

Module Title: Development (ADAD7005_LON)

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Overview/Introduction

For this assignment, I've been asked to create either a software or a hardware instrument based on my preference.

I took the decision to create a soft synth as I felt that I would probably use it more often and it would be a long-lasting instrument, comparing to a hardware device.

Not only that but because I use soft synths in my productions, I knew that if I managed to make a good synth, then this would be a good addition to my collection.

Once I chose the type of instrument I would be building, I had to research the fundamentals of sound design and synthesis in order to understand the parameters and differences between certain synths and what makes them unique.

Based on this research, I then decided on the type of synth I would be making and what parameters I would like to include in it.

At the beginning of the research, I wanted to make a synthesiser that could feature multiple types of synthesis, plus adding step sequencers and FXs.

Most of my research was based on Youtube tutorials, blogs, articles and books. These were crucial to guide me through the project.

Once I did the research I realised how hard and complex it would be to create a synth that I envisioned all by myself. So I changed my mind and went for a Subtractive Synth with an Effects Rack.

This was a reasonable challenge for me to take, taking into account this was my first experience making a synth in Reaktor, which is a program that I had never used previously.

In the end, I managed to make the synth and get it to work properly, which was my ultimate goal. I am now able to create pads, basses and other types of sounds that can be used in my productions.

Research on Sound Design and Synthesis

As it was previously mentioned, I had to do some research to acquire knowledge of Sound Design and Synthesis. As a producer, I've never fully delved into this subject, always using presets and never making sounds from scratch. So I knew that but studying these topics I would not only be able to make the synth but also become a more informed and all-rounded producer.

I started my research on Sound Design and its fundamentals:

Sound Design

I wanted to cover the basics of sound design to prepare myself for making my desired synth. The main question was: "How do we generate a sound coming from a synthesiser?"

Essentially, a sound needs three main factors:

- a sound source which is created by an oscillator (in software synthesis the sound source is made out of computer code) ;
- a filter to shape the tonality of the sound ;
- an envelope to control the volume/amplitude of the sound while this is being played overtime (*see in Appendix A*)

Main Wave Shapes

As a sound source, this could have many different shapes and sizes.

The most commons wave shapes are (*see in Appendix B*) :

- *Sine Wave* - The purest form of tone we could have as it only has a fundamental note and doesn't have any overtones.
- *Sawtooth Wave* - This is a very bright and full sounding wave. It's usually filtered as it can be very unpleasant to the human ear.
- *Square Wave* - *"The square waveform has a hollow quality and is often used to create "woody" or "reedy" tones such as those found in woodwind instruments. It is also frequently used in bass sounds, either on its own or to fatten up a sound, often acting as a sub-oscillator"* (Cann, 2014)

- *Pulse Wave* - This one is very similar to a square wave but with a different width. If it has no width then it's just noise. Some synthesisers like to distinguish the square and pulse, while others only include the square with an option for pulse-width modulation.
- *Triangle Wave* - This wave sounds like it's a mixture between a sine and a square because visually is similar to a sine, but sonically it has more overtones and it's less sharp than a square.
- *Noise* - it isn't exactly a waveform, but a source of sound formed by a colour of noise - *"white noise is the brightest, pink noise is slightly less bright and brown noise is the duller still"* (Cann, 2014)

Filter - Types, Parameters and LFOs

A filter is pretty much a tone control like the ones we would see on an electric guitar.

Main Types of Filters (see in Appendix C)

- *Low-Pass/High Cut*: allows the low frequencies to pass through it by cutting all the high frequencies;
- *High-Pass/Low Cut*: this is the exact reverse of a Low-Pass filter;
- *Band-Pass*: this is a combination of the two previously mentioned filters where they cut the frequency spectrum at both ends, allowing the sound pass in a narrow band. This one usually takes a lot of energy out of the sound so it's recommended to boost the level after filtering it;
- *Notch*: This is the complete opposite of a Band-Pass, as this one only cuts certain frequencies in the spectrum. This could be used as a way to blend/mix two sounds that might take the same frequency register, by notching one of the sounds out in order for them to sit properly.

Filter Parameters

Even though most filters tend to have several controls and parameters (which could differ from one synthesiser to another), they all work the same way. These are the standard parameters to look for :

- *Cut-Off Frequency*: The point where the filter starts to have an effect. (Eg. Start cutting at 5kHz)
- *Resonance*: This enhances the filter by boosting the sound spectrum around the filter cut-off frequency creating a peak, which if used cautiously, can add some bite to the overall sound.
- *Filter Slopes*: This is the rate at which the sound wave is being reduced above the cut-off frequency. The slope is measured by 6/12/18/24 dB/octave filter. Each of these numbers represents the reduction of the sound (in dB). If it's 6dB/octave, then this means that there's a reduction on the level of the sound source by 6dB at one octave, while if its 18dB then it will have an impact on three octaves above the cut-off point.

LFOs

Usually these parameters are triggered by an LFO (low-frequency oscillator) which produces a repeated signal - this is being oscillated below the audio threshold so they're inaudible. This is what is called the *modulation source* (see in appendix D)

The main LFO controls are *wave shape*, *speed* and *depth*.

The *wave shapes* can be the same as the basic shapes mention earlier (sine, triangle, sawtooth, square). Noise it's not a common shape for an LFO due to it being impractical. There could also be a random wave shape modulating the parameters.

The *speed control* affects the frequency of the LFO and it can be synchronised with the tempo of the track, meaning that the LFO completes its cycle through a subdivision of the tempo

of the song (eg. 1/8 note subdivision in a 125 bpm song). This is a great way to add movement to the synth.

The *depth* of the LFO is the amplitude of the effect being used.

"If the LFO's amplitude is zero, no modulation will be heard. As the amplitude is turned up, the depth of the LFO's effect will increase"(Aikin, 2017).

Envelope

There are multiple types of envelopes but the one which is the most commonly used is the ADSR envelope.

This is an acronym that stands for:

- *Attack*: How long does it take for the sound to reach its maximum volume after being triggered;
- *Decay*: How fast the sound drops after reaching its maximum volume;
- *Sustain*: This is the level/volume of the key being held while playing the sound;
- *Release*: After the key is released, this would be the time it would take for the sound to decay to zero (see in Appendix E)

Types of Synthesis

During this research, I found numerous different types of Synthesis. The ones that interested me the most were Subtractive, Additive, Granular, FM and Wavetable Synthesis.

