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Development Module

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Introduction

In this essay I will be detailing the research and work conducted to create my software instrument 'EARTHSONG'. I will be outlining the key principles behind the design and operation of the instrument, as well as discussing both user and personal feedback reflections that informed the progression of the instrument creation. Furthermore I will compare and contrast this software instrument against existing commercial instruments and provide commentary on potential future developments for the instrument.

Instrument Overview

My software instrument 'EARTHSONG' is a sixteen-voice polyphonic synthesiser plug-in made up of four oscillators (Sine,Pulse,Saw and Noise), envelope controls consisting of Attack, Sustain, Decay, and Release, a vibrato LFO for pitch modulation, a variable ladder filter, and additionally three unique audio effect modules titled 'ENERGY', 'FIRE' and 'ICE'. The user interface is designed in two sections: the 'A' panel which features basic controls of the instrument's parameters with a very simple design, and the 'B' panel which provides detailed descriptions of the available controls, as well as a menu of ten preset patches.

'A' Panel



'B' Panel



The basic function of the software instrument begins with a MIDI input signal. When the instrument receives a MIDI note, the Pitch value is sent to each of the four oscillators. Simultaneously, the Gate value generated by the MIDI note is received by an envelope generator containing Attack, Sustain, Decay, and Release parameters which can be manually adjusted by the user (Van Buuren, 2021) to shape the amplitude of the the oscillators.

The Sine wave oscillator generates a sine wave, a geometric waveform that oscillates above and below zero, creating an 's' shaped curve that produces a smooth sound (Hayes, 2022).

The Pulse oscillator generates a pulse wave, sometimes known as a rectangular wave as it is based on an asymmetrical version of a square wave. This creates a brighter and thinner timbre than that heard in a normal square wave (SoundOnSound, 2022).

The Saw oscillator generates a sawtooth wave, a waveform which rises in a straight line from minimum to maximum value, and then immediately reverts to the initial value. A sawtooth wave contains significant amount of both odd and even harmonics of the fundamental frequency which produces clear and harsh sounds similar to that heard in from a saxophone (Wesstein, 2021).

The Noise oscillator generates white noise, an aperiodic sound which jumps randomly between $-0.5 \cdot A$ and $+0.5 \cdot A$, generating an even balance of all frequencies in the audible spectrum (Robehmed, 2019).

Also implemented is a source controlled by MIDI pitch bend events which feeds the pitch input of each oscillator, for creative pitch-bending possibilities between -12 and +12 semitones. The audio output created by each of the respective oscillators has an adjustable volume which can be controlled discretely by the user via the available 'level' knobs on the 'A' panel of the plug-in.

For pitch modulation, I utilised a low frequency oscillator (LFO) which generates a vibrato effect. This functions by creating a low frequency, inaudible sine wave to modulate the pitch of all four oscillators (Sturgis, 2020). The frequency (stylised as 'rate'), and the amplitude (stylised as 'depth') of this effect can be controlled by the user using labelled knobs in the 'Vibrato' section on both panels.

The filter section of the plug-in features multiple user controls for filtering the audio signal: filter type, dB per octave slope, cutoff frequency, and resonance which can suppress or emphasise portions of the signal above or below the selected cutoff frequency (Murphy, 2021). The 'A' panel of the plug-in allows the user to have simple adjustment of the cutoff frequency and resonance, and the 'B' panel invites users to more detailed control of three filter types: 'Low Pass', 'Low Pass + Bass', and 'High Pass 24dB'. The first filter type is the most simple and filters out signals above the determined cutoff frequency at a rate of either 6, 12, 18, or 24 dB per octave - selected by the user. 'Low Pass + Bass' allows for similar sonic results to the aforementioned, but with reduced bass amplitude for a more stable low end response. 'High Pass 24dB' consists of a 4 pole ladder high pass filter, removing frequencies below the cutoff frequency at a fixed slope of 24dB per octave (Korte, 2020).

After passing through the filter, the audio signal is processed by three unique audio effects titled 'ENERGY', 'FIRE' and 'ICE', each named after the element of nature which inspires their sound. The 'A' panel of the plug-in provides simply these names, a small subheading and a dry/wet knob for the user's control of how much of each effect they would like to apply to the arriving audio signal. The 'B' panel provides definitions to the specifications of each audio effect, which are as follows.

