

Name: Dror Margalith
Student Number: 1909469
Module Title: Development (ADAD7005_LON)
Assignment Title: Instrument - FM Stereo Workstation

Introduction

Musicians, composers and producers have been trying to come up with new ideas and design new sounds in order to distinguish themselves from others, be innovative and unique.

Without the invention of the synthesiser, the modern world would have looked and sounded a whole lot different. (TestDrive: Native Instruments Reaktor 5, 2008)
In the last decade, synths have shaped and inspired many new music genres, such as hip hop, with samples that are usually lifted from funk and disco tracks and are utilised by DJs and producers. For example, Minimoog fans Parliament, have been sampled by everyone from Snoop Dogg to De La Soul. Kanye West even has an album that is named after a type of synthesiser (808s & heartbreak). (Finamore, 2018)
The synth has shaped a wide range of musical forms and has had a massive impact on the worlds of TV and film.

Film composers such as Hans Zimmer (Inception, The Dark Knight Rises, and many more), Junkie XL (300, Rise of an Empire, Mad Max, and more), Bear McCreary (Battle Star Galactica, The Walking Dead) and others combine synthesisers with classical acoustic orchestra in a way that the audience can't distinguish between the two, and the end result is epic, impressive and genuinely innovative.

These days, computers have taken over the physical outboard synthesiser with a huge amount of plugins that offer vast sound libraries and many ways to program and design a sound. (Fowler, 2016)

As a full time musician and keyboard player for over 20 years, I have played some of these instruments, but never really delved deep into their programming and algorithms but rather used their built in factory presets.

This research is an opportunity to develop my skills and acquire a deeper understanding of the synthesis world.

Background

In the 60's, Analog synthesisers were inaccessible to most musicians due to the fact that they were large, expensive and were built with complex modular synthesisers. The Moog, for example, was the first commercial synthesiser and is credited with creating the Analog synthesiser as it is known today. (Luther, 2017)

Later on, in the 80's the Minimoog was designed as an affordable, portable, simplified instrument which combined the most useful components in a single device. It was the first synthesiser sold in retail stores. It started by being popular with Progressive Rock and Jazz musicians and later was found in wide use in Disco, Pop, Rock and Electronic music. (Weiner, 2017)

The Minimoog created a solid ground for the digital synthesisers to arise. Synthesisers like the iconic DX7 by Yamaha and the D50 by Roland were probably the most successful and bestselling digital synthesisers in history, up to the point that In the early 80's, the synthesiser's market was dominated by the analog synthesisers.

The DX7 broke into the market with its FM synthesis; a means of generating sounds via frequency modulation, which was developed by John Chowning at Stanford Uni-

versity California. FM synthesis created brighter, "glassier" sounds, and could better imitate acoustic sounds such as brass. (KORSAN, 2015)
With its complex menus and lack of conventional controls, only few learned to program the DX7 in depth. However, its preset sounds became staples of the 80's pop music, used by artists including A-Ha, Kenny Loggins, Kool & The Gang, Whitney Houston, Chicago, Phil Collins, Luther Vandross and Billy Ocean. Its particular electric piano sound was widely used, especially in power ballads.

Max vs Reaktor

I wanted to create an FM synthesiser that would be an all-in-one workstation instrument and include workable sounds in order to create or be part of a full track on any DAW. An instrument that would be powerful and flexible with as many features as possible - Oscillators, Filters, Delay, Reverb, Glide, Arpeggiators and many more. Ideally, the instrument should be flexible enough to allow efficiency and creativity in live performances and in the recording studio.
As mentioned, FM and analog synthesisers are complicated to program and work with. My intention was to create a user friendly one, that even beginners won't feel intimidated to work with.

When looking for plugins/software instruments in order to build a synthesiser, there are quite a few options on the market, but the two main plugins that stand out are Reaktor by Native Instrument and Max for Live by Ableton.

Max and Reaktor are pretty "comparable", in terms of learning workflow - if you learn one, you'll have a decent grasp on the other far more quickly than if you had no experience with either.

