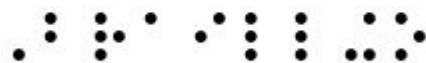




Brailingo



By Company #5

Anastasiia Shpak, Angelique Caballa, Korcan Uyanik, Kunal Gossain, Zhejun Dai

Content

- Introduction
- Technical Case
- Business Case/Costs
- Risk Analysis and Risk Management
- Adherence to Standards
- Self-Reflection
- Conclusion
- References



Introduction



Our Team - Hardware Team



CEO, Kunal Gossain, Electronics Engineering

Electrical Design and Testing, Building Stand/Enclosure, Wire management



CFO, Zhejun Dai, Electronics Engineering

Electrical Design and Testing, Soldering, OCR accuracy testing code, Building Stand/Enclosure



CAO, Angelique Caballa, Systems Engineering

Electrical Design and Testing, solidworks models for braille labels and button caps, wire management, soldering

Our Team - Software Team



CCO, Anastasiia Shpak, Computer Engineering

Braille Module code, Multithreading, Button Algorithm, Software Testing, Validation, and Debugging



CPO, Korcan Uyanik, Computer Engineering

Image processing, Multithreading, Building stand and enclosure, Software Testing, Validation and Debugging

Purpose of Brailingo

Problem to Solve

- Current refreshable Braille solutions for visually impaired in the market only take webpages, digital books, and pdfs as input

Proposed Solution, Brailingo

- Text Scanner
 - Built in Camera to capture English text with various fonts and text layouts
- Braille Output
 - Refreshable Braille display
 - Buttons to parse forwards or backwards through the characters scanned
- Ease of Use
 - Enclosure of camera, computer, Braille display, and UI will resemble a book holder with a light stand to fix text
 - Book holder will have physical groves and guides to help position the book or document

Motivation for Brailingo

Provides another form of accessibility for visually impaired to read physical books.

- For non-Braille books or documents that do not currently have accessible digital formats (.pdf, e-book. etc), Brailingo will allow braille-literate visually impaired to read the physical text sooner.

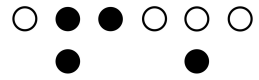
Promotes literacy among visually impaired through braille.

- About 1% of the World 2020 population of 7.79 billion are **severely visually impaired** or **blind**
- Although there are only about 10% of visually impaired that understand braille, **braille literacy has a strong correlation to employment for visually impaired.** 70% of blind adults are unemployed and 30% are employed; however, within the 30 people, 90% of employed visually impaired know braille.

