Creative Music Production

Professional Project

Céin O’Dowd

The Drone Machine. Creating an Intuitive and Portable Digital Instrument for Use in Traditional Music. Can The Two Be Fused?

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Supervisor: Conor Brennan

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Abstract

The Drone Machine, Can modern synthesis and hardware be useful in a traditional music environment? This project investigates this question by designing and developing a synthesiser for use within the context of traditional Irish music. To create this instrument the Bela Board Mini embedded computing platform and the visual audio programming language Pure Data were used. Force sensitive resistors are the input method for this instrument as they allow the user to modulate the instrument depending on how hard they press the keys, in this case it is used to change the volume of each note. Sonic inspiration for this instrument is taken from the uilleann pipes, harmonium and shruti box.

This paper is broken up into multiple sections outlining the different stages of developing The Drone Machine. The first stage documented is the designing and concept development stage which goes into detail on why the choices for physical layout and sounds of the instrument were made. The hardware and software development is also documented in detail with all of the software laid out and its signal flow explained. The circuit designed to input the force sensing resistors into the Bela Board is also documented in detail with circuit diagrams and explanations.

After the instrument was completed a survey was put out to figure out the market potential of this instrument and see if people would be willing to use it in a traditional setting. From this survey final thoughts and conclusions are drawn.

A short demo video was created to show key features of The Drone Machine which can be found in appendix i. A link to the iterations of software from this project is also linked in this appendix

Introduction

Outline

This project aims to create an intuitive and portable synthesiser for use within the context of Irish traditional and folk music. Throughout the project design phases, software development, hardware development and use various cases will be explored. The end goal of this project is to have a synthesiser that is intuitive, simple to play and fits in aesthetically with other traditional instruments.

With traditional Irish music returning to the spotlight and experimental artists taking advantage of new sounds within the genre, a synthesiser designed specifically for traditional music would be useful. It could bridge the gap between traditional music and modern electronic music. The instrument is intended to be easier to use than other drone instruments, making playing traditional music more accessible.

"Pure Data[1]" and the "Bela Board Mini[2]" will be used to develop the software and hardware in this project. This program and board were used as they integrate well together and are designed specifically for audio.

Literature Review

The literature review will discuss references and the impact they had on this study. References include academic journals, web articles and Youtube videos. This will assist in researching ways to create instruments using different microcontrollers and show design choices made by other instrument builders.

Methodology

The methodology chapter discusses the justification for design choices made throughout. The logistics of creating this project will be documented; discussing in detail the software design, circuit design, integration with the Bela board and why choices were made due to limitations of the hardware used.

Analysis

This chapter aims to analyse the final project and point out any observations made along the way. Survey results about the final project are contained within as well as examinations of the sonic output and thoughts on features that could have been implemented differently

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[1] Pure Data is an open source visual programming language used for creating music related software

[2] The Bela Board mini is an embedded computing platform with 8 analogue inputs and 16 digital input/outputs and 2 audio output channels that can be used to run programs developed in a range of softwares.

Discussion

This chapter aims to point out issues that were encountered during this project along with giving thoughts on how the project worked, succeeded and failed to meet its goals. Knowledge gained from the project along with any interesting information will also be documented

Conclusion

The conclusion chapter features final thoughts on the project and summarise the success and failures of the overall project. Future plans for the project are also discussed.

Appendix

Materials referenced in the project and relevant to the project. This will include development notebooks, code and pictures of different parts of the project as it is being assembled.

Bibliography

A list of all material referenced using MLA referencing system.

Literature Review

The literature review will discuss references and the impact they had on this study. References include academic journals, web articles and Youtube videos. This will assist in researching ways to create instruments using different microcontrollers and creating video using ai and generative systems.

Lankum. “The Livelong Day.” John "Spud" Murphy, Guerilla Sound Studios, Meadow, Dublin, Ireland.

The Livelong Day is a 2019 album by the band Lankum that played a strong part in repopularising Irish traditional music. The album features frequent use of drones and long sustained notes on the uilleann pipes, concertina and harmonium.

This album has served as the inspiration for this project as it sparked an interest in drone related music. It will also be useful as a tonal reference for designing the sounds of the synthesiser as it features drones from multiple instruments that are prominent throughout.

31/03/2023, Vicar Street, Dublin. Ye Vagabonds.

Though citing a concert may be unorthodox, this concert is relevant to this project. Ye Vagabonds are an Irish traditional duo that play live with a full band. On the 31st of March 2023 they played at Vicar Street, Dublin.

This event was relevant as they had a synth player present for the gig who maintained drones throughout the songs. This really filled out the low end and shook the room. The concert served as proof of the concept that traditional music can be mixed to good effect with synthesisers.

Moro, Giulio & Bin, S. & Jack, Robert & Heinrichs, Christian & Mcpherson, Andrew. (2016). Making High-Performance Embedded Instruments with Bela and Pure Data.

This paper discusses using the Bela microcontroller board developed by the Augmented Instruments Laboratory at Queen Mary’s University, London with audio programming software Pure Data. Integration with the Bela Board, code optimisation and using external sensors and triggers are discussed.

The authors of this paper set out to educate readers on using the Bela Board and provide a detailed report as to how it works with Pure Data. Instructions are given on various ways to process incoming censor data in order to help get a clean signal as well as how to create clean and efficient code which will run software with minimal latency. This paper is very clear and concise. The use of images to demonstrate the processes described helps to develop a clear understanding of the authors subject matter.

This paper is highly relevant to this project as the Bela Board is a new and exciting way to create musical instruments and effects. It could also be used to design an instrument that provides a unique workflow, along with new ways of expressing different musical ideas.

Gustafsson, Gabriel Vincent Karl, et al. "Kuplen: A Hands-on Physical Model." *Zenodo*, 24 May 2022, https://zenodo.org/record/6576907#.Y4YXTezP0-R.

This paper documents the creation of a digital musical instrument using the aforementioned Bela Board. It demonstrates the process of creating the "Kuplen" and various player reactions to the instrument.

The Kulpen is a novel performance instrument that uses sensors to adjust parameters in a physical modelling synth on the Bela Board. The instrument is constructed from an acrylic dome which is threaded with copper wire connected to capacitive sensors and attached to a disk with elastic, allowing it to move on multiple axes. The software for the synth is run on a Bela Board. The Bela Board works well for this due to its low latency and ability to accept external control signals.

The authors of this paper are Masters students at the Aalborg University in Copenhagen. All of the research in this paper is well explained and the citations have proven useful for other references.

This paper is extremely relevant to this project as it achieves the same goal of creating an experimental musical instrument while documenting the process concisely. It also showcases the Bela Board's flexibility and functions.

Cook, Perry. "Principles for Designing Computer Music Controllers" *Nime*, Nime, 2001, https://www.nime.org/proceedings/2001/nime2001_003.pdf.

This paper discusses the design of experimental interactive music controllers and demonstrates different types of contemporary controllers.

This source gives an outline of multiple computer music controllers and how they are interacted with. The author has provided images of said controllers and gives a brief description on each. This has proven useful to investigate how other makers have developed controllers that experiment with different input methods and sensors to give the user a new and often intuitive way to interact with a musical instrument.

This source could be considered dated as it is from a 2001 conference and with the rapid evolution of computer[3] music and controllers the landscape is very different today. The core principles and key points of this source however still remain valid.

[3] In this context computer music refers to generative and experimental music creation systems rather than digitally created music.

This text has proven to be invaluable as a source of inspiration for this project as it shows the near limitless creative potential granted by attaching sensors and buttons to objects to create new interactive experiences

"The International Conference on New Interfaces for Musical Expression." *NIME*, Nime, https://www.nime.org/.

This website showcases systems and instruments demonstrated at the International Conference on New Instruments for Musical Expression events. It is a useful resource as it documents many experimental instrument builds.

This website is useful with regard to this project as a general inspiration with talks demonstrating how interactive systems are created. As well as that, it provides examples of instruments that experiment with physical form and use unorthodox control layouts.

Moylen, Terry. "A Short History of the Uilleann Pipes." History Ireland, vol. 26, no. 4, July 2018.

In this extract the author documents the history of the uilleann pipes, giving interesting details on where they came from and their use cases over time.

This article is constructed well and conveys the information needed well, however, it doesn't go into much technical and sonic detail about the instrument other than its brief descriptions.

This project uses the information provided in this article to build a better understanding of the uilleann pipes and how they work to help apply their sound to a digital instrument.

"The Platform for Beautiful Interaction." *Bela*, https://bela.io/.

This source is the official Bela Board website. It features technical specifications on the product along with usage guides, projects created using the platform and information about integration with hardware.

The site is well constructed and easy to navigate with the most relevant information being easy to find. This is probably helped by the board being designed as an educational product before being a commercial product.

As it was decided that the Bela Board should be the base of this project, their official website is of great importance. It contains numerous examples on how to integrate the board with hardware along with software integration information and troubleshooting methods.

“FILTERS? Build a Simple DIY Passive Electronic Low Pass Filter.” *YouTube*, 8 Feb. 2017, https://www.youtube.com/watch?v=Ch9w5JtbZSc&t=194s.

This source shows how to build a passive tone filter that removes the high frequencies from a signal when adjusted. The video was published on the channel Look Mum No Computer which creates tutorials for building synthesisers and builds weird over the top instruments.

Unfortunately this reference, while useful for learning the concepts involved in creating a low pass filter, is let down by the poor diagram showing how the filter is wired that makes it hard to tell what wires need to go where. This meant the source was of little use to this project. This is in stark contrast to other videos on the channel which have been immensely helpful in other projects.

Methodology

This chapter discusses the justification for design choices made throughout the project. The logistics of creation will be documented; discussing in detail the software design, circuit design, integration with the Bela Board and the reasons as to why certain choices were made due to the limitations of the hardware used. This chapter is broken up into multiple sections: Initial Planning, Design Development, Software and Integration, A Deeper Dive into Code and Signal Flow, Hardware Development and End Product Naming and Marketing.

Initial planning

The first part of this project was deciding what the synthesiser would be used for, how it would be engaged with and what physical form it would take. Different instruments used in a traditional setting were investigated and the main inspirations are documented below:

The uilleann pipes are an Irish traditional instrument similar to the bagpipes but rather than the user blowing in into them the wind comes from bellows held under their arm. These are generally set to play in one key (D) and feature a drone section that can be held under the melody notes being played. In terms of timbre the uilleann pipes are sharp sounding with the drone being harsh sounding but still carrying low end.

The harmonium is a small pump organ inflated using bellows and played on a keyboard similar to a pianos. They often have 3 registers with one being an octave above and another an octave below the root note. While the harmonium is not a drone instrument it is becoming semi common as a drone instrument within Irish traditional music with a single note being held and modulated in volume by the bellows. The concept of 3 registers was taken from this instrument and applied to this project. Sonically the harmonium is less harsh than the uilleann pipes but still has some harsh harmonics

The Bass concertina is a variation of the standard concertina which is a reed instrument controlled by pushing air through a set of reeds using bellows. Air is let through the reeds by pushing in buttons that open the flow of air. The bass concertina has a harsh bite to it and can be hard to hear the low end without being amplified.

The shruti box is an Indian drone instrument capable of playing only one note at a time. The note being played is set by moving a piece physically stopping the air off to the side. The shruti box sounds similar to the harmonium but without the extra registers and is purely for drones.

For the input method of the instrument multiple options were considered. Touch strips that complete a circuit when touched were considered at first but wouldn't allow for velocity sensitivity and would provide little benefit over using a normal push button to trigger the synthesiser.. Force sensitive resistors were chosen as the final option as they can sense the pressure the user places on them which can be used to control parameters within the software and make the instrument more expressive to the player. The pressure sensing range of the force sensing resistors used is 30g-1000g(see appendix b.1) and provides a nice linear volume increase when pressed.

Design Development

After initial research the development of this project began by taking the instruments investigated and sketching out rough design ideas in a notebook (see appendix a). Using a notebook helped make it quick and easy to draw up concepts and ideas, seeing something physical on a page made it easier to imagine how it would turn out when built rather than looking at a computer. From the notebook two main design ideas were considered. One was a design whereby it was in a box of a similar size to the harmonium and would use force sensitive keys to play notes with a drone section and a melody section played with each hand. Another was shaped more like a hybrid between the uilleann pipes and the banjo, with a drone section at the bottom of the instrument, sitting on the players lap. The melody section then would be in a similar position to the chanter on a set of uilleann pipes. This design would have required a novel fingering pattern similar to the uilleann pipes but with four buttons for eight notes. Both of these designs would have required a learning curve for the player and would have limited the use of volume and tone controls due to the requirement of two hands to play.

Fig.1, Final instrument layout

The final design (fig.1) for the synthesiser uses eight force sensitive keys to play notes across one octave. The keys are laid out in a staggered pattern and every key can be reached with one hand. It also features a volume control, tone control and three toggle switches to engage different registers on the synth. This design, while limited in the melody playing ability, allows the user more expression with the ability to modulate volume, tone and octaves while keeping one hand on the keys. The inspiration for this design layout was the button pattern from the concertina (though the notes ascend in this design rather than being arranged in harmonies like the concertina) along with the multiple registers of the harmonium. The enclosure for this design uses an antique Fry's chocolate box and is reminiscent of cigar box guitars[4]. This

[4] Cigar box guitars are typically homemade guitars created using old wooden cigar boxes as a base. They are popular in blues, bluegrass and country music and generally played in open tunings with a slide.

enclosure design is meant to give the synthesiser a familiar and old-timey feel that will help it fit in with more traditional instruments.

