Design of Hardware For the Operation Of a Braille Teaching Device

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Electrical and Biomedical Engineering Project Report (4BI6)
McMaster University
Hamilton, Ontario Canada

Electrical and Biomedical 4BI6 Capstone Project Report

Design of Hardware For the Operation Of a Braille Teaching Device

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Electrical and Biomedical Engineering Project Report
Submitted in partial fulfillment of the requirements
For the degree of Bachelor of Engineering

McMaster University
Hamilton, Ontario, Canada
January 5, 2010

ABSTRACT

The study was to explore current technology for the application of an electronic Braille display. The display was implemented in the hardware component of a PC assisted Braille learning device. The output was able to represent each letter of the Braille alphabet by mechanically raising and lowering pins to create the tactile dots of Braille. The technology researched and tested for used were shape memory alloys, DC motors and electromechanical relays. Each of which had pros and cons, that had to be examined for the case. The interface pins were controlled by an Aurdino based microcontroller in combination with digital logic. The design worked in series with teaching program and voice recognition. As a teaching tool, basic input functions had to be incorporated such as next and previous to interact with the other components of the Braille learning device.

Keyword: Braille, Flexinol, Relay, Braille Display, Digital, Educational

ACKNOWLEDGEMENTS

Dr Doyle - For His supervision and mentorship in creating the Braille Display

The group members

Jon Hernandez –For creating the software to the Braille display

Brett Lindsay - For creating the speech recognition system

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1 INTRODUCTION

1.1 *Background*

The overall design project is the collaboration of Jon Hernandez, Brett Lindsay and I. The project is to create a personal computer assisted Braille learning device. The problem that we intend to address the growing illiteracy of Braille, in the USA alone it's expected that one out of ten children dependent on Braille will be literate [1]. This can be attributed to the inaccessibility of Braille reading material as well as the lack of Braille education. The device is intended to work with supervised students, and reduce the dependence on Braille educators as sole resources. Part of the focus of the hardware design is to understand and research alternative methods to create a refreshable Braille display and interface.

Piezoelectrics are the predominate technology in the application of refreshable Braille Displays. The piezoelectric is a well known voltage sensitive material, when the lattice of the crystal is deformed a voltage difference is generate. This process also works in reverse, as such when voltage difference is created across the lattice the crystal deforms and reduced in volume. The mechanical result of the piezoelectric is adapted to create a force that raises and lowers a Braille character points. The piezoelectric sits beneath a lever and a voltage is used to raise the dot, others utilize piezoelectric crystals to create linear motors [2].

Designs of Braille actuators range from heating coils with temperature sensitive plastics [3], to using an array of organic perfluorinated polymer transistors with ionic thin-film actuators [4]. These technologies and approaches are mostly within the research domain of the market and have yet to make major contributions to consumer lives and a change in Braille education.

A major issue behind the piezoelectric display is the cost. The piezoelectric material has to be larger enough to raise and lower the points; this creates a larger cost to the device, as the crystals are expensive. What's more is that the deformation that the material goes under has a residual effect on the geometry of the lattice. This change introduces a life cycle to the product, limiting the amount of time the device can be used before replacement is necessary. With replacement come additional costs that make the device more financial inaccessible.

The technologies reviewed for this project were shape memory alloy (SMA), DC motors and electromagnetic devices. For the majority of project was focused on using electronic materials that change shape or volume when expose to a voltage, to achieve the raising of Braille dots. SMAs materials vary from element to element, the most well known is Ni-Ti (Nitinol). SMAs have the ability to compress when exposed to a voltage, this means that at room temperature it can undergo a great deal of deformation, but under the right voltage conditions it will return to its original shape. This return has a certain amount of time delay dependent of the voltage and the material parameters. Like any material it has cyclic load conditions [5] , however for the conditions and the intended loading force (see Table 1) risk of material failure and limited life cycle is nominal.

DC motors vary in size, input voltage and power characteristics. Due to their design and limited constraints here is a lot of room to work with DC motors in the application of a refreshable Braille display. Under the most basic principles of the actuation there would have to two states and two motions, one forward and one reverse to create an raised and lowered point.

The final technology was electromagnetic devices such as solenoids and relays. These devices take a current and under the principals of electromagnetism, create mechanical force through the changing pole of the magnet.

Braille is relatively simple to explain but very difficult to read, without practice. Each character in the standard English alphabet can be represented by a 2 by 3 array of points. The binary state of the points and the combination of them create 2^6 unique character possibilities, however 26 are used to represent the alphabet, and others for punctuation and numbers (see Figure 1).

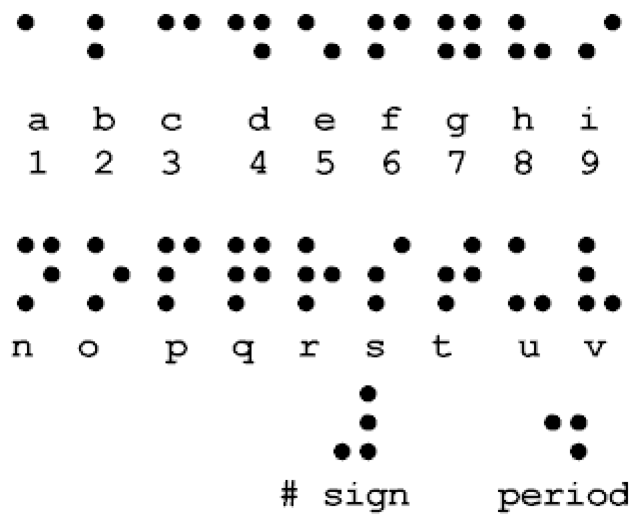


Figure 1- Diagram of Braille Alphabet,

Not pictured are the Braille symbols for numbers, once the # is placed in the sequence the former letters of A,B,C,D,E,F,G,H,I and J become the numerals 1,2,3,4,5,6,7,8,9 and 0 respectively.

The size of the dot and the force, at which the user presses, is another design condition and while there are many preferences we will have to choose one size and design around a limited user force. Fortunately, it is not the case where a design for children would require a smaller force than that for an adult (see Table 1), so there is little concern for age constraining the hardware design.

Table 1 – Force response of Braille characters [6]

Age	Sex	Touch Force	Dot r=.75mm	Dot r=1.2mm	Dot r=1.5mm
10	M	0.03 N	Preferred		
12	M	0.24 N	Preferred		
15	F	0.14 N			preferred
16	F	0.09 N	Preferred		
16	M	0.08 N	Preferred		
16	F	0.39 N		preferred	
17	F	0.05 N		preferred	
20	F	0.37 N	Preferred		
30	M	0.17 N	Preferred		
32	F	0.22 N	Preferred		
33	F	0.20 N		preferred	
36	M	0.08	Preferred		

1.2 *Objective*

The general objective of the project was to create a Braille education system. Most of the development was focused on the SMA and actuator design, as well as the support logic design for the system.

The self imposed constraint was that the device is required to only display 4 characters at a time, is refreshable and has a USB interface. As a teaching tool, basic input functions had to be incorporated such as next and previous to interact with the other component of the Braille learning device

1.3 *Methodology*

The digital logic behind the system was the first development of the project. The created logic design was based on the principal of being flexible enough to use any of the different actuators and to be able to control the 4 Braille characters arrays through the 24 pins (see Figure 2). The best approach to control was to use d latches in combination with a 2-4 decoder to load and hold voltages at the pins. This would allow for the data lines of each array to be in parallel while controlling the load enable of each latch separately by the 2-4 decoder, drastically cutting down on the number of I/O pins. The 4 buttons would have a direct connection to the I/O pins of the microcontroller.

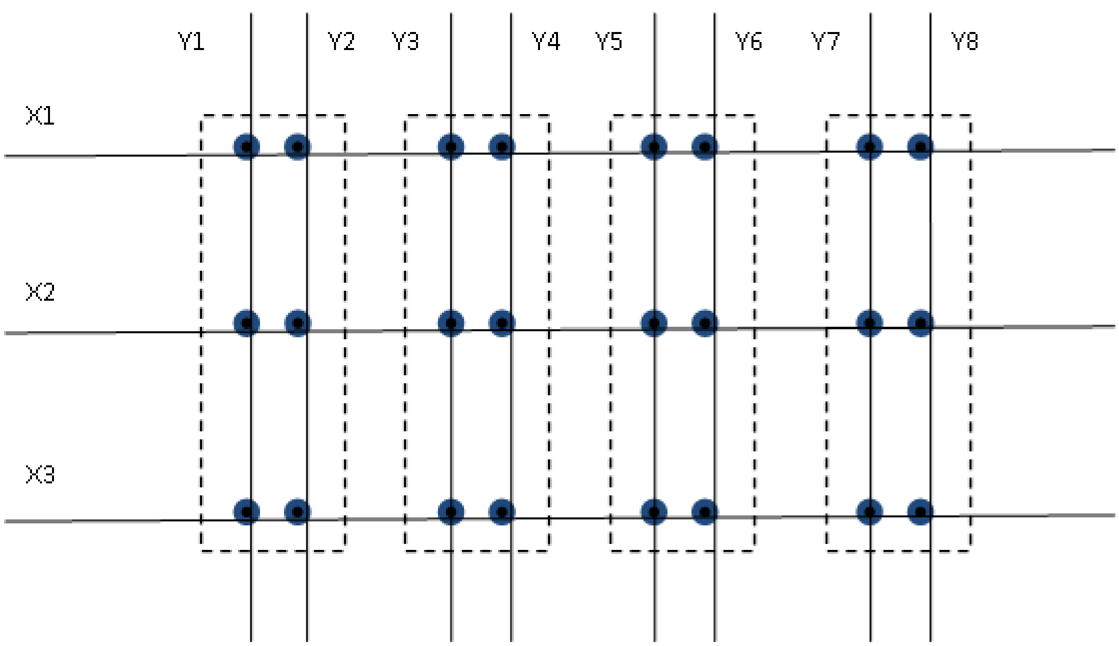


Figure 2 – Braille Pins

Basic outline of the pin geometry, in this figure all 24 pins and groupings can be seen. Character 1 is composed of lines X1-X3 and Y1-Y2, character 2 are lines X1-X3 and Y3-Y4, character 3 are line X1-X3 Y5-Y6 and character 4 are line X1-X3 and Y7-Y8. Each character contains 6 pins to represent each Braille letter.

The first tested actuator was the SMA Flexinol; SMAs are wires that contract in length and expand in radius when exposed to heat. Flexinol has the property of contracting when a current is run though the wire, the radius of the wire indicates the amount of current. A SMA radius of .0015" was chosen for its low current profile. The direction of the contraction force required the actuator design to utilize the same direction of motion to create raised or lowered pin.

The second tested design was the application of DC motors. This application had the benefit of speed and efficiency, as well the fact that the SMA actuator design could easily be adapted into working with DC motors. The draws back were the added complexity of control and trajectory of the pins, with a DC motor the motion had to be able to raise and lower the pins. The other drawback was the possible use of gears to change the mechanisms of the actuator or the torque and speed of the system, both of which require fine detailed component for the application of Braille.

The third and last tested technology was the application of electromagnetic components to control the raising and lowering of the pins. The first component examined was the solenoid, the majority of the solenoid expressed a great deal of force and were cost in power, both of which seemed to be unnecessary for this application. The other components were using the electromechanical portion of DC relays to raise and lower the pins. The technology was consistent and quite reliable, failing only 1 out of 40 consecutive trials. Also the variety of the relays gave the desired force and power consumption.