'ENERGY' is a chorus effect, which generates copies of the incoming audio signal and applies a subtle pitch-shift to them by modulating the delay time of the waveform with a low frequency oscillator. These pitch shifted copies are delayed by 4 milliseconds and then combined with the original signal, thus introducing phase modulation. This leads to a doubling effect which increases the stereo width of the sound. (Kody, 2021).

'FIRE' consists of a distortion effect that saturates the audio signal using clipping. The harmonics generated by this effect increase the perceived loudness of the signal, and by the user's control

can be tailored for a range of applications, ranging from subtle warmth to a more aggressive and harsh timbre (Dixon, 2018).

'ICE' is made up of a combination of delay and reverb effects which serve to add long, ambient decay times to the source material. The input reaches the delay effect first which generates echoing copies of the audio signal at a rate of 120 milliseconds. These delay repeats alternate between left and right outputs of the plug-in, commonly known as ping-pong delay, which in turn adds more stereo width to the sound (Dixon, 2020). This signal is fed to a reverb effect, which digitally emulates the reverberation generated by a sound reflecting off of multiple surfaces (Izotope, 2020). The reverb effect utilised is set to its maximum feedback amount, leading to very long reverb tails after the original input signal has stopped.

During beta testing (see appendix B), the aforementioned effects modules were met with positive intrigue due to their vague titles, with one tester stating: 'The effect modules are great, I love that they are named after the elements - really intriguing.' However, to provide better context for first time users on the 'A' panel who may not understand what the audio effect is doing before reading the 'B' panel information, I added subheadings below each effect name to give a brief description of their audible function.

The final stage of the signal path before it reaches the audio output is a tape machine emulator which introduces a very slight 'flutter' effect to the master output of the signal. Flutter is a high frequency variation in pitch that roughens the tone of source material. It was originally caused by irregularities in tape drive speed during playback of recordings to tape, and its use in this software instrument is to reduce the complete pitch accuracy of the audio output (albeit only very slightly), allowing for a sound more reminiscent of that heard on vinyl records or tape machines (Britannica, 1998).

Instrument Creation Process

The inspiration for the instrument arose from a desire to create a musical software instrument that offered all users ease of use and basic functionality, whilst also providing deeper insight and explanation for those wanting more finite control. I achieved this by designing two unique panels on the plug-in; the 'A' panel, with a focus on simplicity and ease of use featuring a main image and basic controls, and the 'B' panel offering explanation of every effect control as well as visual feedback through meters and parameter values. The result of this provides a minimal amount of distraction for the user, thus focusing the intended creativity on the music being created (Obendorf, 2009). Additionally I programmed ten preset sounds that are available in the plug-in, with the aim to capture a range of sonic possibilities and inspire the end user to craft their own patches.

My software instrument was created using Native Instrument's Reaktor, at Core level. I began by creating a simple two oscillator instrument featuring a MIDI pitch input, a Sine generator, and a Pulse generator. In wanting to develop a more versatile plugin, I grew this configuration by adding two more oscillators (saw and noise), as well as the envelope generator, variable filter, LFO and audio effects. (see Appendix A for signal flow diagram)

The envelope generator, oscillators, and mixers used were sourced directly from Reaktor's internal library, and I additionally utilised Rounds Delay, Rounds Reverb, and Driver from the Blocks collection (Korte, 2015), but adjusted their preset parameters to develop the unique effects module sounds.

I developed a macro containing an audio effect and separate crossfade unit to create a dry/wet knob for each of the respective audio effects available in the plug-in. After passing through the variable filter, the audio signal was split into two paths - the first led to the macro containing the audio effect and then on to the 'wet' input of the crossfade unit. The second path led directly from the variable filter in to the 'dry' input of the crossfade unit, the control of which was chosen to be a knob on the 'A' panel of the plug-in for the user to blend between the wet signal of the audio effect and the dry signal of the un-affected audio. These macros were used in parallel with one another for separate simultaneous audio effects: chorus, distortion, and also reverb and delay, which existed inside of a shared macro.

These audio effect modules were then named: 'ENERGY', 'FIRE' and 'ICE'. The titles derive from the element of nature that they are inspired by and were chosen to be user-friendly and simple to use. The lack of displayed values on the 'A' panel is an intentional choice with the aim to relieve users from mathematical accuracy or precision, and instead allow for focus on feel and more natural adjustment of parameters. The 'B' panel features controls with numeric values, for intricate precision if required in sound design situations.