Software and Integration

After deciding on input methods and design, a basic prototype was made in Pure Data to test the response of the force sensitive resistor. This was done by attaching a FSR[5] to a breadboard[6] and testing it with a simple oscillator[7] running on the Bela Board to make sure the circuit worked and had the correct response by printing the readings coming off of the resistor (see appendix c.1, d.1). After this was tested and worked the development in Pure Data began

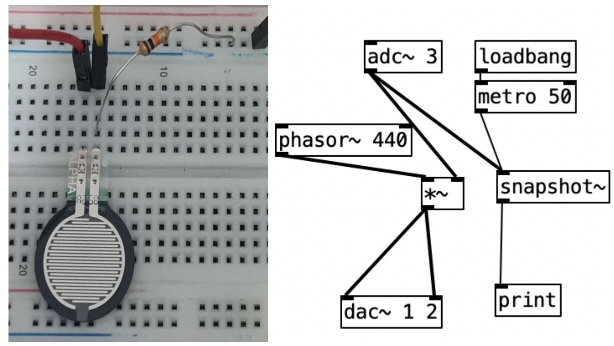

Fig.2, FSR testing

The first iteration of the synthesiser that was built in Pure Data used wavetable[8] synthesis (fig.3) to recreate a tone similar to the uilleann pipes/harmonium. This version of the synthesiser featured more powerful synthesis techniques and an interface for tweaking within Pure Data which also contained a cutoff filter and the ability to change the key. This version was tested with a single voice on the Bela Board and functioned as expected but it unfortunately failed when any more oscillators were added. This was possibly due to the limitations of the Bela Boards processing power, having to read from a table for multiple oscillators or due to an error in communication between Pure Data and the Bela Board.

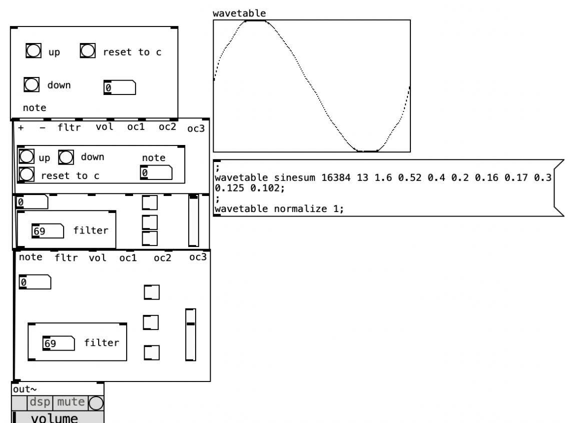

Fig.3, Wavetable synthesiser

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[5] FSR will be used from this point on as a shorthand for force sensitive resistor.
[6] A breadboard is a prototyping circuit board that parts can be easily added and removed from.
[7] An oscillator in this context generates an audible audio wave.
[8] Wavetable synthesis involves storing a set of numbers on a table that can

After the failed wavetable synthesis the program had to be optimised in Pure Data in order to achieve maximum efficiency on the Bela Board. To do this all of the GUI[9] elements of the code were removed as it was only necessary for testing in Pure Data and wouldn't be used by the Bela Board. The Moog[10] style filter was also replaced with a static low pass[11] filter as the Bela Board couldn't accommodate the extra input which would have been required for control. The pitch shifting system was also removed as it caused a stack overflow[12]

After this simplification of the code was completed, the oscillators were switched out from wavetable based to standard types of oscillator. Replacing the wavetable oscillators was a big set back as it was easier to use a wavetable to create custom sounds for the synthesiser that mimicked the instruments it was trying to replicate. To make up for this downfall different oscillator arrangements were experimented with and fine tuned. The final oscillator arrangement was a sine wave for the low register, a sawtooth for the base note, and sine again for the high register. This arrangement of oscillators approximates the sound of a harmonium/uilleann pipes. After the oscillator types were decided on, fine tuning was required to make the amplitudes sound right between the oscillators, as the sawtooth oscillator sounded much louder due to having more harmonic content. A good balance appeared to be multiplying the volume of the sawtooth oscillator by .7 to bring it down and match the others. Filtering was also adjusted to make the synthesiser sound less harsh. The cutoff for this filter was experimented with at 1000-5000 hertz with 3000 hertz being settled on as a final cutoff frequency for each set of oscillators. A hi pass[13] filter was also applied to the high register to give it a more pleasing tone, the high register also skips the low pass filter at 3000 hz. A second lowpass filter was then applied to the output to remove any unwanted digital noise. This cutoff sounds slightly harsh but with the addition of a tone knob it can be tamed, resulting in a more varied output being possible. As the Bela Board can't run directly from Pure Data, each change had to be made by iterating rather than in real time, with each change being loaded onto the board for testing.

Once the final code was completed the Bela IDE[14] was used to set the software to run when the Bela Board is connected to power rather than needing to be loaded from a computer every time it restarts. Once the software set to run by default the program was left running for an elongated period of time to make sure it would crash and use cases were tested such as pressing every key at once and changing all of the toggle switches at once, luckily no new issues arose from this testing.

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[9] GUI refers to a graphical user interface
[10] Moog are a synthesiser brand that pioneered the methods of analogue synthesis we know today, they had a unique cutoff filter at the time called the ladder filter that is still used to this day.
[11] A low pass filter is a filter that cuts off high frequency audio from a certain point.
[12] A stack overflow is a programming error generally caused by the program running out of memory due to a coding error.
[13] A hi pass filter cuts audio frequencies below a certain point.
[14] IDE refers to integrated development environment and lets users of a piece of hardware/software make changes to the program.

A Deeper Dive into Code and Signal Flow

In this section we will follow the signal flow of the final code (fig. 4, appendix d.3) used

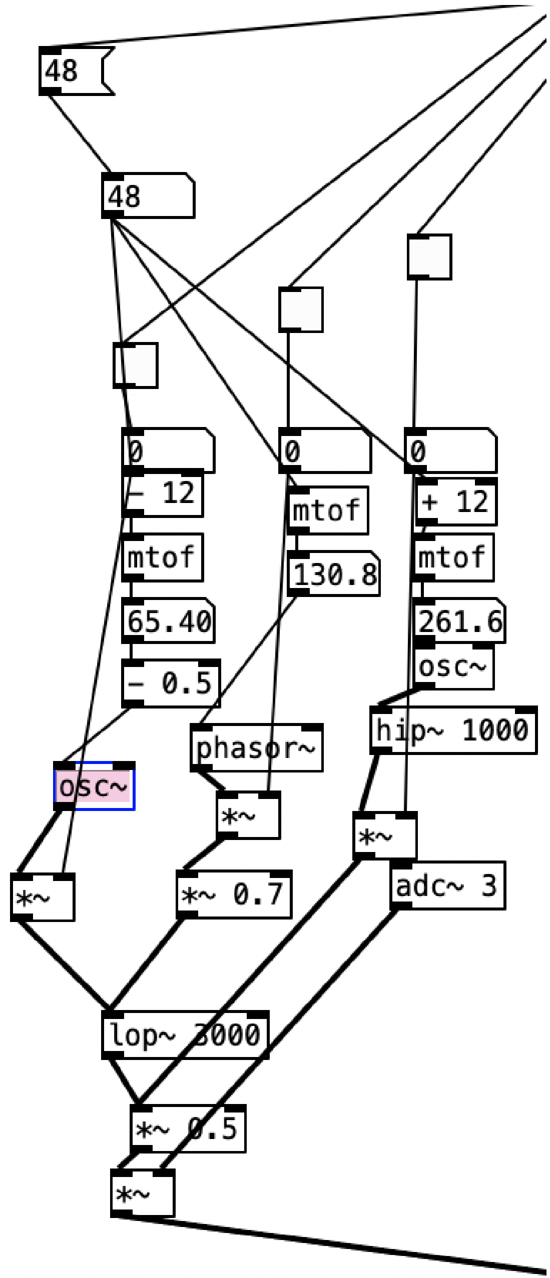

Fig.4, code from a signle set of oscillators

First a midi[15] note is set using a message box, in this case it is 48. From the message box the note is sent to each oscillator in the package (oscillators are handled in groups of 3 for lower, standard and high registers). To change the pitch of each oscillator, -12 and +12 are applied to the lower and higher registers respectively. This makes them each an octave apart from the main register.

The midi notes are then converted into frequencies using the [mtof][16] function as the oscillators require hz values. Note 0.5 is subtracted from the lower register to slightly detune it, this value is slightly different on each set of oscillators to create a slightly out of tune effect as is found on analogue instruments.

From the oscillators the values go into a [*~][17] function which multiplies the value by another input. In this case the values are multiplied by a toggle switch that is set to either 0 or 1 with 0 turning the sound from each oscillator off. After this the sawtooth oscillator [phasor~][18] is multiplied by .7 to match its volume with the other registrars and the high registar goes through a hi pass filter to remove its low end. The main and the lower register then go into a low pass filter before ending up at [*~.5] along with the high register to reduce the chance of clipping[19]. From here there is another [*~] that is connected to a force sensitive resistor to control the volume of the group of oscillators for playing notes. Finally (not pictured) the set of oscillators goes to [*~ .4] along with the other oscillators to stop clipping and exits the board.

[15] Midi is a term for values assigned to individual musical notes that is standardised between all music software e.g midi note 48= c2
[16] [mtof] is a Pure Data function that changes midi to frequency
[17] [*~] multiplies the volume of one signal by another
[18] [phasor~] is a function that creates a sawtooth oscillator in Pure Data
[19] Clipping refers to an audio signal distorting due to surpassing the maximum output level

Hardware Development

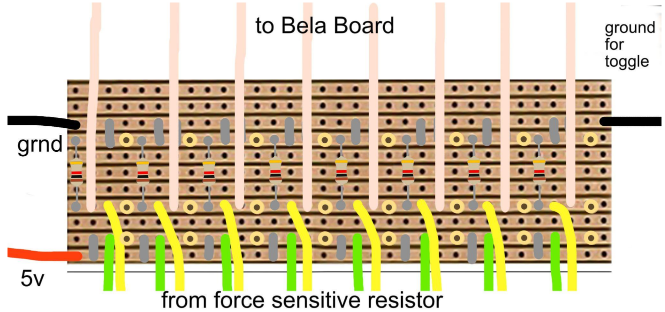

Fig.5, stripboard layout

To run the software on the Bela Board with analogue inputs and digital io[20], the hardware used had to be connected to the Bela Board. This was done by creating a stripboard[21] to keep the wiring clean and less prone to problems. To design the stripboard the breadboard (fig.5) layout was copied and repeated eight times. The use of the strip board helped to keep mess down and made spotting issues easier as the signal flow could be checked with a multimeter to ensure power was going to the correct places. The breadboard also included the ground for the toggle switches which were wired off the board as they only needed 3.3v power, ground and a cable going to the Bela Board.

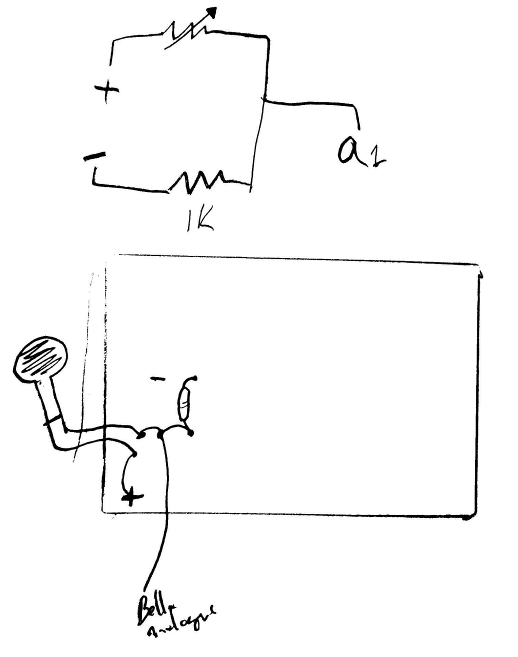

Fig.6, circuit diagram for force sensitive resistors

A 1k pull down resistor was used on the force sensitive resistors to make sure the value stayed at 0 when they are not being pressed. The toggle switches are spdt[22] toggle switches which cut the signal going to the Bela Board when in their off position turning off the relative oscillator.

A fourth toggle switch was also added that bridges the input and output of the root note force sensor and provides a constant drone letting the user free their hand for controlling other parameters. A 1.5k ohm resistor was also added in series with the toggle to match the output of regular pressing of the key.

Throughout the hardware development each stage was tested with the Bela Board to ensure everything ran as expected and also checked with a multimeter to ensure there were no faulty connections of dry solder joints.

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[20] Digital IO refers to the digital inputs and outputs on the bella board that can be set to 1 or 0 for on and off.

[21] A stripboard is a prototyping circuit board with copper traces that can be cut and bridged to send signals where necessary.

[22] Spdt refers to single pole double throw toggle switches.

Due to running out of analogue inputs on the Bela Board an external volume and tone potentiometer were added to add further control to the synthesiser. Having a software control for volume and tone would have been optimal. After the signal comes out of the Bela Board it runs into a potentiometer and then through an rc filter[23] potentiometer.

The stripboard is mounted to the enclosure using standoff screws to keep it elevated from the enclosure. The Bela Board is much less lucky as it is being held in place with double sided tape due to its lack of mounting holes.

The final inputs and outputs for the board are a micro usb connector for power delivery/reprogramming and a monophonic ¼ inch output for audio to be sent to an amplifier/effects pedals.