All of these types have a different feature which made them special in their own way:

Subtractive Synthesis

This type is probably the most common form of Synthesis. We start with an oscillator (as a sound source) which is very rich in harmonics, and then we subtract them with a filter and reshape the volume with an envelope.

“You can think of it like sculpting. A sculptor starts with a large block of material and chisels away until it resembles something else” (Douglas, 2019).

Some of the biggest music hits in history used this form of synthesis. A few examples of synthesisers that have this type are the Minimoog created by Bob Moog and the Roland Jupiter-8.

This type of synthesis was also known as “East Coast Synthesis” in America as there was a contrast between the sounds of the East and West.

Bob Moog made this form very popular in New York, while in other areas like California, pursuing electronic sounds was more experimental thanks to creators like Don Buchla, who invented the Buchla Music Easel, which in comparison to Moog’s creations, this synthesiser starts with a simple waveform and then uses wave shapers to create harmonics making it similar to an additive synthesiser.

Additive Synthesis

This type is very much the opposite of a subtractive synth. This one uses a combination of certain harmonics in sine waves that are added together to create a full and rich sound.

This idea was already being used (before the birth of synthesisers) in instruments like the Hammond Organ where you can add or remove harmonics using drawbars (see in Appendix F)

This is one of the best types to make precise sounds.

Wavetable Synthesis

Now moving to a more sophisticated type, invented in the late 70s by Wolfgang Palm, Wavetable Synthesis features a vast number of wave shapes that are inside an indexed table, and they’re all connected by interpolation in the oscillator, creating a very characteristic sound (see in Appendix G).

“Wavetable synthesis differs from subtractive processes that filter sounds to create new wave shapes, additive processes that sum waveforms, or FM and AM synthesis where modulating oscillators are used to manipulate carrier oscillators to create sideband frequency content” (Mantione, 2017).

FM Synthesis

Its name stands for Frequency Modulation and the most iconic synth to adopt this form was the Yamaha DX7.

This type applies a similar concept as Wavetable, in the sense that one waveform modulates another, but this one starts with a pure sine wave which is the carrier of the sound which will then be modulated by another sine wave (but this one is inaudible). Although the first iterations of FM only had sine waves, there are now more FM synths that include other types of waveforms.

Granular Synthesis

This is perhaps the one that differs the most from all the other mentioned types of synthesis, as this one doesn't use waveforms but recorded samples making it part of the Sampling Synthesis family. The difference between this one and the other samplers is the fact that this one is able to playback the sample in small fractions of time, also known as “grains” which can be easily modified enabling creators more experimentation to make completely new sounds.

The type of algorithm being used has also been implemented as a tool in other virtual instruments and effects outside synthesis.

“Is an extremely powerful audio manipulation system that makes it possible to adjust the speed, pitch, and formant characteristics of audio samples independently of one another, and all in real time if your computer is fast enough (Price, n.d.)”.

Project: Subtractive Synth with Effects Rack in Reaktor

After my research was done on Sound Design and Synthesis, I moved on to Reaktor and started playing around with the program to get a sense of familiarity.

In the beginning, I used Blocks to understand how the routing worked and what I need to do to make my synth playable.

I noticed that to produce a sound on this program I always needed to add a “Pitch” and a “Gate” module. Without these, there is no connection between the synth and the output signal (*see in Appendix H*)

I started realising how easy but at the same time complex, this system could be. Therefore my initial idea of combining multiple types of synthesis (incl. sample-based) was turned into a more realistic approach by designing a subtractive synth with an effects rack.

Building The Synth - Overview

The idea was to make a simple synth that was easy to read and to modify. It was made particularly for people who don't really know a lot about sound design. Therefore, I labelled every parameter to make it easy to use (*see in Appendix I*).

The layout of the synth is pretty straight forward having 3 oscillators as my sound generators, each with their own Low-Pass filter and Resonance, and also a “Detune” and a “Semitone” function, to have the option to make it sound wider and to also have a bigger range in pitch- this allows each oscillator to be in a more specific frequency range.

I also made an Envelope which features the classic ADSR previously mentioned in the essay, and I also included a Low-Pass LFO to modulate the signal, which features a Cut-Off frequency, a Rate/Speed, and a Depth knob to have the option to go in depth and to have more variation. Not only that but, I also included a Synchronisation option to have the LFO locked in to a tempo, plus a reset button so that each time a note is being played, the LFO starts its cycle instead of being played continuously.

The Process and Routing (to check the module - see in Appendix J)

Oscillators *(see in Appendix K)*

I started the synth by making the oscillators. Like it was mention earlier, I needed a “Pitch” and a “Gate” module to begin the connection, as these are the Midi source. Once that was included in the macro, I then added the wave shapes and sent all of them to a switchable “Waveform”, allowing the option to switch between the waves or to simply turn the oscillator off.

I sent the Waveform to a 4-Pole Filter (24dB/octave Filter) and then I created the Resonance and the Low-Pass Filter.

In order to make the LP filter readable by the 4-Pole Filter, I had to convert the range of the frequencies (0Hz-20kHz) into logarithmic pitch values by adding a “Log(F)” module, as the 4-Pole Filter only reads pitch. Then I sent the signal to the output of this module completing the first oscillator. Once that was done I duplicated the oscillator twice having now three oscillators which are all included in an “Add” Math Module in order to connect to the LFO's input.

Envelope *(see in Appendix L)*

This process was pretty simple to make. I made the macro by adding a gate, inserting an ADSR module and added a knob to each parameter. Once that was done, I established the connection between this macro and the oscillators by routing it through the gate signal and inserting it in the oscillators' gate input.

LFO *(see in Appendix M)*

I started this macro by adding an LFO built-in module. For this LFO, I only used the sine wave to be my modulation source. I repeated the same approach done previously in the oscillators LP Filter, by connecting the sine wave through an “Add” module, which includes the conversion between frequency and pitch (where I also made the *cut-off frequency* controller), and connected them both to a Pitch input of another 4-Pole Filter.

I then added a “Depth” controller by simply creating a control connected to the Amplitude input of the LFO.

