Bridging Isles

Drifts of Coupling and Other Hand-Shakes

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Abstract

This dissertation is invested in the composition of music based on the different layers of dynamical coupling that can occur between components in circuits — both through technical and theoretical or conceptual prisms. The main objective was to investigate how the elemental process of coupling can be adopted as a performative and compositional standpoint regarding a user-system interaction with network complexes based on analogue audio and control feedback setups. The central theme this project builds upon is the idea of musical systems designed to be operating — or better yet, operated — within reciprocally affected and variably intertwined structures. This is aimed to be exemplified by compositions and system designs that encapsulate and promote the philosophy of non-hierarchical interaction between sets of components that share energy mutually and can, therefore, be considered as coupled; their resulting outcome manifesting as sonic behaviour is one of synergetic or conflictual relations, bound to change over time in the presence of human intervention that is aimed towards bringing forth their musical dimension.

Contents

Introduction

Feedback has found its place from being a technological symptom into being established as a widely explored technique for the expression of artistic ideas. The musical use of feedback systems, emerging from the later half of the 20th century through the works and practices of notable composers and sound artists to be discussed further on, has been on the forefront of experimental electroacoustic music made in studios and live performances.

This research, rooted in the urge of using analogue audio and control feedback for the composition and performance of music, aims to approach the design of musical systems from an elemental act; coupling. When two or more entities share energy mutually they form a system where the circular causality between the agents renders them to behave as a unified whole. In the case where these components are in themselves based on feedback, the larger system they get engulfed in is often subject to exhibit nonlinearities as a result of the components circular interactions.

The aims of this research project were to investigate the theories and ideas that tackle the role of the user of such systems. As an electronic musician fascinated in working with feedback I felt the need to investigate on the possible standpoints through which I could approach my interaction with those setups; as a designer, user and observer of their output it was evident that my role could not be rigid whilst engaging in the creative act of music composition. In the first chapter of this thesis, I aim to present some of the ways artists that I deem as inspiring to my practice have thought on this. This path is accompanied by a brief reference to the ideas of the theories of Cybernetics and by a scope to allude the captivating power of feedback music to several analogies that might support or exemplify my artistic approaches.

The second chapter is a path through various practical and musical implementations that are both the effects and the causes of those theoretical considerations. This research often drifted between a curiosity for the physical or technical principles that underlie the sonic effects of coupling in feedback systems and how those could be utilised for the (re)implementation or appropriation of electronic circuits and systems. The main culmination of that path is a collaborative development of an analogue electronic circuit based on a second order differential equation that governs what is known and widely studied in physics and theoretical mathematics as the van der Pol oscillator. My initial aim was to make use of it as the main component for the creation of electronic music, thus taking advantage of its inherent nonlinear behaviour of which the musical value was highlighted when placed in interactive sets of other feedback systems or coupled with more van der Pol oscillators. Several indicative designs are included.

The final chapter regards the composition of two individual works intended to operate as a larger piece. One is a result of montaged material of experimentation with the aforementioned nonlinear oscillator, while the other is a composition aimed to make use of several variations of a fundamental compositional idea through sound transformations. This sonic ‘diptych’ is intended as the final work presented as part of my final examination show to support this thesis and this artistic research.

1. Definitions, Analogies & Reflections

Several terms encountered and included in this research are charged with broad meanings and are subject to extensive studies — especially in the domains of engineering and information sciences. It is, therefore, necessary to present here some definitions and remarks on how they can be scoped through the following texts. This does not suggest that their meaning is radically different, but that some of the ideas, topics and theories discussed might operate with greater clarity if redefined within the general framework of this research, which they greatly inspired.

1.1. Coupled Feedback Systems: harvesting nonlinear interactions

The above title already contains a large number of the terms that should be briefly analysed and defined as to how they were regarded here, as well as how they translated into musical ideas that shaped the framework and approaches for this project.

The System: typologies

The term "system" will often appear from here onwards. Thus, it is important to clarify how it should be regarded, or rephrased, within the premises of this dissertation.

A set or network of cooperating *components* — components here can be considered as the most elemental part of the system — is generally called a "system" (System, n.d). Within this project, this term will mostly regard a set of components organised in circular relations through feedback, unless otherwise noted. As these individual systems can be coupled, and thus form a larger system of which they assume the roles of components, it might become slightly complicated to distinguish which level the will be specifically referring to. For now, it is sufficient to establish that the term "system" will refer to a *musical feedback system*, primarily composed with analogue signals and devices in electroacoustic configurations.