An additional advantage to creating macros linked to crossfade units was that it allowed the main user interface to be tidy and simple to use. During creation of the software instrument, the Reaktor Blocks modules visually appeared on the main panel of the unit as I added them to my signal chain, which caused the 'A' panel to appear untidy and full of different units. To overcome this issue, the macros were utilised so that only the dry/wet knob for each audio effect was visible, with no additional controls or visual elements. The goal of the minimal approach to the instrument design is to keep operation as simple as possible for the user, leading to more efficient creative results (Cunha and Rego, 2008).

One limitation of creating the software instrument from within Reaktor was the inability to create a VST plugin version (Hanley and Korte, 2019). One beta tester stated: 'It would be interesting to see if this can be developed into a VST plugin, to make it easier to implement into a live keyboard setup.' Though the plugin makes use of in-built Reaktor modules at present, these effects could be recreated using other modules, and the core of the user interface could be translated well to a VST creation platform, such as SynthEdit (McClintock, 1987).

Visual Identity and Graphical User Interface (GUI)

The visual identity and name of the plugin 'EARTHSONG' derives from an inspiration from nature, described by one beta tester as a 'relevant and current cause'. Each sound included in the preset patches pertain to an element of natural life that has a unique sound identity, for example, 'Sea Breeze' is a patch made up of white noise and a low pass filter with a variable cutoff frequency, which would commonly be described as emulating the sound of waves or wind out at sea (McKinney, 2017).

Polyphonic synthesiser plugins are extremely popular and well known in the music production community, with one reviewer listing four different synthesiser plug-ins in their top ten audio plugin shortlist for 2021 (The Basement, 2021). I felt that a striking visual identity and Earth theme was necessary to give the software instrument a unique identity within an already dense market of polyphonic synthesiser plugins. In light of this, as well as the detailed approach to the signal flow of the instrument, I spent time designing visual assets to increase the visual appeal of the software instrument, and demonstrated a consistent brand theme with blue, green and white colours throughout. The centre image is one of an arial view of planet Earth, chosen with intent to spark inspiration and give a visual representation of the vast world of sonic possibilities available within the plug-in (Plambech, 2015).

I took a minimalist design approach to the GUI on the plug-in to allow for the most simple operation possible for the user (Cunha and Rego, 2008). One disadvantage of this approach is the limitations it introduces to deeper control of the available effects, and an improvement that could be made to allow such control would be to add additional knob elements on the 'B' panel of the plug-in, for example decay time, filter, and room size controls for the reverb effect. This advanced control would allow for more sonic possibilities for the user to explore.

An improvement that could be applied to the visual identity of the plug-in would be a signature typography, for both the main logo title and the parameter titles. This would lead to a more cohesive GUI experience and increase the user's connection to the plug-in's aesthetic (Park, 2019).

Developments made to the plug-in

A need arose during beta testing to have more accurate control over the master volume output of the software instrument. The tester stated that 'A master volume would be really helpful and help me to balance levels in between patches', and additionally, utilising multiple instances of the plu-

gin simultaneously could lead to a cumulative increase in the collective output signal (Bishop, 2001). To meet this need, I added a master volume output control allowing for user adjustment via a knob on both the 'A' and 'B' panels. Additionally I adapted the master volume level to default to 75% of maximum on the preset patches, allowing the user headroom to increase the preset patch volume if required.

In addition, one user sought to understand more of how the 'ENERGY' chorus effect added stereo width, stating: 'The energy chorus effect could be made more prominent - I'm not totally sure what it adds'. In response to this, I utilised a stereo level meter on the 'B' panel of the plug-in, to enable visual feedback of the master output volume level generated by the left and right output channels.

An additional element of visual information that could improve the user's experience would be to have a volume level value displayed by the meter. An apt unit for this reading would be RMS (root mean squared), as it provides a dB reading which approximates the way the ear perceives loudness levels (Modrall, 2021). Such readings would allow the user to develop presets of more accurately similar volumes, as well as to have a numeric confirmation of how the audio effect modules influenced the master output level.

