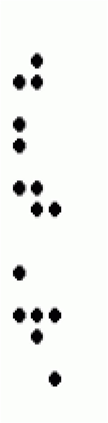

Digital Braille Watch

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Client: Holly and Colton Albrecht

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Abstract

There are various ways for visually impaired people to tell time. They include asking another person, using an analog Braille watch, or 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 was to design a digital Braille watch that does not disturb others and will be easy for the user to read accurately. Three designs were conceptualized and evaluated: electrocutaneous display, vibrotactile display, and mechanical wheel. The vibrotactile method was pursued for prototyping and development. The current prototype utilizes Delphi 5 programming to adapt the digital time as seen on the computer to a scrolling Braille output on the vibrotactile display. Future work for the project includes optimizing the packaging of the device, incorporating a switch to activate the time sequence, and determining a suitable power source for the display.

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 audibly announce 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 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 (Humanware). The client suggested incorporating this technology into the final design. 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 it would be easy for him to use. Figure 3 shows the ten digits that would need to be used on the watch display.

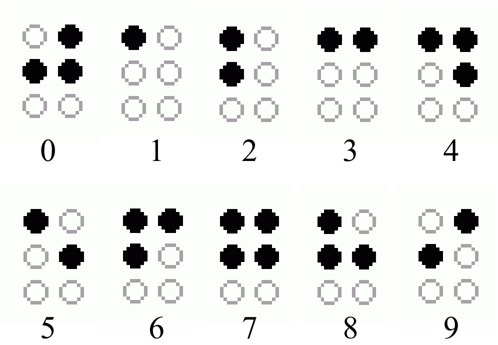


Figure 3: The Braille representation of numbers.

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 24-hour time – eliminate the need to distinguish between A.M. and 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.

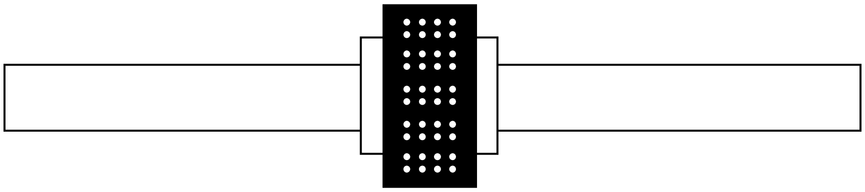


Figure 4: Depiction of client’s idea of a digital Braille watch.

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 24-hour 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 24-hour time, so mechanism indicating “A.M.” or “P.M.” is 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 user.

Design Proposals

During the first half of the semester, we came up with three alternative designs that could be implemented: an electrocutaneous display, vibrotactile display, and mechanical wheel. The following will summarize the three proposed designs for the digital Braille watch.

Electrocutaneous Display

One option for displaying 24-hour 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.

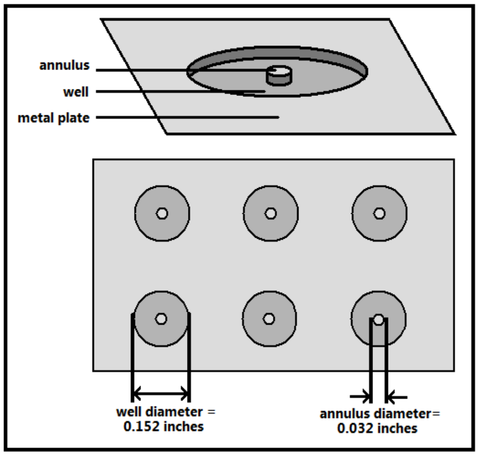


Figure 5: Electrocutaneous electrode, electrocutaneous electrode array, and dimensions as measured in Dr. Tyler's laboratory.

An electrotactile electrode consists of several basic components. An electrode array model in a UW Madison 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 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 (Tyler, 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.

Power supply is necessary 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 display can be placed anywhere on the body, and this versatility 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.

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.

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 6). The clock itself consists of four bands, with each

Figure 6: Standard flip clock
http://jacklambert.files.wordpress.com/2006/06/flipclock.jpg

band containing the numbers required to display the time. For example, in the 24-hour time 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.