2 LITERATURE REVIEW

2.1 *Literature Search*

The most relevant article on the topic of Braille literature was provided by

1)Cho, H., "Development of A Braille Display Using Pizeoelectric Linear Motor." s.l. : SICE-ICASE International Joint Conference, 2006. pp1917.
2)Sriskanthan, N., "Braille display terminal for personal computers." s.l. : IEEE Transactions on Consumer Electronics, 1990, Issue 2, Vol. 36. pp121.
3)Pruittkorn, S., "Touching force response of the piezoelectric Braille cell." Tan Tock Seng Hospital : Proceedings of the 1st International Convention on Rehabilitation Engineering and Assistive Technology in Conjunction with 1st Tan Tock Seng Hospital Neurorehabilitation Meeting, 2007. pp 174.

These first explained the use and the style of the current pizeoelectric display, commenting on the necessity of the device and the new ways to develop linear motor using pizeoelectric to create a longe life cycle and greater stroke length with limited crystal size.

The article by Sriskanthan helped in the exploartion of creating a digital interaface for the appliaction of a Braille device but was limited in the apporach of techolgy to creating such a display by focusing on pizeoelectric systems

S. Pruittkorn work was a very important article as it gave the project the parameters behind the users of Braille. The detailling of the prefrences of size of braille character and the measured force of reading, helped determine the limiations of certain design concepts and the techonolgy that could be used in the appliaction of a Braille display.

3 PROBLEM AND METHODOLOGY

3.1 *General*

While this project is focuses on the design application of several different technologies and not the theory behind designing new technology for the application of a Braille display and interface. However as such there is the necessity to understand the theory behind the material being used in the design process. This is focused on the theory behind the SMA technology as there is already a clear familiarization with DC motors, and electromechanical relays.

For the SMA, flexinol it was found that the material will retain its volume under contraction. Not only did the material supported the correct contraction and force, but it could in theory work under the desired 5v constraint digital logic. With the assumption that the wire is a perfect cylinder, and a 10% longitude contraction [7], there will be a 5% radial increase. Also due to the resistivity of the material [8] there could have been more heat dissipated than previously expected.

The SMA has composite of nickel tin at very specific ratio of 1:1 to acquire the metallurgic properties of memory and contraction. When current or heat is conducted thought the wire, the SMA contracts into a “remembered” state. This memory state can be set to any desired form , it can be set as a cold forge state , or a high temperature state.

The metal at that ratio forms a crystal structure that has two phases , the first is martensitic and the second is austenite . When the metal at a low energy state, in this case room temperature the crystal structure and thus the shape of the wire can deform into any desirable shape . at low stress levels. The low energy state is the martensitic phase of the alloy and has a yield strength of 28-40 Gpa.

However when the metal is exposed to a higher energy state, this can be produced by either a conductive temperature change or in the desired application of a current , the metal reveres the deformation and returns to the set shape. This is the austenite phase of the alloy and it has yield strength of 83 GPa. This state is difficult to deform and has a material profile that is similar to that of stainless steel.

Essentially the one wire behaves as two different metals, since the stress and strain relationship of the metal at different temperatures are different (see Figure 3).

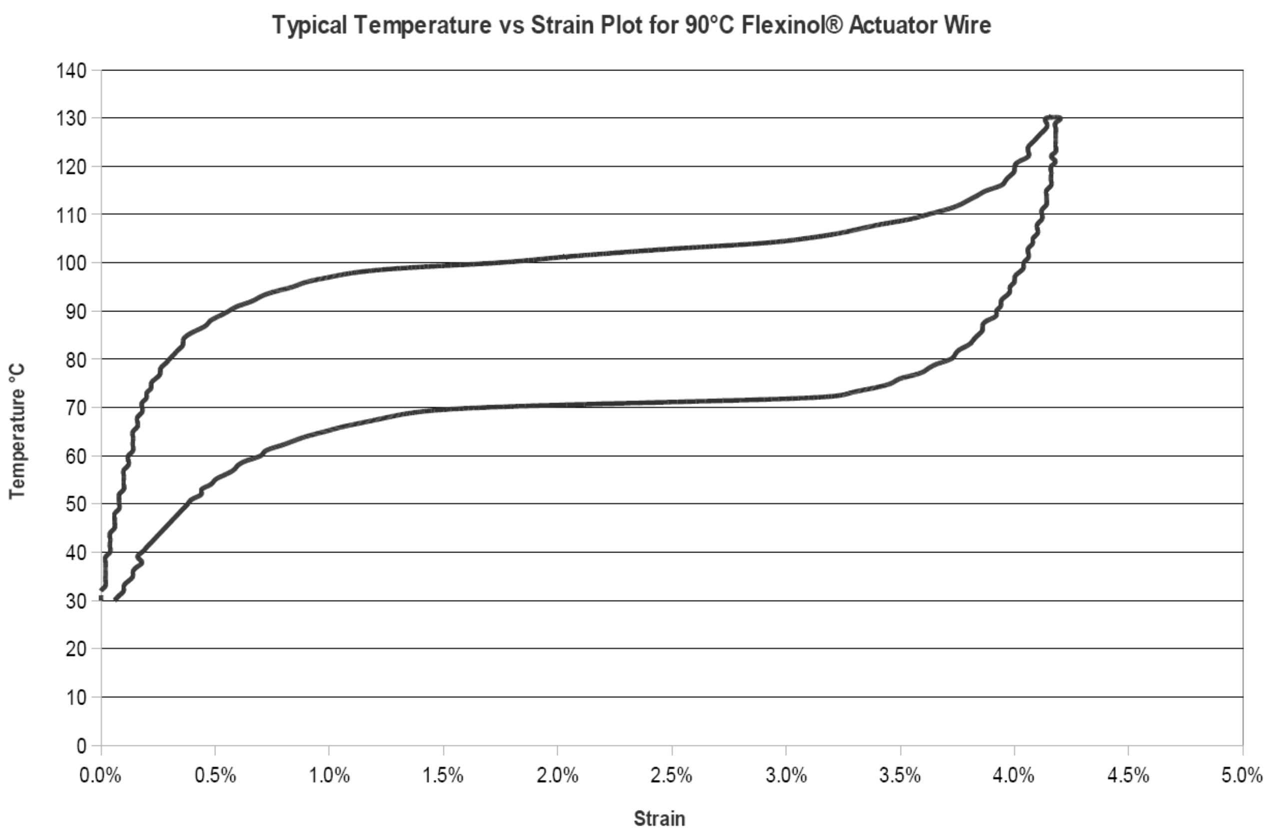


Figure 3 – The Austenite and Martensitic phase of the SMA Flexinol

This graph expresses the two separate phase of the metal Flexinol in their stress strain relationship . Both of the wires are measured under the constant stress of 20Ksi . The bottom line represent wire 1 , which is the martensitie wire at room temperature and express a different strain profile than the test above it. The top curve represents wire 2 , which is the austenite phase of the wire at about 90 degrees Celsius. The major differences can be seen at the initial curve, here the strain on wire 2 is very different from that of wire 2 , this the normal operating region of flexinol.

4 DESIGN PROCEDURE

4.1 *Digital Logic*

The first step in the entire Braille display design was to create the digital logic behind the control system and interface. The designed called for the control of 24 pins and the input of 4 buttons for the user to control the learning software.

At first the idea was to use a microcontroller with a large amount of output pins to control each of the pin separately. The digital out pins of the controller were to turn a metal–oxide–semiconductor field-effect transistor (MOSFET) switch system on and off, the MOSFET would be connected to an underlying power supply network to power each of the actuators. This idea was obscenely complicate and inefficient as such a design would have to call for the use of surface mount parts and milled printed circuit boards and difficult to test.

The next step in the digital design was to use a multiplex approach to the system. This would cut down the need for a vast amount of digital out pins, now the system only needed to used 8 I/O pins instead of 24. 6 pins were set to be the binary state of the pins on one Braille character and the last would be an enable, this enable would be controlled by a 2-4 line decoder that would select which character to load up. This saved a great number of pins and space while still being relatively simply and cost effective. At first the design was using a line selector however that system used and additional pin to pass the desired state on the select line, as the design call for a state of high on the selected pole the decoder was better since it did not require the extra I/O pin.

The issue of how to store and control the actuator was still an issue, initial solution was to use 24 separate d latches to store and change the state of the binary 5 V pins/ actuators. The d latch was the by the best approach as is could be easily controlled by a microcontroller, it stored 5 v data at its output pins and could be used in combination with a multiplexer to toggle the latch enables on and off. This was further simplified by using 1 8 output d-latch for every Braille character, now there only had to be one connection of the multiplexer to the character as opposed the previous 24 wires.

For the microcontroller selection was selected around the constraints of our project. Since we desired to use a USB interface between the device and a personal computer, an Aurdino platform seemed like the ideal choice as constant TTL communication, would require a translation into a USB format and could be a source of noise and error. The microcontroller used was a 2009 Aurdino platform clone with an ATmega168 and USB connection (see Figure 4). It was ideal for the design since it has 14 I/O pins at 40 mA and USB communication, with the Aurdino programming language it's very simple and easy to tweak the controller and a lot of work can be done without the use of a TTL cable/programmer. The current design only requires 8 output pins and 4 input pins, also the ATmega168 has clock speed of 16 Mhz which is fine for the design application. The internal clock can help create the cyclical heating of the SMA, by pulsing the instructions to the pin, to create more uniform contraction. Also the Aurdino platform had easily adaptable thermometer modules for fan/cooling systems, if it became necessary in the phase change of the alloy.

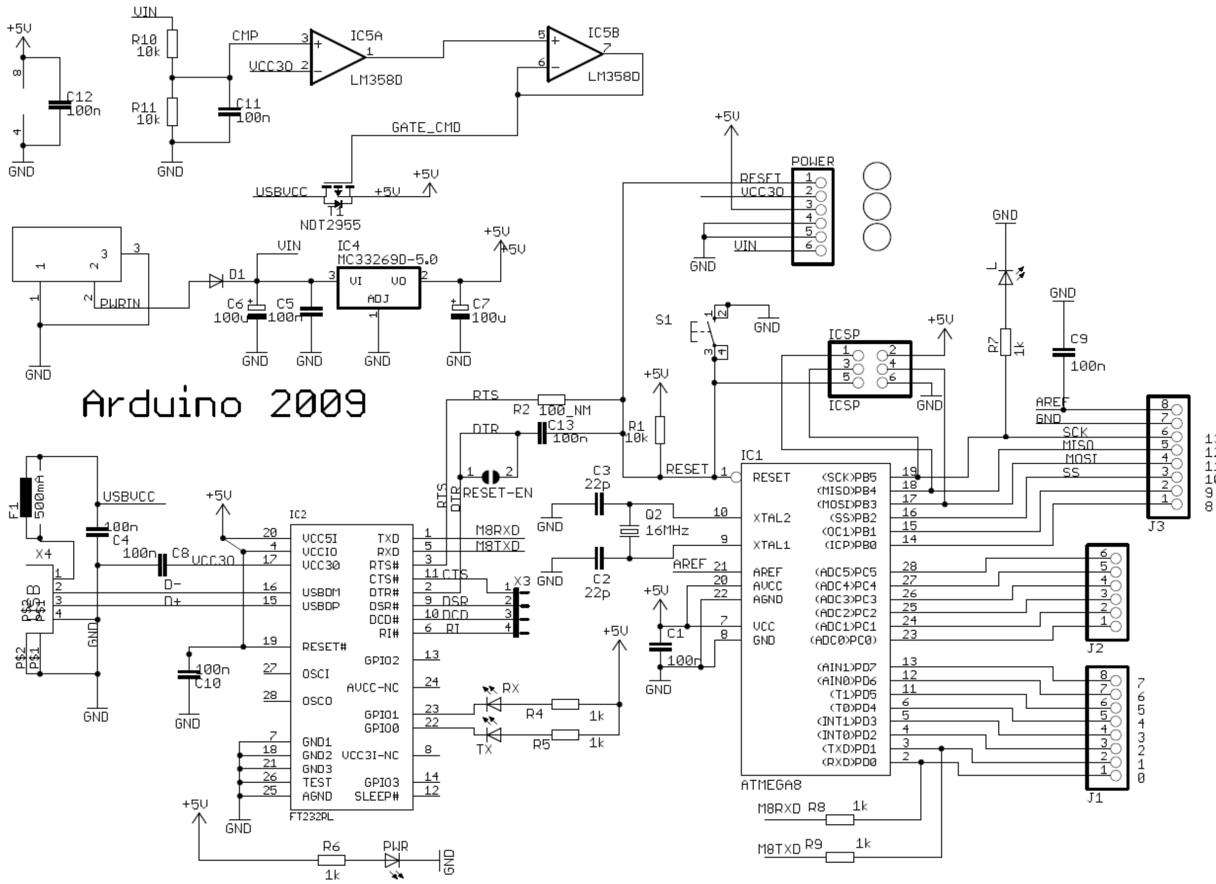


Figure 4 – Aurdino layout

The 2009 Aurdino use the ATmega 168

The system that was purchase was the USB Boarduino clone (see Figure 5) , it is the exact same as the Aurdino however it's smaller and has the built in resistor, capacitors, USB slot and male header pins to attach to a solderless breadboard for prototyping. The USB clone was 75mm by 20 mm, the standard 6 pin ICSP header in case the USB boot loader system fails upload the program correctly, and if necessary to interface with a TTL system.