Feedback systems can be generally categorised as:

1. Positive; where a disturbance or effect is amplified and reinforced.
2. Negative; where a disturbance or effect is decreased and moderated.

These can be further distinguished as:

1. Closed type; no exchange with the external environment.
2. Open type; the system is coupled to the external environment.

This project deals mostly with systems of the open type, as they have the ability to communicate with their external environment, and to therefore interact with other systems and signals. The interaction of two or more such systems most often exhibits a nonlinear character; nonlinearity is an important factor in the topics discussed further on, so we can now attend to define this term.

What is a nonlinear system?

Nonlinear systems are systems of which the output is not proportional to their input. Nonlinearity is intrinsic to all physical systems (Phillips, Harbor, 1988, p. 554). In the domain of sound technology and (re)production, a common example of nonlinear behaviour is the saturation on the amplification a large input signal when a linear amplifier becomes nonlinear in past a certain amplitude threshold in its input.

What are the characteristics of nonlinear systems?

Charles L. Phillips and Royce Harbor distinguish the following as characteristics of nonlinear systems:

> **Limit cycle**; A periodic oscillation in a nonlinear system is called a limit cycle. In general, limit cycles are non-sinusoidal. A periodic oscillation in a linear system is sinusoidal with the amplitude of the system excitation and the initial conditions. In certain nonlinear systems, the amplitude of oscillation is independent of the system excitation or initial conditions.
>
> **(Sub)Harmonic response under periodic input**; A nonlinear system with a periodic input may exhibit a periodic output whose frequency is ether a subharmonic or a harmonic of the input frequency. For example, an input of frequency 10Hz may result in an output of 5Hz for the subharmonic case or 30 Hz for the harmonic case.
>
> **Jump Phenomenon/Resonance**; [..] Suppose that the nonlinear system input is a sinusoid of constant amplitude. Then, as the frequency of the input sinusoid is increased, a discontinuity (jump) occurs in the amplitude of the response. As the frequency is decreased, a jump again occurs but at a different frequency.
>
> **Multiple equilibrium states**; In a linear stable system, all states approach zero (the origin of state space) as time increases, with no system input. For a nonlinear stable system, there may be a number of different states, other than x=0, that the system can approach as time increases, for no system input. These different states are called equilibrium states, and the one that the system approaches is determined by the system initial conditions. This condition is illustrated in a physical system that, when perturbed (disturbed), can settle to a number of different states, depending on the disturbance.
>
> (Phillips, Harbor, 1988, pp. 556-557)

The above can provide an initial ground as to what the main characteristics of nonlinear systems are. Most of them were firstly observed, empirically, in practical implementations that instigated this research project — namely, a practice on ‘no-input-mixing’ which will be discussed further on — and paved the way for later developments and experimentations. To a certain extent, they seeded the curiosity to deepen my understanding for nonlinear dynamic systems and how utilise them for their musical value through modular synthesis. Investigating further on these properties was primarily a way to develop a more informed approach in the ways that networks of feedback systems could be placed to interact and interacted with. Several of these properties, i.e. their "(sub)harmonic response to external input" (Phillips, Harbor, 1988) — a result of mode-locking and synchronisation behaviour — were the epiphenomena of practical and musical experimentations. Therefore, it was not the lack of an external input, as a strictly closed-loop system would exhibit, that motivated this project. Open feedback systems that are able to adapt to other external signals and systems — especially those from other self-sustaining sources — were of primary concern, as they seemed to exhibit a degree of indeterminate sonic variance which could be expanded through interaction. This ability to change based on their inter-connectivity and exchange of energy, or, in other words, the ability to be to coupled to and with other systems is one of the main interest points of this project.

Let us now tackle the term "coupling". This concerns the pairing of two, or more, components in a system (Coupling, n.d). The term had a central role in inspiring this research since it regards two or more components, interacting in conflict and/or collaboration to produce an output as a result of their interaction.