They are both extremely deep, sophisticated and flexible, and although they use different applications, their execution is very similar. (dented42ford, 2017)
Max and Reaktor are based on the same concept, and they can both be hard to master when it comes to developing your own modules, nevertheless, the learning curve of both is quite steep. (delsy143, 2018)

Reaktor has much to offer in terms of ease of implementation and a vast supportive community. It is intended to be a "plug-in environment" which is geared towards building instruments and effects in order to be used in music productions. Also, Reaktor is much more "plug-and-play" than Max is.

Reaktor would be a better option for building a synthesiser as It has better sounding built-in oscillators and filters and a very flexible environment for putting them together. (TestDrive: Native Instruments Reaktor 5, 2008) (astrodislocate, 2017)

Max, on the other hand, has a longer learning curve, but is far more flexible. It has the ability to do both visual and text-based patching. For audio samples, the time stretching algorithms are far smoother and minimise the sound distortion. Max is far more extensible than Reaktor and is better for creating whole "environments" than single-use unit-like synthesisers. It can still be done but in a much more convoluted way in comparison with Reaktor. Furthermore, Max's built-in libraries of signal components, are in a much higher quality and therefore, it would be a better choice for audio related instruments, as long as one is prepared to delve into computer languages such as C, C++, C# or work in pure math. (FutureMusic, 2010) (dented42ford, 2017)

While Reaktor works fine as a stand-alone version, Max struggles. It is less user-friendly and works much better as part of Ableton Live.

One last thing to consider when creating a synth would be whether the aim is to distribute or sell it. Ableton and Native Instruments both have good marketplaces for

those modules. Reaktor may be a bit more widespread since it has a standalone player.

After taking into consideration all of the above, I've decided to go with Reaktor. As my aim was to build a synthesiser workstation, Reaktor was the better choice. Also, as I am a total beginner, when it comes to sound design and programming, the ease of use of Reaktor was definitely the right choice for me. On top of all that, its huge user-library allows to download massive amount of instruments, for free, in order for me to deeply learn and dissect each one of them to the point that I could see all their components and how they're built. As a major source of learning material, I signed up for Reaktor Tutorials, which is a comprehensive deep course for beginners as well as advanced users. (Anagram and Tenandtracer, 2016)

To summarise, Reaktor's definition is "a graphical modular software music studio" that was developed by Native Instruments. It enables musicians and sound specialists to design and build their own instruments, samplers, effects and sound design tools. It is supplied with many ready-to-use instruments and effects, from emulations of classic synthesisers to futuristic sound design tools. (Anagram and Tenandtracer, 2016)

Reaktor structure

Reaktor offers plenty of outstanding presets to work with. A very basic knowledge of synthesis is needed in order to begin creating sounds in Reaktor's structure window which consists of the program's 52 library instruments, 13 effects and thousands of online downloadable free instruments.

Reaktor is divided into 3 main sections:

Instruments - This section offers ready to use instruments and effects that were created by professional programmers. From powerful synthesisers through sample transformers and groove boxes to sequencers and special effects.

This section would be the right choice for musicians and producers who want to jump straight into the water, start using the instruments and apply their sounds into a creative production, without learning how they are built and without making any changes within the instruments.

Patch and Blocks - This section is meant to emulate the conventional old hardware instruments' components and patch them in order for them to create complex combinations of sounds, sequences and instruments.

Each Block is basically some sort of a closed "small" basic instrument (Oscillator, Filter, LFO, Mixer, etc) and the user patches the instruments together, in different ways, in order to create a full whole functioning "big" instrument.

The advantage is the simplicity of the structure and connections, but if the aim is to go deeper into detail and have the full flexibility that Reaktor offers, then the next level would be the right choice.

Primary and Core - A deeply powerful, highly-advanced platform for building any synth, effect, and sound design tool imaginable. Primary is the structural top-level, using a graphical signal flow paradigm with step-by-step event processing. It's where all parameters, events, MIDI and oscillators data are handled. Sound that is created on Primary level is done by using Primary Macros and Modules, which will be explained later. (Native Instruments, 2019)

Core is the deepest structural level, featuring a powerful runtime machine of code audio compiler.