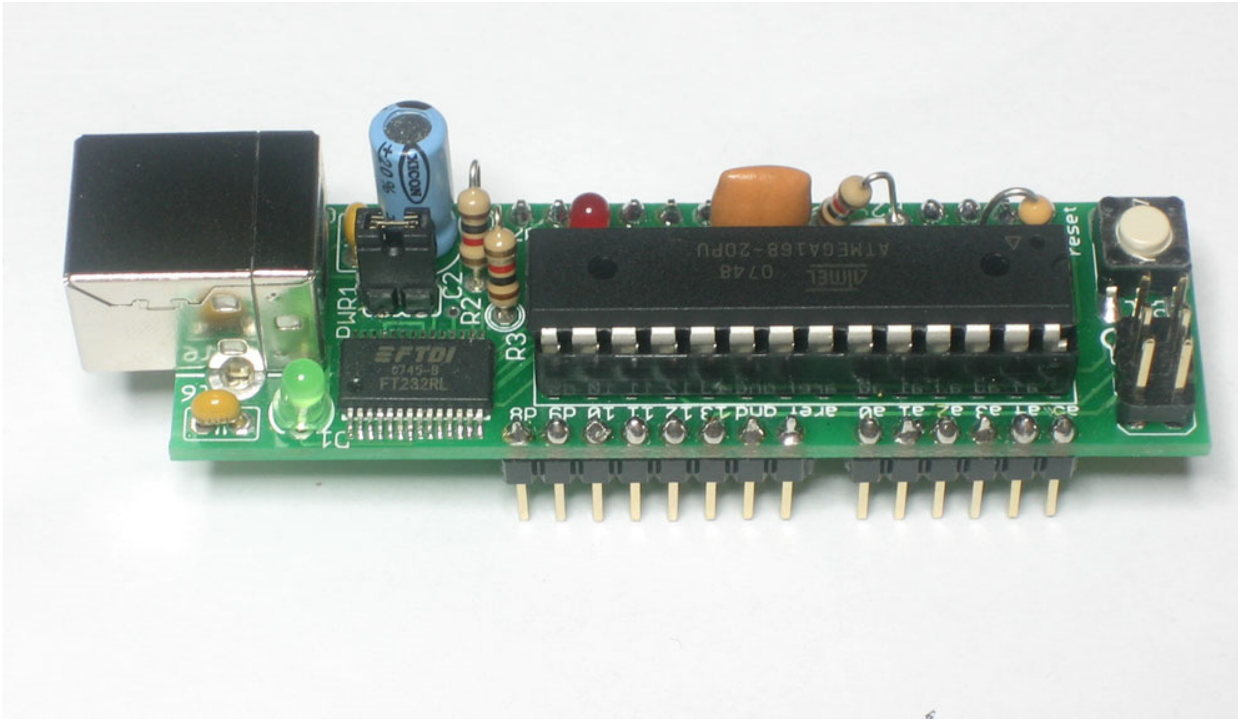


Figure 5- Boarduino, USB Aurdino clone

created by ADA fruit labs, the ATmega168 is uploaded with the Aurdino boot loader program

The overall architecture of the digital logic was laid out as follows (see Figure 6). The microcontroller (Boarduino) expresses the binary state of the Braille pin on the I/O pins, this is connected in parallel to each of the d-latch inputs (4). The microcontroller also controls the decoder with 2 I/O lines and from the decoder output there is a connection to each of the enables of the latch enables on the d-latches. The output of the d-latch pins are to be connected to the actuator.

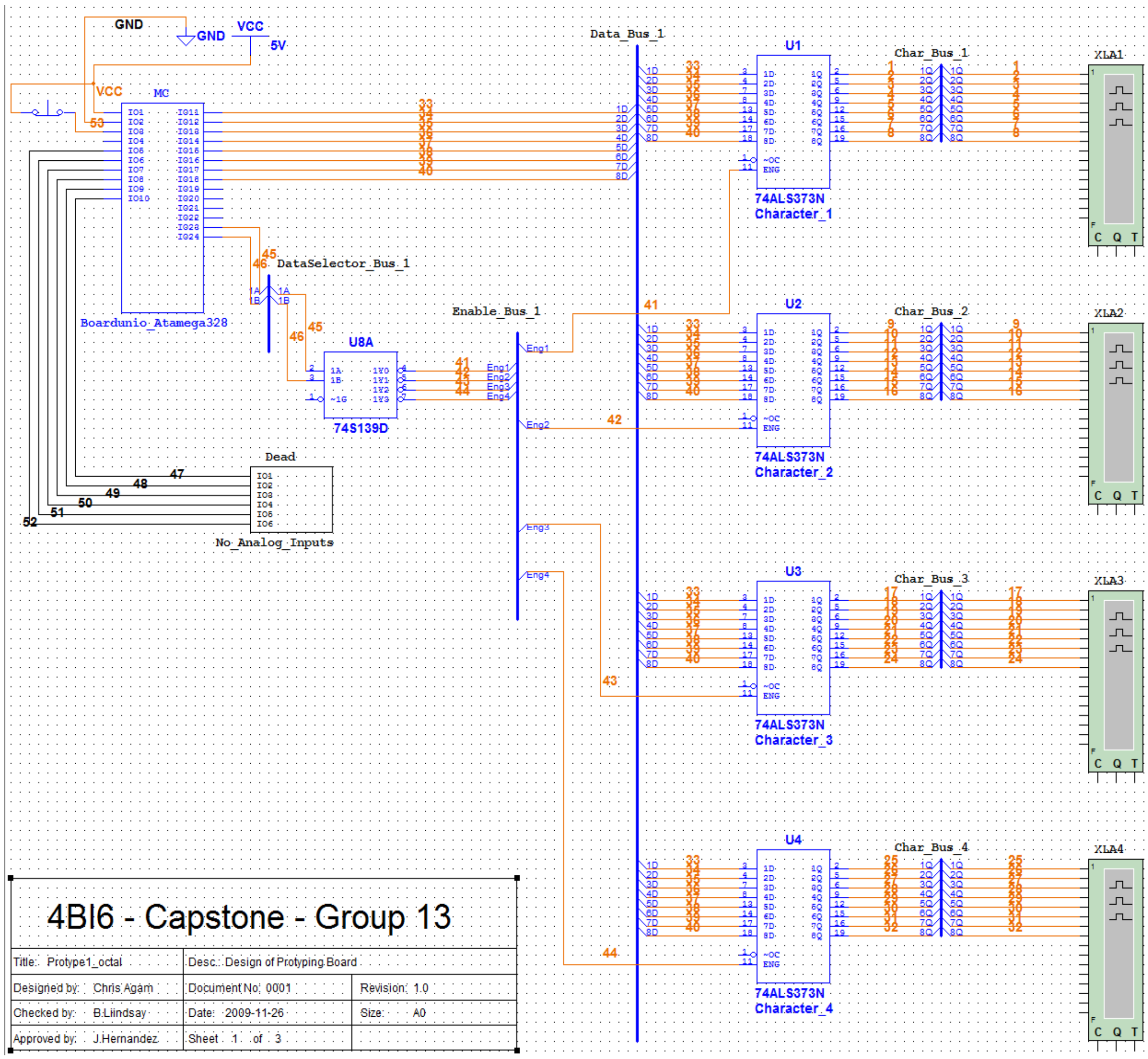


Figure 6 – Designed Digital Logic Architecture

The selected 2-4 decoder was the DM74LS139N it is a two pole select system that operate in the 4-5 V high range (see Figure 7). On the board it's powered by the USB supply and connected to the same ground of the USB, the enable is on constant high and the second pole is being used (see Figure 8). The I/O pins that control the decoder are d0 and d1 which relate to A2 and B2 respectively.