The “Rate/Speed” function was made by creating a knob which was connected to the Frequency input of the LFO. But then the routing changed because I added the Tempo Sync.

I made an ON/OFF Switch and linked the Rate controller to the Off option so that whenever the Sync option is off, the rate has to be manually changed in the synth.

To make the Tempo Sync work, I added a module called “Tempo Info” which is Reaktor’s tempo source.

Then I had to make the subdivisions in order to choose the synced rate. To make this possible, I created a list module (see in Appendix N).

I connected these two signals by using the “multiply” math module and linked them to the On option of the “Tempo Sync”.

Then I inserted the “Reset” trigger, which can be found in between the gate and the Sync Input of the LFO. I made it by adding a switch module, and a constant with the value 0 and connected it to the Off trigger- in case we don’t want the LFO to reset.

After all of these parameters were created, I routed the 4- Pole Filter to the Output of this whole macro, and created an Input signal which was connected to the “In Input” signal of the 4- Pole Filter - to be able to connect the envelope and the oscillators and finish the circuit of the whole synthesiser.

The last addition was the Master Volume controller. This one is connected to the output signal of the synth through an Audio Voice Combiner, which mixes a polyphonic audio signal into monophonic.

Effects Rack (see in Appendix O)

After the synth was made I wanted to add some effects to make it more flexible and to sound more interesting. I started by making a Chorus (see in Appendix P)

“Chorus effects thicken your signal by copying it multiple times, colouring the copied signals, and playing them back slightly delayed” (Reverb, 2018)

To make the copied signals I started by making two “Single Delay” modules.

Then I added 2 sine waves to modulate the delay time of these modules. This was made, again, by using “Log(F)” module creating two controls for Frequency and two for Amplitude.

I added a constant with the number 2 to make the delay time above 0 because the sine waves were outputting a value between -1 and 1 - it's not possible to use a negative value as an input to a delay time.

This made sure that the delay time stayed positive. These values were then linked to the delay modules.

I then made a Depth controller by using a “Crossfade” module, where I sent the non-delay signal to 0 and the delayed signal to 1. Then I just created the knob to be able to use it on the effects rack.

Once the Chorus was done I made a Delay effect (*see in Appendix Q*).

I started another macro with two Single delays and made a delay time knob which is controlling both of the delays.

I added two saturators to the output signal of these modules. The reason for that was to use it as a limiter to prevent the delays to sound louder than the source signal.

Then I made a feedback loop by sending the output signal of the delays back to its input by using a duplicate module called “Multiply Add” where the first two ports of these modules are multiplied and then are added to the third port. I inserted the input signals of the macro on the third port and the output signals of the saturator on the second. The first port was used to create a feedback knob to have the option to control the amount of feedback on the effects rack.

To finish this delay I needed a parameter to determine how much I wanted to use this effect on the synth. So I made a Dry/Wet parameter by again, using two “Crossfade” modules where I connected the dry signal of the macro to 0 and the wet signal to 1.

Once that was done, I complete this circuit by sending the output signal of these crossfades to the output signal of the macro in order to connect it to the next effect which was the Flanger.

To make this one, the approach was pretty much the same one I used for the Chorus effect, but instead of using two “Single Delay” modules I only used one.

Moving on to the Distortion effect, this was a simple effect I added mainly to just give a little boost to the synth without crushing its sound (*see in Appendix R*)

To create the distortion I used a “Clipper” module, which is a signal modifier that features a minimum and a maximum limit that allows controlling the amount of distortion being used.

To create the Distortion knob I used another “Crossfade” module where I used the same principle mentioned earlier, by sending the dry signal of the macro to port 0 and the distorted signal of the “Clipper” to port 1. The last thing to add was another ON/OFF Switch by simply sending the dry signal to the Off port and sending the distorted signal coming from the “Crossfade” to the In port. Then I finished the whole circuit of the project by sending this signal to outputs of the whole ensemble (*see in Appendix S*)

Conclusion

I was happy that I managed to build a functional synth from scratch. I found it to be a bit difficult at the beginning, but once I started understanding what each module could do, it became more intuitive, making this experience enjoyable.

At the same time, I am humble enough to admit that the synth doesn't sound as good as other synths. If I had to choose between my synth and a synth made by a company (eg. Serum, Massive etc) I would probably choose the company's synth due to it sounding better, having better aesthetics and having more options.

Still, I consider this to be the first experiment of many more to come. I intend to study more about this program and make more synths. Perhaps one day I'll be able to create my own sounds and nobody else would be able to replicate them.

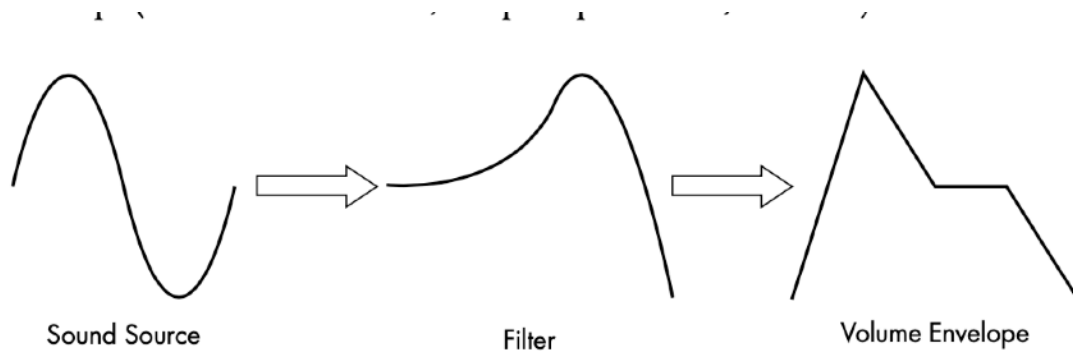
I was also surprised by how much I had learned about Sound Design and Synthesis, which I am sure I will use this knowledge and apply it to my future productions.

The only negative experience I had while making the synth was when I couldn't make a reverb effect due to the lack of information. This is because the software isn't as popular as other synths. Most musicians and producers don't want to be making synths from scratch, which makes this "Reaktor culture" very small.