I chose the Primary method in order to build my workstation so that I could go deep into the instrument and have full control and understanding of the signal path as well as be able to structure and design the instrument to my needs.

The synth

My synth algorithm starts with a MIDI note signal. Along with the MIDI pitch I added two pitch knobs, one for semitones that goes up and down three octaves, a range that gives the flexibility to create low deep bass sounds as well as high airy flute sounds. The second pitch knob is for fine tuning which is quite effective when an oscillator tone is being detuned in comparison with another oscillator tone. For example, when slightly detuning one of two oscillators, it would create a Chorus effect, and if detuning one or all oscillators in a more drastic way it could create a sound resembling a music box or if low pitched - scary drones.

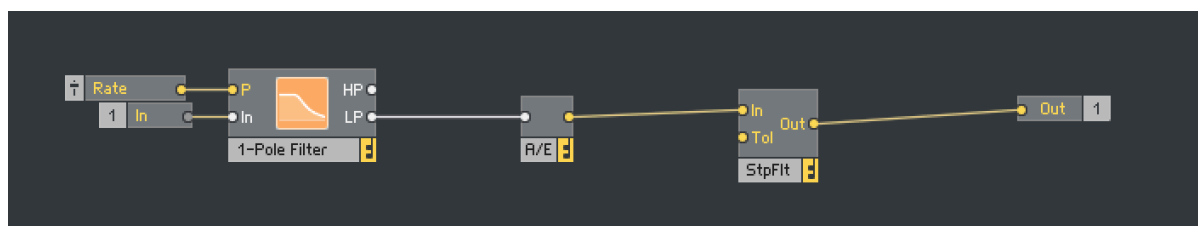
In practice, it took me quite a bit of time to figure out how to connect multiple items to one item. Reaktor has a very clever and sophisticated menu called 'Math' which can do many mathematical calculations that create various complex combinations. In my case, I used the 'Add' feature in order to be able to connect three knobs - MIDI note pitch, semitone and fine tuning - into one oscillator input.

Then, I wanted to have a Portamento effect option. Portamento is when the note is sliding from the last pitch to the new pitch.

Apparently, building the Portamento effect was very complicated and needed me to go deeper into Core (coding), therefore I decided to go with a simpler but similar effect called Glide. The Glide effect is when a note is played, and the pitch slightly glides to the chosen tone.

The Glide effect was made with a 1-Pole Lowpass which is a low pass filter. This filter has two inputs, one for the note pitch and the other one that actually functions as a delay for the low pass. Connecting a knob (Rate) to this delay input, gives control and can determine when the low pass will kick in and start affecting the signal. (Fig 1) Because the output of this filter connects into the pitch input of an oscillator, it actually controls the pitch and creates the glide effect. (Sputnik, 2006)

