

The Arduino – Lo-Fi Granular Synth

Introduction

My interest in analogue synthesis began very early in my career as a Sound Engineer but as music production moved pretty quickly toward digital in the mid 2000's my interest waned in the quest to keep up with the times. The quality as well as accessibility of software synths improved dramatically during this time as well which led to me working more in the box.

I was very inspired by the lectures from Helen Lee using the BBC Micro Bit and Arduino to create synth style instruments and pretty much all the capabilities for analogue instrument creation out there. This led me to my decision to build and create the Arduino Lo-Fi Synth.

I really wanted to try and create something which could be practical as well as something I would be able to use in my creative process. I also wanted to finally get to grips and really understand analogue synthesis down to circuit level. I really liked the Arduino Uno as well as their company and open-source philosophy as well as the capabilities it presented. So, I decided this would be the platform I would use to build and create my project with.

Martin Russ refers to analogue, as a range of values which are presented in a continuous, rather than a discrete way. Continuous, implying making measurements all the time and also infinite resolution.

However, the grain size on magnetic tape or noise level in an electronic circuit prevents it from being truly continuous. Discrete meaning individual sample values taken at regular intervals rather than measuring them all the time, assuming that the samples are a good representation of the original signal. An Analogue Synthesizer uses voltages and current to directly represent both audio signals and any control signals which are used to manipulate those signals. (*Martin Russ, 1996 p.64, 2.1*)

Granular synthesis is a basic sound synthesis method that operates on the microsound timescale. It is based on the same principle as sampling. However, the samples are not played back conventionally, but are instead split into small pieces of around 1 to 50ms. These small pieces are called grains which may be multiplied and layered on top of each other and may play at different speeds, phases, volume, and frequency, among other parameters. (https://en.wikipedia.org/wiki/Granular_synthesis)

An Arduino is a hardware controller using a single board of microprocessors and it is open source. (<https://www.arduino.cc/en/guide/introduction>) (<https://audioordeal.co.uk/can-you-make-synth-with-arduino/>)

Using the definitions above and the instructions for the design and code I have found on www.instructables.com the instrument which I have decided to create is the Arduino Synthesizer. (<https://www.instructables.com/The-Arduino-Synthesizer/>)

Research and Approach

The Arduino Synth is an analogue granular lo-fi synthesizer which uses an Arduino as the main controller. It was originally prototyped on a bread board for testing and then later transferred to a protoboard which I would be using in the final build of my instrument.

My idea was to build a Lo-fi Synth which would emit a signal or voltage which could be controlled by the potentiometer pots which would modulate the Pitch, Attack, Decay and Grain Repetition Frequency.

This would have a to have a practical application in my creative workflow and also be something that I could possibly expand on later as well and also possibly have commercial or consumer value and application.

I do however believe that the benefits this project could have as a tool for electronics education could possibly be more practical and accessible for electronics, enthusiasts, hackers and learners. In terms of how I would market this product once finished would be based on this principle. A tool that could be used in practical music production scenarios but also as an education tool used by electronics teachers. It could then be sold or distributed as a completed instrument or as a kit.

The idea of creating a lo-fi synth, in this day and age, where most sounds and samples even digital synths are very “clean” was very appealing to me. In most applications and creative processes, producers and engineers apply various amounts of harmonic distortion] to the sound in order to create the analogue “warm” sound or vibe we love to hear in music and is reminiscent of the analogue recording techniques and methods used in years gone by.

(<https://www.masteringthemix.com/blogs/learn/experts-guide-to-using-harmonic-distortion-in-music>)

I spent a lot of time trying to find ways to create my synth. I bought the BBC Micro bit first as it seemed the simplest and easiest way of acquainting myself with electronic synths.

I managed to build and play a fruit (Orange) using the controller. I also created various sounds and tried various ways of coding it.

I enjoyed playing with the Micro Bit, but I felt it would be more challenging to create something with a more hands-on approach and something which would involve soldering and connecting electronic components.

The BBC micro bit had most of the electronics built in and to build or create things involved more coding than soldering and wiring together components which I really enjoy doing.

I then decided I would use the Arduino Uno as my main controller.

I liked the fact that I would have to put most of it together using a bread board, capacitors, resistors and would possibly involve a bit of soldering work as well as building the casing that it would go in. I would also have to be able to interpret a schematic and follow the instructions laid out in order to put it together and make it work.