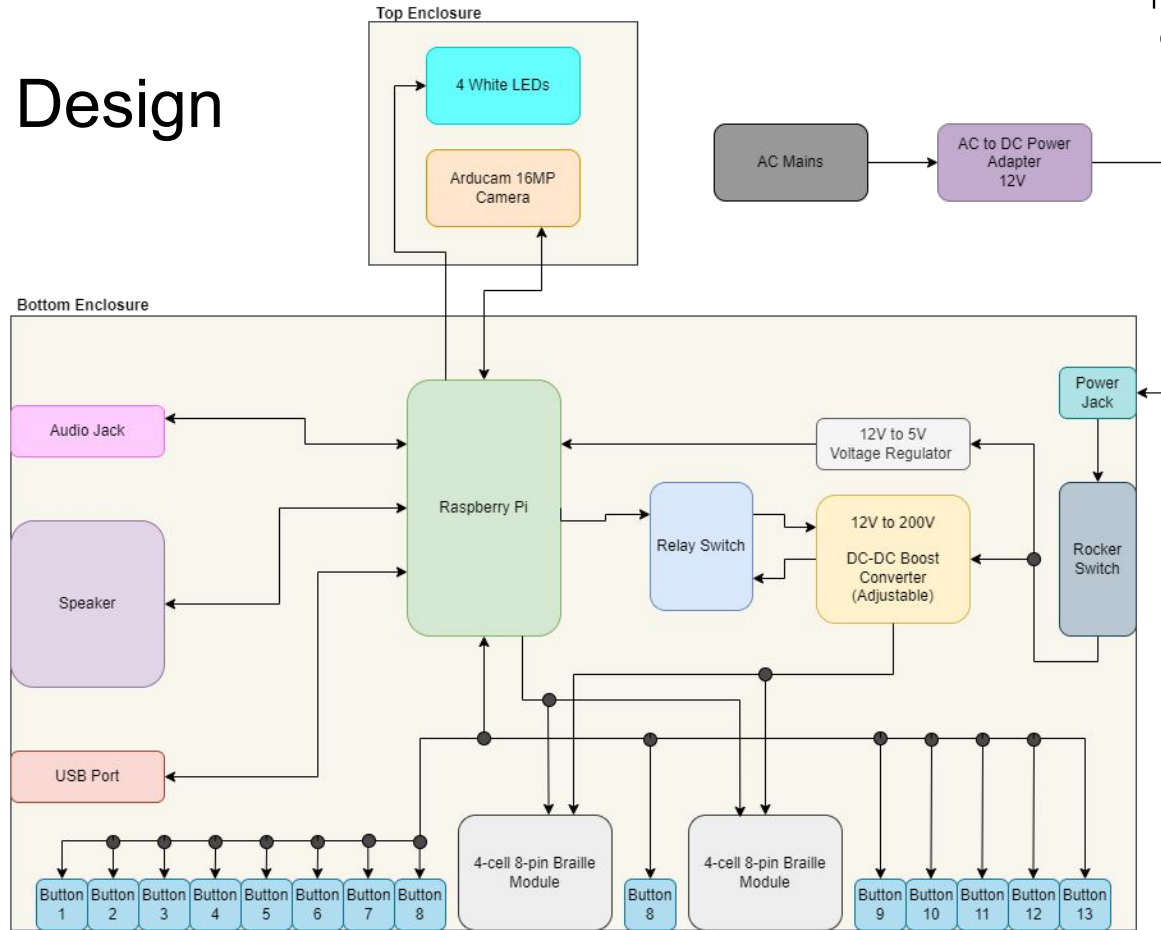


Technical Case

Technical Case

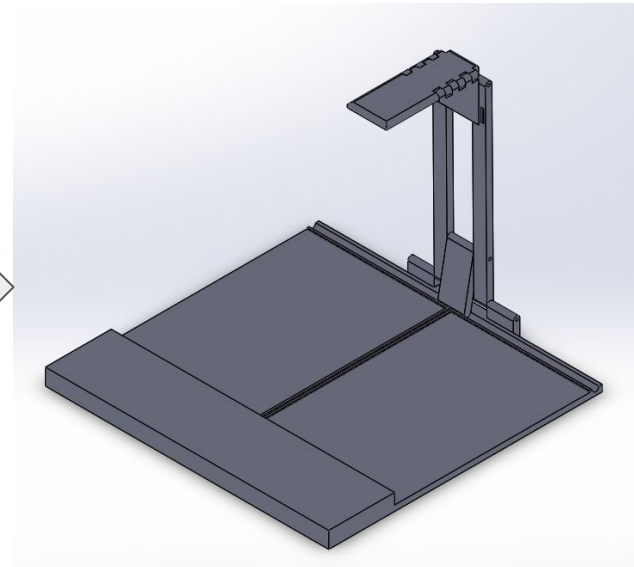
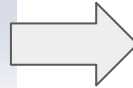
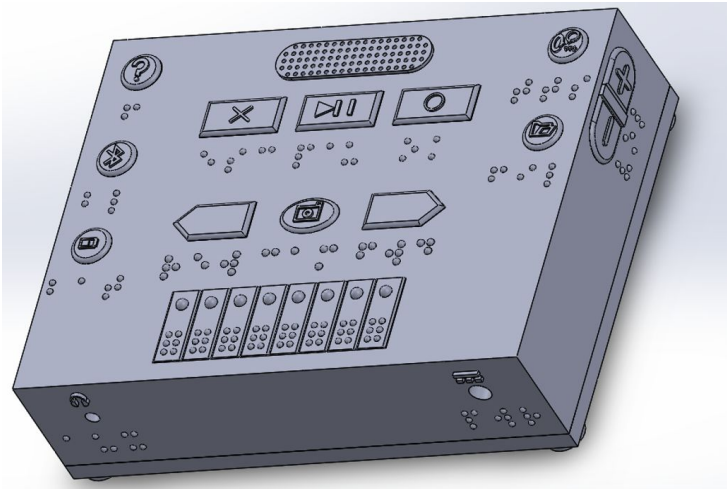


System Level Design

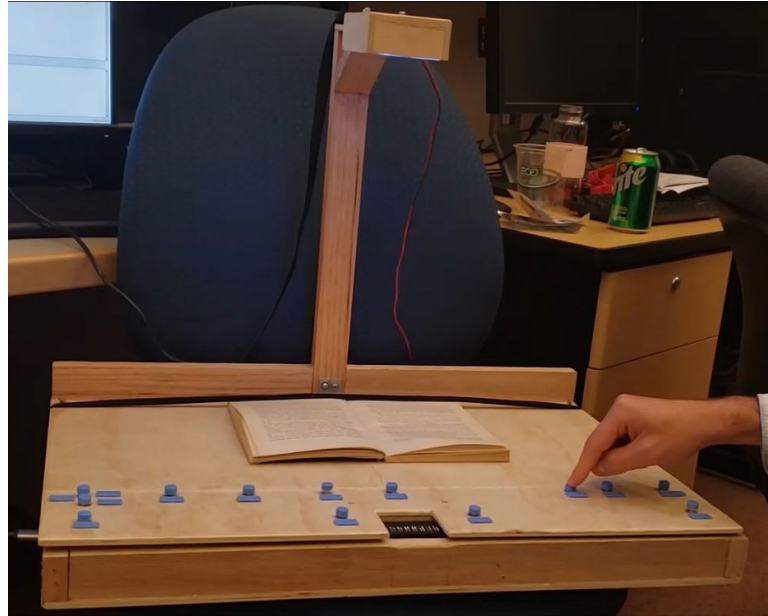
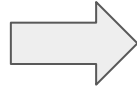


Hardware Design and Progress

- Major components includes camera, power circuit, processing unit, control panel and 8 refreshable braille cells
- From Photography Camera to Book Holder/Scanner with Camera Stand



Book Stand



Materials for Enclosure

- Wood - Stand
- Plastic - Wire Channels
- Nuts, bolts, washers and inserts - secure components and wiring
- Elastic band - secure book
- Polylactic Acid (PLA) - Braille labels and button caps



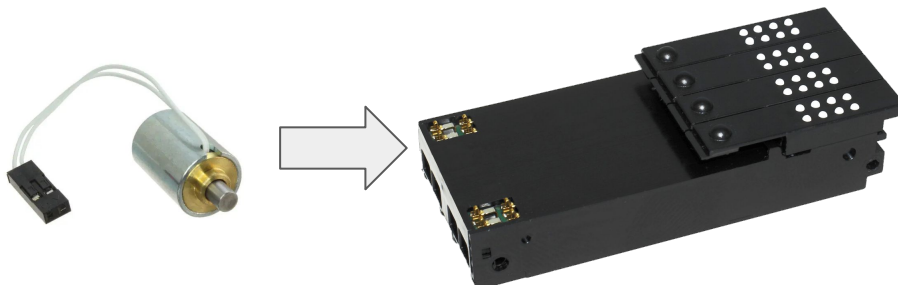


Selection of Components

- Camera
 - a. Raspberry Pi Camera (**5MP**)
 - b. Raspberry Pi High Quality Camera (**12MP**) with **manual focus** and **CS lens, 63 deg FOV**
 - c. Arducam Pivariety camera (**16MP**) with **autofocus, 80 deg FOV**