Fig 1 - Glide effect via 1 Pole filter



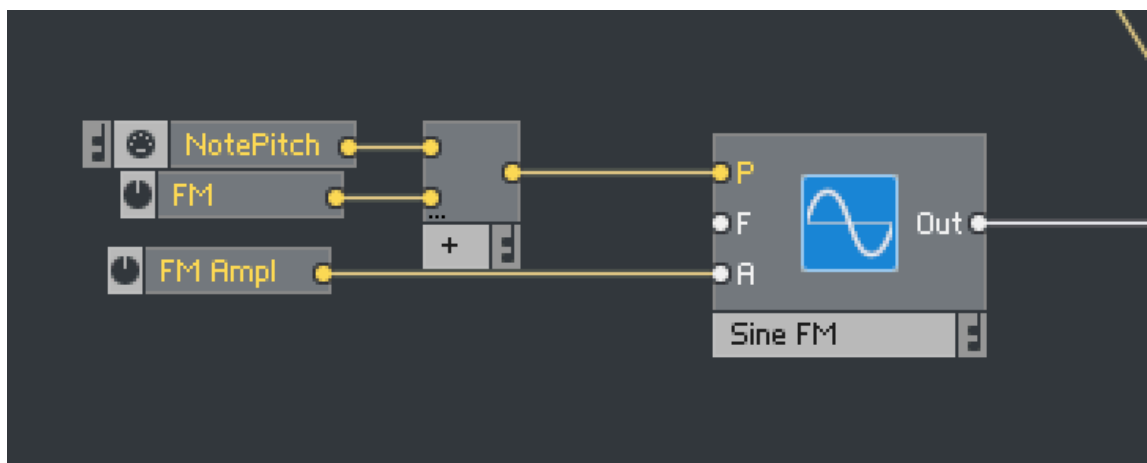
Next in the signal path there are 3 synthesiser Macros that are connected to a mixer. Macros are self contained structures, like folders, that hold other patched-together objects, like oscillators, filters, effects, and many other modules and components. They are designed to organise various parts of a complex instrument into sub devices.

At this stage, I had to make the most important decision in regards to the type of oscillators to use for this instrument. Reaktor offers a large variety of oscillators and as I wanted to create and emulate an FM synthesiser, the obvious choice was an FM oscillator.

In each synthesiser there are four FM oscillators (Sine, Saw, Pulse and Triangle) which are all controlled and modulated by an ADSR. The ADSR is one of the most used wave modulators and by modulating the amplitude of the wave generator, it shapes the sound in the most fundamental stage and helps the producer to create simple as well as complex sounds.

Each of the FM oscillators' frequency is also controlled by another sine oscillator. This sine oscillator is a frequency modulator and it distorts the sound and changes its pitch. (Fig 2)

Fig 2 - FM sine oscillator



It's quite hard to predict exactly what impact the FM would create, but it gives the sound programmer a wide variety of options to create unusual sounds. a common use of FM synthesis is when programming percussive, metallic, bell like sounds.

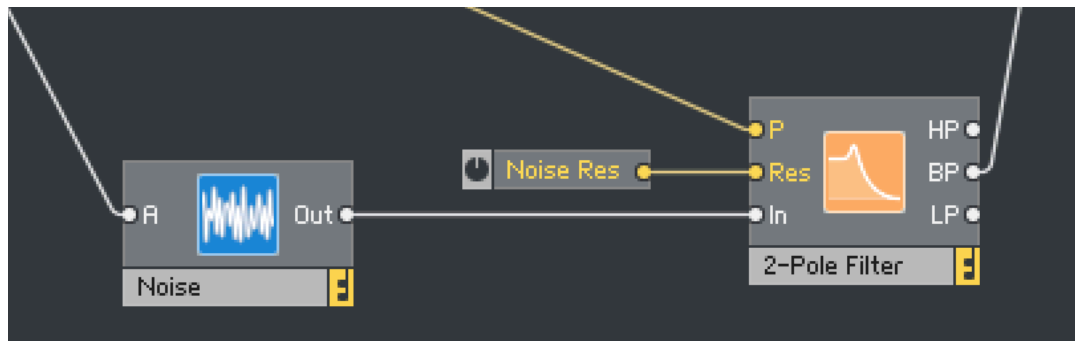
Plugins like FM8 by Native Instruments and Ableton's Operator FM synth, are both used in today's music. Operator, for example, has found itself in many artists hands including Skrillex, who is a successful American DJ, producer, singer, song writer, and Monolake, who is a busy german electronic music producer, to name a few. (Specials, 2011) (Ableton, 2014)

At that point, as I wanted to be able to create a full track with the Stereo Workstation, I realised that I might struggle to achieve it without having a sound source for drums. A sine wave, when properly tweaked by the ADSR (short attack, medium amount of decay, and some sustain), can be a good source for a kick drum. But in order to create a Hi Hat or a Snare sound I needed to add a Noise oscillator, which is provided by Reaktor.