I have a very hands-on approach to most of what I do, and I have very limited to no experience coding or using code which affected my decision-making process.

I was also encouraged by the fact that people openly shared their code for creating these instruments and it would be as “easy” as copying and pasting the code and uploading it to my Arduino Uno controller.

I could find the instrument/s I wanted to create in this case an Analogue granular Synth and then upload it to the Arduino controller and then build my analogue synth.

I also found many other synths and basic Arduino project codes on the Arduino IDE I downloaded. Which would also be the interface I would be using to load the code onto the Arduino Uno in order for my synth to work. I tried a few of these codes for some basic instrument types but no one of them was fit for the purpose or design for the synth I wanted to create.

Through Google and YouTube worm holes and the lectures from Helen Leigh, I found my way to the Instructables website where I found the design I liked and the code for it.

Thus, began the creation of the of my Arduino Synth.

How it works

In order to understand how my lo-fi synth works, it is necessary to understand that the term analogue synth has become imprecise.

Most true analogue synths did not really continue to exist after the late 70's.

Most synths these days are a hybrid of analogue and digital technology to varying degrees. (<http://www.muzines.co.uk/articles/how-analogue-synthesizers-work/2551>)

The Arduino is able to output sound using a library that has been developed called the Tone Library.

By creating an interface and a program that can call certain values to be output to an audio out.

The sound is created by playing the same sound grain, or samples over and over again at very high speed. Our ears and brains turn this into an audible hybrid of the repetition rate and the original grain, and it sounds like a constant tone.

The grain consists of two triangular waves of adjustable frequency, and adjustable decay rate. The repetition rate is set by another control.

(<https://www.instructables.com/The-Arduino-Synthesizer/>)

The Arduino Synth would need to be put together using various components.

- Five 10K Potentiometers (A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If you only use two of the terminals it then acts as a variable resistor or rheostat). (<https://en.wikipedia.org/wiki/Potentiometer>)
- LEDs (Light Emitting Diode is a semi-conductor which emits light when an electric current is passed through it) (<https://www.ledsmagazine.com/leds-ssl-design/materials/article/16701292/what-is-an-led>)
- SPDT switch (Single Pole Double Throw Switch only has a single input and can connect to and switch between the 2 outputs, meaning it has one input terminal and two output terminals.) (<https://www.miww.com/spdt-switch/>)
- Light dependant photo resistor (LDR's detect the presence of level of light when used in an electronic circuit) https://www.electronics-notes.com/articles/electronic_components/resistors/light-dependent-resistor-ldr.php
- Arduino
- Arduino Protoboard
- Tactile Switch (A switch that is perceptible by touch)
- Project Enclosure
- 1/8 Audio Jack
- Solid Core wire
- Heat shrinks
- Breadboard (A breadboard is a construction base for prototyping in electronics)
- Jumper Wires
- 10K Resistors
- 220K Resistors
- 9V Battery
- 9V Battery Clip
- Size M Coaxial DC Power Plug

The Code

The code I used to program my Arduino Controller was originally written by Peter Knight with contributions and modifications by David A Mellis and Tom Igoe.

The code is loaded onto the Arduino using the Arduino IDE and defines and controls the parameters the synth is able to operate and be controlled by.

I would be able to use a signal generated using a library that has been developed called the Tone Library.

By creating an interface and a program that can call certain values to be output to an audio out.

PWM (Pulse Width Modulation is a technique for getting analogue results with digital means) <https://www.arduino.cc/en/Tutorial/Foundations/PWM>