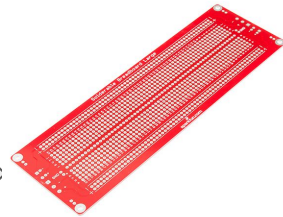
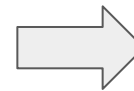
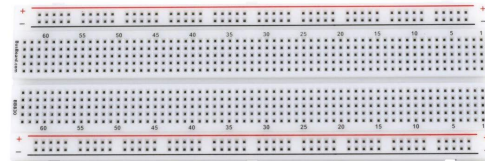
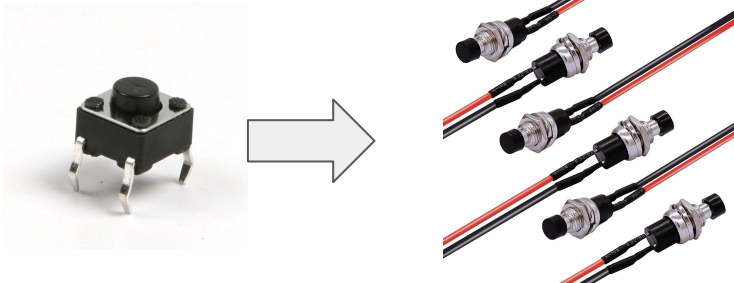
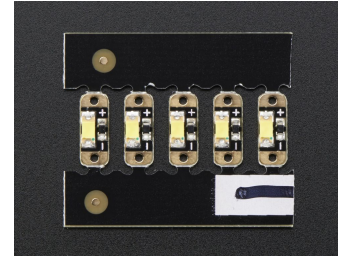
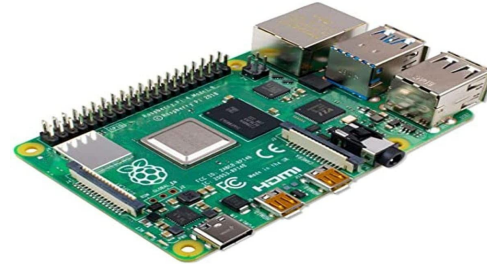
- Braille Output: **Solenoids** into professional **Braille Module**





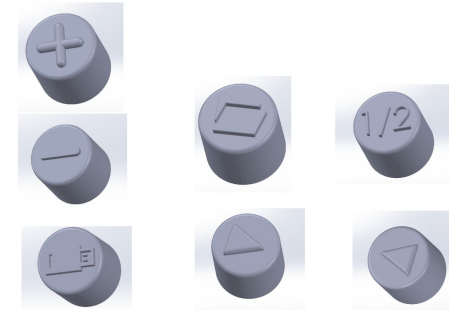
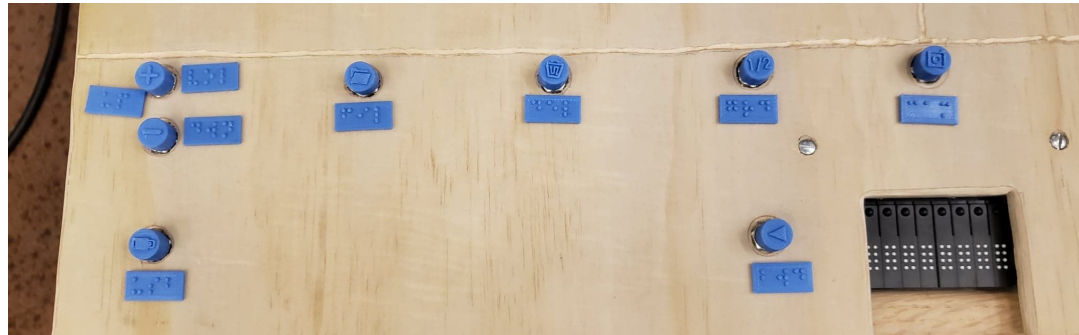
Processing Unit and Buttons

- Processing Unit: Raspberry Pi 4B
- 4 LEDs for Illumination
- Circuit: Breadboard to Solderable Protoboard
- Buttons: **Tactile Switches** to **Mini Push Buttons**
 - Easier to design caps for and to install



Button Caps and Braille Labels Close Up

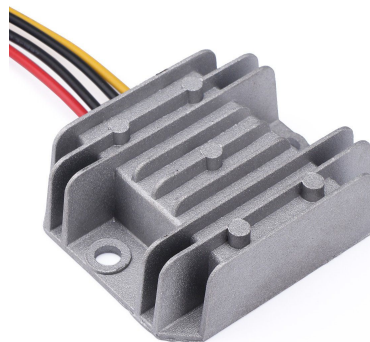
Button Caps and Braille Labels Close up



Hardware Design and Progress (Cont)

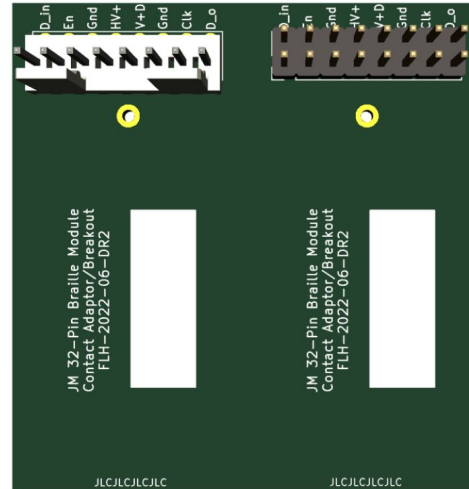
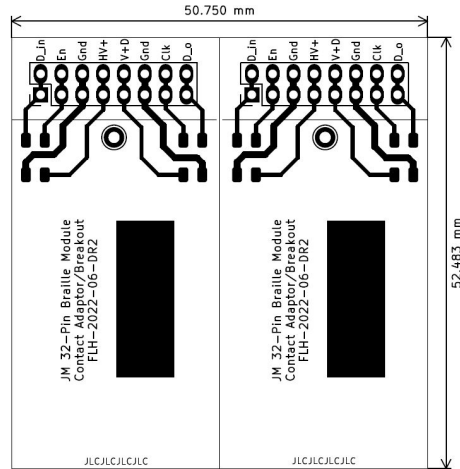
Power Circuit

- 12V to 200V Boost Converter
 - For Braille Module Piezoelectric Strips
 - Relay to Control Input
- 12V to 5V Regulator
 - For Raspberry Pi
- Rocker Switch
 - Main Power Switch



Hardware Design and Progress

Fred Heep created a PCB for the Braille Modules due to their pins



Software Design and Progress

All software is coded in Python

- Image Processing
- Optical Character Recognition
- Braille Module Programming
- Button/Algorithm Programming



Image Processing

- Process
 - RGB
 - Grayscale
 - Adaptive Histogram EQ.
 - Adaptive Thresholding

- Create
 - Images of words one by one (for multithreading)
 - Process concatenated images of words (for multithreading)
 - Single shot (whole page, single thread)
 - Accuracies comparable, single shot best ~%10 change.