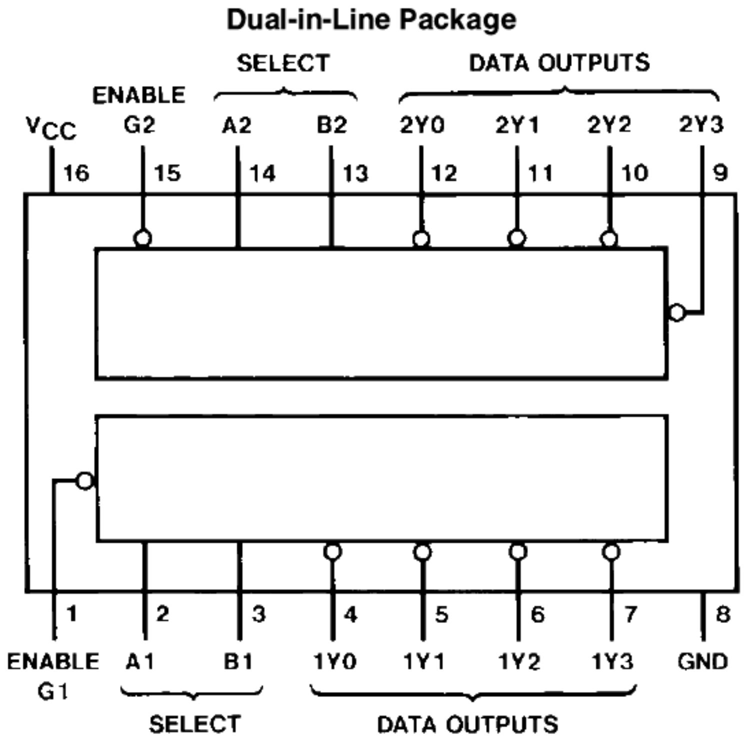


Figure 7 – Connection Diagram of DM74LS139N

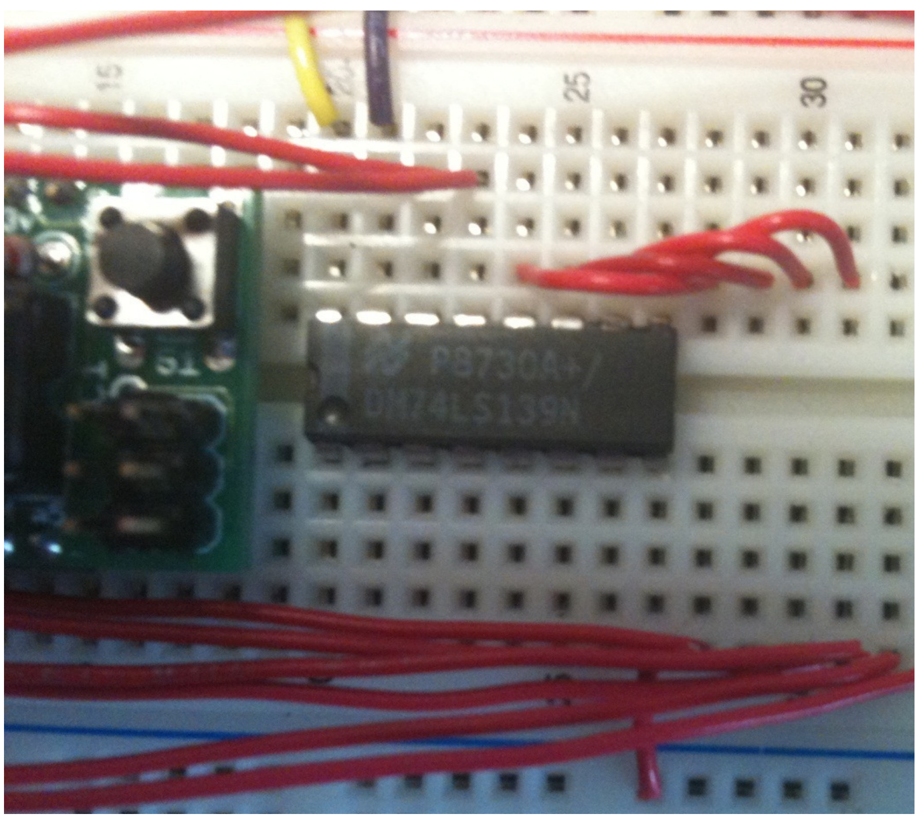


Figure 8 – Connection on Board of DM74LS139N

The selected d-latch was the SN74AHCT373N (see Figure 9). It is a tri-state octal d-latch, the tri-state was chosen in case there need to be a reverse current and the d-latch had to have the 3rd state of high impedance. Each of these d-latches were soldered on to a separate PCB and held in place with sockets, female headers were used to create quick connection and to avoid soldering wires to the board in case of damage.

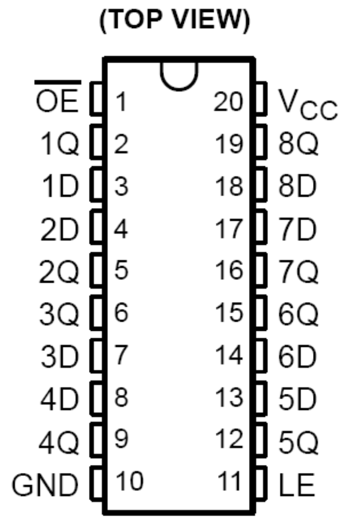


Figure 9 - The Connection Diagram of the SN74AHCT373N

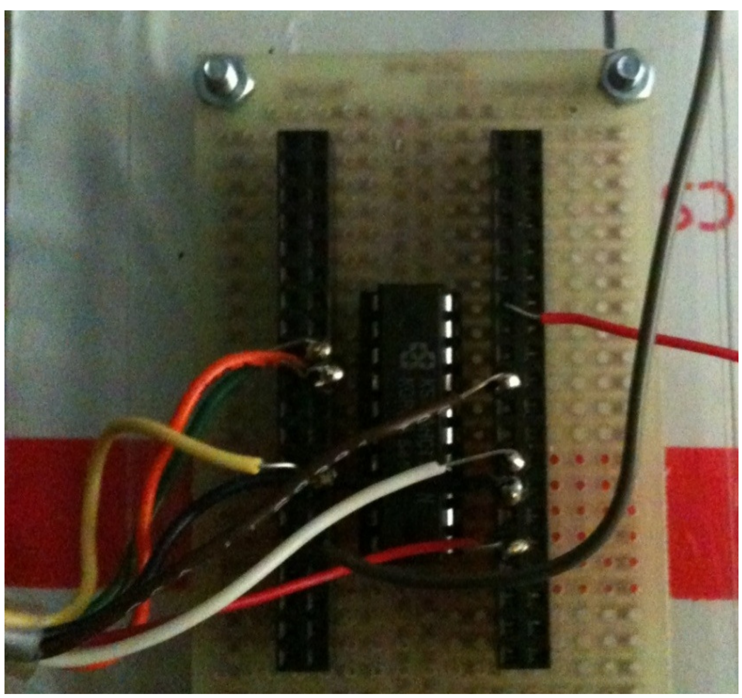


Figure 10 - Connection on Board of SN74AHCT373N

The latch input was connected to the microcontroller as d8 to 1D, d9 to 2D, d10 to 3D, d11 to 5D, d12 to 6D and d13 to 7D. This setup was imposed by the geometry and spatial needs of the actuator system.

The d-latches were not powered by the USB Boarduino supply but by a separate 5V regulated source and grounded to it (see Figure 11). The voltage regulator in use was 5 v at 1A well above the needs for powering the chips.

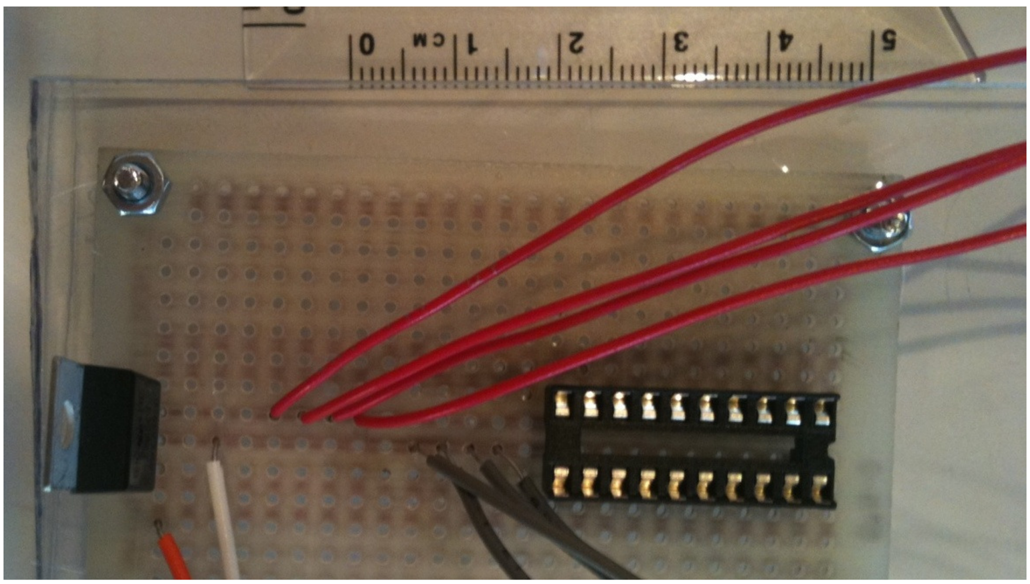


Figure 11 – Connection of Board of Power Supplys

The orange wire is connected to the input voltage the wire is the input ground, the grey wires are the grounds for the d-latches and the red wires are the 5 V regulated power for the latches.

4 input buttons were also installed to the create the interface between the hardware, user and software (see Figure 12). Also ribbon cables were used to make the connection between the microcontroller, decoder and the d latches (see Figure 13)

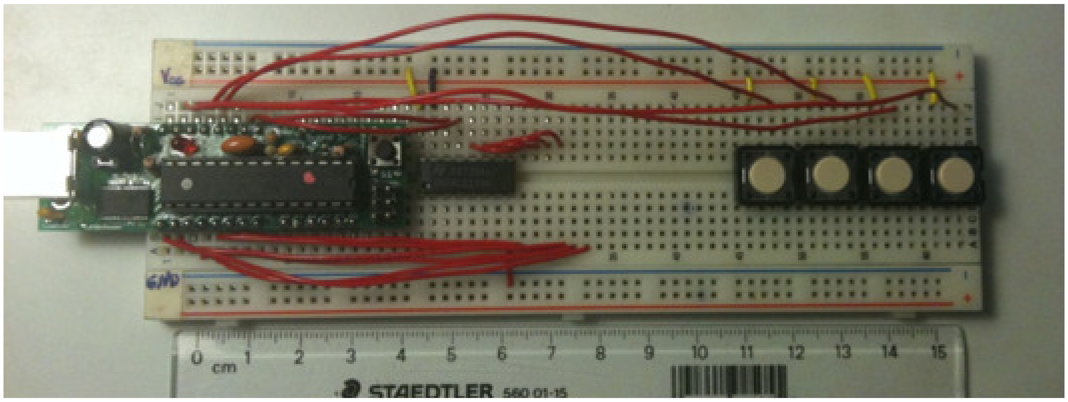


Figure 12 – Connection of Aurdino, Decoder and Input Buttons on board

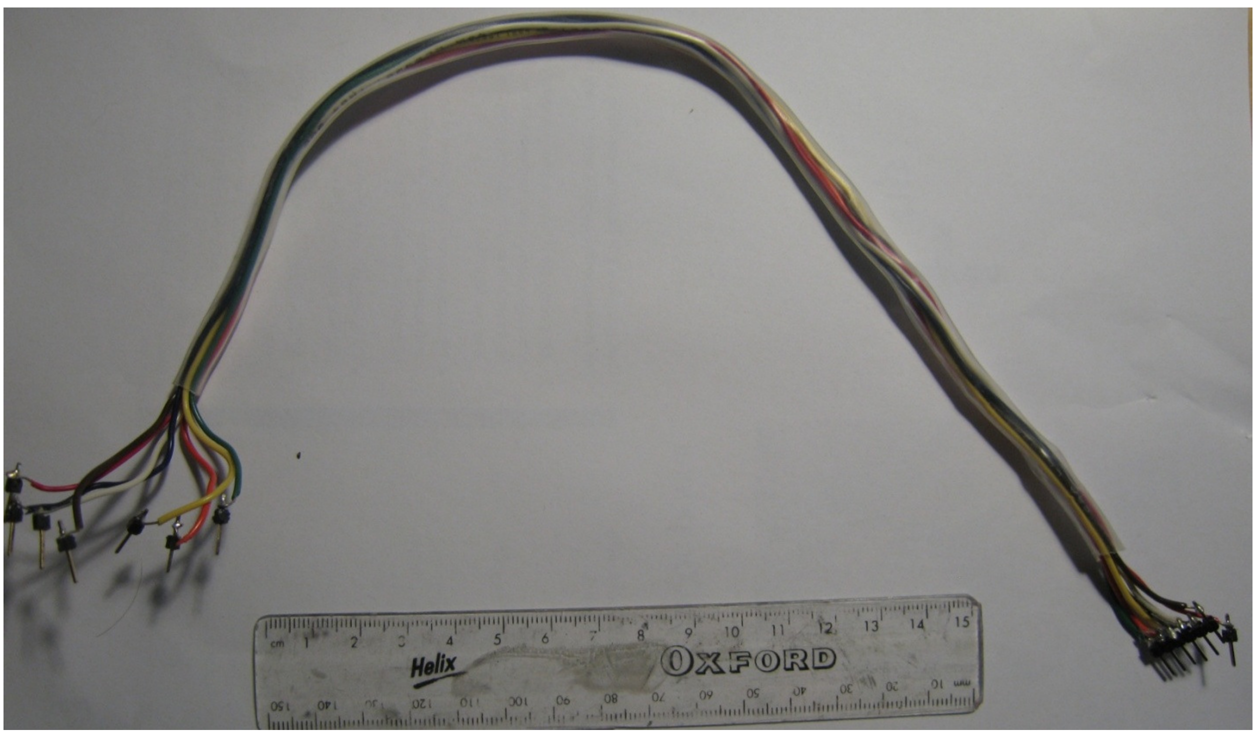


Figure 13 – Custom made ribbon cables

These connection used between the d latch and the microcontroller and decoder. There are 4 separate cables to support each of the latches, within each of the cables are 7 wires of different colours and are solders to the male headers for easy connection to the breadboard and the d-latch PCB.