Analog in 0: Grain 1 pitch

Analog in 1: Grain 2 decay

Analog in 2: Grain 1 decay

Analog in 3: Grain 2 pitch

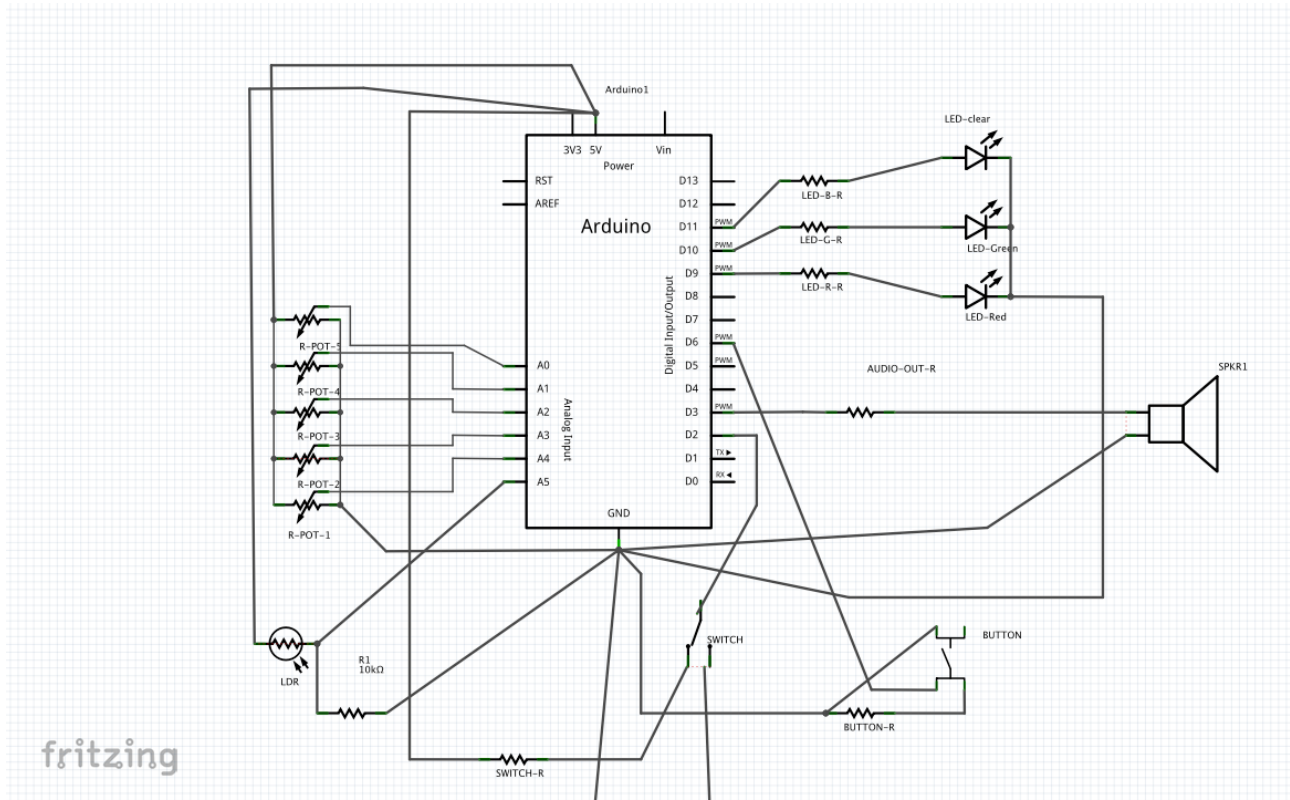
Analog in 4: Grain repetition frequency

Digital 3: Audio out

Schematic (www.fritzing.org)

A schematic is a picture that shows a diagram of a circuit for any electronic machine or instrument in a simple using symbols. It represents the components of a process, device or other object using abstract, often standardised symbols and lines.