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.

Designing the rest of the circuit would involve replacing the digits by Braille cells, as shown in Figure 7. 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.

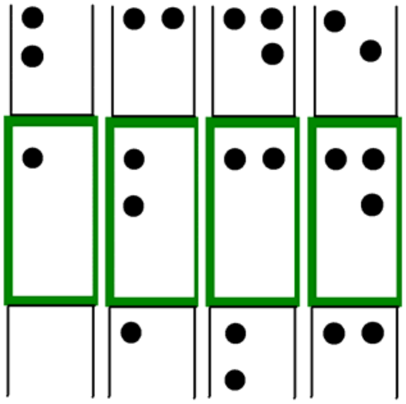


Figure 7: Depiction of the mechanical wheel display.

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 from 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

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 8, 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.

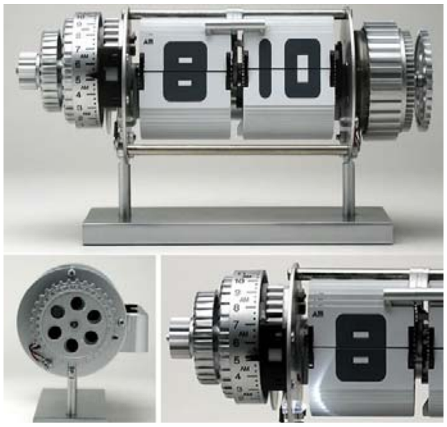


Figure 8: Gear mechanism, standard flip clock
http://technabob.com/

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.

Vibrotactile Display

A more traditional approach to displaying Braille involves dynamic mechanical components. One such design, in which pins are lowered and raised to activate the dots in a Braille cell, 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.

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 9. 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

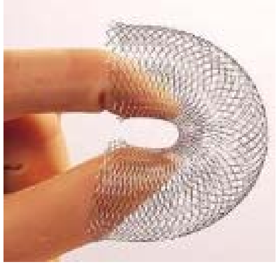


Figure 9: Smart metal alloy, shown as a deformable stent. It has many other applications in medical technology for its flexibility and “memory” abilities.
http://www-civil.eng.ox.ac.uk/people/zy/research/stent.jpg

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 10, 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 10: 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

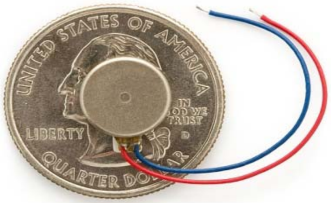


Figure 11: A shaftless vibro-motor cell, capable of moderate vibration while drawing a small amount of power.
http://www.sparkfun.com/commerce/product_info.php?products_id=8449

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 11. 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. 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.

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 nonetheless 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.

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.

Current Prototype

Programming Circuit

Initially, a microcontroller to simulate the clock circuit was considered. However, microcontroller kits, which cost about $130, are too expensive under the client’s budget requirements. Instead, the team decided to implement LabVIEW, a graphical user interface that allows a person to design mini-programs that execute specified functions. However, the interface in LabVIEW was excessively complicated (since none of the team members have any experience with it), and thus, the team decided to use Delphi 5 (Borland), an object-oriented program, to accomplish the task of simulating a clock circuit.

In creating a program that represents 24-hour time on the vibrotactile display, the following conversions were performed:

1) given time string to integer numbers
2) standard time into twenty-four hour time
3) individual digits into Braille display

The program designed uses the basic time counter provided in Delphi to keep track of the time, which is stored in a variable. After separating the tens hours and the ones hours (as well as the minutes) using the div and mod functions, the program takes the output and scrolls through the list of digits (0-9) and matches the numeral version of the time to the Braille version of the time. This output is converted to a voltage on the personal measurement device (PMD), which is shown in Figure 12. The PMD used is analogous to a breadboard; the ports provided are capable of supplying analog, digital and variable supply outputs and are also capable of taking digital inputs.