A further development of the software instrument came about by creating ten unique presets, available for users to select at ease via the 'B' panel 'preset' list. Each patch features signal from a combination of the varying oscillators available, and utilises the filter and effects modules to provide a demonstration of the instrument's core sounds. The sonic capabilities of the instrument can be expanded further as users adjust the on-board parameters, and by using the menus of the plug-in host Reaktor, users can create and save their own presets for easy recall during creative sessions (Hanley and Korte, 2019).

Additional improvements that could be made to the software instrument include discrete control over the envelope shape of each individual oscillator. Currently, the Attack, Decay, Sustain, and Release envelope generator feeds amplitude information to all four oscillators, meaning that the envelope shape is shared. The potential for more unique sound design would be increased by having four separate envelope generators, one for each oscillator, to allow users to shape the wave shapes in more numerous ways.

Furthermore, providing an envelope generator to shape the filter envelope would also widen the creative possibilities within the instrument, as the filter could act independently to the envelope shape fed to the wave oscillators. To implement this whilst holding true to the instrument's core values of simplicity and ease of use, a simple Attack Sustain Decay Release (ADSR) envelope would be suitable (Apple, 2021). One beta tester suggested: 'You could add a drop-down list to allow the envelope generator to be applied to any one of the four oscillators, or to the filter.' This would allow the user to select whether the envelope generator applies its envelope shape to any one of the available oscillators, or to the variable filter, and even have separate ADSR levels for the multiple sources.

In light of the aforementioned improvement suggestions highlighted by testing, future iterations of the software instrument could feature a settings menu that would allow users to activate or deactivate elements of the visual controls. For example one user may prefer to see simply the oscillator volume levels, the main envelope generator for all oscillators, and the dry/wet effects module knobs. Another user may prefer to have visual and direct control over more intricate details such as the time between each delay repeat, to allow for automation within a Digital Audio Workstation (DAW). This personalisation would be beneficial to the user, and the option to adjust the GUI could invoke new inspiration for musical creativity (Igarashi, 2000).

The feedback given during testing was positive and users expressed interest surrounding the GUI of the instrument. One producer praised the intricate detail offered by the 'B' panel, whereas a songwriter/artist who took part in the testing enjoyed trying out the different presets and basic controls of the 'A' panel, for its ability to provide synthesiser sounds that were easy to use. The preset menu was described by another tester as providing 'a good range of varying sounds despite the limitations of a four-oscillator instrument', and that 'whilst the tone generation part of the instrument is simple, the included audio effects offer many more possibilities to spark ideas'.

Comparison to existing commercial instruments

In the modern music production market, there are many synthesiser plug-ins that seek to emulate the sound of polyphonic analog synthesisers. The popularity of these plug-ins is oftentimes due to their affordability, as well as capacity to offer high sound quality, preset memory, and processing power to the user without taking up physical space as a hardware instrument would (MusicRadar, 2021). One example of a hardware synthesiser which inspired the creation of my software instrument would be the Prophet '08 which utilises analog oscillators, additional modulation sources such as four low frequency oscillators, and sixteen voice polyphony (Sequential, 2021). Despite the signal chain of my software instrument existing entirely digitally as opposed to the Prophet '08's analog signal path (Sequential, 2021), the utilisation of effects modules in my plug-in helps it to mirror more closely the sound of its hardware synthesiser inspirations.

Furthermore, another advantage of digital processing in music production within a DAW is the ability for a processor to look ahead in a digital audio stream to buffer input samples and predict what audio processing must be done in advance. On the contrary, an analog circuit must take in an input voltage and output voltage in real time with no perceived latency (Hummel, 2016). Additional advantages to software instruments as opposed to hardware instruments include the capabilities of MIDI editing, such as quantisation - the artificial adjustment of MIDI information to shape timing and pitch after recording a performance (Wherry, 2006).

Audio effects such as reverb, delays, chorus, and distortion can be found in both the Prophet analog synthesisers and in 'EARTHSONG' (Sequential, 2021). Additional effects in the Prophet range include ring modulation (an amplitude modulation effect where an input signal and a carrier signal combine to create two brand new frequencies (Fox, n.d.) and phase shifter (an audio effect which takes advantage of out-of-phase sound waves interacting with each other (Anadigm, 2004). These effects could be included in further developments of my software instrument to more closely match the non-linearities of analog synthesiser instruments (Hummel, 2016).