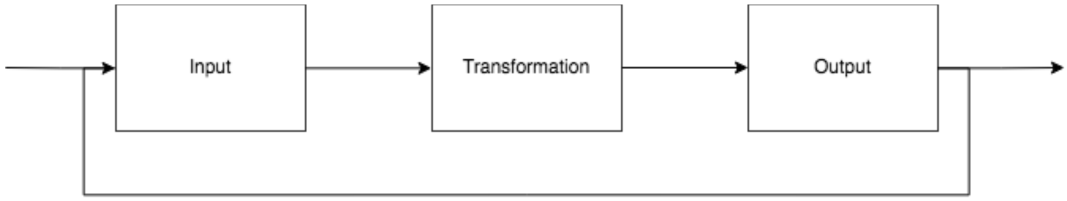
An initial inspiration were the works of Dario Sanfilippo and Andrea Valle, namely their papers *Heterogeneously Coupled Feedback Systems. The |. (Bar Dot) Project* (Sanfilippo, Valle, 2012) and *Towards a Typology of Feedback Systems* (Sanfilippo, Valle, 2012), where the authors gave a general overview on musical feedback systems. The terms "coupling" and "coupled" appeared often, so it was deemed worthwhile to begin deducing from there; in a feedback system components share energy mutually, and can therefore be considered as coupled. So if two, or more, such systems were to be coupled they would give way into a complex whole exhibiting unforeseeable results as products of the nonlinear interaction between the coupled sub-systems. Could the notion of coupling then be approached as the cornerstone for designing feedback-based systems for music? If so, by utilising variable coupling as a method bring forth even more musically interesting results and scoped as a synergetic result of user and system? How does the 'weight' of the human agent's role drift in such complexes when focusing real-time interaction on the dynamics of these relations between systems and signals? These were some of the questions and ideas I tried to begin to consider while on the path of aiming to broaden an understanding and a point of view on composing electroacoustic music.

Before delving on more specific topics and realisations upon the previous questions, there should be a distinction on ways that systems were considered to couple and how coupling was regarded in the various levels of interaction and organisation within the framework of this project. The majority of implementations here will refer to analogue signals and voltage-controlled devices throughout most chapters, however I will try here in this chapter to introduce the ideas in a more generalised context.

Feedback systems as 'isles'

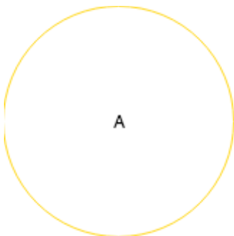
Let us first designate the lowest level of feedback system to be encountered in this dissertation; as previously mentioned, the term "system" refers to a similar set of circularly configured connections, as depicted in the picture below. This can be considered as an self-sustainable, yet not closed, network that is comprised of components coupled in feedback.

A general and basic signal flow can be depicted as such:

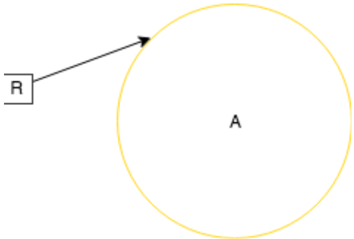


The scientific domain that has been mainly invested in studying and observing such types of systems is Cybernetics. The term was introduced by Norbert Wiener during in his book *Cybernetics: Or Control and Communication in the Animal and the Machine* (Wiener, 1948). Cybernetics aimed in posing a theoretical multidisciplinary framework for the study of control in systems based on recursion and circular relations (Müller, 2000). The first iteration of the theory, called First Order Cybernetics aimed into the study of systems where the observer was regarded as decoupled from the system under observation (Ashby, 1956). Let us proceed with this notion, for now.

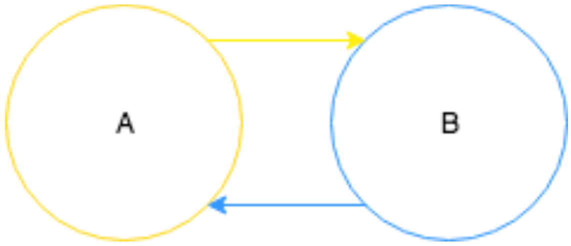
The above system can be re-imagined on a higher level in order to better facilitate the description of more complex systems to be described further on. I will use the the term *isle* in order to describe a set of components with circular causality. This analogy can be pushed to a further abstraction, which due to the components' circular relation could also be described as a circle, used here primarily for the sake of graphical simplification:



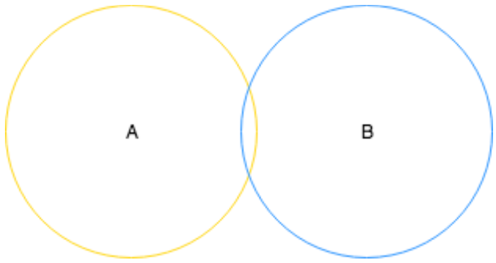
This is isle *A*. As we have established above, it is open to external disturbances and so, when it is subjected to such it will also be bound to change. When configured as such, this isle can be considered as *coupled to* the external disturbance *R*. In this case, changes in the input of *A* will not affect the properties of *R*.



Let us now assume that there exists another similar isle *B*. By interconnecting *A* and *B* to mutually affect each other, in feedback, we can obtain and depict their interaction as:

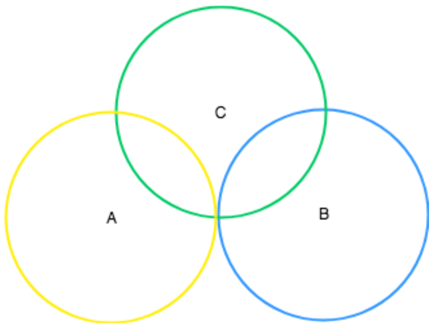


We could also further this abstraction as such:



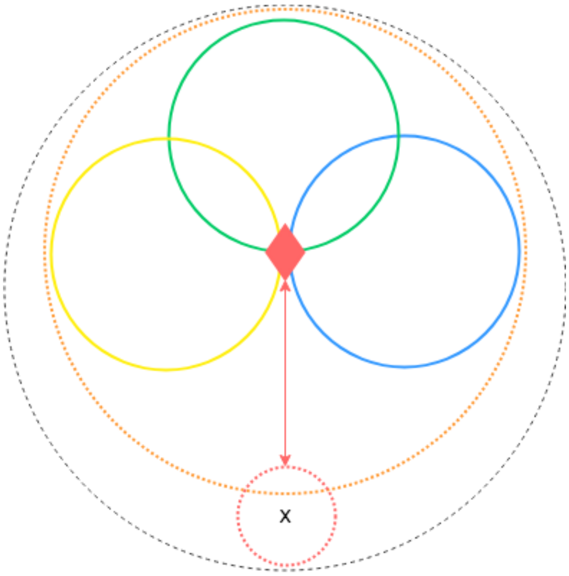
The isles here can be said to be *coupled with* each other. According to William Ross Ashby, in such a configuration the feedback properties can inform us of the properties of the whole (Ashby, 1956).

However, there can be another similar isle, *C*. Interconnected with *A* and *B*, the emerging system can be shown thus:



Ashby further states that it is when the number of interconnected components rises from two, that the organisational complexity renders any knowledge of the individual parts' known properties inadequate to fully inform us for the properties of the larger system; it is wiser to consider this complex system not as an "interlaced set of more or less independent feedback circuits" (Ashby, 1956), but rather as one. This type of network is what can be regarded as the mid-level system within the framework of this project: *a network of mutually coupled isles*. Given the fact that these isles — and their interaction — are based on circularity, the system's behaviour is nonlinear; a local change will often disproportionately affect the global behaviour. In some cases, complex systems can be adaptive; “turning what happens to their advantage” (Waldorp, 1993). These characteristics pose an interesting challenge for human interaction as the stimulus for creating music. A disturbance can be internal or external; in the latter case, it can also be one from a human agent or, as Ashby states, the “experimenter” - let us note her as *X*.

Thus, we obtain:



The above picture aims to depict an the high-level of what a coupled system was considered here; based on the ‘cross-talk’ between isles, the organisation of their signals and the human interaction, all is engulfed into a unified whole. As a cognitive counterpart the “experimenter runs the experiment and [he/she are] coupling [themselves] temporarily to the system that [they are] studying” (Ashby, 1956). The human agent, now coupled to the events taking place within the given running experiment, is offering their intuition to the system’s output unfolding in time, whilst observing it and formulating knowledge. Second Order Cybernetics — often called the Cybernetics of Cybernetics — build upon the notion that observer should be studied as an essential part of the observed system. So essential, that “if the properties of the observer are eliminated [..] there is nothing left.” (von Foerster, 2003, p. 289).