End Product Naming and Promotional Material

Fig.7, Promotional poster

After the physical and programming aspects of this project were completed the next step was deciding on a name for the instrument crested. Upon reflecting on the purpose of the synthesiser the name "The Drone Machine" was decided on as it gets the point of the synthesiser across straight away. It is self-explanatory to those who are familiar with the drone feature of Traditional Irish Music. For those not in the know, it could be mistaken for flying drones, but given that this device produces tones which are low but can also soar, it is a fun word play.

[23] Rc filter refers to a lowpass filter made up of a resistor and a capacitor, this is a very simple form of filter.

Analysis

This chapter aims to reflect upon the project and analyse in detail the outcomes. Surveying, audio analysis and development critique have been used to break this project down in this chapter.

In order to assess interest in this kind of instrument a survey was conducted via Google Forms. There were twenty one respondents to the survey. Realistically the survey was intended to be taken by musicians, alas, one participant was not. When asked about whether or not they played Traditional Irish Music, 61.9% were in the negative, 39.1% in the positive. Following this, interest in the kind of device being constructed was explored, with 81% saying they would in fact be interested in this instrument. When questioned about which features would be of the most importance to them, the main concerns were adjustability and control with regard to filtering, tone, pressure sensitivity and the ability to add effects. An image of The Drone Machine was shown to the respondents and when asked about their interest in the machine and their reasons as to why, the overall response was positive. The design was complimented for aesthetic appeal, touch sensitive keys and a genuine curiosity was expressed regarding the tone and different sounds such a device could produce. One respondent was very insightful, saying:

“Yes. Traditional design mixed with new technology allows for new possibilities without compromising on authenticity” (appendix g.1, response 11)

The results of this survey demonstrate an interest in The Drone Machine and its various capabilities with regard to the fusion of features of Traditional Irish Music and modern technology and sounds.

Regarding the device itself in terms of performance, it achieves the main goal of producing a drone sound effect whilst being expressive and dynamic. It has multiple registers and an overall pleasant tone which can blend seamlessly with the acoustic flavours of Traditional Irish Music.

It is of compact construction, fitting into a backpack, meaning it meets the goal of portability, and is as light as the box of chocolates from which the case derives its construction. The case itself has an old fashioned appeal, being from turn of the century advertising and featuring a warm colour palette. It does not look shiny and new, as it really is in the inside and in terms of its technological aspect, but instead seems quaint and familiar, something we might find in our grandparents house.

In terms of the physical interactions with the board and its inputs and outputs, the final synthesiser features eight force sensitive resistors which each correspond to a given note in the preset key. These resistors sense the pressure placed on them and use it to change the volume of the note being pressed. The device also has three toggle switches used to turn on and off three registers of the synthesiser with the furthest left being for the sub octave, the middle for the main octave and the right controlling the high octave. There is also a toggle near the root note[24] that turns on a constant drone for that note which then allows their hands to be free to use other controls.

The synthesiser also features an analogue volume and tone control that can be used to set a desired tone and output level or to modulate the tone of the instrument while playing it. The IO[25] on the device includes a monophonic ¼ inch output jack for connecting to amplifiers/pedals. It also has a micro usb connector that can be used to power the device and upload new code to it. A monophonic output was chosen so that the device will have better capabilities when it comes to connecting to amplifiers and pedal boards. Had we used a stereo output it would have made the device compatible with headphones, but this solo listening experience is not in tune with the shared experience that is a key feature of Traditional Irish Music.

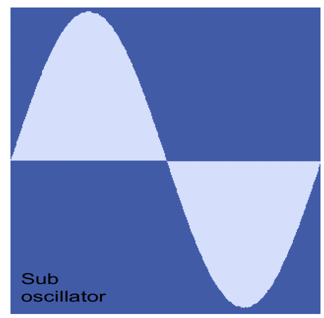

Fig.8, Low Register

Analysing the audio from the synthesiser we can see that the low (fig.1) and high (fig.3) registers are both sine waves with the middle (fig.2) being a sawtooth wave. There appears to be some mild distortion on each of the waves, which in other cases would be an issue but doesn't subtract from the sound of The Drone Machine in its context of use. The cutoff filters applied throughout the programming signal flow didn't have as much effect as anticipated but extra headroom was left as there would also be an analogue tone control implemented.

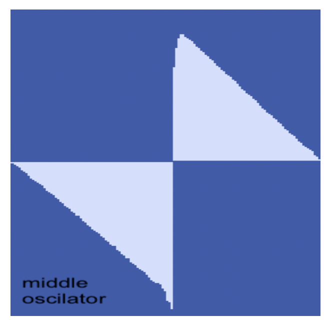

Fig.9, Middle Register

The frequency response of each oscillator was also documented (appendix h.1), the aforementioned distortion can be seen especially on the lower register. With the oscillators summed together a smooth frequency response is created.

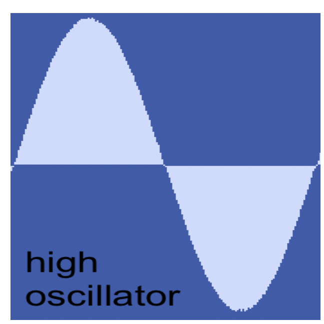

Fig.10, high Register

[24] Root note refers to the first note in a musical key/base note of the key
[25] IO refers to the inputs and outputs to connect the device to external sources

Discussion

This chapter aims to point out issues that were encountered during this project along with giving thoughts on how the project worked, succeeded and failed to meet its goals. Knowledge gained from the project along with any interesting information will also be documented

The first issue encountered during the undertaking of this project was the limitations regarding the number of analogue inputs on the Bela Board. This meant that the volume and tone couldn't be controlled via software and as such a more limited analogue circuit was required.

Being stuck in one musical key is less than ideal, and it would have been satisfying to create a device which could alternate keys. A possible solution would be the addition of two buttons which would transpose the key in semitones. These buttons would then be linked to an addition system in Pure Data which would add or subtract to the midi notes thereby adjusting the key.

The board requires external power, and as such needs access to a power source, as it is not yet battery powered. It could be possible to add a rechargeable battery back which would power the Bela Board over a mini USB connection. This was not achieved throughout this project due to concerns regarding the overpowering or underpowering of the board which could possibly have resulted in damage to the device. Also, if power were to be delivered in this way, reprogramming the board over USB would not be possible without the opening of the box and risking damage due to exposure.

There were some difficulties encountered with regard to the volume and tone controls. The taper on the volume control was too steep, meaning the control was less precise and tapers more quickly than desired. This issue could be resolved by switching out the current potentiometer. Attempts were made to do this with a B100k ohm[26] potentiometer and a A500k ohm[27] potentiometer but a much lower value would potentially be more suitable, such as an A1k ohm potentiometer. This kind of potentiometer was unfortunately unavailable at the time of creation of this device.

The tone control had a similar issue, with it not being as responsive as desired. Currently it runs on a B5k ohm potentiometer and a 22nf[28] capacitor. This issue could be resolved by replacing the potentiometer with a B1k ohm one.

Durability is a concern with this particular model of The Drone Machine. The box itself is almost 100 years old. While it is solid yet light, made of thinly sheeted wood, there is some deterioration around the edges which is the result of general wear and tear. This could pose problems further

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[26] B100k ohm refers to a 100 kilo ohm potentiometer with a linear taper
[27] A500k ohm refers to a 500 kilo ohm potentiometer with a logarithmic taper
[28] 22nf refers to a capacitor with a value of 22 nanofarads

down the line. This wooden construction is also going to be sensitive to moisture and damp. As such, warping and the tightness or possible lack thereof surrounding joins could be an issue. Similarly, were the machine to be dropped, the sturdiness of the box could be called into fatal question. A possible way to resolve this would be a purpose built casing of wood or metal that aesthetically matches the original enclosure. A plastic casing would undermine the more traditional feel and aesthetic the instrument has been designed to incorporate.

An extra possibly 3 way toggle switch that would allow the user to switch between different oscillator types could be a useful addition to the synthesiser, allowing the user more flexibility in the overall sound of the instrument.

Due to the nature of The Drone Machine's force sensitive keys and its derivation from the harmonium, it is designed to sit on a flat surface during operation, or at the very least, the users lap. As such, no strap was required to be added to the instrument.

This project successfully completed the task of creating a drone synthesiser for use within traditional music that is portable and compact.

Future development of this project encompasses two main possibilities. The first being making a fully analogue version of the synthesiser with powered rather than passive volume and tone circuits. This version of the synthesiser would be very flexible for modification and customisation, one drawback of this way of creating an instrument like this is that each oscillator would need to be built and with The Drone Machine having 3 registers 24 oscillators would need to be built for the level of polyphony[29] to remain the same . Another possible option would be the development of a digital circuit which would allow all the controls to be completed in software. This version of The Drone Machine would signify greater flexibility in the default sounds, as well as allowing the user to switch between sounds than an analogue version. This would however, limit the ability to modify the synthesiser after creation.

[29] Polyphony refers to the ability to play multiple notes at once on an instrument.

Conclusion

The conclusion chapter features final thoughts on the project, the effect it has had as a learning process, future plans for the project and if creative and academic goals were achieved.

Having completed the project, I am overall, pleased with what has been created and excited to see how it can be used by future performers in both a traditional and non traditional music setting. Seeing how other performers use the instrument in unintended/unexpected ways will also be interesting.

Learning about the integration of software and hardware was a fascinating process. It requires the consideration of simultaneous processes, which is an overall addition to general thinking abilities. This has provided a new way to look at development processes in tandem rather than two separate parts that meet at an end goal.

Developing the physical object with consideration to ergonomics and aesthetics to meet a particular design goal was challenging but also very interesting. It could be taken in many different directions in terms of physical design, but the choice to maintain a simple, rustic approach is more in keeping with the atmosphere of the Traditional Irish Music setting.

Having the capability to develop custom hardware to cater to specific needs could also be useful in creating more accessible instruments for people suffering from illness, injuries and disabilities. This is a something that could be explored in future projects with a design philosophy based around accessibility

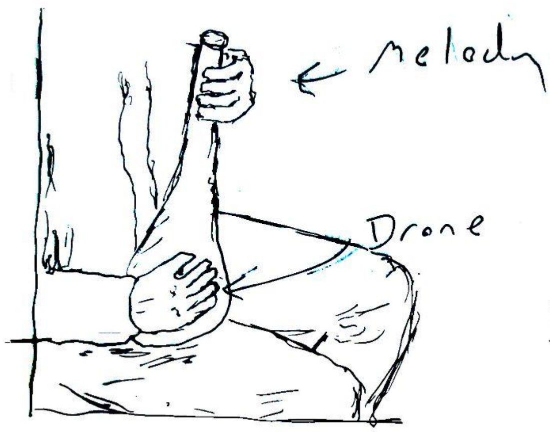
With regard to future development of The Drone Machine, it is intended for real world use. As such, features will be added in time which will enable more control regarding potential keys, volume and tone improvement, extra switches to enable multiple drones and battery technology to ensure the machine can operate independently from a power source.

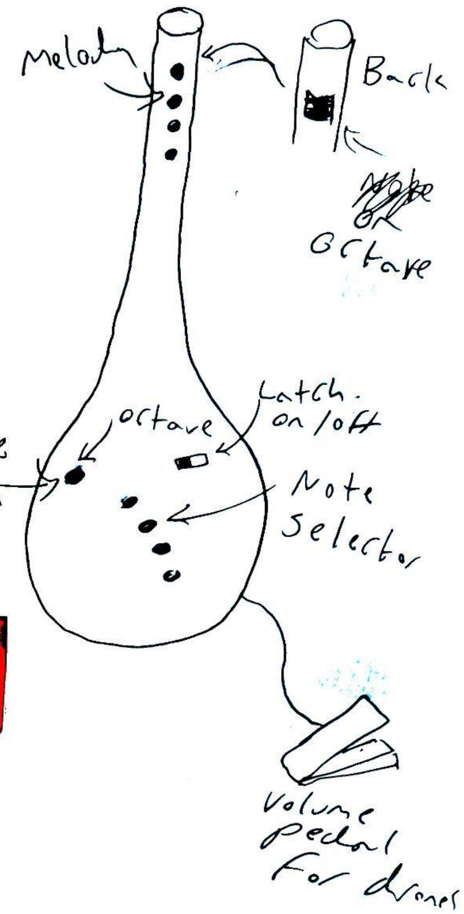
Having learned about hardware and software integration, I am overwhelmed at the possibilities regarding the creation of devices such as The Drone Machine. It seems like almost anything is possible thanks to the technology we have available to us today. The future will see me attempting to create more musical devices that cater to specific needs and wants of the various .musical genres