The noise oscillator has an Amplitude input and a signal output. As there isn't much information about this generator except for it's basic functions in the software manual, I needed to use some of the knowledge I gained while doing the research as well as some trial and error method. Connecting the ADSR plus a MIDI pitch note to it's amplitude created a constant noise sound, which isn't what I was looking for. Finally, by connecting it's output to a low pass filter signal input, and connecting the MIDI pitch note into the filter's pitch input, I had full control over the noise generator's shape, frequency and pitch. (Fig 3)

All four oscillators are connected to a filter with three outputs to choose from (LP, BP, HP). The filter obviously has a pitch cutoff control and a resonance control. To make it more sophisticated, I added an ADSR in order to control the frequency of the filter. One of the fun effects that this combination created, thanks to the ADSR, was the wha wha effect.

Fig 3 - Noise generator signal



In order to be able to control each synthesiser's volume, I added to each one a master Volume knob. Traditionally, most analog sounds are designed to play in a Mono format, but as I prefer all my synth sounds to be in Stereo mode, I added a Pan control to each of the three synthesisers which, when panned, would result in a wide stereo sound.

Another decision to be made along with the mono/stereo programming consideration, is the number of voices that the instrument will be able to play at a one time, or in other words, its polyphony. As a default, Reaktor is set up to play only one voice, i.e monophonic. The more voices added, the stronger the CPU has to be. Reaktor provides a Measure CPU Usage function, and as I increased the number of voices, I was able to monitor the CPU load. As a keyboard player, I've decided to set it to 8 voices, which would allow me to play single lead lines as well as full chords. (Native Instruments, 2020)

During this set up there were a few connections that turned red and no sound was produced. The reason for that, is that Reaktor allows the connection of two monophonic modules to each other, as well as a monophonic module to a polyphonic. But does not allow to connect a polyphonic to a monophonic, which makes sense as a monophonic module would not be able to input more than one voice at a time. This issue was resolved by making sure all the instrument's modules and macros are in polyphonic mode.

An analog workstation will not be complete without a sequencer, repeater or any of the alike. I wanted to have the option to have a pumping sound effect in various speeds as well as creating other interesting wavy effects yet in a more basic way. To achieve that, I connected to each one of the synthesisers an LFO. I also added a sync option to the LFO, so it can be synced to the host DAW, therefore it could be used as a pumping sequenced sound. The use of mathematical calculations in order to create subdivisions for the LFO tempo, when synced to the host software, is quite complicated, but the result is impressive and makes it incredibly useful when adding it as an effect in a backing track. When the LFO is not in sync mode it can be manually adjusted and can produce other effects such as Tremolo. (Fig 4)

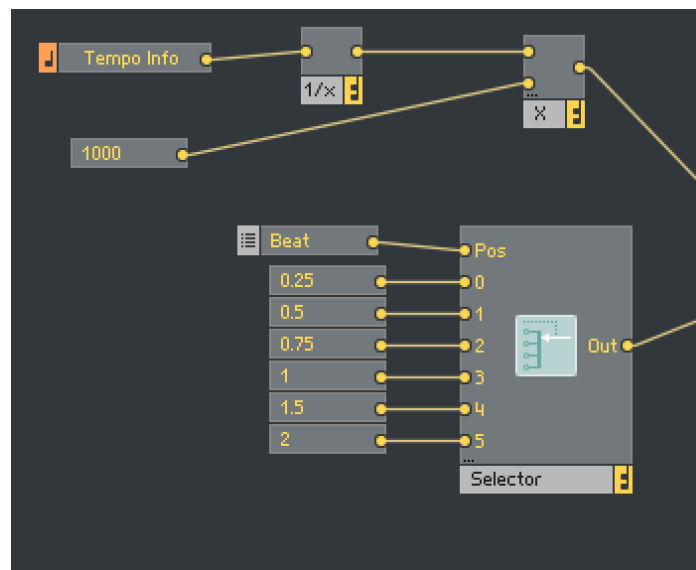
Fig 4 - LFO front panel



As I was approaching the end of the project, I wanted to add a feature which I thought was going to be simple and fun to create but ended up as being the most complicated part to learn to structure - the STEREO DELAY EFFECT.