This idea was adopted as a standpoint in this project, not so as to relieve myself from any responsibility for the outcome; on the contrary, it reinforced the notion that without the presence of human interaction the systems to be designed and tempered with in this project would risk being musically ‘incomplete’. The vitality of the human presence was viewed as the *bridge* between technology and creativity. Thus, the particular interest in the context of this project regarded feedback networks of sets of musical “islands of automation” (Llewelyn, 1989) placed so as to explore ideas on their organisation and their outcome as sound.

1.2. No governors

One of the first considerations I encountered was whether there is — or should be — any sense of ‘authority’ when interacting through music with a complex system; to approach this creative relation with an intention of collaboration or one of control?

This was mainly instigated by the ideas Toshimaru Nakamura expressed in interviews reflecting on his performance with a ‘no-input mixing board’ — a technique he popularised as a live electronics approach. He mentions that he tries to retain a “high level of resignation to the system and its output” (Nakamura, 2014). He considers himself as being *adrift* by the musical output of his instrument.

Sanfilippo refers to this user-system, or human-machine, relationship as a “non-hierarchical interaction” (Sanfilippo, 2011). This is rooted in the Second Order Cybernetics philosophy that the user becomes part of the system as an active component, navigating through a parametric space that streams as sound, meaningful to us as the musical expression of that coupling. This navigation is continuously informed by the output for reaching any compositional or performative ‘destination’. Through the active, but still at times observant, participation of the operator, certain behaviours and properties of a given system can be revealed and perhaps, then, pose the system under use as closely resembling a musical instrument.

The notion of navigation, deeply rooted into the theories of Cybernetics — the very term is derived from the greek verb “κυβερνώ” (*kee-ver-nō;* to govern or navigate) — is often presented through model examples like the steering a vehicle such as a car, a ship or an airplane. Whilst a ‘governor’ of a system, the user is directing the choices and decisions based on the responses’ relation to the environment it is placed in. Along that balance act, choices are also based on the directionality for a ‘journey’.

In the field of Cybernetics there is a high teleological inclination, a focus on the future states of a system’s behaviour. When scoped within a musical-artistic context, perhaps this directionality can obtain a much more ‘fluid’ influence on the steering, as is in the cases of an improvised performance. We could, then, consider the emerging sound is both the *environment* and the *vehicle*; as a *stream*. So, I was concerned as to why should I hold the fallacy of thinking I could impose myself upon that stream of sound — which, in any way, is a result of my own scheming. I could instead at least imagine it as carrying me along with it, both of us being shaped as music unfolds? A river will carry along its path anything it physically can; the rest can probably either corrode or adapt.

Despite the fact that the idea of navigating is primarily referring to the assertion of control — and thus, predictability and stability — an artistic context might be able to afford addressing the aim with a slightly higher license of freedom from any absoluteness of teleology. Any ‘errors’ or lack of control will rarely result into hurting anyone severely, so they can be welcomed here, since they might give way to the unexpected. This illusive artistic freedom could promote creativity, relieved from the implications of power and control relations — despite the fact that these would nonetheless be posed towards devices; we could consider them to animate through the use we organise, and thus express a crucial part of us: our creative intentions.

A navigator of a ship, is required to possess a high level of expertise and experience. An instrumentalist, i.e. a cellist, is likewise expected to possess both those attributes. Their experience gets formulated through practice and errors, and thus, the expertise gets later formulated through their experience. In both of the previous examples of the ship and cello — as with many others — *control* is often used to describe the possession of both properties; usually when someone or something is said to be *in* or *under control,* respectively, it is suggested that stability is ensured to a certain extent in a given situation. But should the weight lie always upon the *possession* of control over a given system we are interacting with, and in particular, when it comes to music? Should the aim be on *playing the* instrument? What happens if the instrument reacts and changes in complex mannerisms?