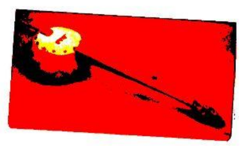
Appendix A

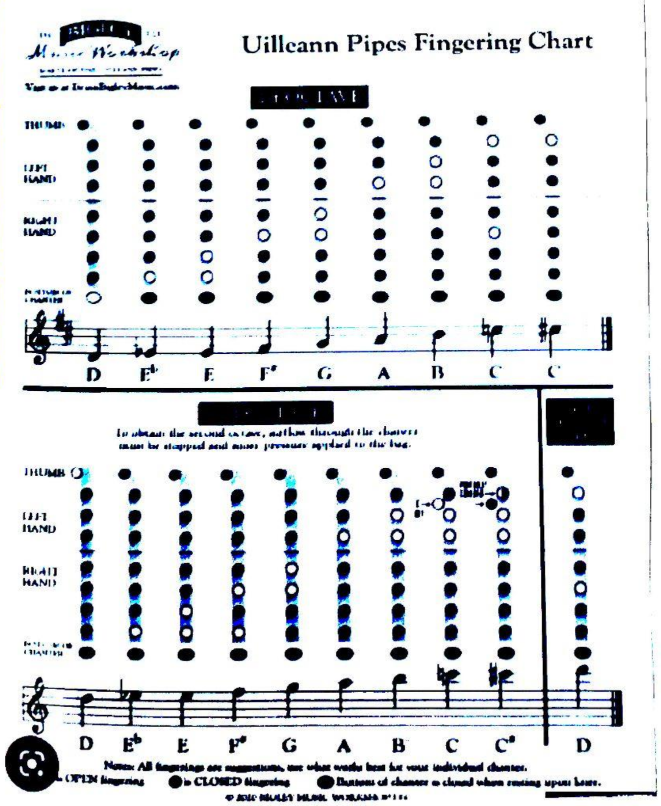
a.1, *Early research*

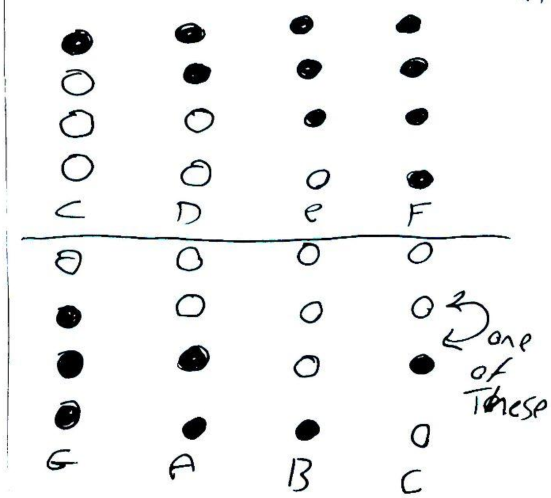
Early Gourd Banjo

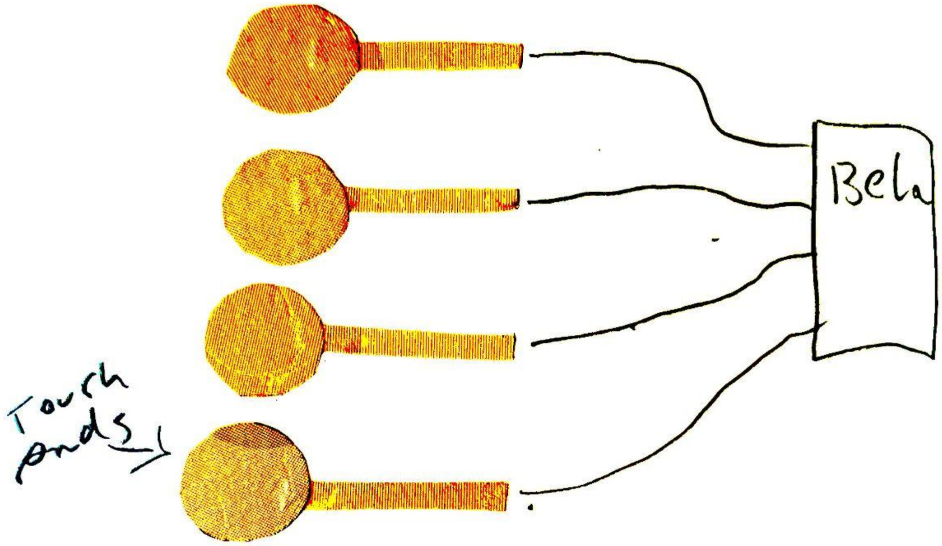


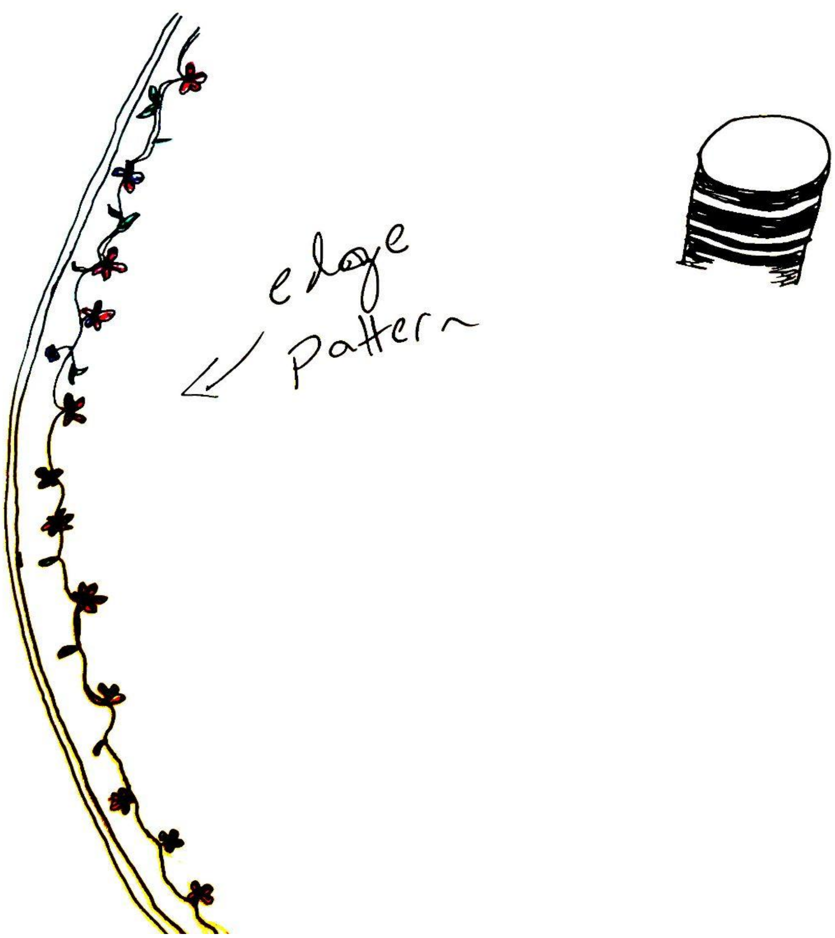




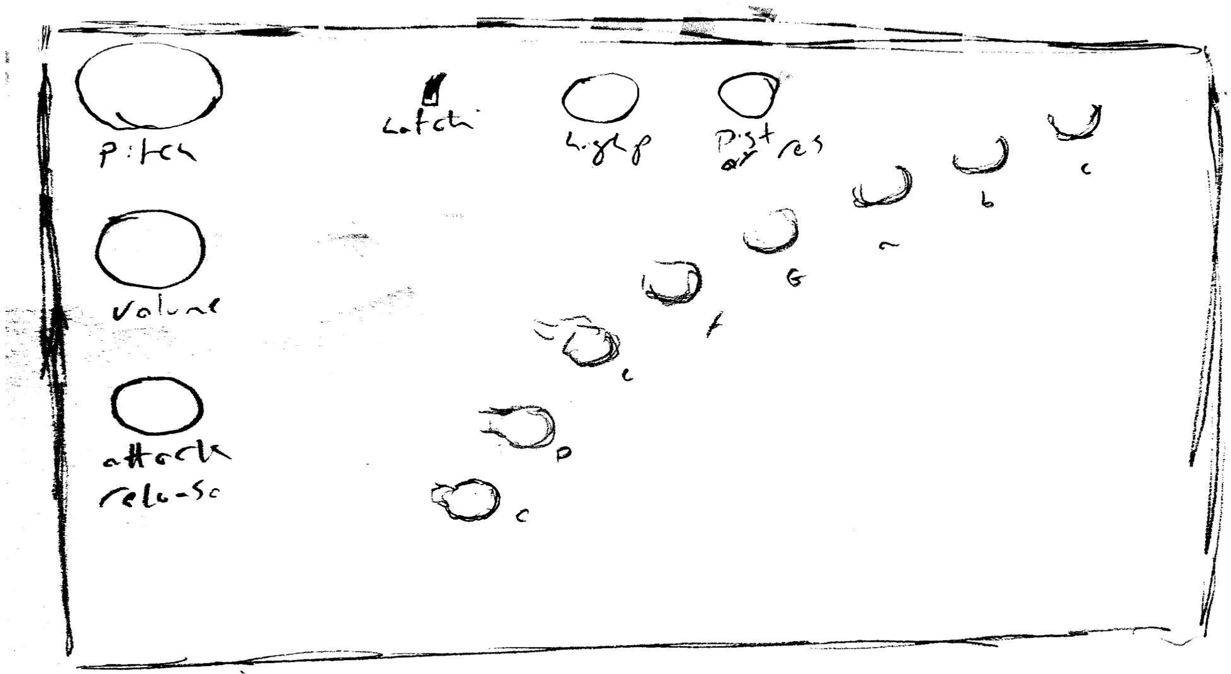


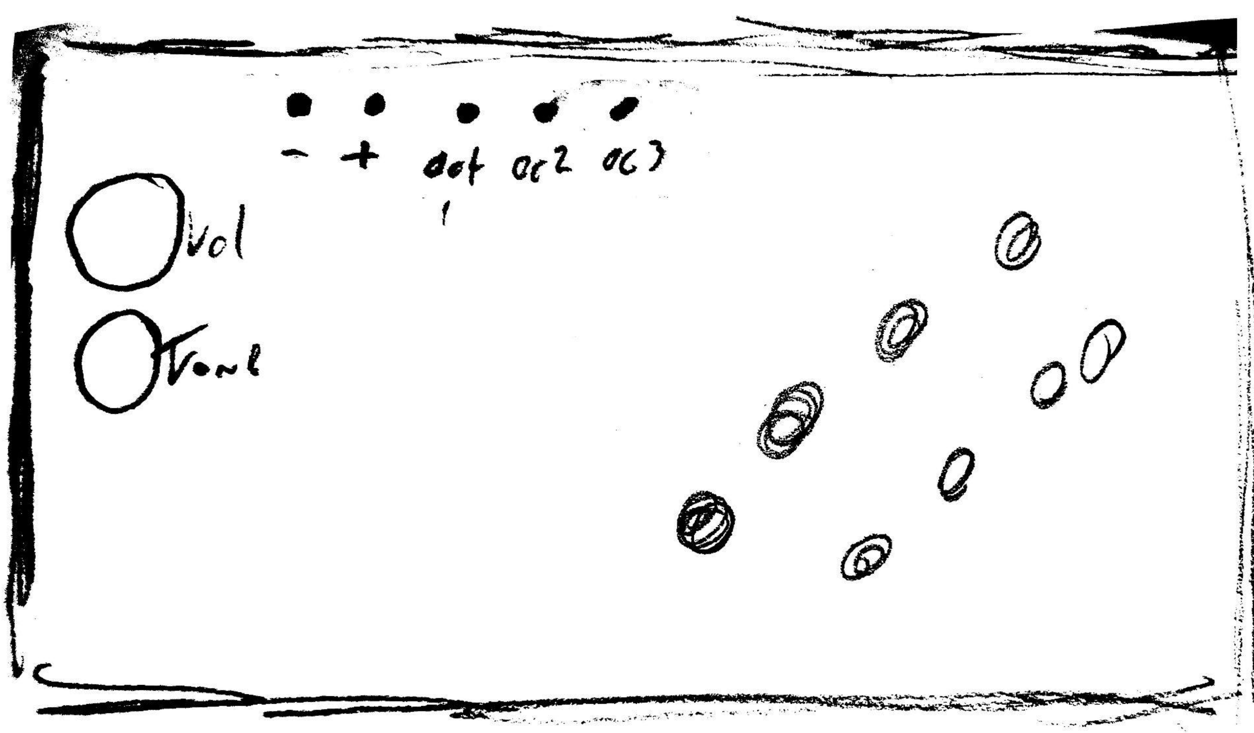



Touch pads
Bela

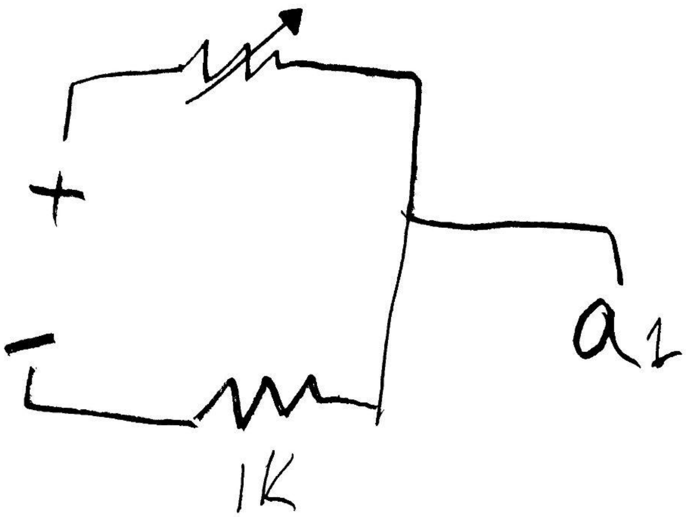

edge pattern

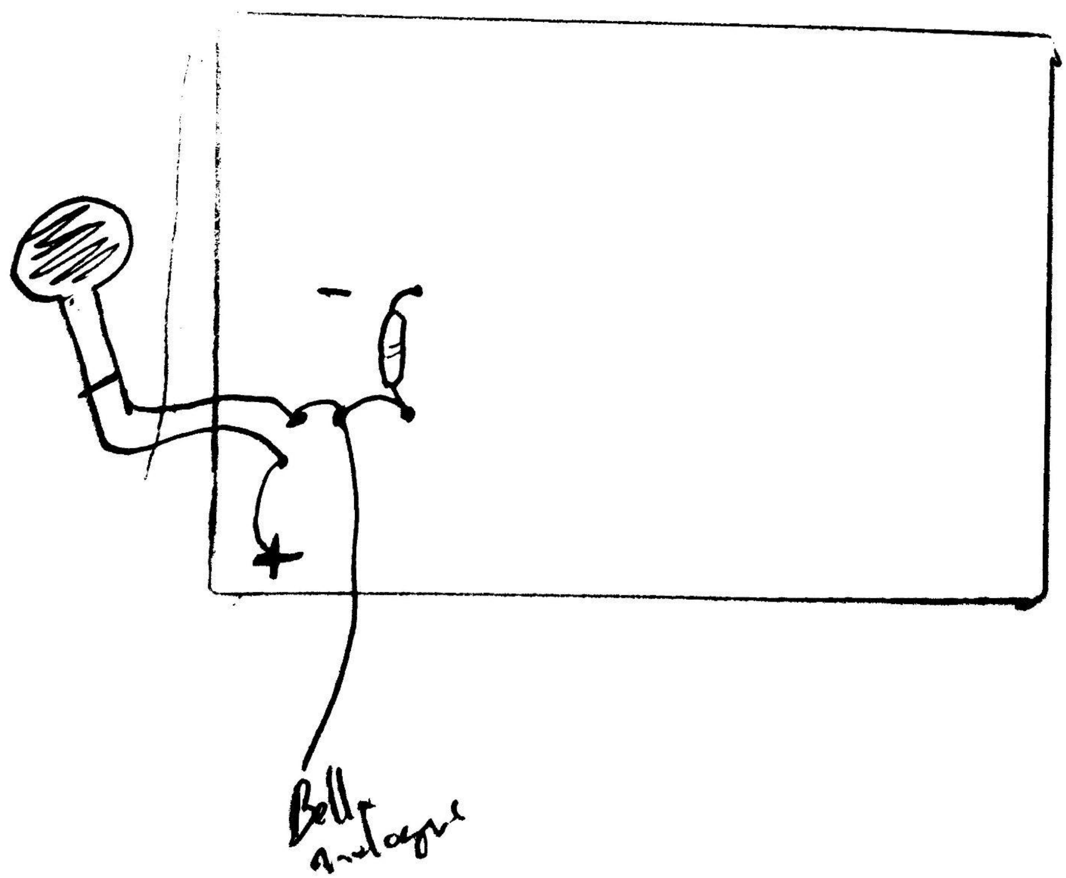
A.2, *Close to final layout*





a.3, circuit design for FSR



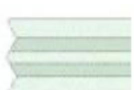
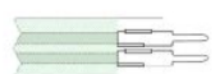


Appendix B

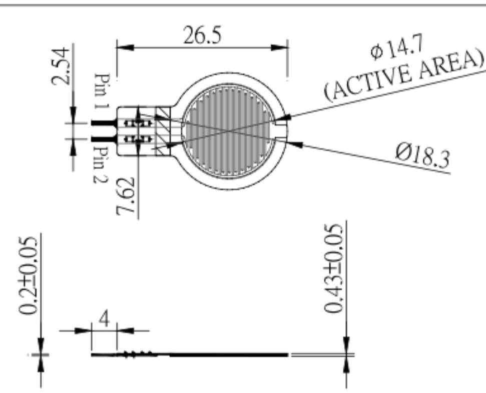
B.1

INSPECTION ITEM	SPECIFICATION
FORCE SENSITIVITY RANGE	30g～1000g (0.3N～9.8N)