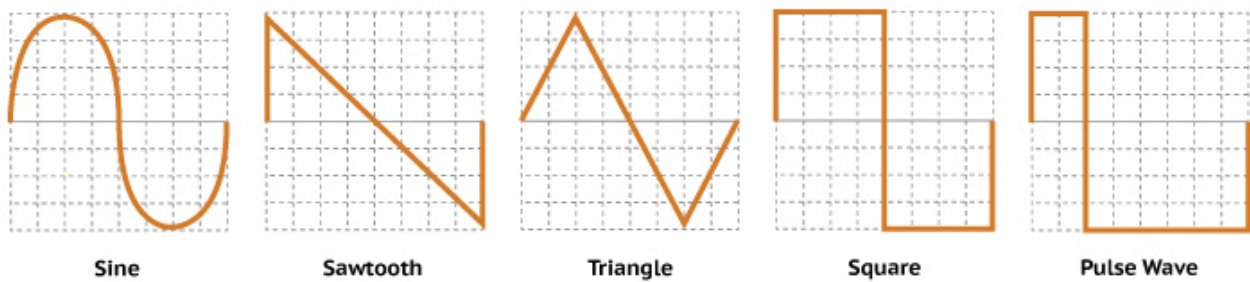
Nevertheless, there is a sense of community in this culture and I feel like I am part of it now.