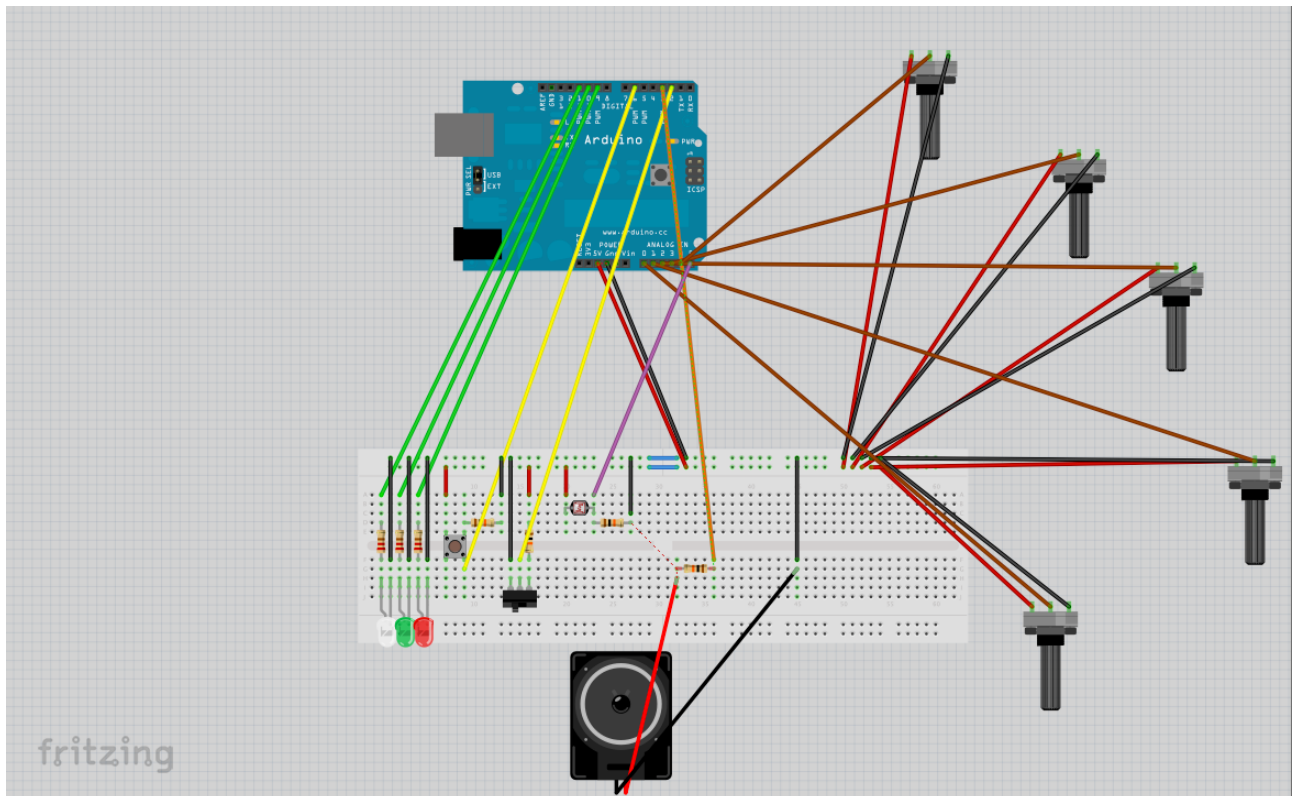
(<https://www.thoughtco.com/what-is-a-schematic-diagram-4584811>)



Breadboard

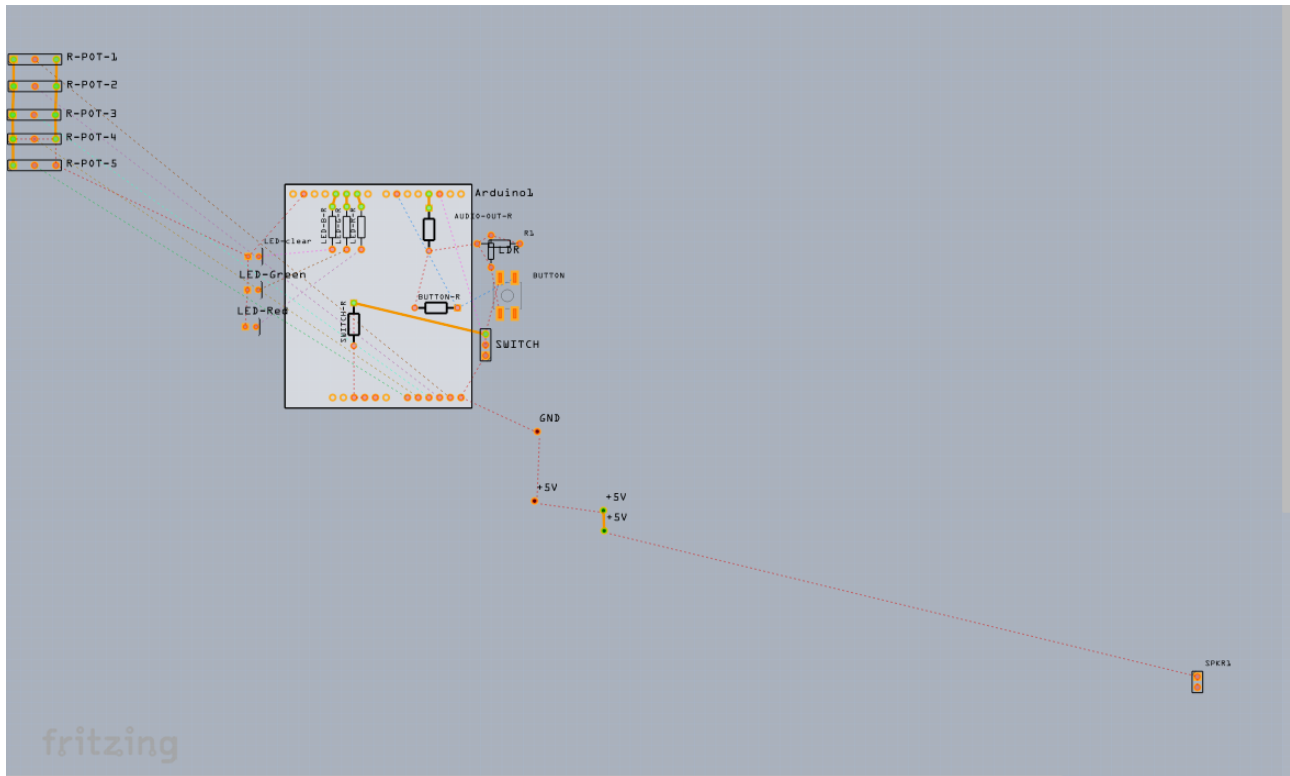
A breadboard is a construction base for prototyping electronics.