Optical Character Recognition

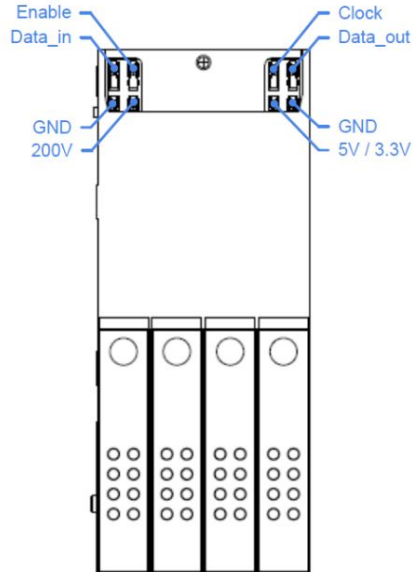
- Tesseract (Google-Apache License 2.0)
 - Accuracy: 65% - 97% (Levenshtein distance)
 - Whitelist characters and parse text in order to get rid of big errors
 - ML Speed: ~20 seconds
 - No detection test ~10 sec
 - Inverted page test ~10 sec
 - Total of ~40 sec

Algorithm

- Multithreading interfered with RPI clock
 - Wrong characters, locking defeats the purpose of multi threading
- Single thread word and sentence recognition took to long
 - User can access quickly but processing whole text takes time
- Single thread one shot processing (saved to filesystem)

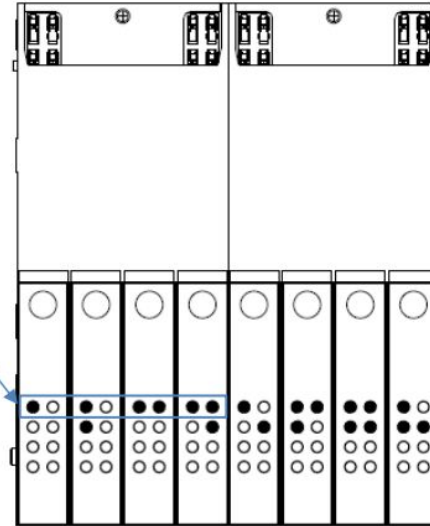
Braille Module Programming

- Synchronise with the clock
- letter encoding



last byte to shift

```
0b01010000
0b00000000
0b11011110
0b00000000
0b11111111
0b00000000
0b11111111
0b00000000
```



```
0b01000001
0b00000000
0b10010000
0b00000000
0b11111111
0b00000000
0b11111111
0b00000000
```

first byte to shift

Button Programming

- Hardware glitch (small random triggers) patched with software
- USB not implemented, re-purposed to Shutdown
- Delete Button Not implemented

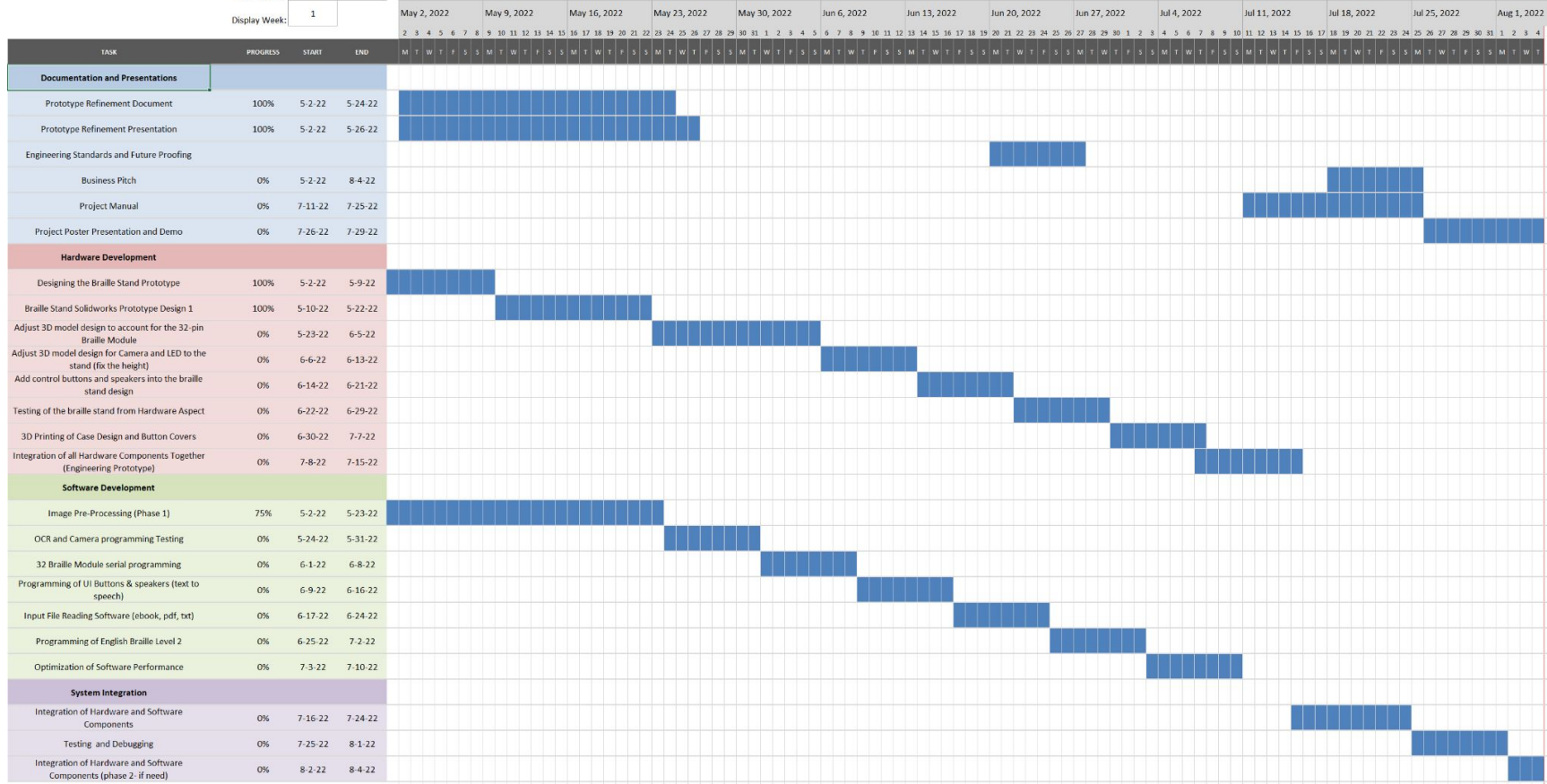


Cradle to Cradle

- Lots of the Nuts, Bolts, and Washers can be reused
- PLA, used for 3D prints, is environmentally friendly and can be recycled
- Wood can be composted or repurposed for other projects
- Wire Clamps and Wire channels can be used for other at-home wire/cable management