The reason it was so complicated was that it had many mathematical features that were quite hard to understand. Finally, I managed to overcome some of the obstacles by watching the online 'Reactor Tutorials Course' and build a delay that features Delay time, Feedback and Dry/Wet , as well as a Sync button which enables it to sync to the host DAW. In the Sync option there is a menu for musical delay divisions (1/8, 1/16, 1/8T...etc), which when in stereo, gives a huge and interesting delay, as it can produce a different effect time on each side of the stereo outputs. (Fig 5)

Fig 5 - Delay ensemble subdivision



One of the issues that I encountered and did not manage to resolve when building and using this delay effect, was when adjusting the delay time with the provided knob, it created an annoying sound when used while the music is running. Another small unresolved problem was the Dry/Wet button which was hard to adjust and even harder, for it took a few tries, to bring into the fully dry position. (Fig 6)

Fig 6 - Delay effect front panel



Reaktor offers a very detailed and flexible front panel design components such as, various colours, knobs sizes and shapes, fully customisable arrangement of all the components of the instrument. There are also free downloadable templates from the Native Instruments website. At this stage, and as I was planning to keep adding more features, I decided to go simple and only changed the knobs styles and the front panel colour.

Although the arrangement of the panel is flexible, some of the components need to be in the "right" place (Macro) during the early stages of the programming, which was turning out to be difficult as I couldn't make some of the changes unless I went back to the primary initial setup.

In use

After finishing putting together and connecting all the instrument's components, I've used the new instrument via Logic Pro. The results were beyond expectations, and I've had hours of sound creation as well as putting together a few musical parts into a cool track.

In order to gain full control of the instrument, I connected my Korg NanoKontrol MIDI controller, and assigned some of the Workstation's knobs to the Korg's faders and Knobs. The procedure is as simple as in any other MIDI communication between DAW software and a MIDI controller; When the Reaktor is in the Panel view and the "Learn" MIDI symbol is switched on, then the synth learns the moves of the Korg's knobs and faders.

This method gave me more control over some of the more important synth features such as ADSR, Delay and Glide effect, in real time performance when recording parts, as well as later, when working on arrangements.

As I was very happy with my own creation, I wanted to compare it to a more established market synthesiser. For that comparison, I used the EFM1 by Logic Pro, which is also an FM synthesiser. I must say that I was surprised by how close my synthesiser sounded to the EFM1. Nevertheless, The main immediate difference was the beautiful and well thought front panel of the EFM1, as opposed to mine, which was and still is quite basic and would definitely need some time and effort put into the design work in the future.

The EFM1 frequency modulator was much more powerful than mine and made a more intense changes on the main oscillator. That could be due to the use of better oscillators, more complex combinations and connections between the components as well as the use of more complex Math features.

On the other hand, my synthesiser's built in stereo delay as well as the panning various options, made a huge difference with the width of the sound. Also, the fact that my LFO has the option to sync and un-sync to the hosting DAW brings more flexibility than the EFM1 which can only work in sync with the DAW.

Finally, the fact that I knew my synthesiser well, and was familiar with its structure, made me "play" it better and in a more creative and intuitive way.