Figure 12
Personal Measurement Device
http://images.google.com/imgres?imgurl=http://directory.adeptscience.co.uk/

There are five relevant ports on the PMD. One is ground, and the others activate one Braille display dot each out of the four dots used on the display. The corresponding output ports on the PMD used are 25-28. The program also incorporates a series of 'tester' buttons that allow the user to check whether each Braille number is functional. The PMD, in response to a binary output, is interfaced with a circuit that activates the motors (as well as the LED lights, which are collected in parallel with the motors, for display purposes). When activated by the program, each output port provides a voltage of 2.8 V. However, as discussed in the testing section, this voltage is towards the high end of the vibrotactile motor tolerance; 13 Ω resistors are added to the circuit in a voltage divider to prevent overloading on the motors (please refer to Figure 13).

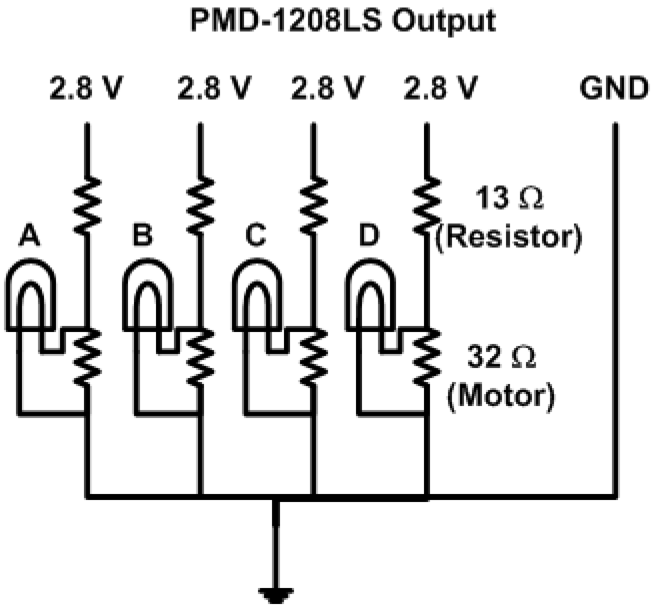
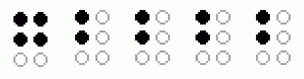


Figure 13: Circuitry components of prototype. The LEDs show visually which motors are activated.

During testing, times such as 22:22 were difficult to read because the signals for the four two's did not change throughout. Therefore, the program also incorporates a one-second time delay between each digit, and to signal the beginning of a display cycle, all four motors vibrate simultaneously. Thus, the time 22:22 would be displayed as follows:



The use of the Delphi 5 has the ability to change the steps in the process and allows easy implementation of the program. However, the programming approach is not realistic, because it is not an ideal representation of the pocket watch as desired. Implementing a microcontroller is also not recommended for the final design for this reason. An integrated clock chip is preferable, because it will be small and difficult to tamper with.

Vibrotactile Display

The heart of the vibrotactile display is four shaftless vibration motors supplied by Sparkfun Electronics. The motors are arranged in a 2 x 2 grid, such that each motor represents one of the four dots that make up a Braille number. The motors require 2V and draw 100 mA combined when all four are running, which is small enough to be powered by a Lithium battery. They are roughly aligned in parallel to each other, not considering logic gates, as well as to the LED's during testing.

During initial testing of the motors, 0.7 V was the threshold for feeling any vibration. However, 1V was the minimum voltage for which two-point discrimination could be achieved with the motors set at a distance of 12 mm from the center of one to another. To ensure that the user would strongly feel the motors and distinguish between them, we chose to use 2V.

While digital clocks have four digits – two for the hour and two for the minutes – the vibrotactile display contains enough dots to comprise one digit. The purpose of having one digit is to conserve space, as having enough motors for four digits would take up too much space for ergonomic feasibility as a watch. Thus, the display will begin a cycle to scroll through each digit, when prompted by the user. For example, if the user requests the time at 8:23 a.m., the display will show, in sequence, an "all on" indicator flash, followed by a zero, pause, eight, pause, two, pause, and a three. With the exception of when the display is prompted to display the time, it is off and not using power. This makes it more efficient than an alternative that must constantly maintain the current time or have other mechanical parts.

Budget

Table 2: Summary of costs for the project.