Gantt Chart - Start of ENSC 440

Project Start: Mon, 5-2-2022
 Display Week: 1

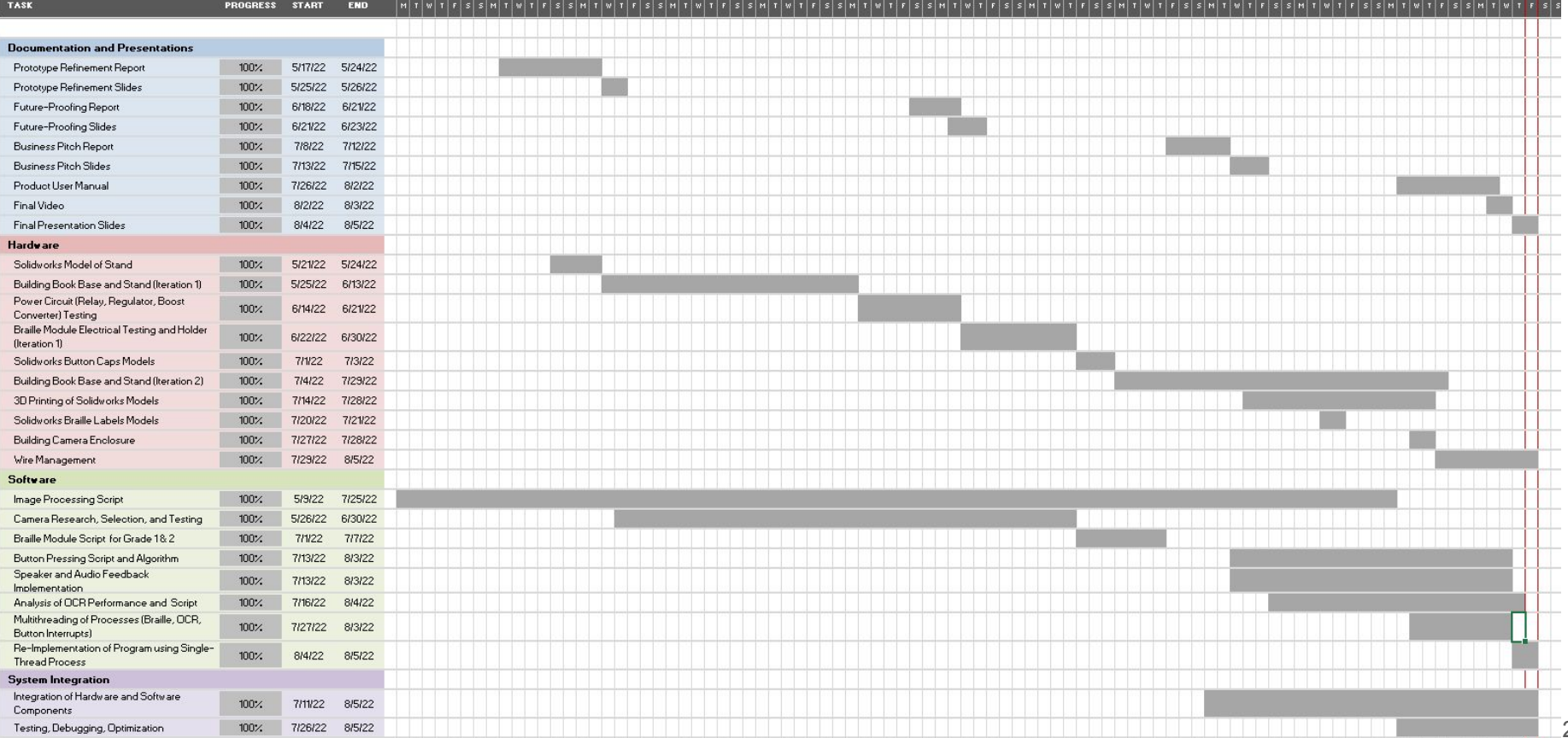


Gantt Chart - Actual Progress



Today: Fri, 8/5/2022
 Display Week: 1

May 9, 2022	May 16, 2022	May 23, 2022	May 30, 2022	Jun 6, 2022	Jun 13, 2022	Jun 20, 2022	Jun 27, 2022	Jul 4, 2022	Jul 11, 2022	Jul 18, 2022	Jul 25, 2022	Aug 1, 2022
3 9 10 11 12 13 14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31