(<https://en.wikipedia.org/wiki/Breadboard>)



PCB

A printed circuit board mechanically supports and electrically connects electrical or electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate. (https://en.wikipedia.org/wiki/Printed_circuit_board)



Challenges and Obstacles

Purchases made on impulse are an obstacle to progress! First lesson learnt! After multiple amazon deliveries and a new collection of various resistors, capacitors, diodes an Arduino UNO controller, a BBC micro bit and an Elegoo Uno R3. My frustration grew. I began starting projects and would only get to a certain point before realising that I did not have the correct components, or the part was not available or would take weeks to be delivered.

This was one of the many issues I faced before actually knowing exactly what I wanted and was a very time consuming and frustrating exercise.

I do believe it was necessary because not only did it help reacquaint me with all of the components used in creating electronic instruments, but it also helped me to understand and learn what each of the components were and how I would eventually use them in my final project. This helped in my decision-making process and aided in helping me to narrow down the essential components, I would require building my Lo-fi Granular Arduino Synth.

Then I started the research and development phase. I had many ideas on what I wanted to create, and this aided in the amount of time spent trying to get things to work.

I really wanted to show that I could not only build the required instrument but that I could innovate and improve it as well. So, I spent a lot of time trying to combine two of the Arduino projects together so that I could show some innovation on my granular synth.

I tried to combine an Arduino Mini Min or Theremin style instrument with my Lo-Fi synth.

I began by building them both separately and tried to get them to work individually but then I faced my first major setback and obstacle.

I could not get any of the codes that I had found to load to the Arduino using the IDE. I then tried to use various types of USB cables and different types of computers, mac and pc, to try and load the code onto the board.

This was to no avail as there was clearly an issue with my machine reading the device.

I then bought another Arduino controller and thought this would solve the issue. It did not!

It eventually took copious amounts of research and scanning through forums and fixes, including trying to get assistance from Ciaran and Helen the electronics lecturer to try and find a solution.

The answer eventually came as a result of basically having to restart my machine and load the USB direct to the port instead of using any peripherals. I also realised I had not been selecting the board and the port in the IDE. So after a few tries my machine eventually recognised the Arduino and I managed to complete the first stage of my

research and development.

I got the analogue granular synth to make sounds and I was able to modulate them using the potentiometers wired to the bread board and then to the Arduino.

I then set out to test to see if the second part of the project would work, which was to build the mini min or theremin style instrument.

(<https://www.instructables.com/MiniMin-a-Theremin-Style-Instrument-From-6-Compone/>).

I then encountered the same issues with my mac not recognising the Arduino or even seeing it connected to my machine but eventually after many tries, I was able to upload the code to the board.

Once I managed to load the code and figure out why it was not loading initially, I struggled to actually get the theremin to work and after a number of days of persisting with this I decided to try another approach which was to build a slightly less complicated Light Theremin using just a photo resistor.

(<https://create.arduino.cc/projecthub/sumanbargavr/light-theremin-c28a1d>).

I managed to get this to work as well.

The next issue I faced was trying to combine the code of the two instruments so that I could use the Theremin to control the pitch of my Lo-Fi synth.

This did not work out and after many days of research, forum searches and many different types of combinations, I decided to simplify my original idea and just make a really good version of one of them.

I decided I would innovate it by making it look and sound the best I possibly could and use all of the components I had acquired to make it in my own style.

The final hurdle came when I started building the enclosure for the synth.