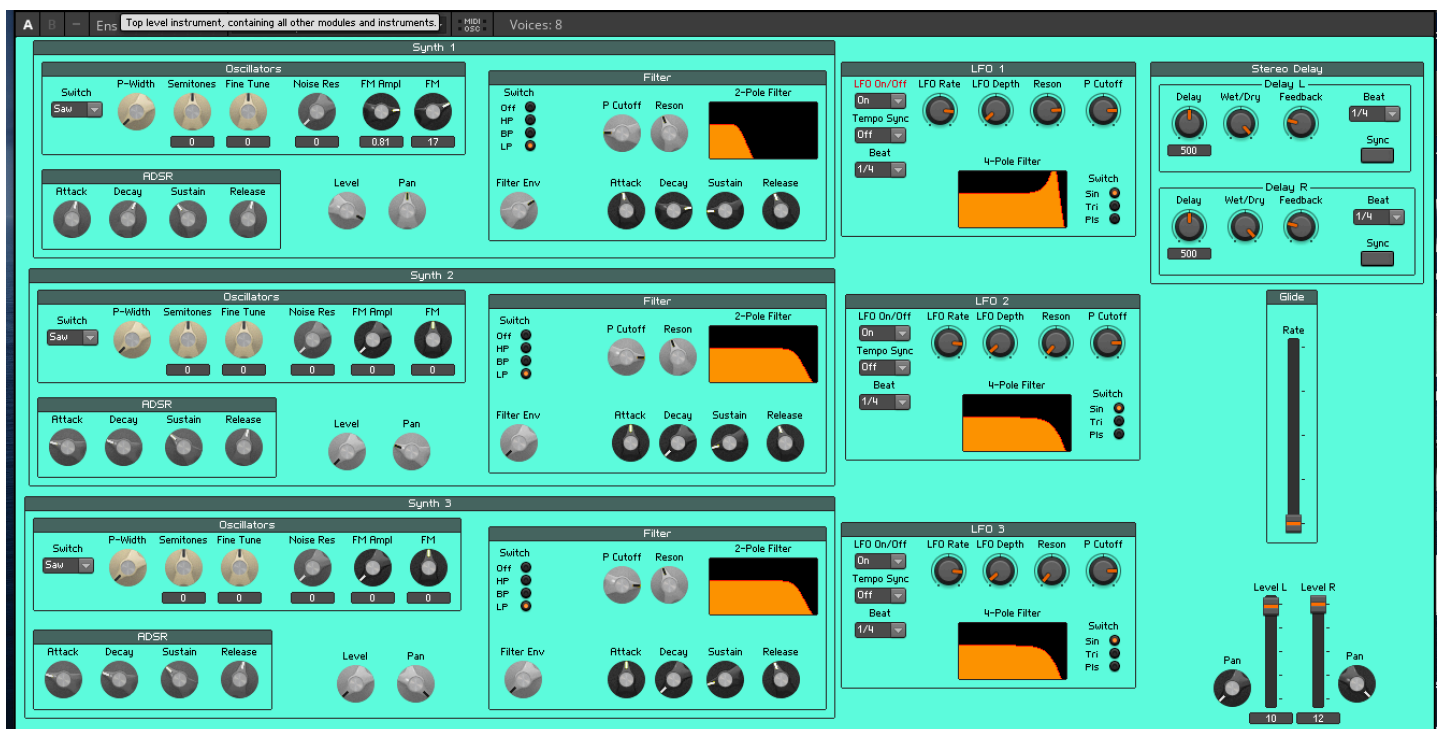
Final words

As I wanted to create a one stop power workstation, I'm still missing some important features in this new instrument such as Reverb, 16 part Sequencer, Sampler, and a few more features that Reaktor contains. Also, the different connections and combinations that can be done in Reaktor are endless and those would create massive and complex sounds. (Fig 7)

As mentioned before, although Reaktor allows the user to download, copy and paste, ready made macros and instruments, I wanted to create it all by myself and get deep into the understanding of how each module works. Therefore, at this stage, I've decided to leave out some of the features.

By researching Reaktor, I merely managed to scratch the surface of this incredible world of analog and digital synthesisers and I intend to keep exploring the synthesis world and integrate it further into my workflow.

Fig 7 - FM Stereo Workstation front panel



Bibliography

FutureMusic, 2008. TestDrive: Native Instruments Reaktor 5. [online] p.single page. Available at: <<https://futuremusic.com/2006/05/09/testdrive-native-instruments-reaktor-5/>> [Accessed 5 July 2020].