Business Case / Costs

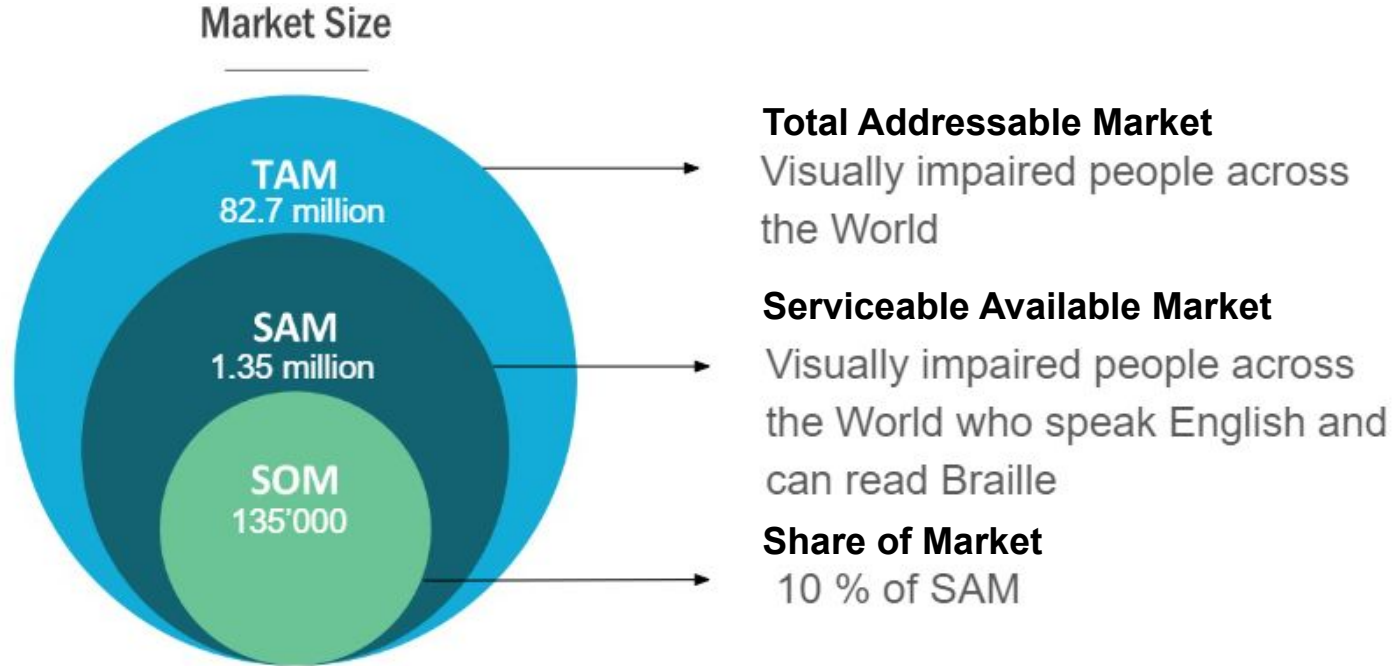
Business Case / Costs

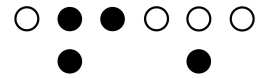
Ideal Customers

- General Schools and Libraries
 - Lots of schools care about **accessibility**.
 - Dedicated Reading Stations as not all books are digitized.
- At-Home Reader
 - Potentially those who have experience using Braille in school/library want to continue **reading books at home**.
- Dedicated Braille Teaching schools
 - Used as **teaching tool** in both physical book aspect and digital form e-books, especially for beginner students



Market - TAM, SAM, SOM



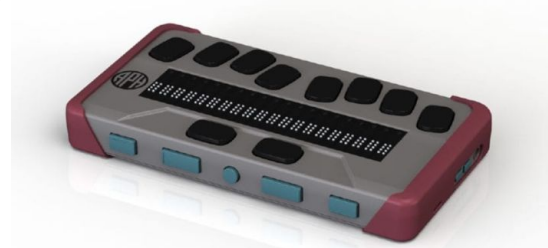


Competition

- 20 cells
 - Brailiant BI 20X braille display
 - 2,035.00 USD
 - Chameleon 20
 - 1,715.00 USD
 - Orbit Reader 20
 - 649.00 USD
- > 20 cells
 - \$3,500 - \$15,000



Humanware™



Costs of Current Prototype Materials

- ~\$1,000
- Note: Does **not** include 405W Expenses and components excluded from our current iteration.

Mechanical Parts			
Equipment	Brand	Model	Price (CAD)
1/4 inch x 2 Feet x 4 Feet Birch Plywood Handy Panel [5]	Alexandria Moulding	621644	27.28
1-inch x 2-inch x 4 Feet Red Oak Hardwood Hobby Board S4S x 3 [6]	Alexandria Moulding	00Q33-40048C	25.74
6-32-inch Hex Machine Nut - 18.8 Stainless Steel - UNC - 28pcs [7]	Paulin	848-216	2.97
#6-32 x 3/8-inch Flat Head Square Drive Steel Machine Screw, Zinc-Plated, 31pcs [8]	Paulin	846-650	2.97
1" Corner Brace, Zinc-Plated, 4pc x2 [9]	Everbilt	859-703	7.54
Wire Channel Non-metallic White [10]	Legrand Wiremold	NMW1	14.49
Hex Nut 1/4" X 35 [11]	Keystone Electronics	9902	2.11
Machine Screw Pan Phillips [12]	Keystone Electronics	9600	4.31
3/8-inch Cable Clamp Black x20 [13]	Paulin	400-524	8.2
Electrical Parts			
Female to Female Jumper Cable x 40 (20cm) [14]	PiShop	285	3.45
Male to Female Jumper Cable x 40 (20cm) [15]	PiShop	283	2.95
Raspberry Pi 4B Starter Kit, Pi 4B Memory Size: 4GB [176]	PiShop	K2B-1349-4GB	134.95
AC/DC Desktop Adapter 12V 60W [17]	Phihong USA	PSAC60W-120	25.34
32-Pin-Braille-Module x 2 [18]	Johnson Matthey	440003211A	432.3
Raspberry Pi Camera Cable 1m [19]	Adafruit Industries LLC	2143	5.46
CBL USB2.0 A RCPT TO A PLUG 3' x 2 [20]	Adam Tech	CA-USB-AM-AF-3FT	9.66
Panel Mount Stereo Audio Extension [21]	Adafruit Industries LLC	3319	5.46
Breadboard General Purpose Plated Through Hole x2 [22]	Sparkfun Electronics	PRT-12699	27.52
Camera Cable Joiner/Extender x2 [23]	PIMORONI LTD	8086-002	4.80
Barrel Connector 2.1MM Splitter [24]	Adafruit Industries LLC	1351	4.08
2.1_5VDC Barrel Jack to USB-C [25]	Adafruit Industries LLC	4536	7.61
Mini External USB Stereo Speaker [26]	Adafruit Industries LLC	3369	18.41
Grove SPDT Relay 30A [27]	Sparkfun Electronics	103020012	2.70
Grove Servo Branch Cables 5 Pack [28]	Seed Technology	110990057	7.47
Capacitor Tantalum 0.1 uF 10% 50V Radial [29]	Kyocera AVX Components	TAP104K050SCS	13.26
Heatsink 0.093" X 0.042" Black x 50 [30]	Alpha Wire	F2213/32 BK161	8.25
Arducam 16MP IMX298 ISP Camera Module [31]	Arducam	B0323	77.99
DC-DC Buck Converter 12V 24V to 5V 5A 25W [32]	DROK	90581	15.79
Wired Momentary Switch SPST NO x 18 [33]	TWTADE	PBS-110-X-BK	50.97
2.1x5.5mm DC Power Cable Jack Adapter Male + Female x 10 [34]	VCE	JT001AB-10P-CA	9.99
DC-DC Boost Converter 8-32V 12V to ±45V-390V [35]	Dpofirs	Dpofirs8wgnmv9y7h	19.20
TOTAL			\$ 983.22