Appendices

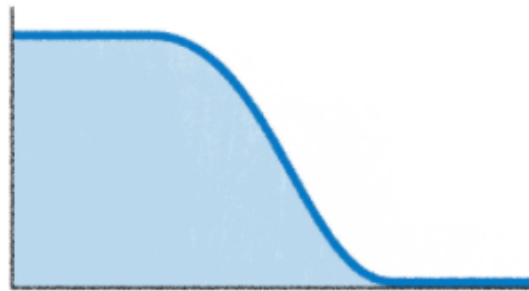
Appendix A- How to generate a sound



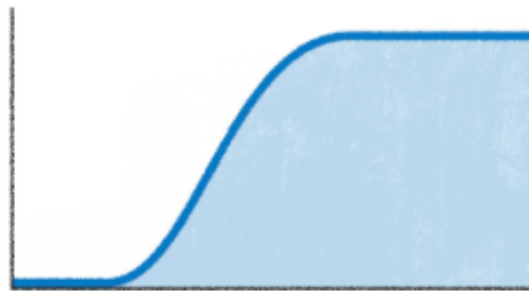
Appendix B- Basic Wave Shapes



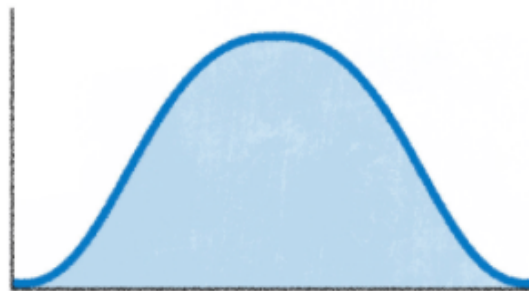
Appendix C- Types of Filters



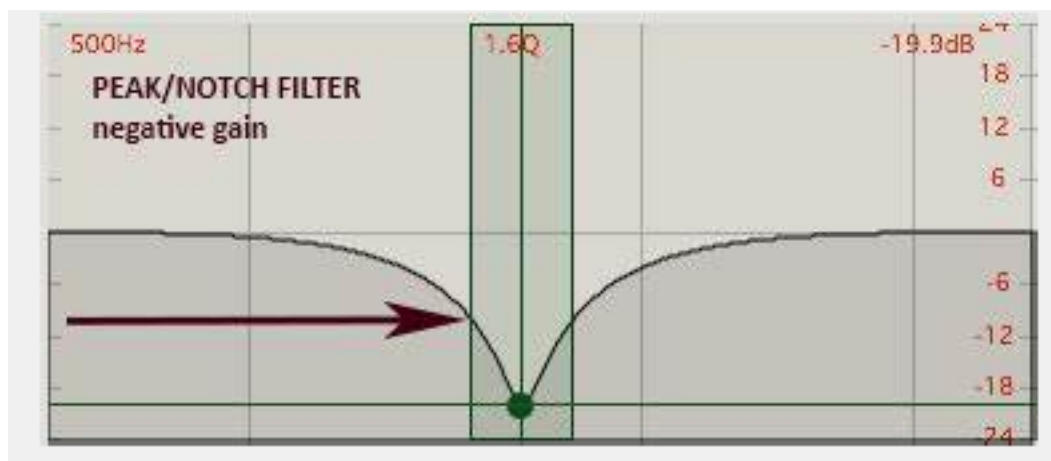
Low-pass filter



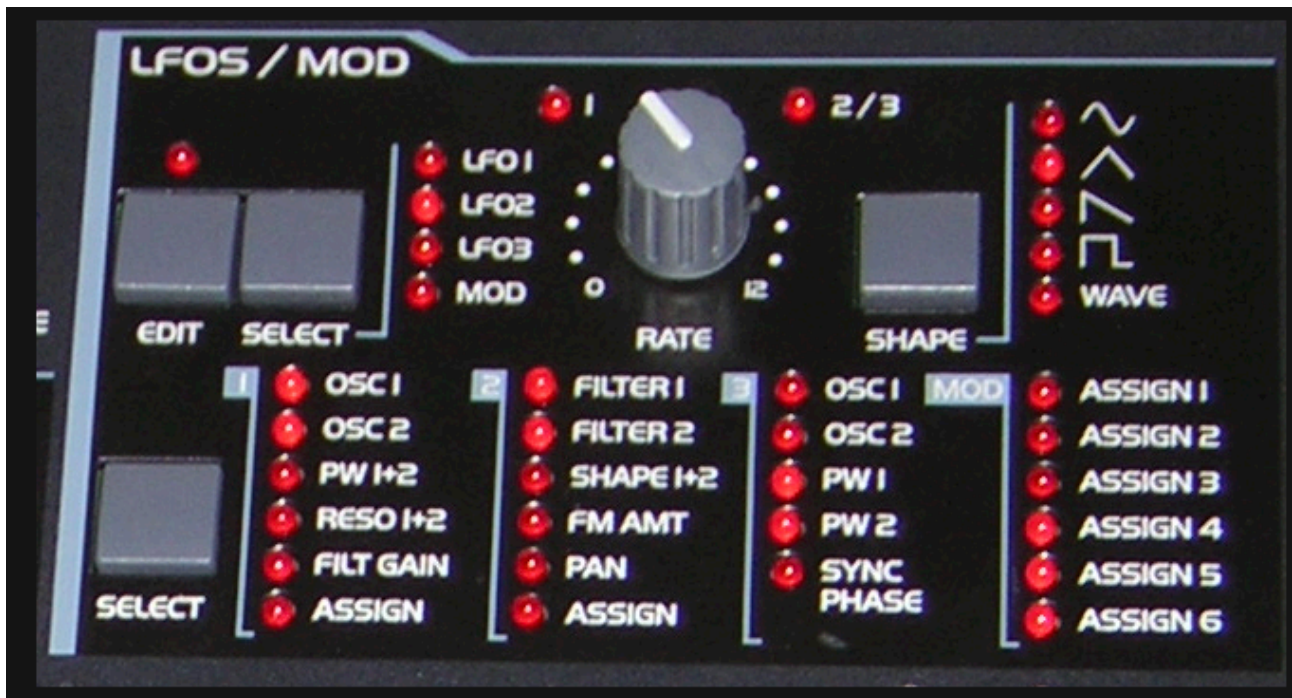
High-pass filter



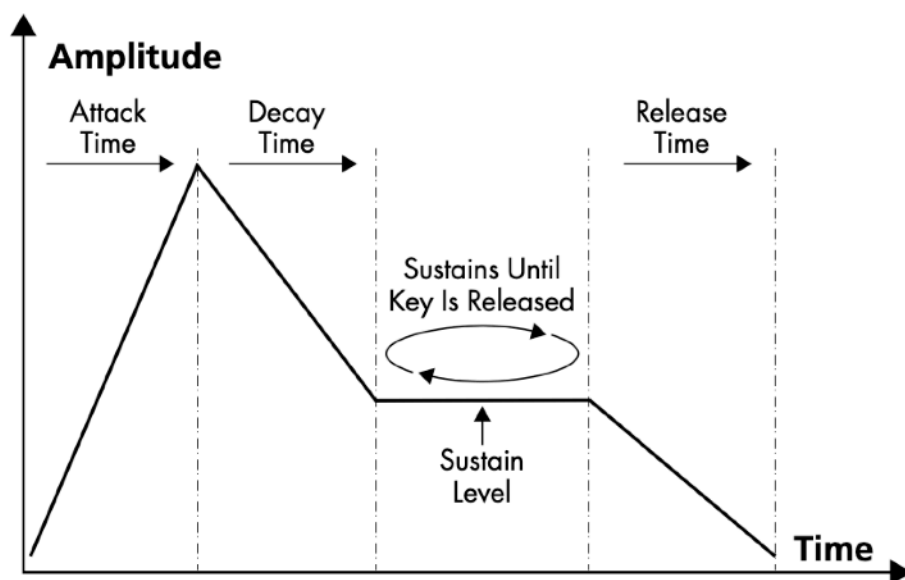
Band-pass filter



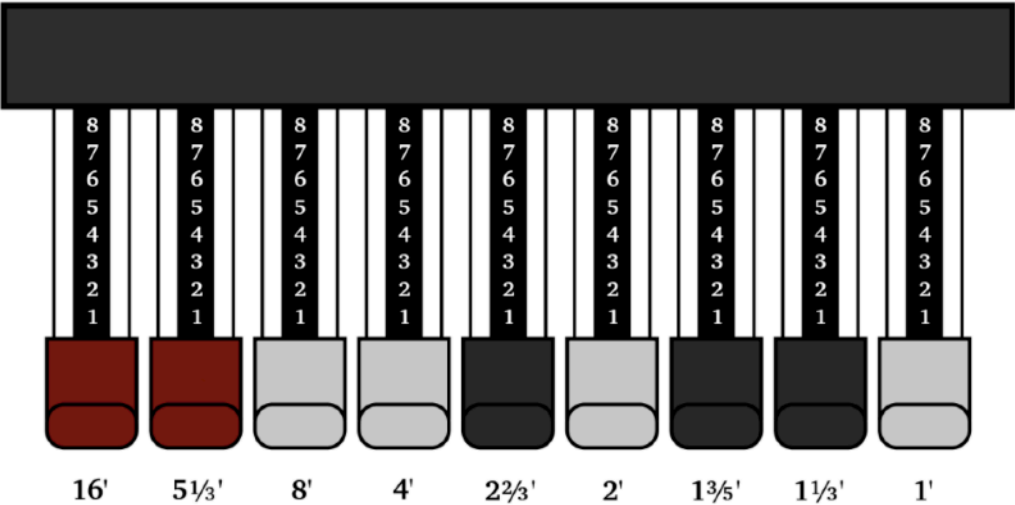