FORCE RESOLUTION	Continuous(Analog)
STAND-OFF RESISTANCE (UNLOADED)	>20MΩ
FORCE REPEATABILITY (SINGLE PART)	2%
FORCE REPEATABILITY (PART TO PART)	5%
RESPONSE TIME	<1ms
LONG TERM DRIFT	<10% log10(time)
HYSTERESIS	10%
LIFE CYCLE (WITHOUT FAILURE)	>5 Million
OPERATING TEMPERATURE	-30°C to +85°C
HIGH HUMIDITY STORAGE	+70°C, 85%RH x 96hrs
HIGH TEMPERATURE STORAGE	+85°C x 120hrs
LOW TEMPERATURE STORAGE	-30°C x 120hrs

CONNECTOR OPTIONS

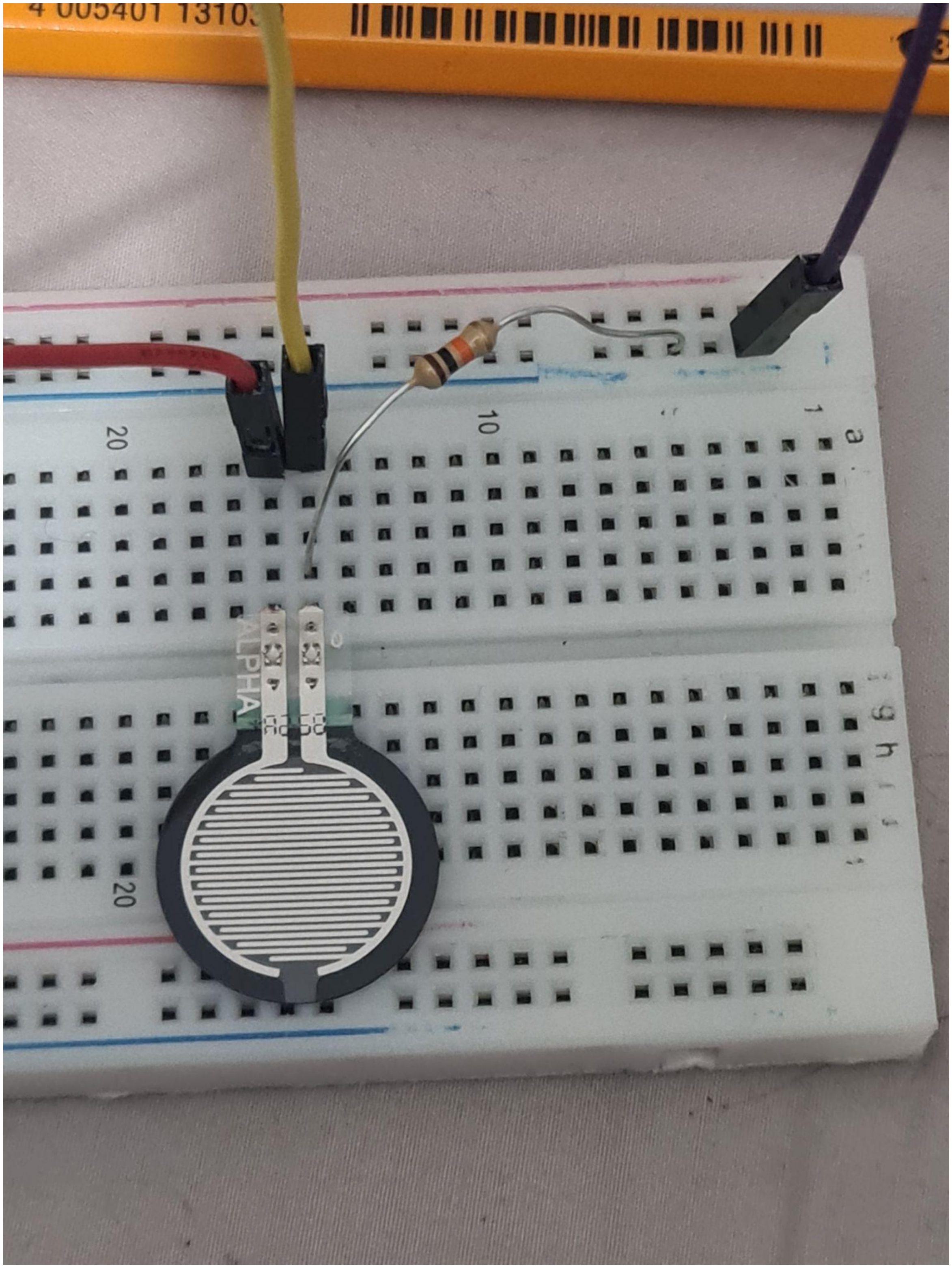
Bare Tail	Female Contacts	Solder Tabs (pin)	Female Contact with Housing
			

Design and specifications presented here are for the standard parts only. Please kindly contact us for your special requests and ask for the current technical specifications before purchase and/or use.