Table A.1 - Gamma Prototype Variable Cost Breakdown

Financing

- Engineering Science Student Society Funding
 - Obtained \$1650 Cad

- Wighton Funding
 - Will apply at the end of 440



Mass Production Changes

Electrical

- PCB Fabrication
- 2 -> 5 Braille Modules (**8 cells to 20 cells**)
 - Justifies price of \$2,500,
- Costs of Typical Electrical Lab Equipment for testing, troubleshooting, for future products and maintenance

Mechanical

- Wood -> ABS **Mould Injection** for Enclosure and Buttons
- **Foldable Design**
- Costs of Machine Shop Equipment, 3D Printer for prototyping newer products and improving current design

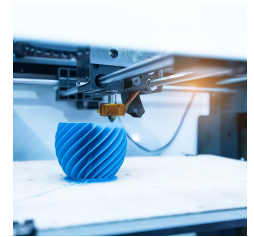
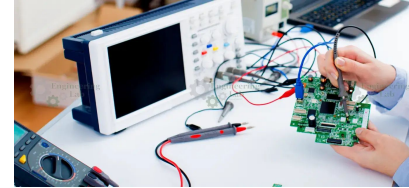
IP Protection and Licensing

- Trademarking
- OSHA Nationally Recognized Testing Laboratory (NRTL) Program Licensing for Electrical Standards

Payroll

- **5 of us** x 51,797 per year = \$258,985

Distributor



Mass Production Costs

Components cost less in bulk

Components	Cost to Produce 1,000 Units	
	Best Case	Worst Case
Mechanical Parts		
6-32-inch Hex Machine Nut - 18.8 Stainless Steel - UNC - 28pcs	2970	2970
#6-32 x 3/8-in Flat Head Square Drive Steel Machine Screw, Zinc-Plated, 31pcs	2970	2970
1" Corner Brace, Zinc-Plated, 4pc x2	7540	7540
HEX NUT 1/4" X 35	2110	2110
MACHINE SCREW PAN PHILLIPS	4310	4310
Electrical Parts		
Female to Female Jumper Cable x 40 (20cm)	3450	3450
Male to Female Jumper Cable x 40 (20cm)	2950	2950
Raspberry Pi 4B Starter Kit, Pi 4B Memory Size: 4GB	134950	134950
AC/DC Desktop Adapter 12V 60W	25340	25340
32-Pin-Braille-Module x 5	531205	1080750
Raspberry Pi Camera Cable 1m	5460	5460
CBL USB2.0 A RCPT TO A PLUG 3' x 2	5708.56	9660
Panel Mount Stereo Audio Extension	5460	5460
Breadboard General Purpose Plated Through Hole x 2	27520	27520
Camera Cable Joiner/Extender x 2	4800	4800
Barrel Connector 2.1MM Splitter	4080	4080
2.1 .5VDC Barrel Jack to USB-C	7610	7610
Mini External USB Stereo Speaker	18410	18410
Grove SPDT Relay 30A	2700	2700
Grove Servo Branch Cables 5 Pack	7470	7470
Capacitor Tantalum 0.1 uF 10% 50V Radial x 20	5278.2	13260
Heatshrink 0.093" X 0.042" Black x 50	6736	8250
Arducam 16MP IMX298 ISP Camera Module	77987	77987
DC-DC Buck Converter 12V 24V to 5V 5A 25W	15790	15790
Wired Momentary Switch SPST NO x 18	50970	50970
2.1x5.5mm DC Power Cable Jack Adapter Male and Female x 10	9990	9990
High Voltage DC-DC Boost Converter 8-32V 12V to ±45V-390V	19200	19200
TOTAL	\$ 992,964.76	\$ 1,536,757

Table A.2 - Mass Production Components Costs

Other Fixed Costs	Cost to Produce 1,000 Units	
	Best Case	Worst Case
Digital Multimeter, Fluke, 8846A 120V [40]	3171.64	3171.64
Laboratory Programmable Power Supply, GW Instek, GPS-3030D [41]	290.51	290.51
Oscilloscope, Rohde & Schwarz, RTC1000 [42]	13911.3	13911.3
3D Printer, Comgrow, Ender-3 Pro [43]	399	399
Soldering Iron, X-TRONIC [44]	69.8	69.8
Smoke Absorber, Kulander [45]	59.99	59.99
Drill Press, King Canada, KC-116FN [46]	579	579
Band Saw, Ryobi, BS904G [47]	148	148
Spindle Sander, Wen, AT6535 [48]	298	298
Nail Gun, Milwaukee Tool, 2746-20 [49]	399	399
Craft Rotary Tool, Dremel, 2050-15 [50]	69.98	69.98
NRTL License for Electrical Standards [ana4]	28820	43230
Distributor Fees	500000	1000000
PCB Manufacturing (Specific) [51]	2256.2916	2256.2916
Injection Moulding Material [52]	1421	1421
Injection Moulding Production [52]	1099	1099
Injection Moulding Tooling [52]	43900	43900
Patent Application [53]	203.59	407.18
Patent Maintenance, One more year [53]	50	100
Trademark [54]	335.93	335.93
TOTAL	\$ 597,482.03	\$ 1,112,145.6

Table A.3 - Mass Production Components Costs



Price

Each Mass Production Unit will be sold at 2,500\$. By selling 1,000 units....