4.2 *SMA*

Due to the freedom of the flexinol in theory several different designs were worked on. Each of the designs had to include a force bias, this the force required to deform the material once it was contracted, while there are materials that "remember' multiple states, flexinol only has one and has to be deformed to become another. The first was a simple spring design, where the contraction of the spring would raise the pin (see Figure 14).

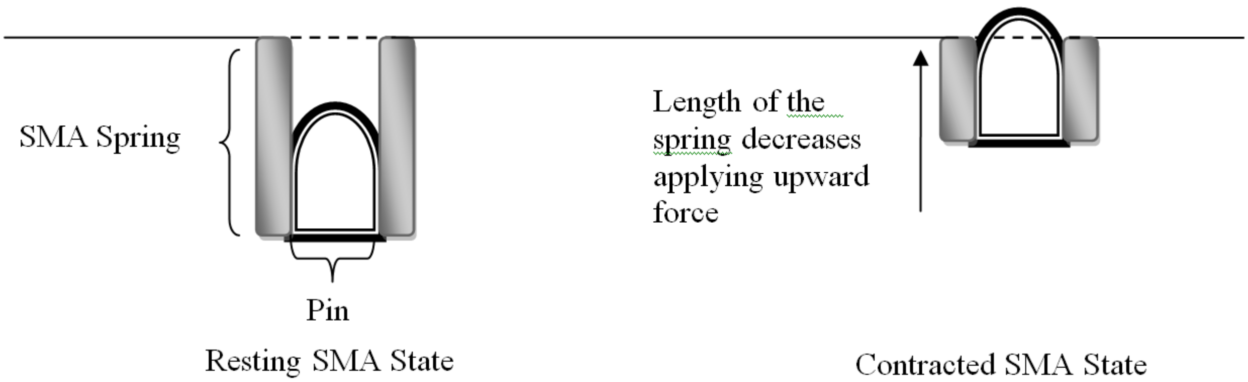


Figure 14 – SMA Actuator Design 1

The force bias of this system was either a weighted pin that could deform the wire or a spring operating the reverse direction that can be overcome by the flexinol force.

Another design was to use the contractive force to squeeze the pin into position. A spring would be wrapped around a sleeve and within the sleeve the pin would rest. When the spring contracts the sleeve would close, forcing the pin to push out (see Figure 15).

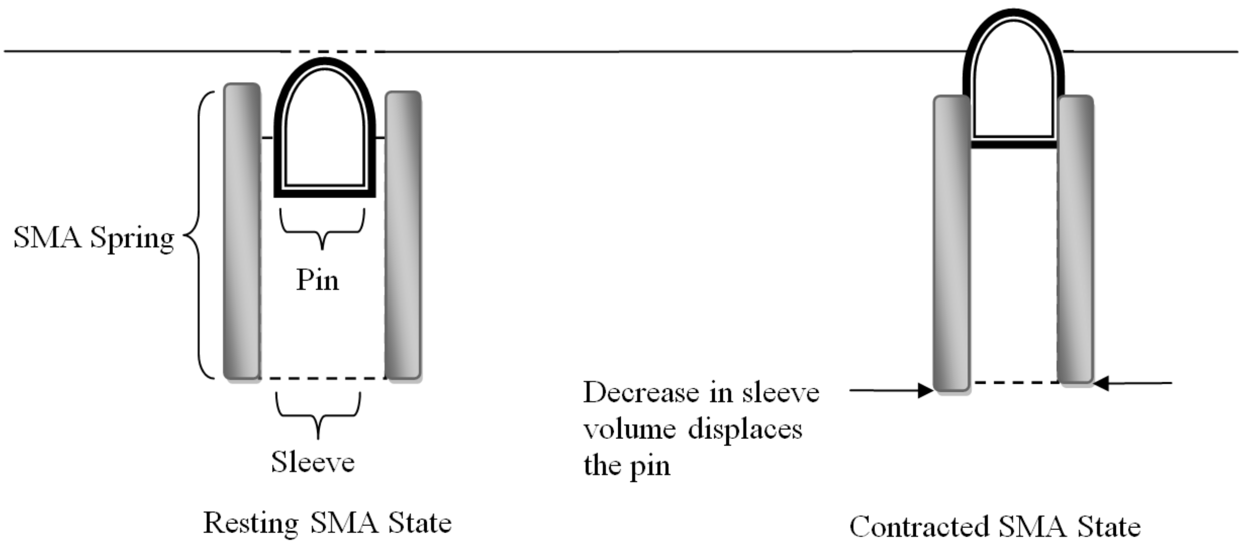


Figure 15 – SMA Actuator Design 2

The force bias of this system was either a weighted pin that could deform the wire or a spring operating the reverse direction that can be overcome by the flexinol force.

The third design was based on material that the Dynalloy Inc supplied. Another simple design, the mechanisms of the design are based off of a lever topology, as such since the force of the actuator exceeds that of the load, the exchange of force for distance can be used to create a larger stroke distance with the larger force (see Figure 16).

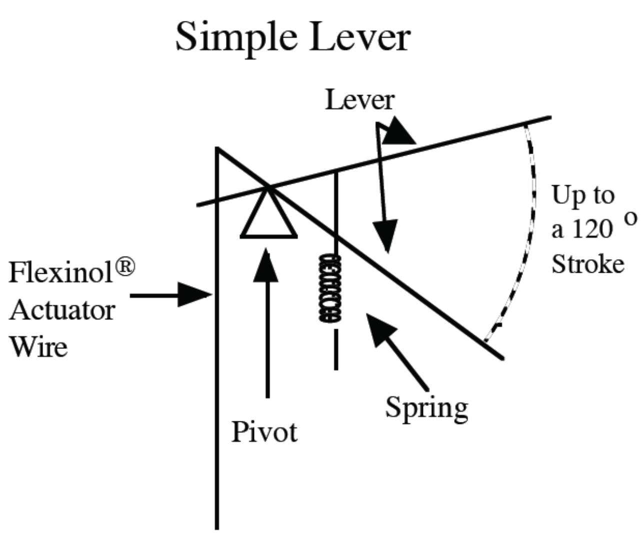


Figure 16 - SMA Actuator Design 3

The stoke distance is dependent on where the fulcrum of the system is placed.

The final design of the SMA actuator used the concept of a level. A SMA wire would pull a large fulcrum/ wheel that would raise the pin by overcoming the bias force provided by a spring (see Figure 17). This was constructed by using an acrylic frame with a dowel and cork fulcrum and small screw as a Braille pin.

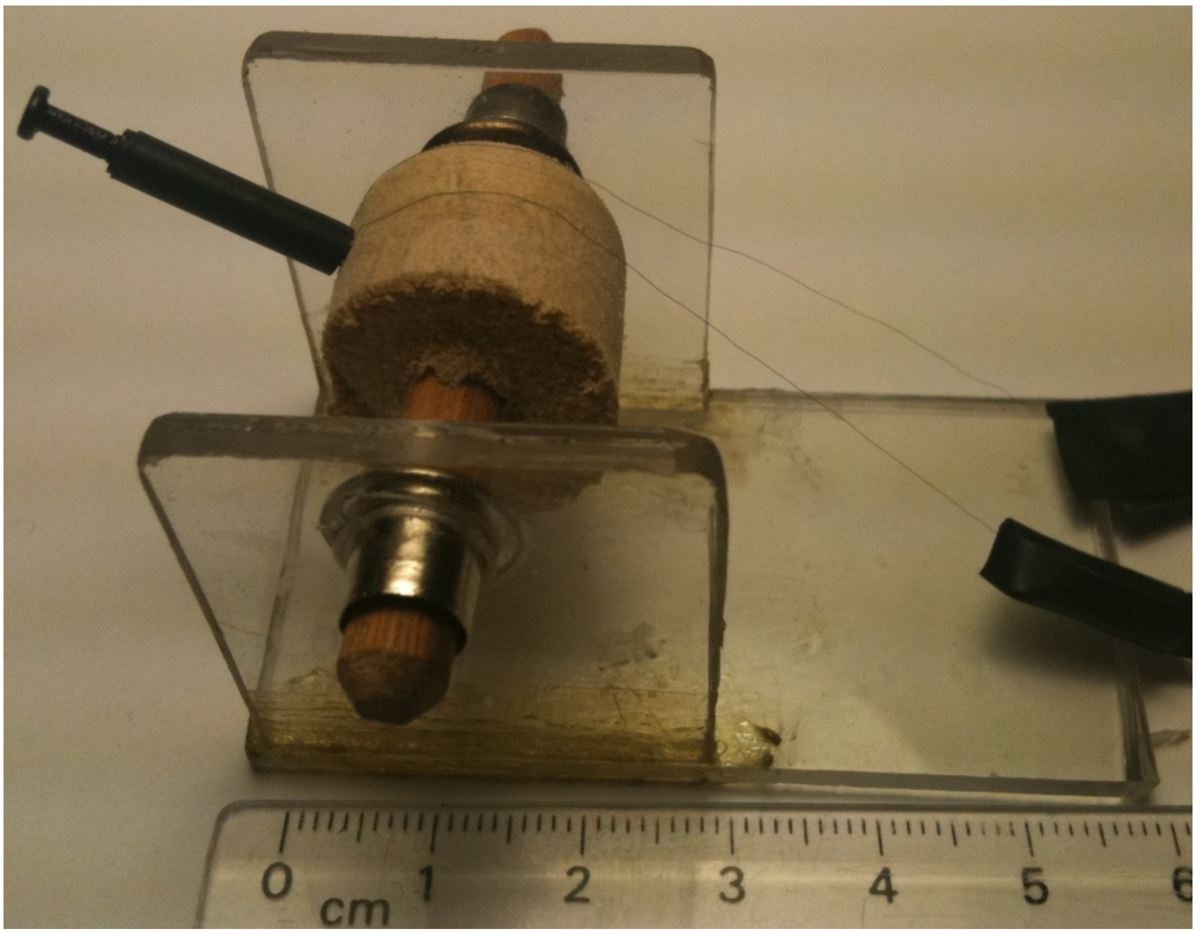


Figure 17 – SMA Actuator Design 4 s

The SMA is looped around the pin and held in place to the board. When the SMA contracts the wire force pulls the pin up beyond the rest position given by the bias force.

The size of the flexinol is related to the amount of current that has to be used to create a contraction (see Table 2) . The current of the microcontroller was 40 mA so the diameter of 0.0015” was chosen, the amount of force that was necessary was small so it was a suitable choice.

Table 2 – Flexinol Operation Statistics

Wire Diameter Size	Resistance Ohms Per Inch	Maximum Pull/Force (grams)	Approximate* Current at Room Temperature	Contraction Time	Off Time 70 C Wire	Off Time 90° C Wire
0.001"	45	7	20mA	1 sec.	.10 sec	.06 sec.
0.0015"	21	17 g	30mA	1 sec.	.25 sec	.09sec
0.002"	12	35 g	50mA	1 sec.	.3 sec	.1 sec

The wire is self was very small and difficult to work with as flexinol cannot be solder as the heat could damage/ change the electronic profile and the dynamics of the wire. The necessary contraction of the wire at 5% required a 15 cm wire to give a change of 0.75 cm (see Figure 18).