MF01A-N-221-A06 	

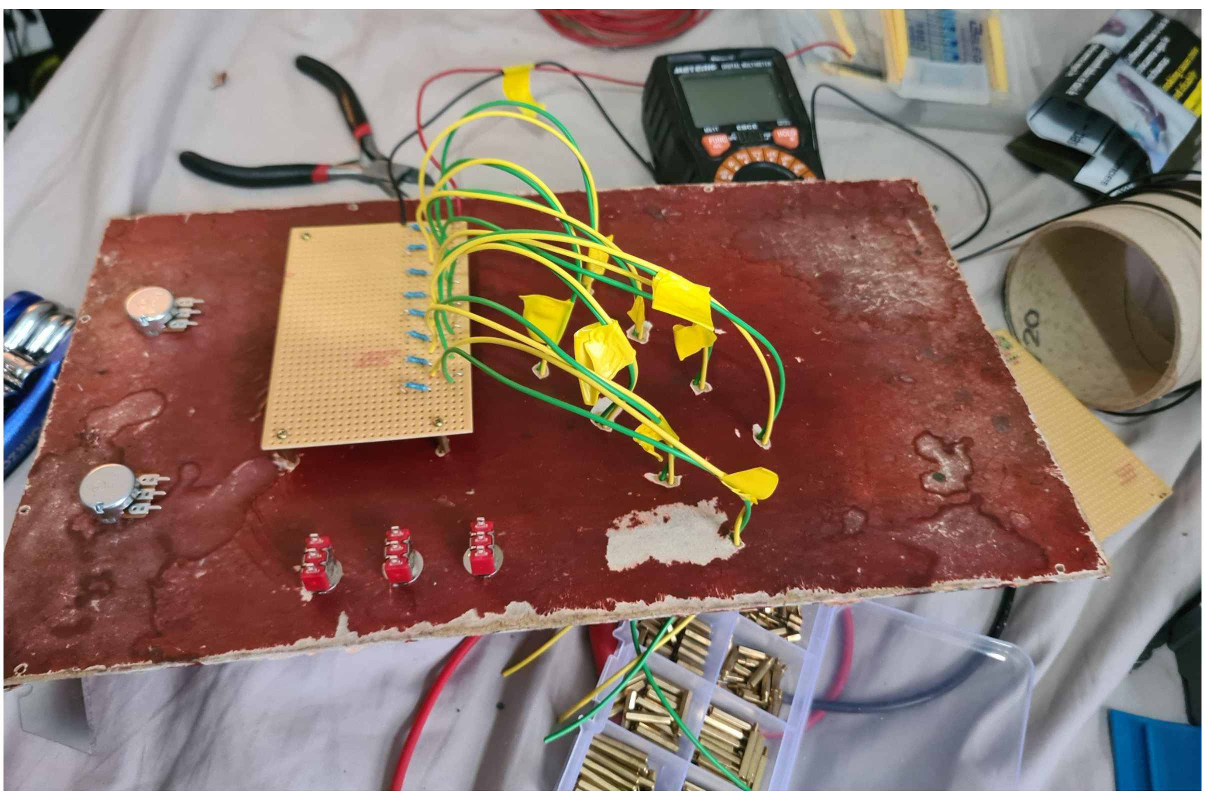
Appendix C

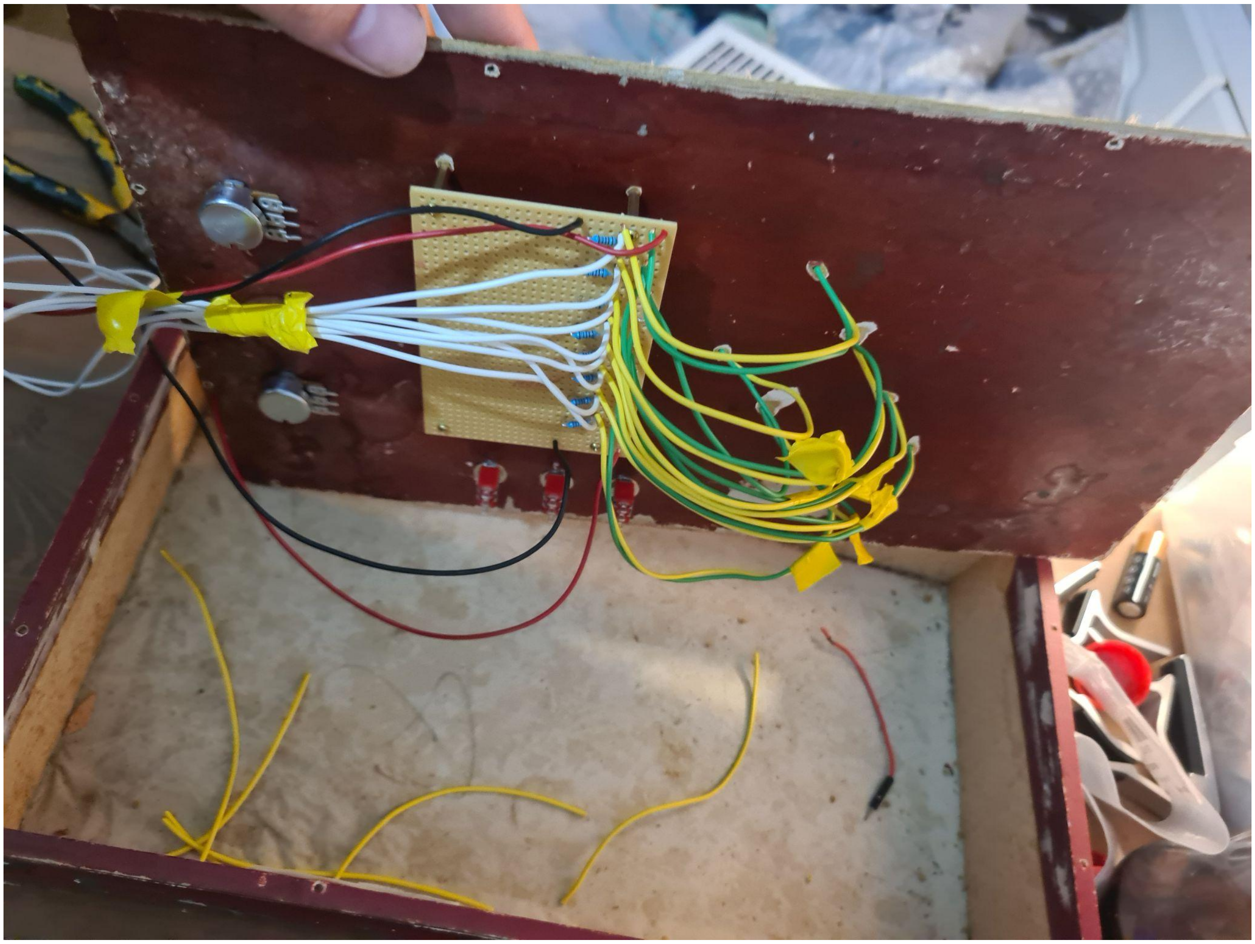
c.1, *testing fsr*



c.2, *finished front of instrument*

c.3*, Circuit for force sensitive resistors*

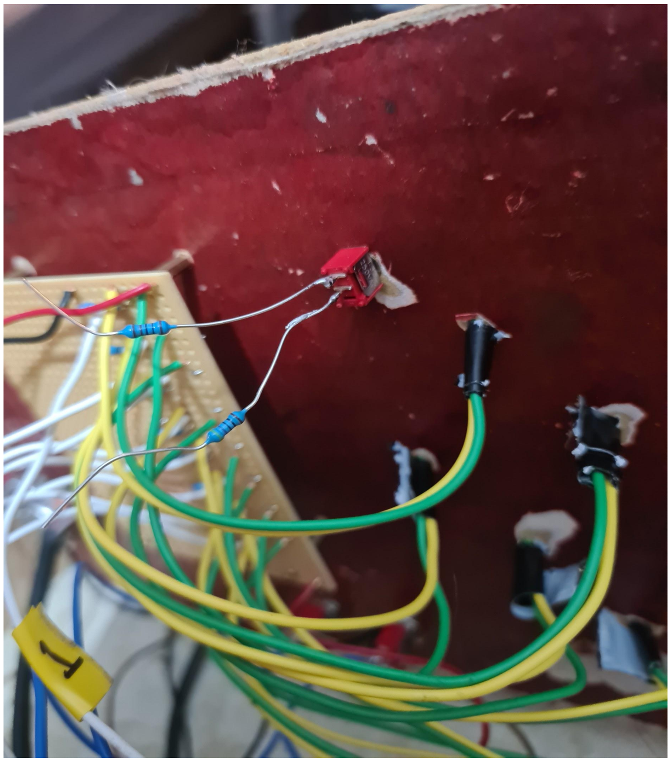




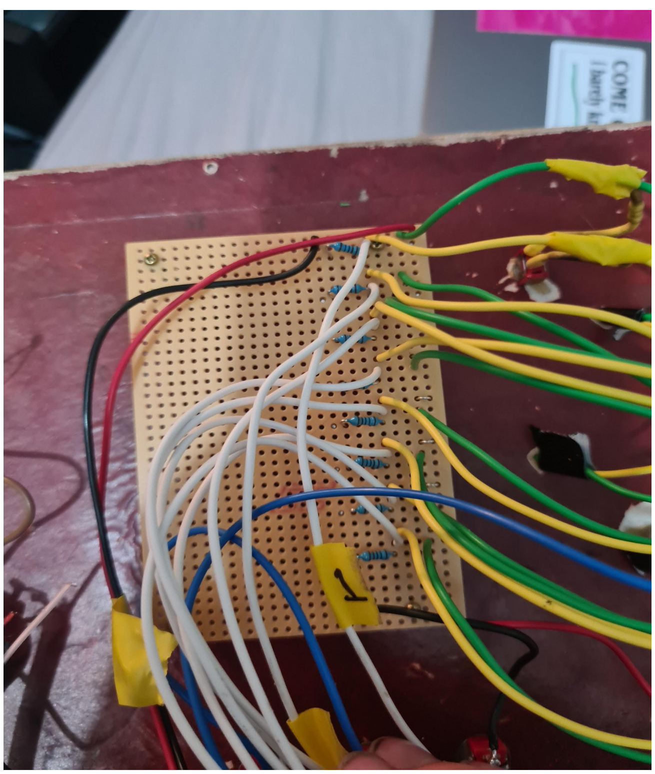

BY APPOINTMENT
To H.M. The KING.
FRYS
Belgrave
SORTED
VOLUME
TONE

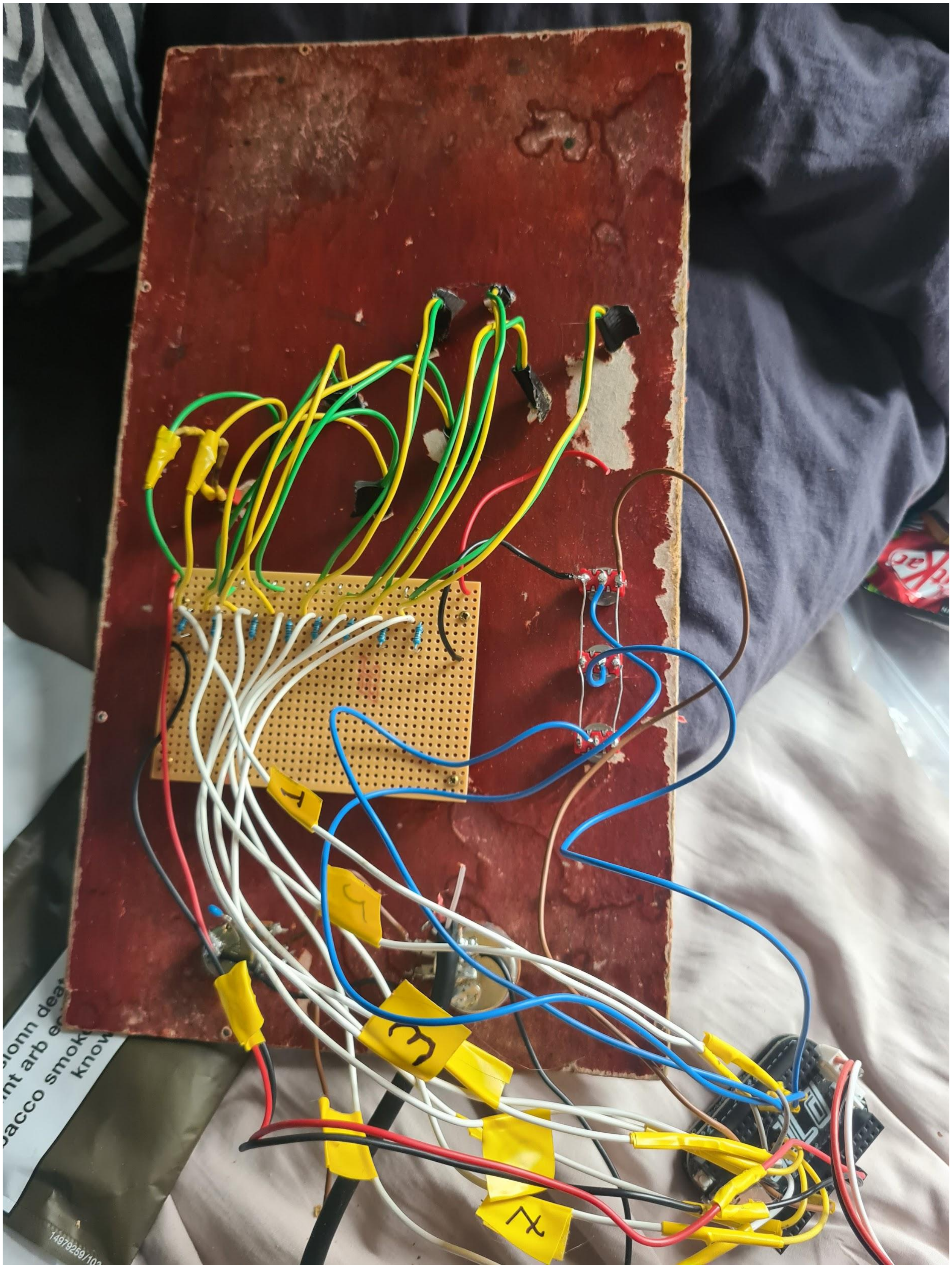

FRY'S
CHOCOLATES
ASSORTED

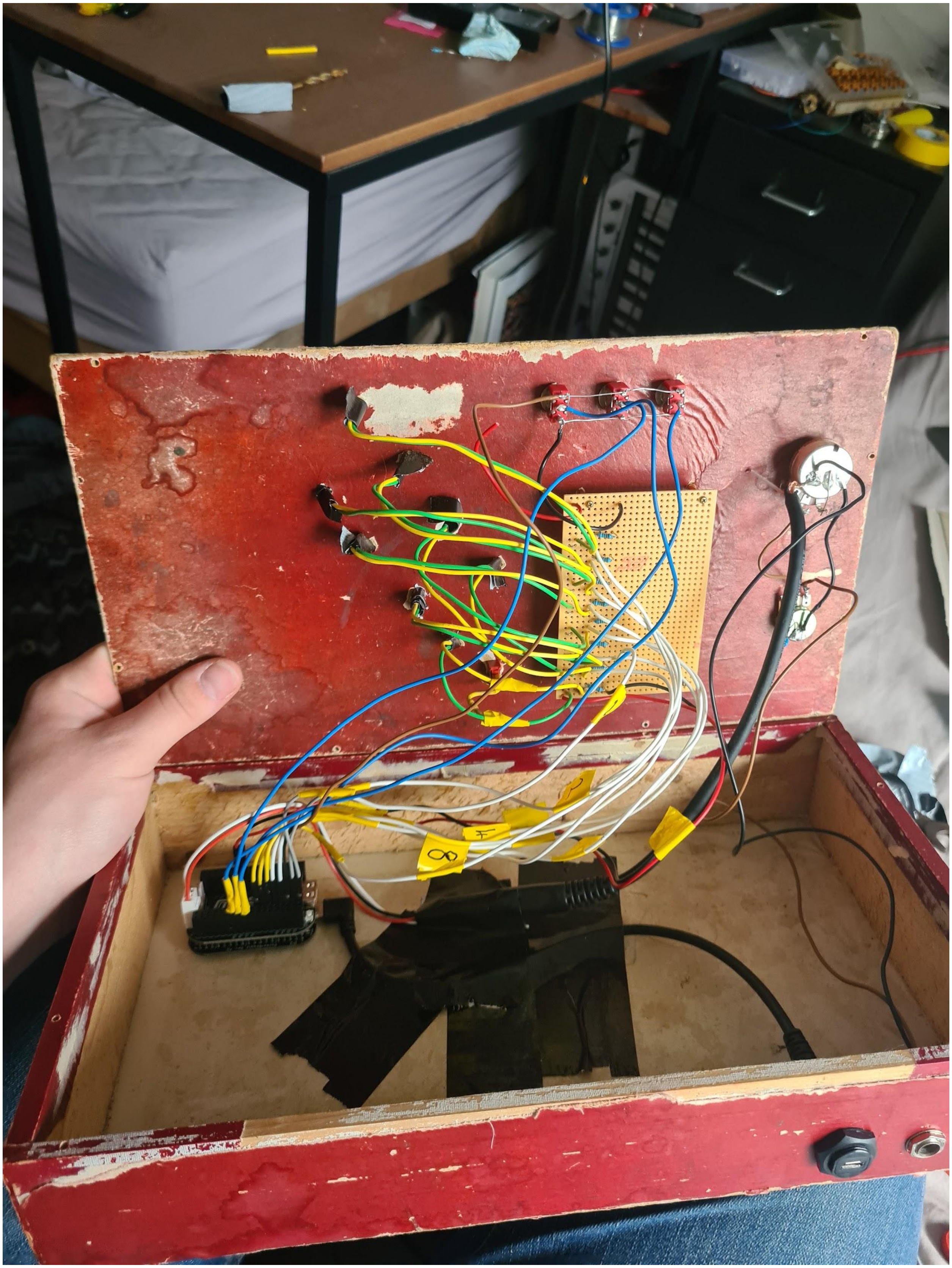
c.4 *root note drone switch*



c.5 final circuit board

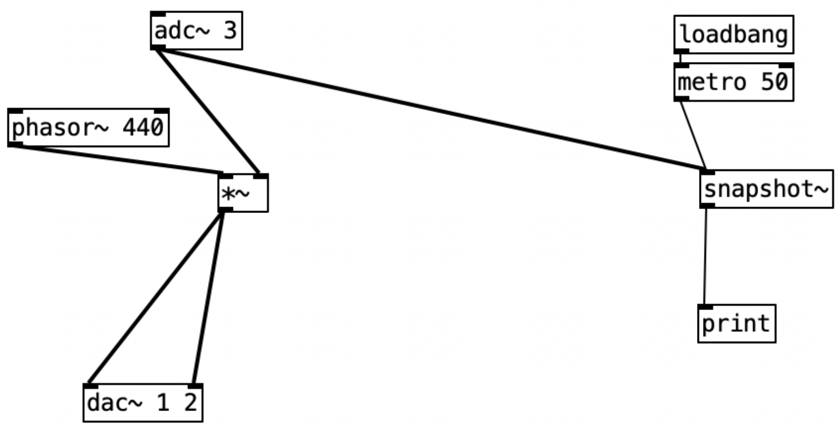




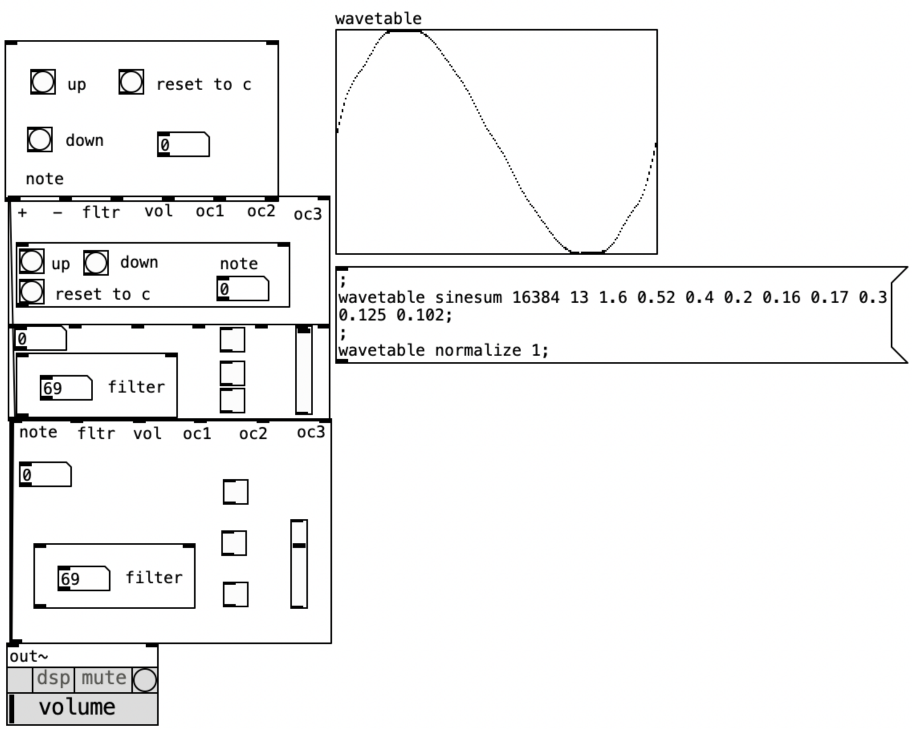


Appendix D

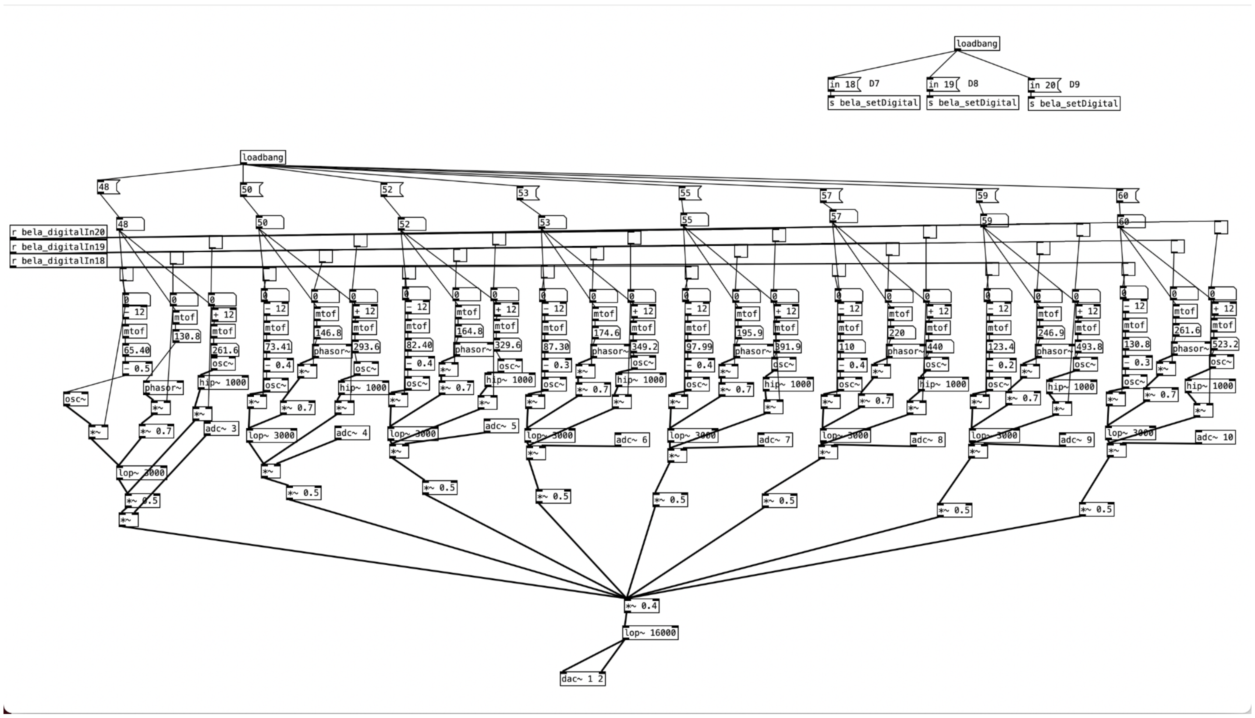
d.1 *initial test oscillator*



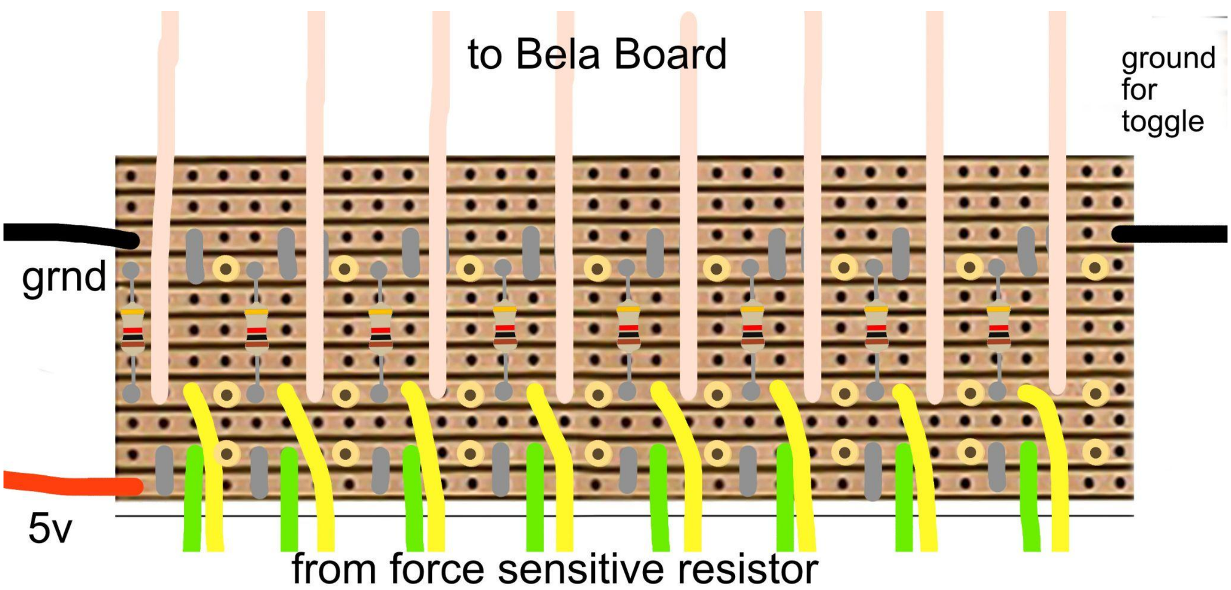
d.2 *failed wavetable synthesiser*



d.3 *final synthesiser code*



Appendix e



Appendix f


My Drone Got A Little Machine
BY APPOINTMENT
To H.M. The KING
FRY'S
Belgrave
SORTED
CHOCOLATES
VOLUME
TONE

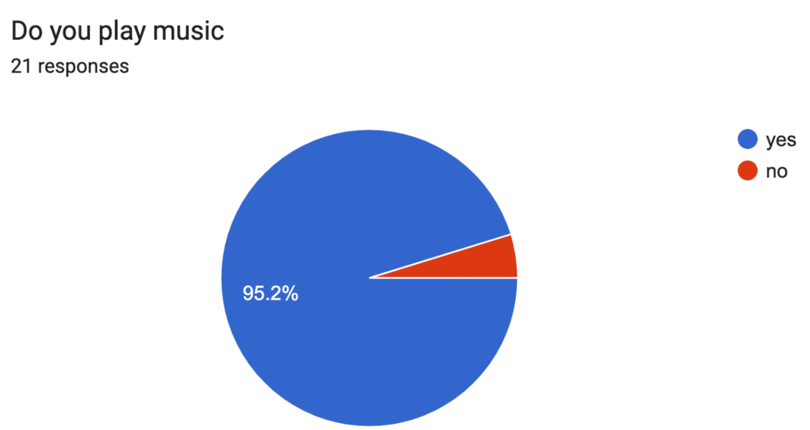
Appendix g

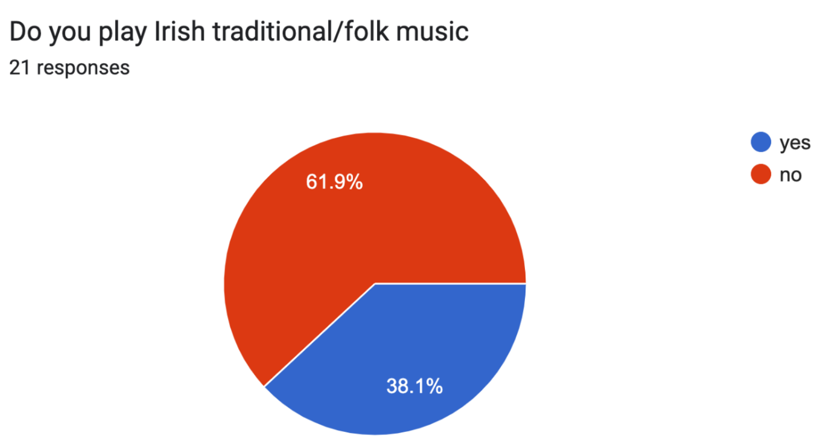
g.1 google forms survey results

Do you play music	Do you play Irish traditional/folk music	would you be interested in a drone synthesiser with force sensitive keys	if yes what features would be most important	would you be interested in this instrument? why?	does the instrument look intuitive?	would you feel comfortable arriving at a pub music session with it?
yes	no	yes	A output jack, control over the parameters and midi capability would be nice as well	Yes, due to the interesting design I am intrigued to see what it sounds like	Yes	Yes