- **Best Case Scenario**

- **285 Units** Must be Sold to Break Even
 - Cost \$1,590,446.79 for 1,000 units = **\$1,590 per unit**
 - Distributors worst case takes 20% of sell price
 - NRTL License can be up to ~28,000\$

$$\text{Best Case Break Even} = \frac{258,985}{2,500 - (992,964.76 + 597,482.03)/1000} = 284.739$$

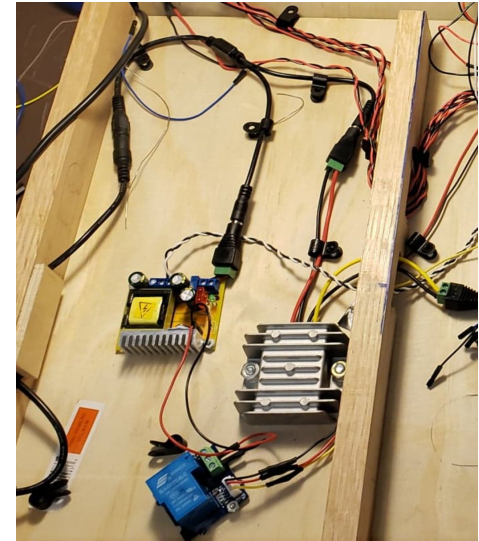
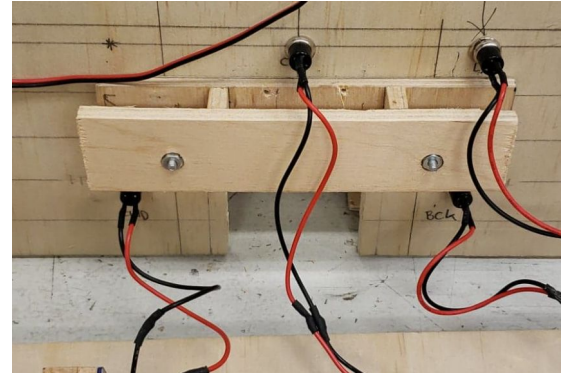
- **Worst Case Scenario**

- Calculation resulted in a **negative number**, -1739.27964, suggesting costs outweigh cell price
 - Cost \$2,648,903.60 for 1,000 units = **\$2,648 per unit**
 - Distributors worst case takes 40% of sell price
 - NRTL License can be up to ~43,000\$
- Possible Solution: Increase price to **at least \$2,700** per Unit

$$\text{Worst Case Break Even} = \frac{258,985}{2,500 - (1,536,757 + 1,112,146.60)/1000} = -1739.279641$$

Safety ,Risks and Hazards

- High Voltage risk (200 V DC) - Separated circuit in enclosure
- Braille module pins - Fred designed PCB for Braille module
- Movement of internal parts - Secured all internal components
- Book orientation - Solved using software



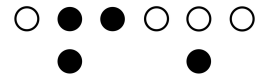
Business Risks

- Device has multiple components. These may be hard to source and gather
- High component cost e.g Camera and Braille modules
- Not meeting break even point in terms of sales.

Plan B if Commercialization Plan Fails

- Scale down, sell stand and braille device separately
- Invite public investors
- Mergers and acquisitions





Adherence to Standards

Adherence to Standards

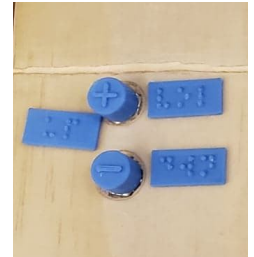
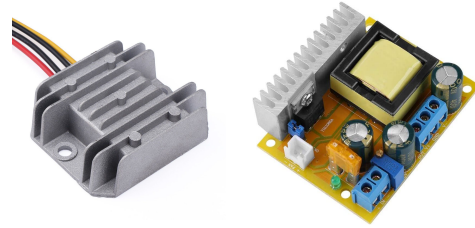
Standards Applied to Project

IEC 6038:2009 Standard Voltages

- **12V** is one of the standards DC input voltages - Used as AC Adapter Voltage Output
 - Raspberry Pi takes **5V** input - Voltage Regulator
 - Braille Module takes **200V** High Voltage - DC/DC Boost Converter Used

ISO 9241 Ergonomics of human-system interaction

- Part 210: Human-centered design for interactive systems
 - Provides Accessibility through Braille labels and raised decals, audio feedback
 - Survey feedback from 2 blind persons
- Part 500: Ergonomic Principles for the design and evaluation of interactive systems
 - Edges of enclosure are sanded and filetted



Incorporated Feedback from the Course and Meetings

- Book securing structure implemented - elastic band
- Separating power circuit from signal processing circuit
- Meeting Braille Standards and Form factor
- Fixing Camera to a proper height with LED as light source.
- Read the previous page/ file after shutting down the device

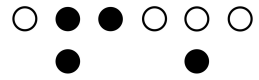
What We Would Do Differently

- Manage time wisely
- Constrained the type of input(physical medium) to a certain standard
- Start testing earlier and gather data about the accuracy
- Integrate modules earlier to see if they clash (multiprocessing and braille module)
- Don't buy online, buy local
- Come up with a realistic design from ENSC 405 W and polish the product further in ENSC 440

What We Learned

- Machine Shop skills
- Project Planning: Better component choices
- Implement class related skills: Electrical and Software.
- Soft skills such as communication and teamwork





Conclusion



Project Summary

Brailingo

- Braille Solution with integrated book scanner/system for visually impaired
- Provides easy use through audio feedback, and braille labels
- Book scanning is guided through physical grooves and a book strap

Future Plans

More Prototyping...

- Custom **PCB for entire system** (DC converter, regulator, buttons, Braille modules)
- Adding **circuit protection** (fuses, overcurrent protection)
- Use more **powerful hardware** for computing (image processing, OCR)
- More **testing of smaller text sizes** (eg. business cards, sizes smaller than A5)
- Further development of **File System**, Storage/Saving/Deletion, USB input
- Addition of **Braille-only feedback** (without audio)
- Construction of stand with **lighter material** (e.g. plastic).
- Work on **foldable** stand
- New design that allows **compatibility with external Refreshable Braille devices**.
 - Design Control Panel to be detachable and rechargeable.
- Create **new button caps** and braille labels for shutdown button

Get more feedback from Blind Community

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Thank you!

Questions, Feedback, Comments?