Closing a loop back again to another point in Nakamura's philosophy regarding musical performance, we can quote him on:

> I think I find an equal relationship with no-input mixing board, which I didn't see with the guitar. When I played the guitar, "I" had to play the guitar. But with the mixing board, the machine would play me and the music would play the other two, and I would do something or maybe nothing.
> (Nakamura quoted on Meyer, 2003)

A suggestion here, within the general context of a heuristic interaction with feedback systems, can be that the performative intentionality could centralise around introducing dynamical relations between components; instead of *playing* a system — in a notion closer to that of when playing an instrument, one can *play with* the system's organisational architecture itself by tuning the interactions of its components. Designing these inter-relations in a way that they can be variable and dynamic in time, could bring forth certain musical characteristics, as a result of a variance over time. Thus, the very notion of being in control asserts new weight. Especially in the cases of systems comprised by inter-connected self-oscillating elements in complex systems, where the indeterminate and non-linear response of their interactions — and, by extension, the behaviour of the overall system — suggests that the multifaceted role of the human agent as designer, user and recipient of the outcome is highly dependent on an observational, estimative and, in total, intuitive nature. This intuitive agency "developed while experimenting with the physical system, plays an important part in the design process" (Phillips, Harbor, 1988, p.4).

The responses of this design can be observed and classified in order to later inform a projection of what other kinds of variations could emerge through a "knowledge and calculation of possibilities" (Debord, 1958). Yet, this knowledge and calculation might tend to remain within a certain degree of uncertainty, since any change that occurs will place the system into a new set of dynamics that will not necessarily be exactly corresponding to a prior state the system went through. How can the human agent address this indeterminate character and how do the instances where control can be lost translate in the auditory result? Should that be regarded as failure?

From here on, I will speculate on these ideas by centralising the focus through some brief analogies that aim to exemplify ideas that appeared over time and practice during the time of this project.

1.3. *Kairòs:* Feedback music and its (epi)phenomena

Techniques of audio feedback might often be regarded and approached as a sonic 'wild-card'; positive feedback is implicit to instability, can prove difficult to tame and seem mysterious to fully understand and predict — one can think of the instrumental paradigm of microphone coupled to a loudspeaker and how it transformed from a technical symptom to a creative technique (van Eck, 2017). On the other hand, negative feedback is the cornerstone for control, as found, for example, in the design of amplifiers or electrical circuits in general. In between these two points and with the will to turn a 'problem' to a means for artistic exploration, an electronic musician can aim to formulate inventive ways to create with. First, he or she also needs to first tackle any problematics of how to take on observing and organising such sonic complexes.

Certain musical vocabularies and techniques can be extrapolated even through nonlinear interaction, where the slightest change can result in an overall behavioural shift. This character, neither random nor periodic but "on the edge of chaos" (Waldrop, 1993), makes that interaction seductive by resonating it to our image and likeness or to the way physical systems operate; the conditions in a given moment are delicate and any future state reached is resulting within the threshold where the estimation of dynamic potential and an a priori experience coalesce.

A key motivation for basing a compositional practice on coupled feedback systems was that their organised complexes seemed to offer sounds that could gracefully deviate from abstraction to association as material of interactions' implicit musical gestures. This outcome, when coupled with the humane tendency to associate meaning in what is observed, or expressed as sound, could then be strongly suggestive to the further unpredictable and subjective associations for a listener — the experimenter being the first one. The abstraction inherent in synthesised sound could alleviate the output from being semantically overbearing.

In other words, this is attracted me to shaping sound based on feedback signals: the output often seemed familiar, as if it had an a life of its own or as if it belonged to a place, regardless of it being synthetic or the degree of its plasticity.

In parallel, I encountered what Henri Bergson had written in his 1889 book, *Time and Free-will: An Essay on the Immediate Data of Consciousness*; "if musical sounds affect us more powerfully than the sounds of nature, the reason is that nature confines itself to expressing feelings, whereas music suggests them to us" (Bergson, 1910 p.15). I mention this here, as I found it inspiring and resonating with the way I tended to perceive, shape and think about *electronic* sounds. I favoured the idea of electronic music as holding an abstract sound field that could often be reminiscent of the 'mnemonic' and intriguing to the imaginary.

Electronic music appeared decades after Bergson had written this thought in his doctorate thesis. We should, of course, consider that it referred to the music of his time, thus his notion was formulated before the emergence of electronic music. One could be curious what he would have to say in response to the flexible semantics a synthesised electronic sound can bear. Could experimental and electroacoustic music be even more capable of being suggestive of feelings? An electronic sound might find its expressivity, not in contrast to a natural sound, but due to the ability to be directly inspired by and moulded like it. This might be a mimetic act at times, yet an inspired one.