Appendix D - LFO Parameters



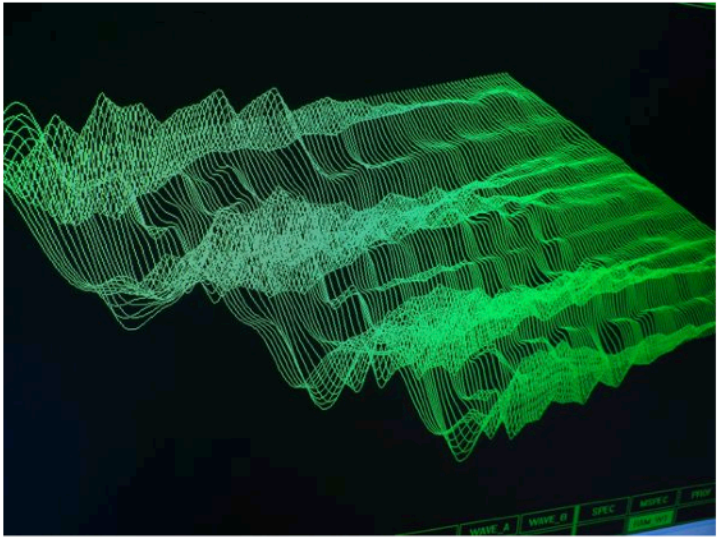
Appendix E- ADSR Envelope



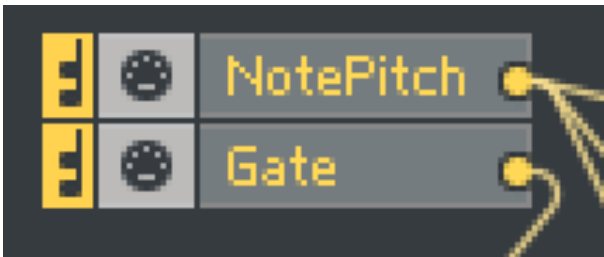
Appendix F- Organ Drawbars



Appendix G- Visual of Wavetable Synthesis



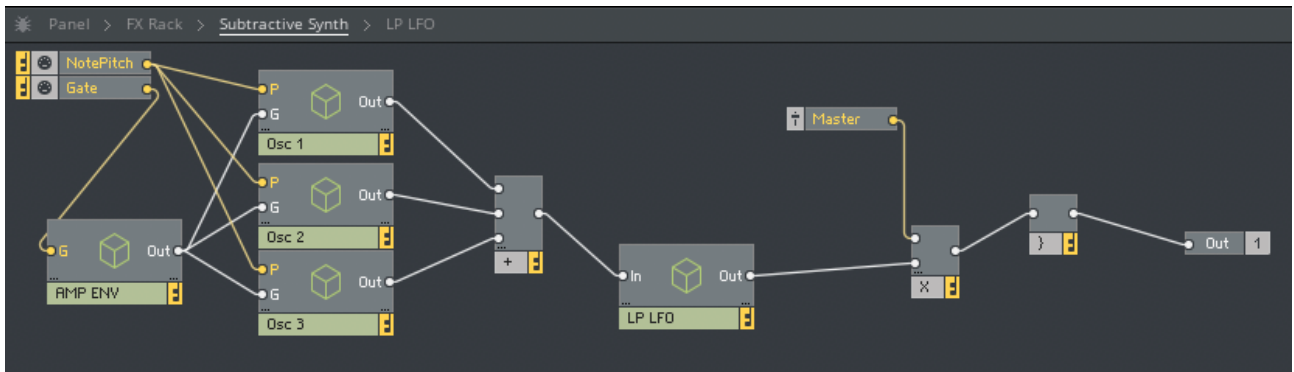
Appendix H- Gate and Pitch in Reaktor



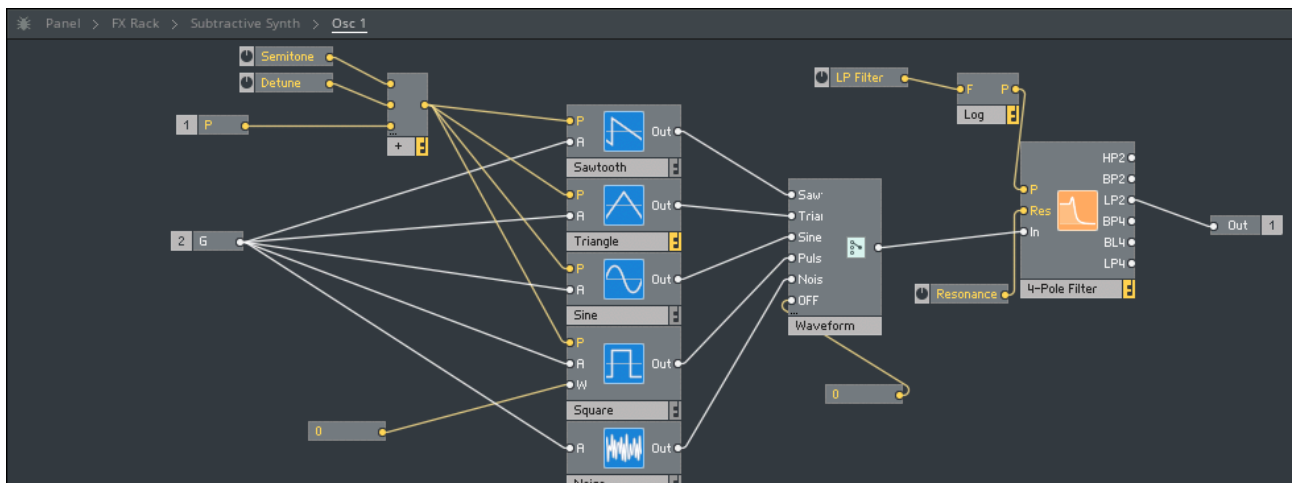
Appendix I- Overview of the Synth in Reaktor (Oscillators, Amp Envelope, LP LFO)



