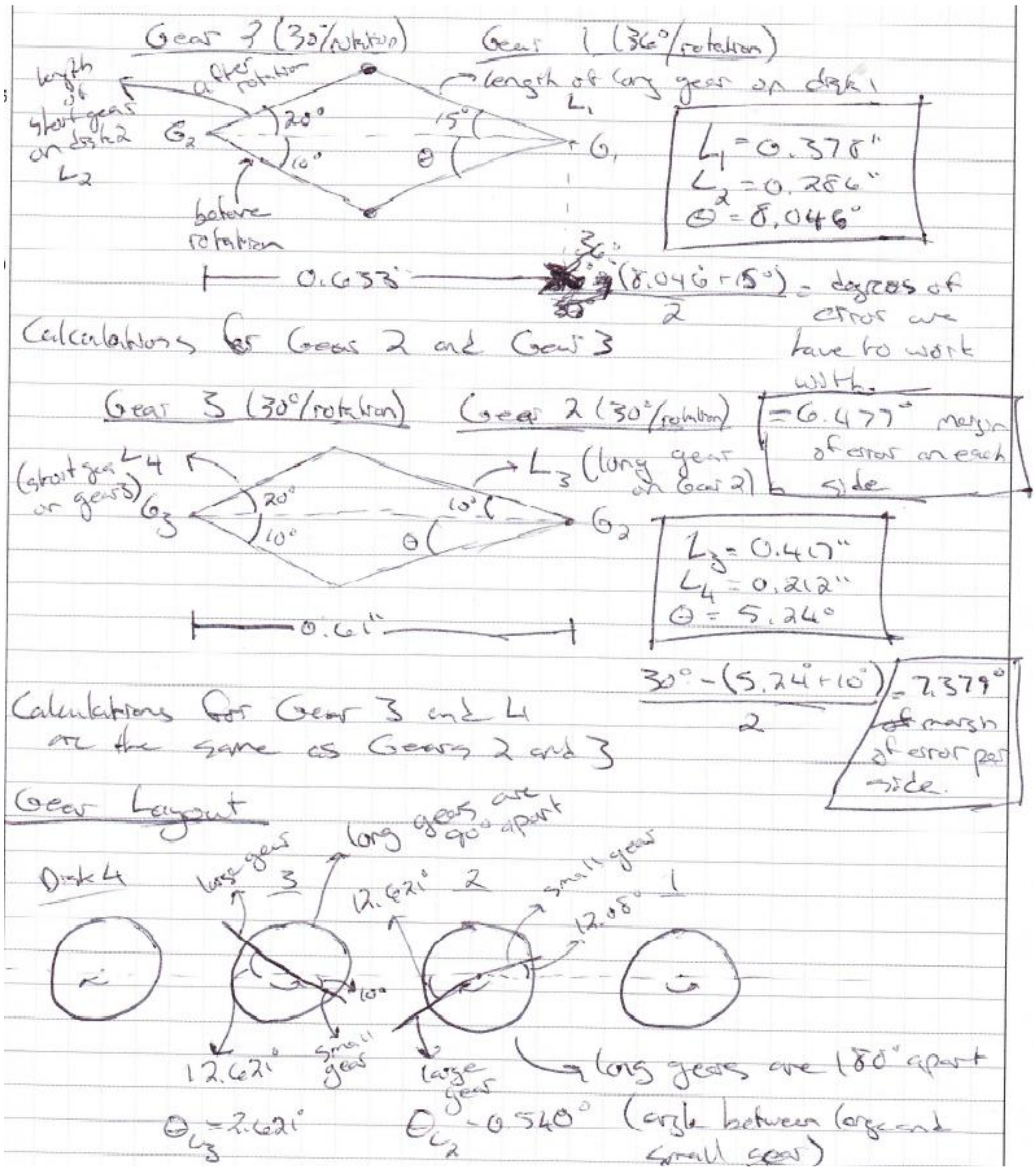
Calculations for the disk spacing:



Gear interactions for disks displaying the minutes:



Gear Calculations:



Appendix D: Executive Summary

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

Approximately 10% of visually impaired individuals in the United States (41 million) know Braille, while 40 million can read Braille worldwide. In order to determine the time, the visually impaired currently depend on talking or tactile analog watches. However, talking watches are disruptive, while tactile analog watches are difficult to read and fragile. Holly and Colton desire a watch that uses the Braille number system with standard spacing. The developed prototype is superior to the existing technology in the market due to its ease of use, utilization of standard Braille numbers and its ergonomic design. The technology has great potential and can be utilized to improve the daily life of the visually impaired.

Minimizing size while still maintaining a high degree of precision was the foremost difficulty faced in designing the watch. In order to display the time using standard Braille spacing, the watch parts had to be accurate within several thousandths of an inch. Fortunately, this precision was made possible by the availability of the Viper printer, which provided an accuracy of 0.002 inches, making the completion of a successful prototype possible. Although the prototype is not a permanent solution, it has the potential to be scaled down to standard analog watch size if assembled using a custom rotating mechanism, while experiencing an increase in durability if constructed from metal.

The prototype includes four gear-disks, sixteen spring-controlled pins and multi-component casing, which contains the various components. The top surface of each gear-disk has raised and lowered surfaces specific to each disk. Four pins reside above each disk in a particular location and move vertically to display a certain Braille combination dependent on the raised and lowered surface combination beneath the pins. Due to the designed gear system, providing a constant rotation to the first gear-disk provides control for the entire watch. This technology is different than any other present in the market today and can be patented.

Having a functioning prototype from last semester that used a similar mechanism has validated our preliminary design. Furthermore, conducting a survey of Colton's visually impaired classmates resulted in positive feedback. Enhancing the previous mechanism allowed for the implementation of standard Braille spacing and a reduced cost and size, while making the current prototype ergonomically improved. Overall, the design has met all of the client's requirements and offers a technology that can significantly improve the daily life of the visually impaired.

Appendix E: Gantt Chart

Team 21: Digital Braille Watch

Task	January		February				March				April				
	21	28	4	11	18	25	4	11	18	25	1	8	15	22	29
Project Research and Development															
Researching	X	X	X	X	X										
Brainstorming		X	X	X	X										
Design Matrix/Cost Estimation					X	X									
Design Selection					X	X	X								
Ordering Materials								X	X	X	X				
Prototyping					X			X	X	X	X	X	X	X	
Testing												X	X	X	
Final Prototype															
Deliverables															
Progress Reports		X	X	X	X	X	X		X	X	X	X	X	X	
PDS		X													
Mid-semester Presentation						X	X								
Mid-semester paper						X	X	X							
Final Presentation														X	
Final Paper															
Meetings															
Client		X													
Advisor	X	X	X	X	X	X	X	X		X	X	X	X	X	

Appendix F: Budget

Date	Item	Per Unit Cost	Extended Cost
3/11/11	Mini Compression Springs (x25)	$1.00	$25.00
3/11/11	Continuous Sweep Mini Quartz Movement	$5.99	$5.99
4/1/11	Mini Stepper Motor Board	$9.90	$9.90
4/1/11	5V FTDI Basic Breakout	$14.95	$14.95
4/1/11	5V Arduino Pro	$19.95	$19.95
4/1/11	5V DC to DC Step Up – 1 x AA	$10.95	$10.95
4/1/11	5V DC to DC Step Up – 2 x AA	$10.95	$10.95
4/1/11	AA Battery (x8)	$0.50	$4.00
4/1/11	Momentary Push Button Switch (x3)	$0.50	$1.50
4/1/11	Mini Push Button Switch (x3)	$0.35	$1.05
		TOTAL	$104.24