Finamore, E., 2018. BBC - A Tribute To The Synth: How Synthesisers Revolutionised Modern Music. [online] BBC. Available at: <<https://www.bbc.co.uk/programmes/articles/3ryZCdIXtpkNG3yRI3Y7pnh/a-tribute-to-the-synth-how-synthesisers-revolutionised-modern-music>> [Accessed 5 July 2020].

Fowler, M., 2016. Sounds Of The Future: A Historical Primer On Synths In Sci-Fi Movies – Soundfly. [online] Soundfly. Available at: <<https://flypaper.soundfly.com/tips/sounds-future-history-primer-synths-sci-fi-movies/>> [Accessed 5 July 2020].

Luther, R., 2017. MOOG ARCHIVES Home Page. [online] Moogarchives.com. Available at: <<http://moogarchives.com>> [Accessed 5 July 2020].

Weiner, S., 2017. Minimoog: The First Truly Portable Synthesizer. [online] Daily.redbullmusicacademy.com. Available at: <<https://daily.redbullmusicacademy.com/2017/10/instrumental-instruments-minimoog>> [Accessed 5 July 2020].

KORSAN, S., 2015. Yamaha DX7. [online] www.w3ki.com. Available at: <https://www.en.w3ki.com/wiki/Yamaha_DX11> [Accessed 5 July 2020].

dented42ford, 2017. Reaktor Versus Max - Gearsclutz. [online] Gearsclutz.com. Available at: <<https://www.gearsclutz.com/board/music-computers/1152936-reaktor-versus-max.html>> [Accessed 5 July 2020].

delsy143, 2018. NI Reaktor Vs Ableton Max For Live : Edmproduction. [online] Reddit.-com. Available at: <https://www.reddit.com/r/edmproduction/comments/7p87pi/ni_reaktor_vs_ableton_max_for_live/> [Accessed 5 July 2020].

astrodislocate, 2017. Reaktor 6 / Max 7 / Max For Live - MUFF WIGGLER. [online] Muffwiggler.com. Available at: <<https://www.muffwiggler.com/forum/viewtopic.php?t=176035>> [Accessed 5 July 2020].

Anagram, S. and Tenandtracer, 2016. Reaktor Masterclass. [online] Reaktor Tutorials. Available at: <<https://www.reaktortutorials.com>> [Accessed 5 July 2020].

Native Instruments, 2019. REAKTOR 6. [online] Native-instruments.com. Available at: <<https://www.native-instruments.com/en/products/komplete/synths/reaktor-6/>> [Accessed 5 July 2020].

FutureMusic, 2010. Ableton/Cycling '74 Max for Live review. FutureMusic, [online] Available at: <<https://www.musicradar.com/reviews/tech/ableton-cycling-74-max-for-live-231184>> [Accessed 5 July 2020].

Native Instruments, 2019. REAKTOR 6. [online] Native-instruments.com. Available at: <<https://www.native-instruments.com/en/products/komplete/synths/reaktor-6/>> [Accessed 5 July 2020].

Sputnik, K., 2006. Using A 1 Pole Filter To Control Glide.. [online] NI Community Forum. Available at: <<https://www.native-instruments.com/forum/threads/using-a-1-pole-filter-to-control-glide.32981/>> [Accessed 5 July 2020].

Specials, C., 2011. Interview: Skrillex On Ableton Live, Plug-Ins, Production And More. [online] MusicRadar. Available at: <<https://www.musicradar.com/news/tech/interview-skrillex-on-ableton-live-plug-ins-production-and-more-510973>> [Accessed 5 July 2020].

Ableton, 2014. Robert Henke Aka Monolake: Mono On Mono -- Robert Henke Celebrates 10 Years Of Minimalism In Music-Making. [online] Ableton.com. Available at: <<https://www.ableton.com/en/pages/artists/monolake/>> [Accessed 5 July 2020].

Native Instruments, 2020. Reaktor 6 Building In Primary. [online] Native-instruments.com. Available at: <https://www.native-instruments.com/fileadmin/ni_media/downloads/manuals/REAKTOR_6_Building_in_Primary_English_2015_11.pdf> [Accessed 5 July 2020].