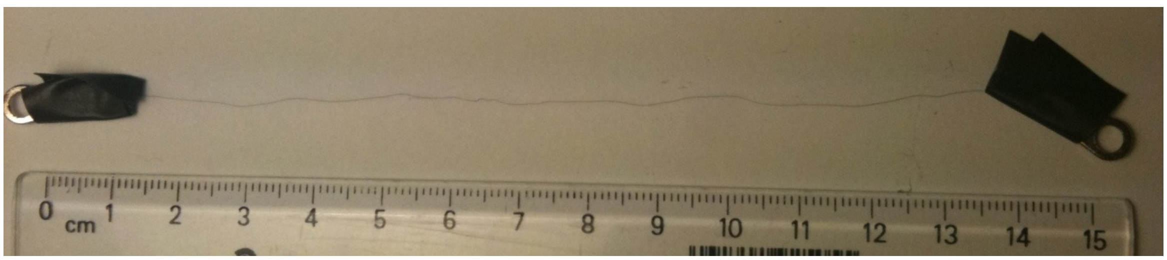


Figure 18 – Flexinol Actuator wire used in SMA design.

In the design of the actuator , cyclical heating of the SMA is important, it allows for the material to contract in a more uniform manner and helps extend the cyclic life of the material. One way of doing with is to use AC current with it's smooth curves and constant change the heating would be ideal (see Figure 19).

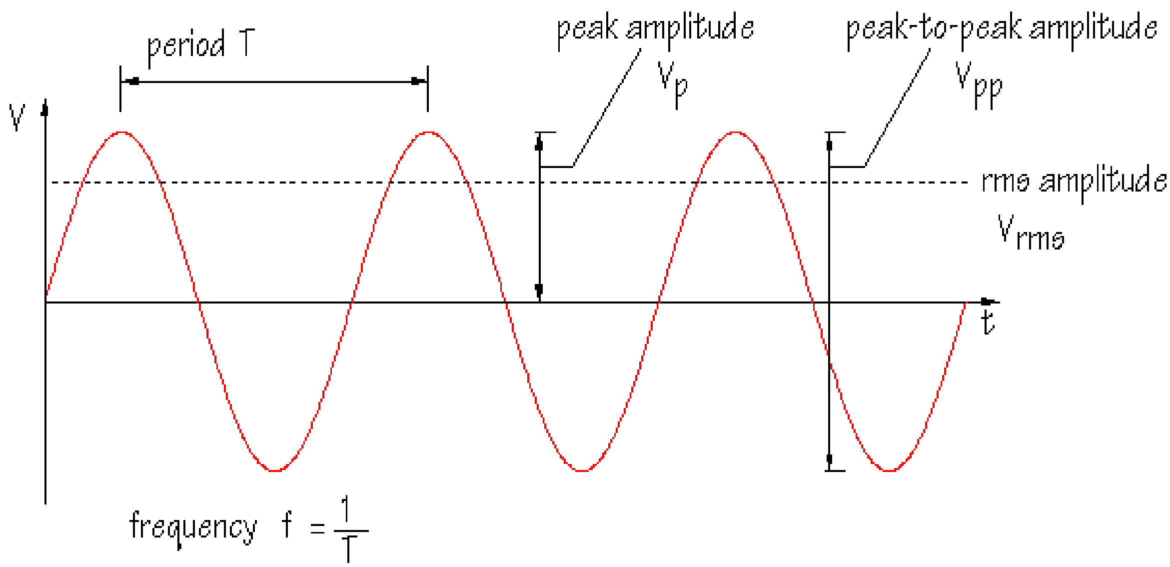


Figure 19 – AC Cyclical Heating

The rms value of the wave would have to be 5 V in order to get the correct contraction, and the frequency would have to just right.

However avoiding analog in the system was ideal due to the processing and the inaccuracies. As such an alternative to AC was create to give cyclical heating , a periodic square wave function (see Figure 20). Here the square wave is generated by switching the enable on the latches on an off, or by loading up each one in a loop. This would create a periodic function of heating that would be similar to that of a square wave. The only issue would be to figure out the most effective frequency and that the change would not be as gradual as the AC power. However the avoidance of AC freed up several microcontroller pins and reduced the number of wires that had to run to each supply line. As the AC system would have needed additional pins or design components to create 6 AC input to the actuators that would have to be controlled by 5v high digital logic.

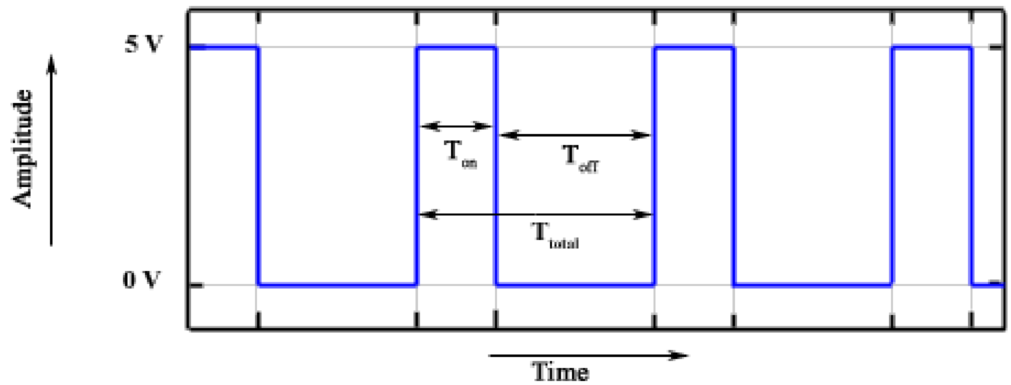


Figure 20 – Square wave Cyclical Heating

4.3 *DC Motor*

During the year it was understood that DC motor applications while in theory motors were efficient, there were too many challenges when it came to the controlling the system. The overshoot and the instability of the system was too much to handle and it was clear that it is a poor choice from the application of a Braille display. For instance the DC motor would have to know the current position and the trajectory to raise and lower the Braille points, this would mean sensors and further processing and would stain the system.

4.4 *Relay*

Electromechanical relays use electromagnetic to create a force by creating a B_0 field. Its very reliable and repeatable, the cycle life under normal use is almost infinite as there is no stress on the system. In the use of an actuator there is and induced life cycle by the load, in this case it's the gentle press of the finger on the pins, still under this force the spring coefficient of the relay itself is relatively close to the force generated by touching Braille.

The first design of the relay actuator was using a large 9v input relay and the second was using the same principals but with a smaller 5 v input relay at 30 mA that would work better with the digital logic (see Figure 21).

Figure 21 – Relays side by side

The two on the top are the 5 V relays and and the two on the bottom are the 9 V relays The ones on the left are un adapted relays and the right are the relays that have been taken apart to use the actuator.

While the 9 V raise the leveler arm when current passes through it, the 5v lowers the lever, this is because the 9 V is on the bottom and the magnet pushes the arm up and in the 5 v the arm is brought down by the magnet.

The 9 V has a greater stroke length than the 5 V and has a greater force , due to the proportional relationship between current and magnetic strength. In this application of actuation the 5 V at 30 mA was ideal it has a quicker reaction time and the stoke length of 5mm is more than enough to simulate Braille characters (see Figure 22 and Figure 23). Also the component was the right power rating for the integration in the digital logic system.

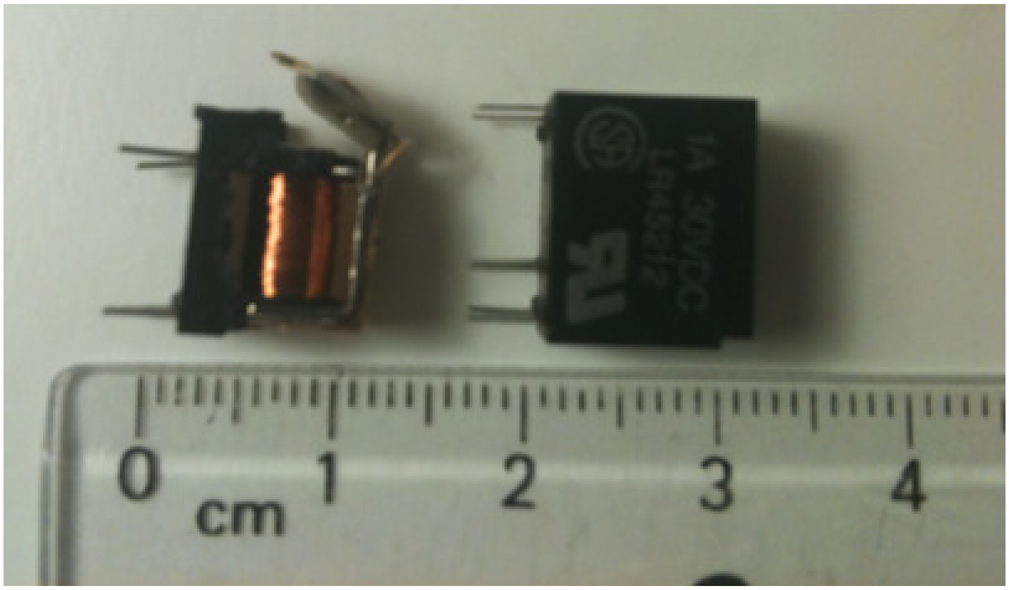


Figure 22 – 5v Relays side by side

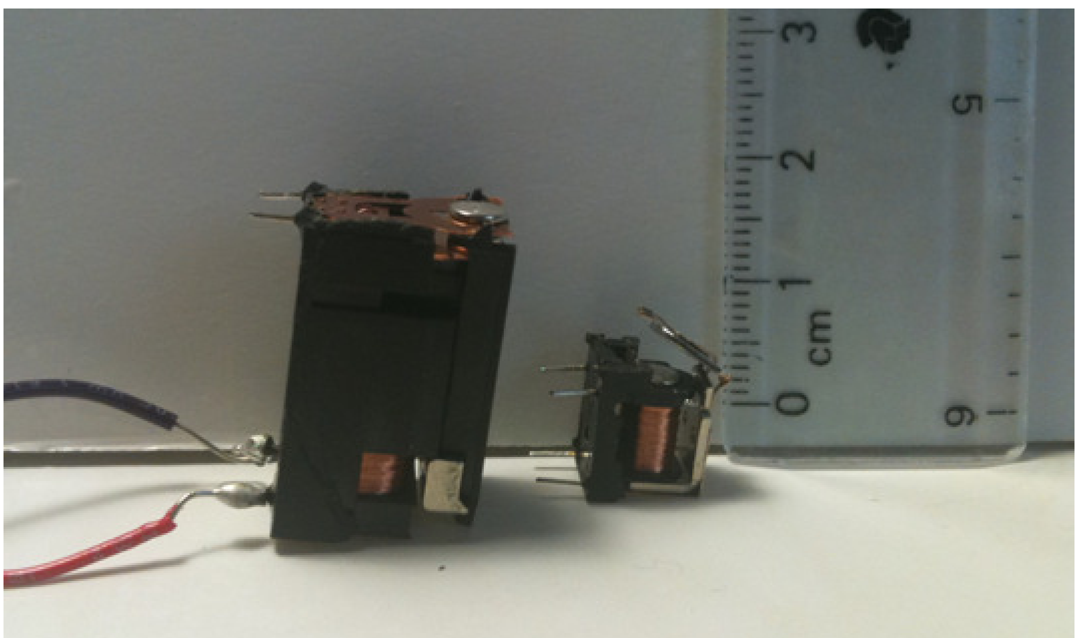


Figure 23 – 9 V and 5 V relay side by side s

The height difference is quite noticeable with the 9 v on the left and th e5 v on the right , the 9 v relay is about double the stroke at 8mm

The 5v 30 mA relay were implemented into the system, the part that was chose was the Aromat HY1E. 24 relays were taken apart by filing down the black plastic encasing and using needle nose pliers to assist. Once removed lead and ground wires were soldered the relays were place together to represent a Braille character and the mounted to acrylic (see Figure 24). Finally, each unit had a silicone pin adhered to the top of the lever (see Figure 25).