I bought a nice case for it to go in and started by drilling the holes creating and shaping all the aspects for the various components to go in.

I then soldered all of the wires to the potentiometers as well as to the LED's and soldered all the components to the Arduino and connected the peripherals using a protoboard.

I then started to put everything in place but when I tested it, it did not work.

This was a major setback as I was beginning to run out of time. I then had to completely dismantle the box as well as all the components and went through the arduous task of testing everything using a multi meter.

I then set about rewiring everything from scratch and painstakingly did this a few times and still it did not work.

I tried to methodically test every component using a voltmeter to make sure that everything was still working.

I thought about the possibility that the solder wire I was using was maybe too thick and then bought some new components so that I could test the circuit again and get it working on the bread board and try and do it again using new components in order to get this synth working and doing what it was supposed to do.

It seemed to me that two of the potentiometers were not working anymore and I gathered that it could be because I may have affected it when I was soldering the cables to it.

This then took me another couple of days to rebuild and eventually after copious amounts of testing and retesting. I tried to create a new and more simplified version of the synth and eventually I managed to get it to work.

Improvements or Modifications

One of the ways I thought about improving my synth would be to have a jack input that I could plug an external instrument directly into the synth in order to control the voltage such as a guitar or piano and use it as an effects pedal in order to manipulate and create cool sounds in the same way a stomp box is used.

Another improvement or modification I thought would be a good addition to the synth could be to combine the original synth idea with another instrument such as a light theremin or theremin style instrument. This would be another way of controlling the input voltage using motion sensors or light dependant/photo resistors. I would need a bit more time to test and possibly get some help with re writing the code as this is not my forte.

In my application of this analogue synth, I wanted to use a guitar effects pedal and an envelope filter to add a bit of extra bite to the sound and also a few more manipulation controls to give it a type of modular feel.

This would have given me the ability to create a truly unique sound and approach to my creative music making process and production.

Many of the analogue synths on the RC Arduino site can produce many different sounds but all use the same basic technique to generate their sound.

So, a development on these projects would be a modular synthesizer which allows the user to easily combine the techniques used by individual projects to produce new instruments.

I would like to be able to control or create a synth using Midi and I have found that there are various modifications that can be added to the Arduino to make this possible. (<https://www.instructables.com/How-to-control-DIY-Synth-with-MIDI/>)

Comparisons

There are many lo-fi analogue synths on the market currently that compare to the synth I have created.

Most notably the MAM MB33 Retro

(https://www.thomann.de/gb/mam_mb33_retro.htm?sid=94d090130524434717861519c12be0ae)

This particular model has very similar functions to the synth I have built however there are a few functions I have not been able to add to my own version. Such as the auto slide function, switch for autotune, ENV modulation depth control, VCF input jack, socket for MIDI input and it also uses 12V AC / 800 mA power supply.

Another product on the market in the same category is the Korg Monotron Duo Analog Ribbon Synthesizer. (<https://www.juno.co.uk/products/korg-monotron-duo-analog-ribbon-synthesizer/440155-01/>)

The differences with this Synth are that it is based on a combination of 2 oscillators in unison to provide rich analogue sounds, while tuning them to different intervals. One of its main features are an enhanced ribbon controller keyboard and has a scale function such as the Kaossilator with chromatic, major, minor or off scales.

Feedback and beta testing

My beta testing involved testing and trying various incarnations of the same style or type of synth using various codes found on the Instructables websites as well as with in the Arduino IDE.

Eventually settling on the Arduino Lo-fi Granular Synth.

Once all of the technical issues had been dealt with. I faced probably the hardest challenge in creating my instrument. I had tested the synth using the bread board and jumper cables but once I started to transfer the project from the bread board to the proto board and solder the wires to it, was when I was faced with a major issue. I had completed soldering all the components together and built and spray painted the casing as well as attaching everything together and once it was completed it didn't work.

So, in hindsight I would have to be a little bit more detail orientated and methodical in my approach and also take special care when soldering.

Reflection

I have always liked the idea of building an electronic instrument. I studied Sound Engineering years ago and I had to build a DI box as one of my projects, but this does not come close or even compare to building the Arduino Synth.

It has also been quite a few years since I have had to solder anything or put anything together in this way.

I do feel that this process and project has improved my understanding of analogue synthesis and I feel very competent that I can now carry on and try to build something a bit more ambitious for my next project.

I would like to try and build a Moog style synth next.

Watch this space!

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