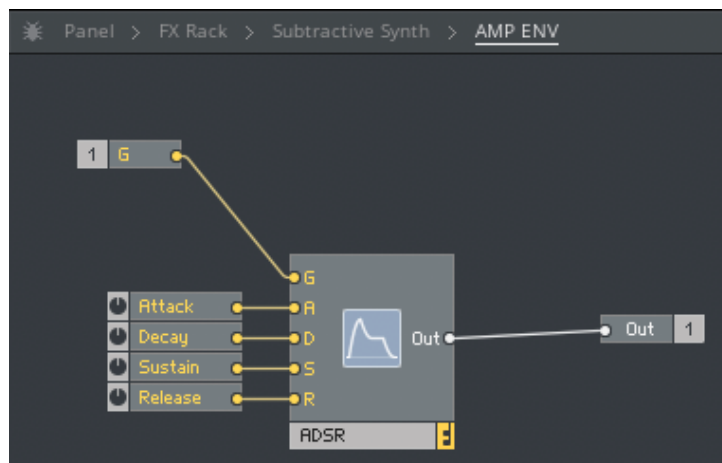
Appendix J- Subtractive Synth Macro



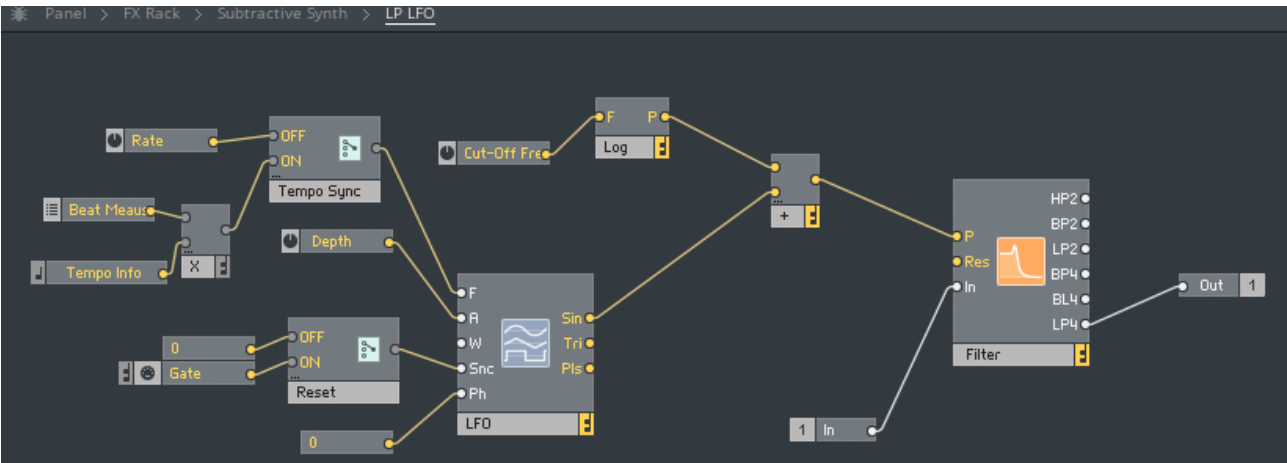
Appendix K- Oscillator Macro



Appendix L- Envelope Macro



Appendix M - Low Pass LFO Macro



Appendix N - Subdivisions List

List

Beat Measre

Function

Info

View

Connect

ENTRIES

Number

7

APPEND

INSERT

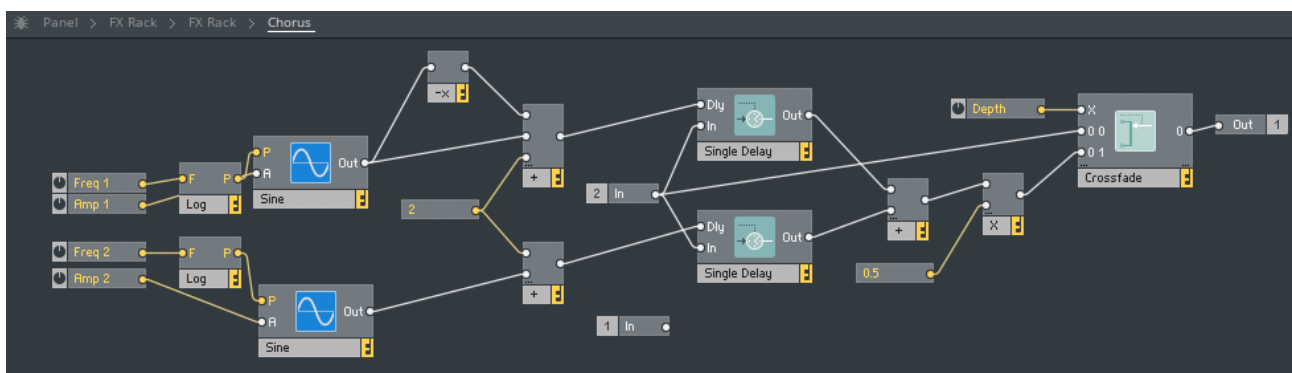
🗑

#	Label	Value
1	1/2	0.5...
2	1/4	1.0...
3	1/4 T	1.5...
4	1/8	2.0...
5	1/8 T	3.0...
6	1/16	4.0...
7	1/16 T	6.0...

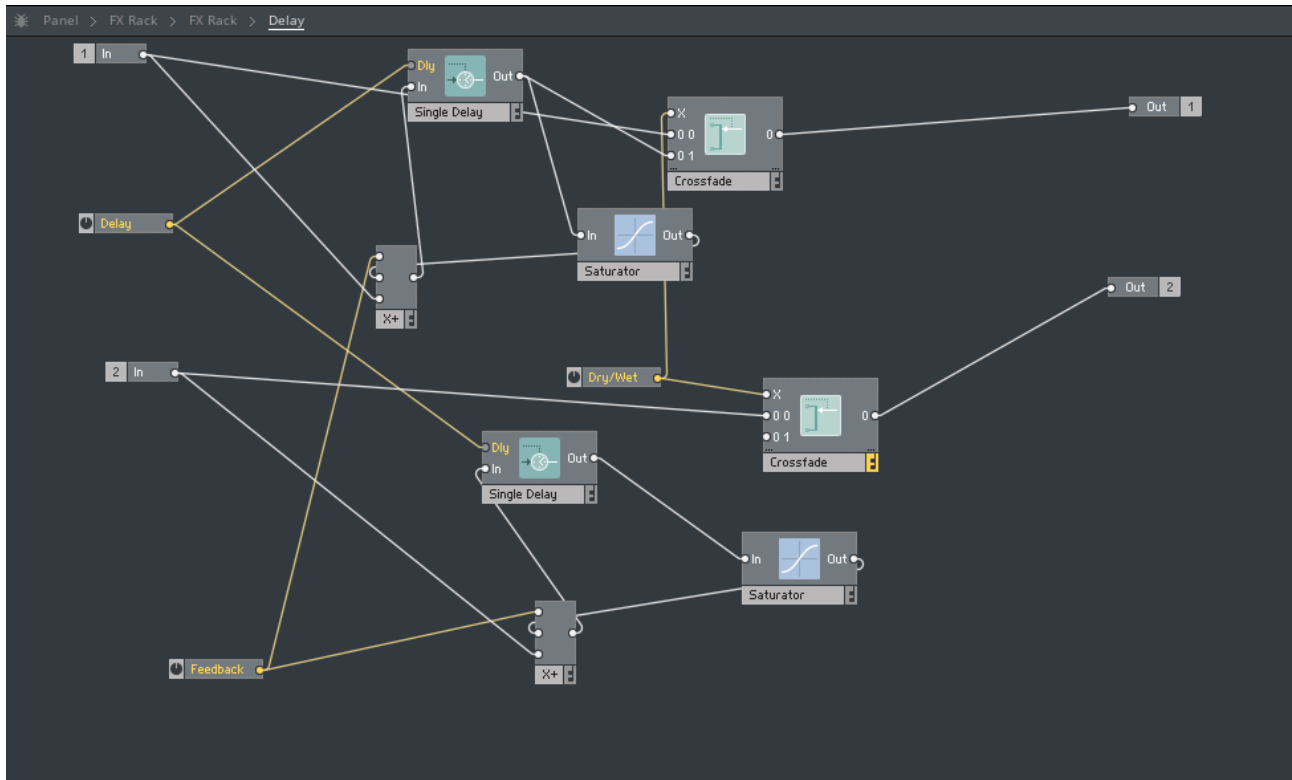
Appendix O- Overview of the Effects Rack (Chorus, Delay, Flanger, Distortion)