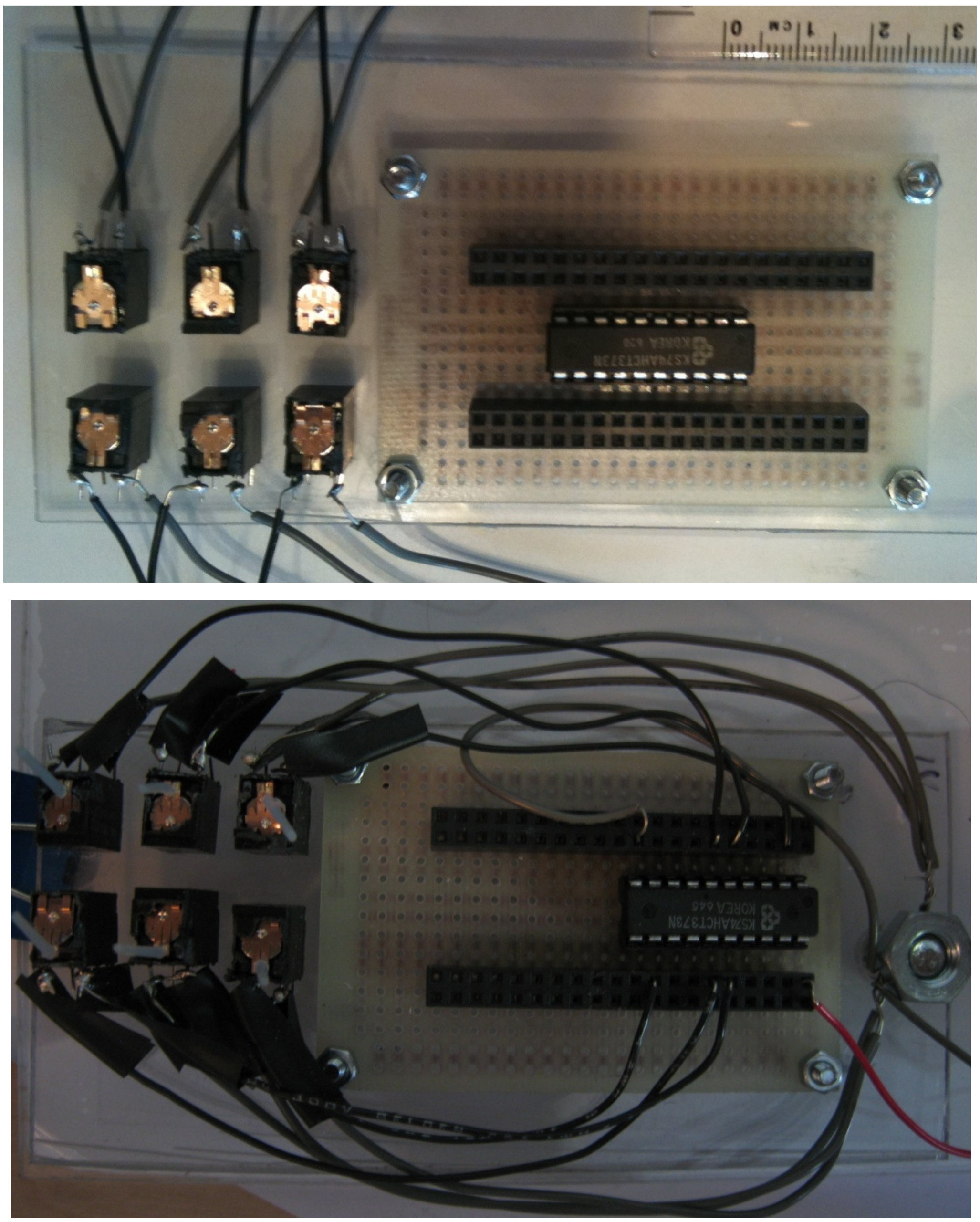


Figure 24 – Layout Relay Actuators

To the left of the image there are the six mounted relay actuators and to the right are the d-latch control units. Both are mounted onto the same piece of acrylic for each Braille character. In the second image the pin have been mounted and the wired to the d-latch.

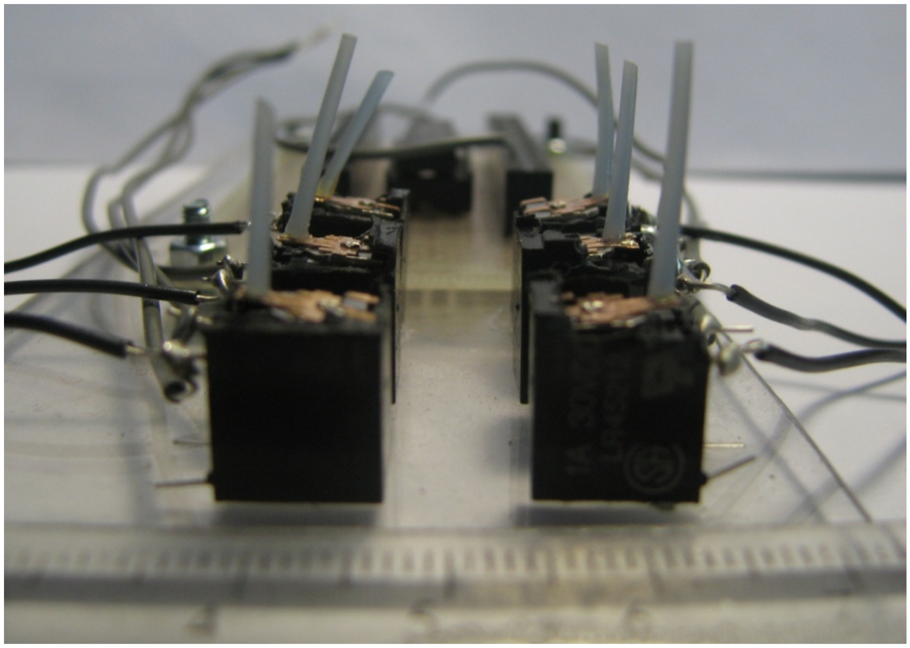


Figure 25 – Mounted Actuators with Silicone Pins

The relays were attached to the d-latches which were then connected to the decoder and microcontroller (see Figure 26) to complete the design (see Figure 27).

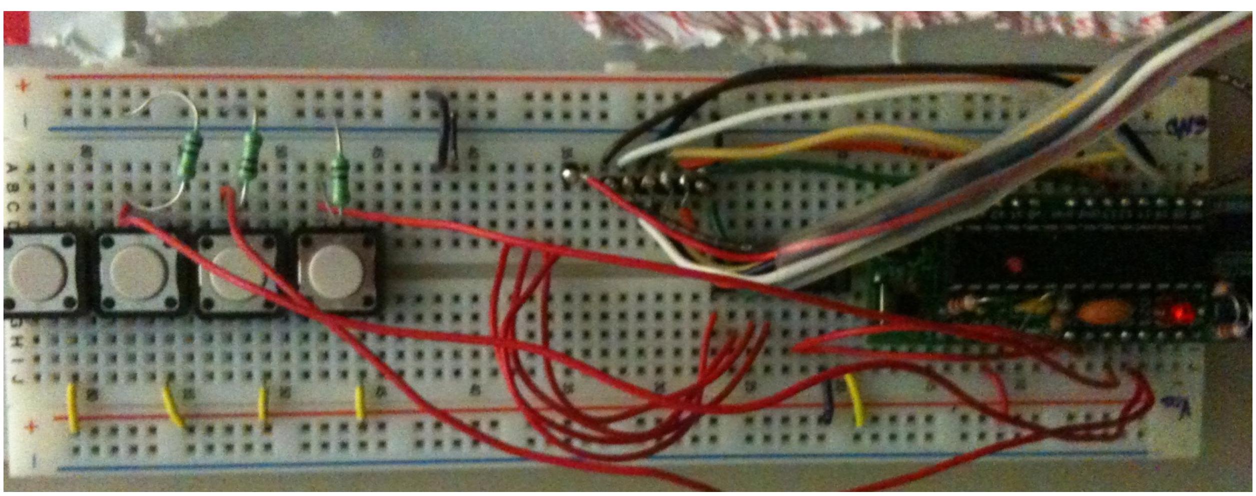


Figure 26 – Ribbon cable connections

These are the data line connection of the d latch to the microcontroller. 6 are for the Braille pin input and one is for the enable, which lead to the microcontroller and decoder respectively.

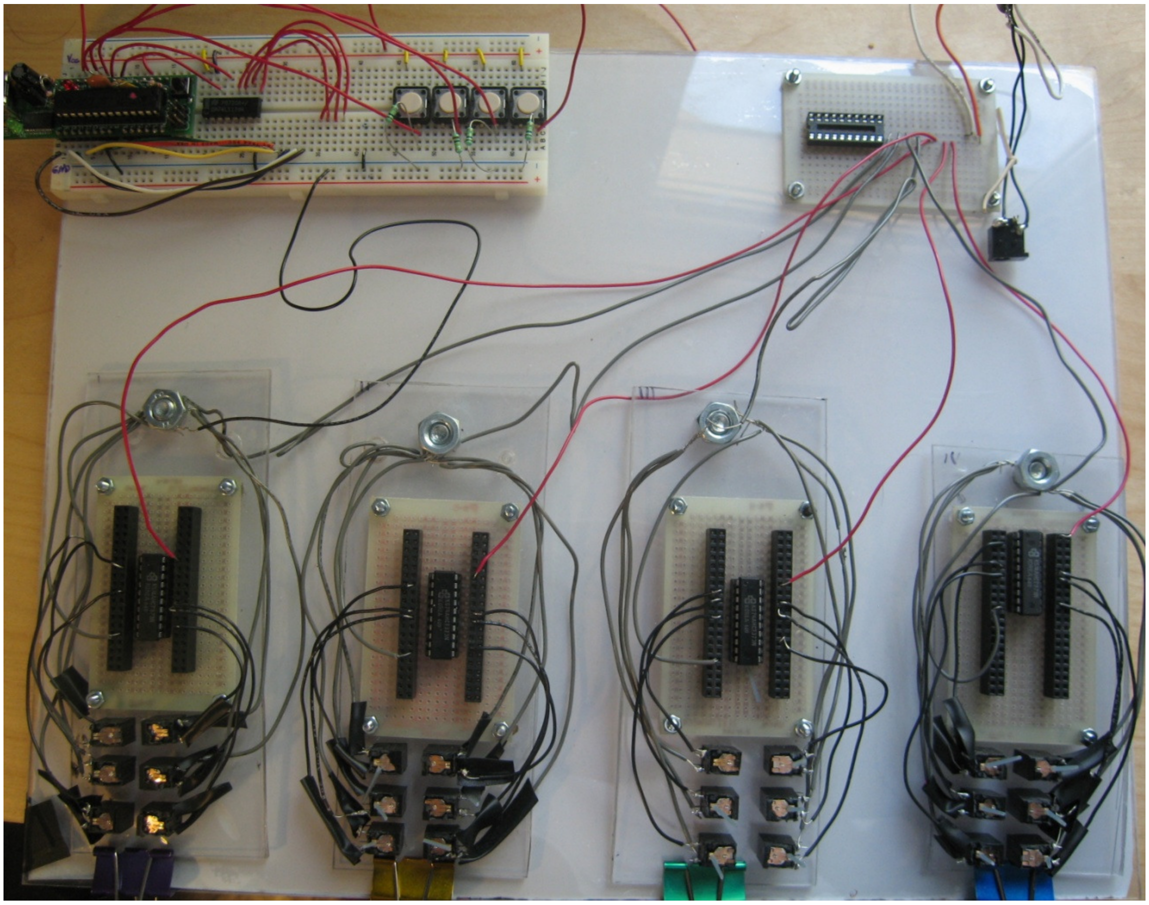


Figure 27- The Finished Braille display

The ribbon cables were removed to show the system more clearly and the placement of the components.