Item	Cost
shaftless vibromotor cells - Sparkfun Electronics	$49.00
roll of electrical tape	$3.50
100 ft of 22-gage wire	$4.00
push button on-off switches	$3.50
rubber sealant/adhesive	$4.50
battery holder	$0.99
Total	$65.49

The above table shows the costs made this semester to build the prototype.

Conclusion

At the conclusion of this semester's work, the client was able to test out and review the prototype work thus far and provide critical feedback as to what aspects work well or should be revised. For the vibrotactile display, our client was comfortable with the concept of vibrating pins rather than mechanically raised and lowered dots. His suggestion would be to spread the dots out more, so that there would be less chance of vibration translating from one dot to the other. He also expressed that reading all four with one finger simultaneously is not necessary, so long as each number is displayed long enough for the user to touch all dots and interpret the digit displayed. For the current programming, the pausing between digits was good for the user to know when the next digit is coming. Adding in the potential for additional information, such as date, seconds, etc, is still desired. These additional features will be considered in future semesters of work as the programming is adapted to laptop independent clock chip circuitry.

Ethical Considerations

In designing and beginning to prototype the digital Braille watch, quality was heavily weighted in all decisions. As there are other time-telling products on the market for the visually impaired, a new product must meet and surpass the standards set by its predecessors to be beneficial for the user. While the analog Braille watch displays the time, is not always easy to read accurately. If the hands are close together, the user easily misinterprets the time. This type of complication is avoided with 24-hour time, because each digit can be read individually with a pause between each digit. Digital time is less ambiguous than analog time, making it a more reliable product. As prototyping continues, using quality materials and thoughtful construction techniques, this product will function correctly and reliably for the user.

Safety was also an important consideration during the design process. Both the user and environment in which the digital Braille watch would be used in should not face any safety risks associated with use of the product. More specifically, all electrical components must be weatherproofed to prevent shock, and the display must not have sharp corners or edges that could harm the user or damage other objects or people about them. The four vibration motors have raised bumps that allow the user to differentiate between Braille dots, and these should not be made too sharp as to cause pain when touched or to catch on clothing or other objects in the user’s environment. Many of these issues can be resolved with a flip cover to protect the display from damage and climate conditions, as well as protect the user and environment from potential electrical or physical harm. As work continues toward a final product, safety will continue to be a forefront concern.

A final consideration of this project was to work toward a product that is accessible by many individuals with vision impairments. Other Braille display products can cost upwards of several thousand dollars, putting them out of an acceptable price range for some individuals who would otherwise benefit from them. Creating another expensive device will not benefit as many people as a simpler and more inexpensive product. Pursuing vibration displays instead of mechanical pin-raising models cuts material costs down to less than a hundred dollars per watch. By keeping costs low, this product will be more affordable, and its benefits will be more widespread.

Future Work

The finished product will be packaged as a pocket watch capable of displaying the current time in Braille. To achieve this, several aspects of this project will require modifications in two places. First, a working model that meets the fundamental needs of displaying time in Braille must be completed. Second, more work can be done to add other features to enhance the functionality of the device. This technology is potential patent material and should be handled appropriately.

For the programming and controls, the Delphi program must be adapted into an independent circuit that outputs the time to the display when cued by the user. There are clock chips and other counters available to serve as a time-base. For this device, the output must be formatted to the vibration motor array so it can be read as Braille. Cuing the watch to display the time could be done simply as pushing a button or potentially by incorporating it into a flip cover. Opening the cover could trigger a sequence to begin displaying the time after several seconds. It would also serve as physical protection for the display.

The display must be modified to optimize vibration sensation isolation and improve reading accuracy. This may require a change in vibration intensity, incorporating different vibration insulating material, or redesigning the bumps on each of the vibration motors. According to our client, rearranging the dots to create a larger display would improve reader accuracy by minimizing unintentional vibration of one dot by another. Once accomplished and tested to ensure the changes made the improvements desired by our client, the display and circuitry must be packaged as a single unit with an independent power supply. This final product will be pocket sized so the user can carry it with them without disrupting their daily activities.

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Project Design Specification

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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 24-hour 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 24-hour 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.