yes	no	yes	Analogue synthesis	Yes	No	No
yes	no	yes	Usability	Yes	Yes	Yes
yes	no	no			Yes	Yes
yes	no	yes	Ability to play any note	Yes. It looks funky	Yes	No
yes	no	yes	keys	its has keys	Yes	Yes
yes	no	yes		say	Yes	Yes
yes	yes	yes	Sweepable filter, fine tuning, distortion (?), MIDI in/out if you're feeling	Fun and nice	Yes	Yes

			adventurous			
yes	no	yes	Fast response / limited lag/ ability to shift the speed	Yes	Yes	Yes
yes	yes	yes	Good volume or dynamic control. Ability to add effects or alter the sound.	Yes. Traditional design mixed with new technology allows for new possibilities without compromising on authenticity.	Yes	Yes
yes	no	yes	Accurate pressure sensitivity, standard outs, midi maybe. Ability to adjust oscillator		Yes	Yes
yes	yes	yes	Control over the tone	Yes looks deadly	Yes	Yes
yes	no	no		Yes	Yes	Yes
yes	no	yes			Yes	No
yes	yes	yes	Foot pedal of various uses	To agitate the trad purists	Yes	Yes
yes	yes	no		Looks complicated	No	No
yes	no	yes	The tone would have to be	Yes	No	Yes

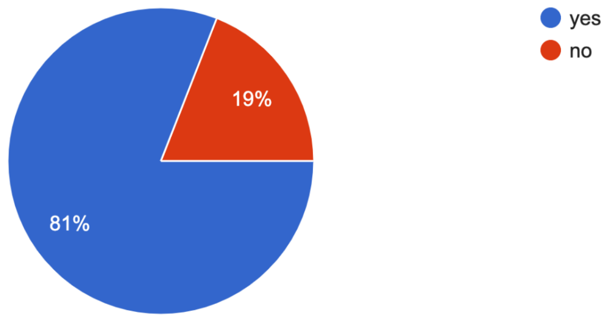
			pleasant			
yes	yes	yes	Weighted keys	Yes. To Switch up the traditional setup	Yes	Yes
yes	yes	yes	LFOs, effects, a filter, audio out feature and midi capabiliti es.	I'd be interested, it looks like it would make some strange sounds and has some knobs to play with	Yes	Yes
yes	yes	yes	LFO, two oscillator s	Looks wicked, touch sensitive keys	Yes	Yes





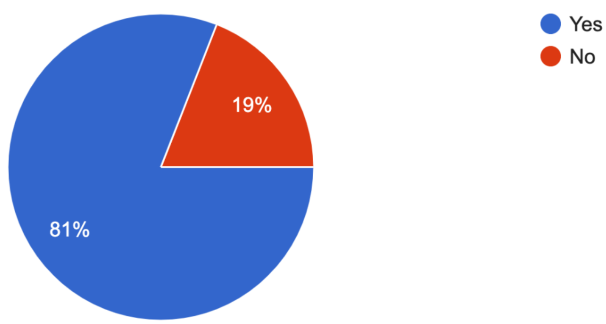
would you be interested in a drone synthesiser with force sensitive keys

21 responses



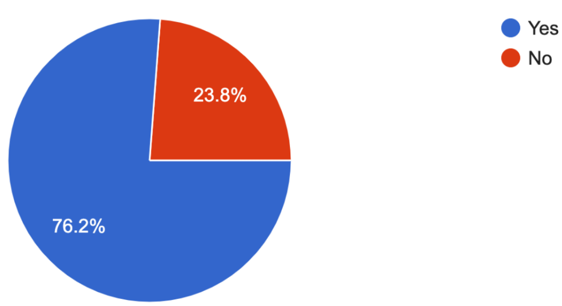
does the instrument look intuitive?