5 Results And Discussion

5.1 *Digital Logic*

The testing on the Aurdino was quite rigorous. First the I/O pins were each tested when loaded up with a set of instructions, this proved to work as the voltage measured across the each pin with the difference to the USB ground was in the range of digital high 4-5 V. Then next test was each of the ribbon cables to check for noise and transmission, this was done in the lab with an oscilloscope and a 5 v source. Once again the wire functioned uniformly with little disturbances, which was surprising as the wires were not fibrous just standard single strand. Follow that was the transmission if the data from the microcontroller through the ribbon cables which proved to be successful as well as the changing states of the decoder and the powering of the decoder. The buttons were tested and failed; the purchased button did not have and internal resistance, this was quickly correct by Jon Hernandez by placing resistors in at the switches and ground to allow current to flow.

The next test was the power supply, from the 5 V 2 A source the regulated voltage was 4.63 V regulated, which I found odd, however I dismissed the fact that 5 V reg is an ideal case and that 4.63 V was a realistic voltage. This proved to be part a mistake later. That was fixed by using a separate 5 V supply.

The next to be test were the d-latches, each test was first performed away from the microcontroller with the 5 v regulated power supply. Data was manually loaded on the latch by using a separate 5 v supply, on all 4 latches the system worked, however some changes had to be made. The OE line was originally grounded to the system but this proved to be somewhat unstable in that remembered states would lose voltage and the system had the most minor delay present. The OE line was set to float and the system was better, other oddities were when measuring the set low state of the output pin it would be measured as high, this problem was resolved when it was noticed that the 5 V measured low instantly dissipated once a circuit was formed using the output pin, it just needed to discharge. That problem took several testing sessions to notice.

The latches were then tested with the chosen actuators and the system also preformed consistently. However when the test was performed using the microcontroller it did not provide consistent results. All of the previous tests were performed several different times with different components and it all was successful, this was done over a two week period.

The test between the microcontroller and one latch powered by the USB was tested and the system worked fine. On the day of demonstration the problem was realized and a solution at that time could not be put in place. The problem was that the power supply ground and the USB ground was not the same there was a 1.43V difference between the two, as digital logic and systems are driven by voltage differences the discrepancy created the logic errors observed. At this point the voltage regulator was removed as it was not supplying the correct voltage and a separate source with a much high current was used. The ground of the supply was connected to the ground of the microcontroller, however this connection had to be removed as it was overheating the Boarduino, most likely from reverse current issues. To prevent damage the demo was preformed with success with the use on one latch/ character.

5.2 *SMA*

The initially flexinol testing was a success as the contraction measured was the desired 5% contraction. The first test was done by taking the flexinol wire deforming it and subjecting it to the 90 – 100 degree Celsius heating via hot water. The straight wire was coiled at room temperature when exposed to the heat the wire reversed the deformation and became straight, this process took only 1.5 seconds on average of 20 trials. However it was notice that it was easy to push the material beyond reversible deformation, due to the size of the wire.

When the actual wire was tested in the application of the actuator, the system failed. During the testing a function generator was use to create the contraction current. The first test was at 5v with a square wave, this created no contraction after 10 seconds, the same test was done with a sine wave and also proved to failed. The set was at 6 v , with no result then 8 v and finally 10v . After these cyclical heating trials failed, straight DC loading was done on the wire at 5 V, 6 V, 8 V and 10 V, for 20 seconds no of which contracted the wire.

Upon inspection the points of failure can be attributed to two specific sources, the electrical connection and deformation. It's was very difficult to make a secure and reliable connection for the SMA as no solder can be used , the tested wired proved to have poor connection properties, and did not pass the correct current. More over the handling of the hair thin wire is difficult as from the test show that the wire had permanent deformation with several kinks in the previously straight wire. The flexinol wire on scale of 0.0015" was very difficult to work, even under high power the wire would not contract , while all the part were rated at the correct power levels the wire would barely heat up and not reach the 90 degree Celsius operating temperature.

In theory the problem of obstacle to overcome in the SMA Braille display was suppose to be the overheating of the system and the correction management of heat dissipation the real problem was under heating the wire and the possible quick dissipation of energy.

5.3 *DC motors*

Testing was not even conducted as the approach was abandoned once it was rule as an ineffective and infeasible way to create a referable Braille display.

5.4 *Relays*

Over the course of making the relay actuator, 4 broke. In every case the problem was the same , deformation of the lever during the removal of the encasing. The lever arm is not only the point of motion on the relay but it is also the spring that creates the force bias. This force bias is used to keep the lever arm up, when the arm and therefore spring is changed the force bias changes, in most cases the force bias was increased. The increase force bias resulted in the lever arm not coming down and lower the Braille dot when turned on. The magnetic force generated by the 5 V at 30 mA was not enough to overcome the much greater spring, as it is not designed to in the normal operation of the relay. To correct this it was just easier to replace the relay and to reform and try to adjust the spring coefficient manually.

The points that did not work were X1-Y1, X2-Y1 X2-Y3 and X1-Y6 (see Figure 2). During the testing of the d-latches each relay was tested with a 5 V source separately to ensure conductively, each one was successful with limited to no loss of power. Then each unit was tested with the corresponding d-latch configuration from the 5 v regulated power supply all of which were successful. Then the Braille units where tested by a direct connection to the microcontroller, just directly plugging the ribbon cable to the I/O and attaching the USB power supply to the latch and the latch enable, each character separately operated as expected. However due to the logic error of uncommon ground the Boarduino and the 5 v power supply. Then the system was tested to see if it could run on the USB power alone however the power of one working latch was .33 W and the output of the USB supply was rated at .4 W so during demonstration only one character could function at a time and not all 4.

The relay system was also very quick to react changing character in under 0.5 seconds as the current generated the magnetic field. Overall the relay's provided a more than adequate stroke length and force to be used in the test application.

6 Conclusions And Recommendation

6.1 *Conclusion*

The most successive technology tested was the DC relay under the principal of electromechanics. The DC motor was by far the most inappropriate technology for the use of a Braille display as control systems and encoders to know its exact current position in order to move to the next state would have been complicated and not robust enough for practical use.

The most studied technology the SMA Flexinol has the property of contracting when a current is run though the wire, and proved to be inconsistent. A SMA radius of .0015" with a low current , a cyclic heating did not have the desired contraction. In testing of the SMA it was found to be very slow if not unresponsive. The fatigue and the delay of SMA was a result of the material being difficult to work with . Since the system would required so much energy to heat and cool the wire and the extensive time to complete one action, the approach was rejected.

The relay is a physical switch moving between two states based on whether the magnet is on or off. Once taken apart the mechanical portion can be used to raise and lower a point based on the binary state of the magnet, this was the easiest and most reliable technology to use. The only drawback was that the relays had to be taken apart before being used, making them each a little different but not noticeably.

The digital logic error was due to a poor assumption that the ground from the same socket was going to be the same. Due to the difference, the logic had errors, that translated in to the wrong letters appearing on the display.

6.2 *Recommendation*

For the future of this project it's vital to correct the logic issue, by placing a new voltage regulator in place that provides the correct current and voltage, and to create a common ground. This has already been done post demo day.

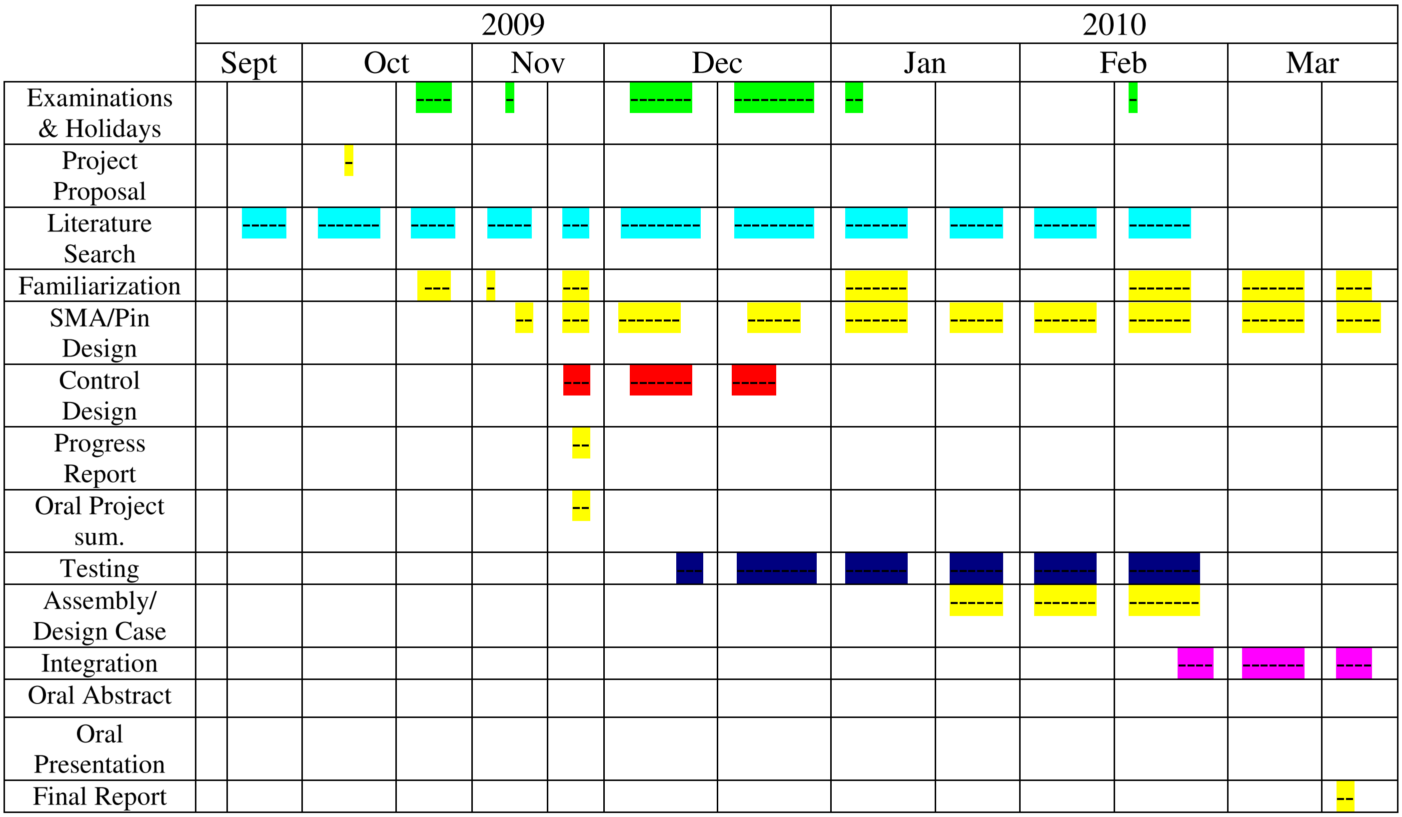
The area of expansion on this project would be to increase the voltage of the pin system to create a more robust system with the 9 V relays as they are sturdier in construction and have a long life cycle than the 5 V relays. The 9 V would also create a larger force and a much larger stroke length which could create a better character for people just learning Braille. Further testing would be required on a Braille literate population to determine the effectiveness of the learning system.

7 APPENDIX

7.1 Gantt Chart

Christopher Anand Agam (0654022): Braille Hardware Design

Date Issued: October 9th, 2009   Date Revised: April 5, 2010



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