An example of this was the case of Jaap Vink's work. I was fortunate that my research project was under way when a collection of his works was reissued. I was thus introduced to his music, which I found very inspiring; already through the first listening it stood out to me for two reasons.

First, it was aesthetically pleasing and quite different from other works I had listened to thus far; through its inherent tension and gradual motions it effortlessly instigated images of 'organic' textures — to try and further place words on it will not suffice or do it much justice.

Secondly, it seemed familiar. I must have heard this 'sonic world' before. Indeed, I found out that Vink was a prominent Sonology staff member and responsible for the lectures of Voltage-Control Techniques prior to my teacher, Kees Tazelaar; he was, in turn, a student of Vink. An extended variation of one of the systems that Vink had designed making use of a filtered, tape-delayed and amplitude-modulated feedback setup had been demonstrated by Tazelaar in the aforementioned lectures and it had already caught my attention. The lessons in the Analogue Studio were of high value for me; they were my main motivation in visiting Sonology in the first place, as I wished to learn more on analogue synthesis techniques. That particular system stood out, purely based on how it sounded and how painstaking it seemed in order for it to be set properly.

From what I have come to understand by now, others before me had the same impactful experience when first encountering these sounds. Seeking to find more about Vink, I ended up on an article dedicated to him, written by Hans Kulk. There, I was glad to read more about him, resonating with and illuminating my interests and music practice. I quote here:

> [..] the recordings are results of continuous sonic/technical exploration, experimentation with the medium, and those recordings allow us to be part of Jaap's search-process and sound-world; during that process, the road was of more importance to him than the final destination. The works could therefore be denoted as 'process documents'.
>
> (Kulk, 2017)

What seems to enhance Vink's music and make it so captivating is his engagement to a performance and a sonic exploration with the systems he designed. If one chooses to look for 'a hand controlling the music' it can be seen, yet the resulting output is so powerful that it renders the 'hand' inaudible; its presence is delicately integrated in the sonic gestures. This was an observation to learn from and a characteristic to strive for.

In the light of the collection of his works reissued in 2017 by Groupe de Recherches Musicales (GRM/ Editions Mego, 2017), more information on Vink emerged; his music referred to as creating "a physical place" (Frere-Jones, 2017), or that to get to witness him "work in the studio was to hear the studio coming to life" (Tazelaar, 2017). Inspiring, indeed.

Later on, it was suggested to me to look into another venerable figure, also affiliated with the Institute of Sonology, for his music and ideas; Roland Kayn, a composer of feedback-based electroacoustic works which he coined as "cybernetic music".

His pieces often span to the extent of many hours and are the result of complex processes designed and improved over large periods of time (Patteson, 2012).

I was overtaken for some time in lightly placing the approaches of Vink and Kayn adjacently, as a brief informal case study aimed to inform my considerations and extract a personal stance on whether the composer's role is to be found within or above these sound complexes that are based on circular relations.

It could be noted here that the two worked together; often Vink assisted Kayn in the technical realisations for his compositional ideas (Kulk, 2017), so this loose superposition of the two individual approaches might be helpful to a certain extent. I have already mentioned how Vink is said to be consciously engaging to his music-making processes. For Kayn, this position seems to have been a weighted point of consideration and often seemingly presented as a problematic he aimed to be discharged of as a composer. I would like to stand on his mention that "the composer is entirely divested of his original function" and that the compositional options lie within choosing "whether to intervene, guide, and direct, or whether [he/she] is prepared to accept what emerges as an auto-generative procedure" (Kayn, 1990). It is fascinating to also notice how Kayn scoped the idiosyncrasies of electro-acoustical systems as a result of "malfunctions" (Kayn, 1981). These 'welcomed' errors, carry with them further indeterminacy to an already 'vivid' output. Furthermore, Kayn also refers to working with systems based on analogue electronics, stating that the ephemerality of the electric current and the absence of any mnemonic capacity can render the overall response even more fleeting and thus, greatly "authorised to unleash improbable phenomena" (Kayn, 1990).