In comparison to current popular polyphonic synthesiser software instruments, 'EARTHSONG' generated a significantly lower central processing unit (CPU) reading when active in a DAW during a test. The plug-in was compared to four other polyphonic software instruments: the Slate Digital ANA 2, the U-he Tyrell N6, the Air Vacuum Pro, and the Vital, each receiving a simple MIDI sequence and generating audio in Ableton Live 10. The mean peak CPU reading found for the four competing synthesisers was 20%, whereas the 'EARTHSONG' software instrument reached a peak reading of only 14%. This provides a significant advantage when compared with other plug-ins, to allow the user's CPU to remain low whilst using the instrument, and to afford for more instances of the plug-in in the same DAW set-up without additional CPU issues that could slow down the user's operation (Babbo, 2021). A producer/keyboard player who took part in the beta testing process described having CPU as low as possible within a DAW as 'very important, especially for busy productions and live keyboard use'.

In continuing the comparison with the four aforementioned existing software instruments, 'EARTHSONG' offers fewer available presets - just ten as opposed to the Slate Digital ANA 2 approach to a preset library which renews frequently to offer new inspiration to users (Slate, 2021). In light of this, a potential future development for the software instrument could be an online library of presets that a user could browse and install at their discretion, with the view to users creating and uploading their own patches to share with the user community.

An additional feature utilised in existing commercial software instruments such as the Air Vacuum Pro is an in-built arpeggiator, (Cumberland, 2013) which uses MIDI as a synthesis tool to cycle through a series of notes synced with the operating tempo set by the user (Lavoie, 2020). To apply this function in my software instrument, I would add a MIDI arpeggiator to the input signal of the plug-in using one of Reaktor's built-in modules, and link this to an 8 step sequencer display on the 'B' panel of the unit to offer user's control.

Conclusion

User testing and personal refinement choices allowed for the plugin to develop additional controls, including a stereo level meter and master volume adjustment overall. The on-board audio

effect modules were popular and received positive feedback during beta testing, due to their simple descriptions and ease of use via the dry/wet control knobs. Potential future developments for the software instrument include adding additional envelope generators to correspond to each individual oscillator, a filter envelope, and more finite control of the reverb, delay, chorus, and distortion effects. To expand an environment for user creativity, additional presets could be made available from an online database, with the option for users to design and upload the patches that they have created.

The visual design is influenced by the natural world and utilises earth-themed branding with the view to provide creative inspiration for the user. Additionally, when compared with existing commercial instruments, unique audio effects and low CPU usage helps the plug-in stand out in the polyphonic software instrument market, despite falling short in the number of built-in presets and lack of additional MIDI processing.

The software instrument 'EARTHSONG' provides a unique emulation of an analog polyphonic synthesiser by featuring four oscillators, a variable filter, LFO pitch modulation, as well as chorus, reverb, delay, and distortion effects, all passing through a tape-emulation processor to add a flutter effect to the final output signal. The user interface consists of two unique panels, the main 'A' panel featuring minimal design and basic controls of the instrument, and the 'B' panel offering more detailed control and definition to the adjustable parameters available.