21 responses



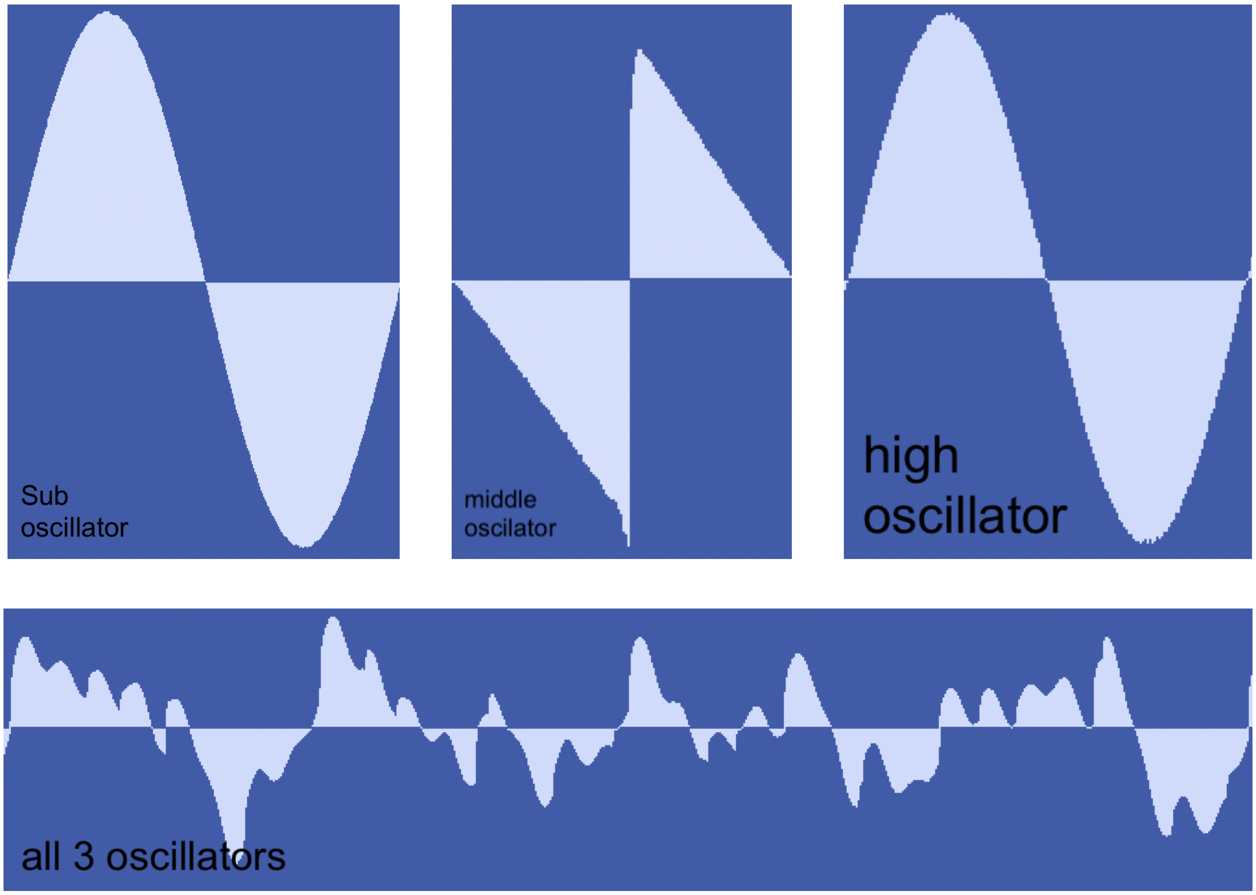
would you feel comfortable arriving at a pub music session with it?

21 responses

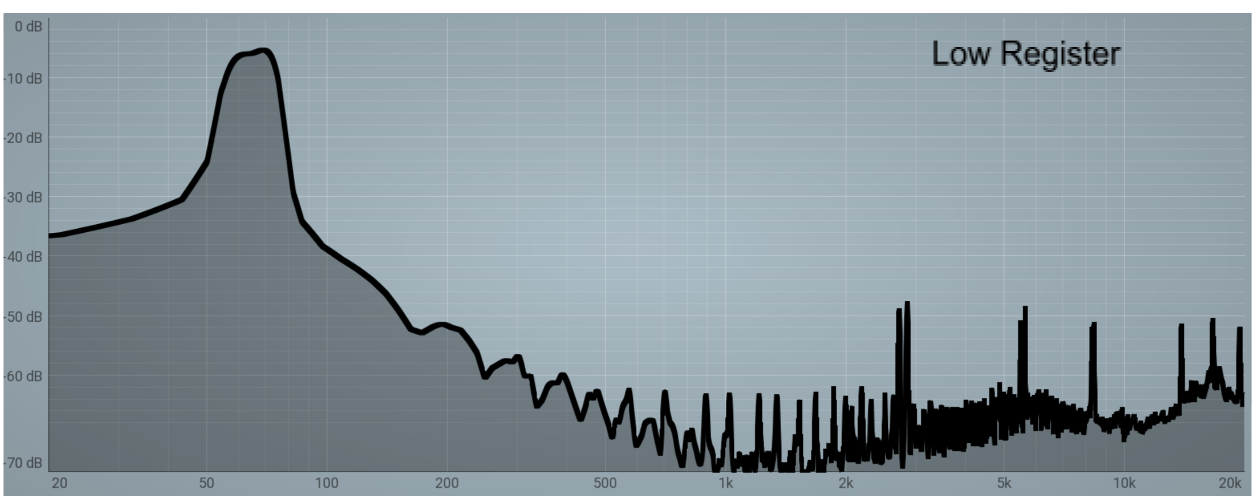


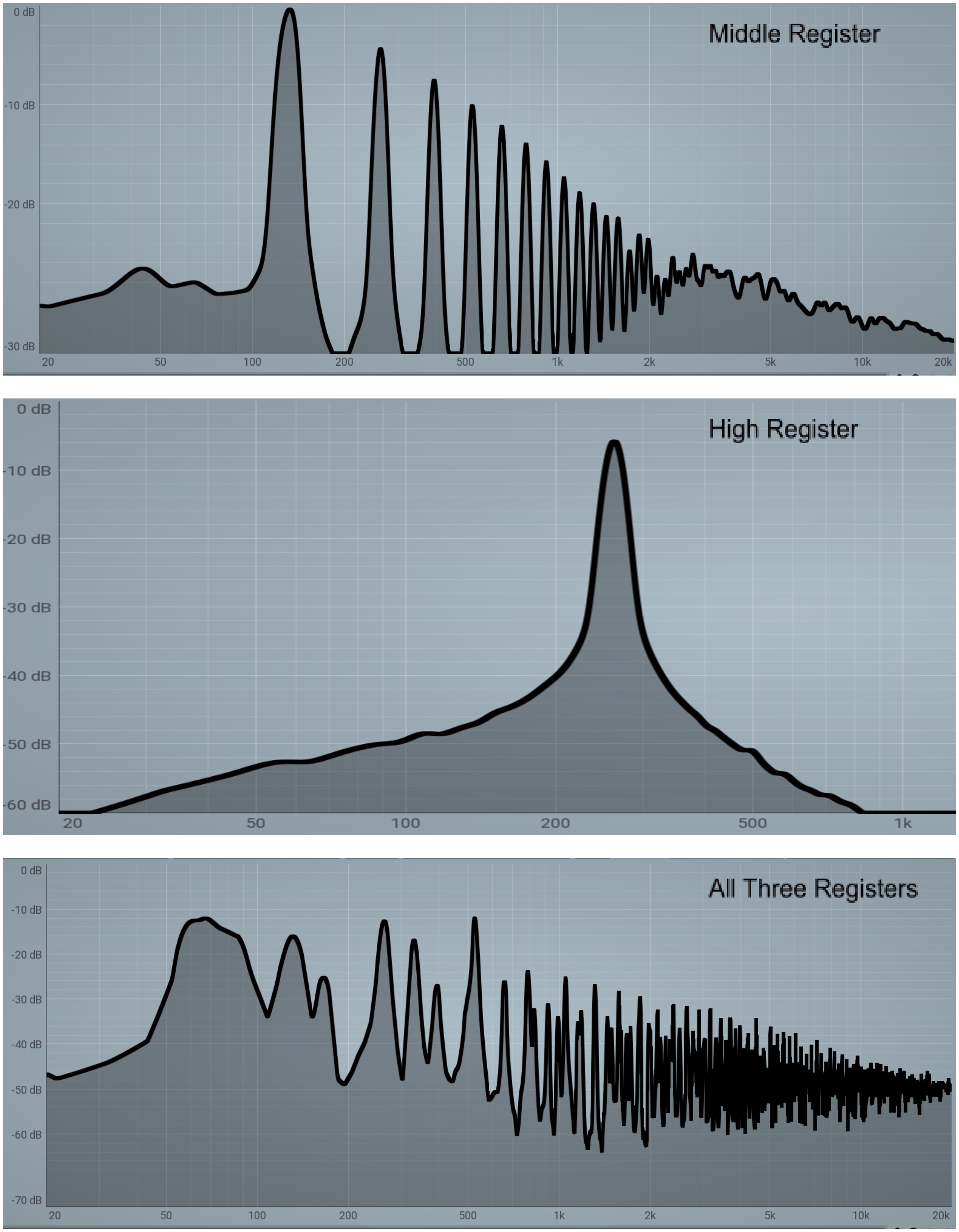
Appendix h

h.1 each oscillators wave



h.2 frequency response of each oscillator




Middle Register
0 dB
-10 dB
-20 dB
-30 dB
20
50
100
200
500
1k
2k
5k
10k
20k
High Register
0 dB
-10 dB
-20 dB
-30 dB
-40 dB
-50 dB
-60 dB
20
50
100
200
500
1k
All Three Registers
0 dB
-10 dB
-20 dB
-30 dB
-40 dB
-50 dB
-60 dB
-70 dB
20
50
100
200
500
1k
2k
5k
10k
20k

Appendix i

This Youtube video was created to demonstrate the key features of The Drone Machine and showcase its sounds:

https://youtu.be/8iYY8sRb6y0

Folder containing code created during this project:

https://drive.google.com/drive/folders/1ZDfGgpWqPmBkjJmhaWPtNidhfFJsMQO0?usp=share_link

Bibliography

Lankum. "The Livelong Day." John "Spud" Murphy, Guerilla Sound Studios, Meadow, Dublin, Ireland.

31/03/2023, Vicar Street, Dublin. Ye Vagabonds.

Moro, Giulio & Bin, S. & Jack, Robert & Heinrichs, Christian & Mcpherson, Andrew. (2016). Making High-Performance Embedded Instruments with Bela and Pure Data.

Gustafsson, Gabriel Vincent Karl, et al. "Kuplen: A Hands-on Physical Model." *Zenodo*, 24 May 2022, https://zenodo.org/record/6576907#.Y4YXTezP0-R.

Cook, Perry. "Principles for Designing Computer Music Controllers" *Nime*, Nime, 2001, https://www.nime.org/proceedings/2001/nime2001_003.pdf.

"The International Conference on New Interfaces for Musical Expression." *NIME*, Nime, https://www.nime.org/.

Moylen, Terry. "A Short History of the Uilleann Pipes." History Ireland, vol. 26, no. 4, July 2018.

"The Platform for Beautiful Interaction." *Bela*, https://bela.io/.

"FILTERS? Build a Simple DIY Passive Electronic Low Pass Filter." *YouTube*, 8 Feb. 2017, https://www.youtube.com/watch?v=Ch9w5JtbZSc&t=194s.