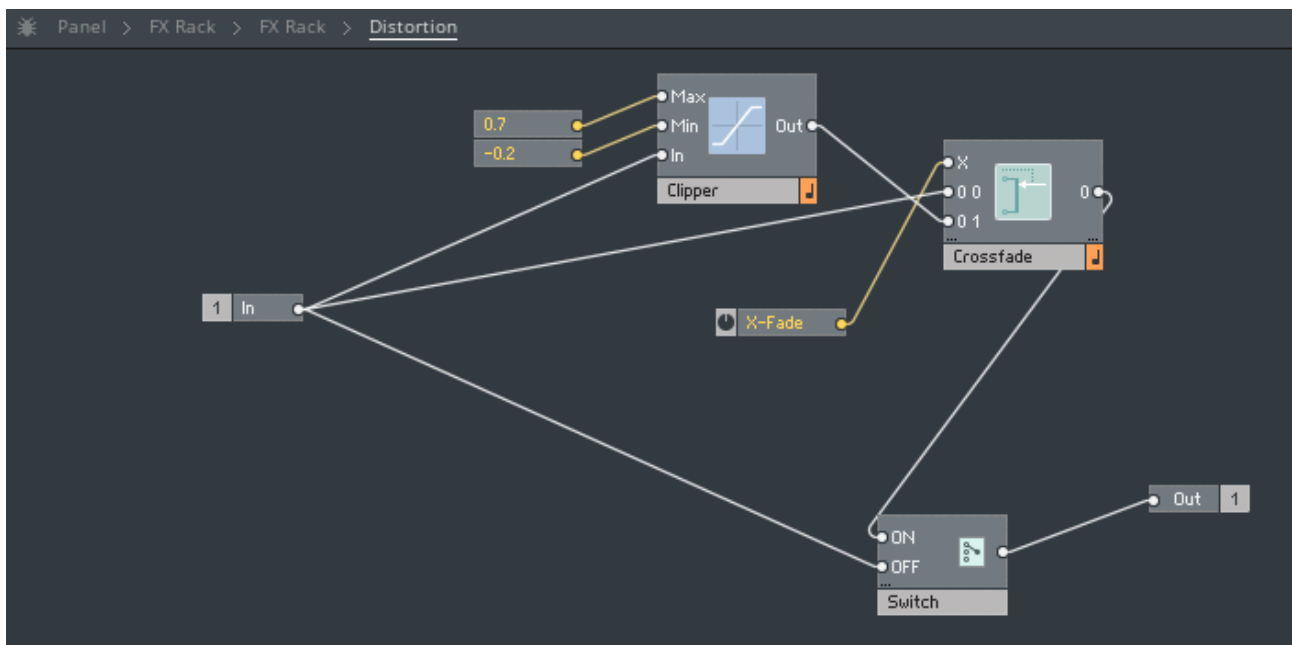
Appendix P- Chorus Macro



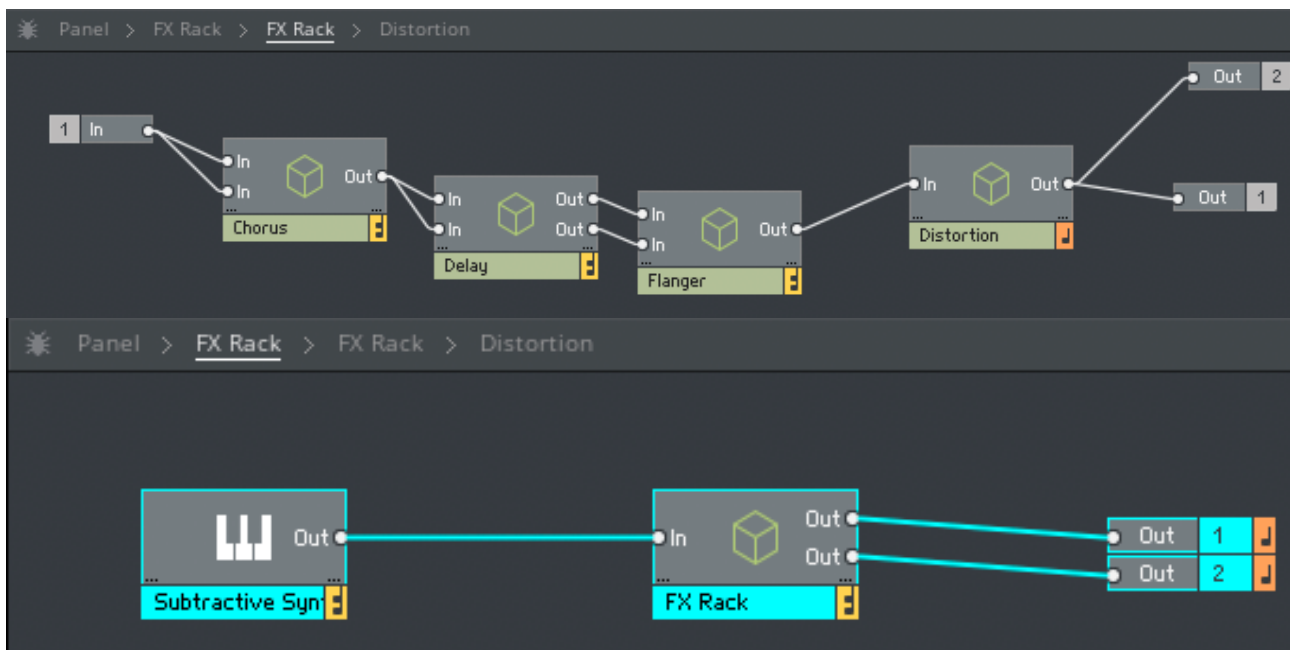
Appendix Q- Delay Macro



Appendix R- Distortion Macro



Appendix S- Effects rack Macro finishing the circuit



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