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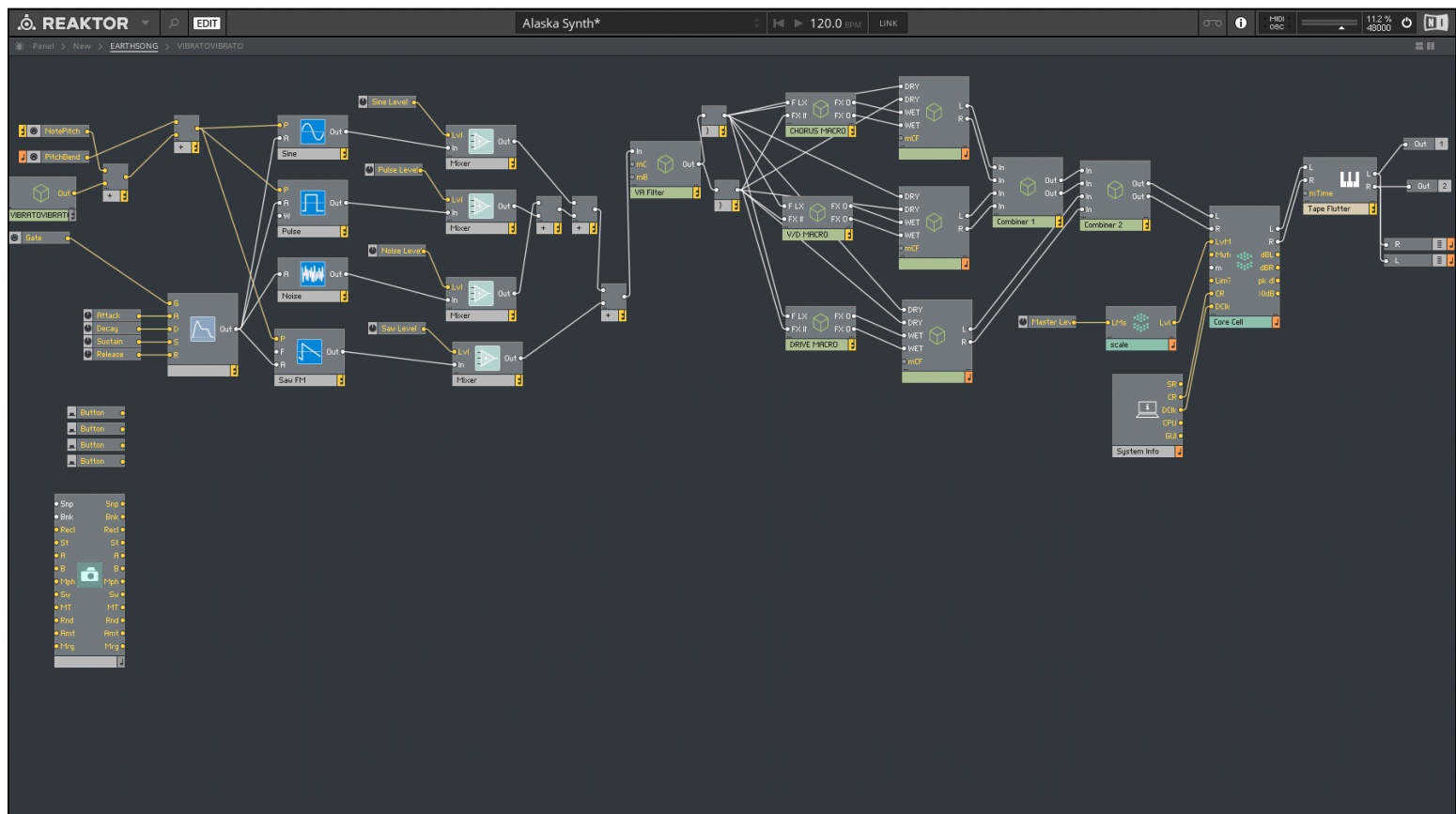
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Appendix A

Reaktor Signal Flow Diagram



Appendix B

Beta-Testing

Three musicians were given hands-on experience with the software instrument and provided verbal feedback.

NAME	ROLE	INITIAL IMPRESSIONS	IMPROVEMENTS
Isaac Anderson	Songwriter/Producer	'The environmental partnership supports a relevant and current cause.' 'The colour scheme and graphics looks really appealing.' 'Good to have the in-depth controls on the B panel.'	'It would be great to hear a wider range of sounds - the current presets are best suited for a vintage synth-pop genre.' 'I think the energy chorus effect could be made more prominent - I'm not totally sure what it adds - at full level only introduces a very slight chorus effect to my ear.'
Nathan Gill	Producer/Keyboardist	'Great use of the reverb effect, reminiscent of the Valhalla Shimmer.' 'I particularly love the 'sea breeze' preset - great effect.' 'a good range of varying sounds despite the limitations of a four-oscillator instrument' 'whilst the tone generation part of the instrument is simple, the included audio effects offer many more possibilities to spark ideas'	You could add a drop-down list to allow the envelope generator to be applied to any one of the four oscillators, or to the filter.' 'It would be interesting to see if this can be developed into a VST plugin, to make it easier to implement into a live keyboard setup.' 'A master volume would be really helpful and help me to balance levels in between patches.' 'The low CPU usage is very important, especially for busy productions and live keyboard use.'

NAME	ROLE	INITIAL IMPRESSIONS	IMPROVEMENTS
Gideon Akpovi	Songwriter/Artist	'The effect modules are great, I love that they are named after the elements - really intriguing.' 'This definitely inspires me to create, would love to spend more time experimenting with it.'	'It being inside Reaktor makes it a little harder to use, it's not as straightforward as other plugins I would use when recording demos.'