In an article dedicated on Roland Kayn's music, Thomas Patterson poetically mentions that it "aims to confront us with an experience of time almost beyond human conception: *kairos,* the unforeseeable and unrepeatable event" (Patteson, 2012).

The word 'kairos' (pronounced kè-ròs, from the greek word *καιρός* meaning 'the weather') is interestingly attributed here to the phenomenology of the output of audio and control feedback systems. It aims to allude to something powerful that we can observe and then try to understand or predict in order to operate in many levels: technological, social, and more. A force in which humanity found a foe and an ally, and the more informed our interaction with it became, the more the illusion of control over it was nurtured. Certainly, we can argue that the technological progress of human infrastructure has thus succeeded in defying phenomena that would otherwise bear severe destruction, and has circumvented the ways we are contingent to such immense forces. Lest this thought drifts more than necessary, let us stay on the metaphorical use of the term for describing, as Kayn said, these musical "improbable phenomena".

Few have pointed it out better than Nicolas Collins. I quote him on:

> My initial infatuation with the beauty of feedback's skin and risqué behaviour grew richer with my appreciation of its inner workings. The balance of responsiveness and independence, of implacable science and seductive invitation, is rife with metaphorical implications. It's a natural phenomenon with social overtones.
> (Collins, 2002, p.7)

I will now try to go on this reference to a "natural phenomenon" that seems to jump out in descriptions about feedback music, by mentioning an inspiring and, at first sight, non-musical example that is local to where this dissertation was realised. I must note having a slight initial restraint in mentioning it, yet I assume it might indicate a scope on the aforementioned instances where the idiosyncrasies and errors, which we could pose as 'a problem', are turned into a means for the solution — this could allude to the 'no-input mixing' technique or to the creative use of acoustic feedback.

The Sand Engine — or Zand Motor, as it is known in Dutch — is an artificial sandy peninsula, constructed on the Dutch North Sea shore between the sea-side towns of Kijkduin and Den Haag, as a means of natural protection from floods (Jan Baltissen, 2016). The strong water currents overtake the deposited sand mass and cast it along the coastline, thus reinforcing any losses on land that acts as a barrier between the ocean and the coastal regions of the Netherlands. The ingenuity behind it, and the reason that it is mentioned here, is that it turns the main agent from problem the solution; there is a shift of a system's use based on the interaction we seek with it. I find this way of thinking, inherent in this grand task, rather inspiring in conjunction to this reference of natural phenomena in feedback music.

Based on that notion, I had to consider that in playing feedback I could not expect what a given interactive system has to offer, but only to anticipate its response. To a certain extent, that was based on an informed knowledge that accumulates through what my interaction with the system would be providing as experience. I could then indeed choose how to use the fruits of that (musical) coupling. Despite being unable to demand when navigating through the 'environments' this interaction creates, yet we can devise ways to formulate an organisation which could yield musical behaviours, that could potentially convey to that vaguely desired 'destination', or telos. But that should not be the primary concern. David Tudor, a prominent figure in live electronics performance with audio and control feedback, states that interaction with his electronics is "an act of discovery" and that he tried "to find out what's there and not to make it do what [he] want[s]… to release what is there" (Tudor quoted in Austin, 1989).

This can in itself be regarded as a byproduct of the cognitive loop enclosing experimenter and experiment and it could directly reflect their synergetic relation. Nonetheless, the destination can be more open to fluctuation in music and thus, less important than the journey, or process, itself. It can often deviate from any original intention and it might not be proportionate to the steps taken to get there — were they to be strictly quantised as a set of commands and subsequent responses. Yet if we were to reduce that process to a strict recipe of parameterisations, would it be sufficient? This can certainly help shape a more informed and methodological approach in the future, and to establish an imprint of a pseudo-map of what can be possibly further extractable. But since the output of complex and nonlinear systems shall never be repeated in *exactly* the same way, we could consider that inside the human interaction with nonlinearity and feedback "there is no there there" (Stein, 1937, p.298). A past state is never to be re-attained intact or replicated, and there is a natural beauty to this that can be contained in the music that emerges from such properties.

Additionally, when this interaction is open to holding a certain degree of intuitive flexibility, and often improvisation, it becomes a dialectic between the human and the devised complex system, as an extension of ourselves and the means of musical expression. This dialogue facilitates an awareness of who we were and what we were looking for at that point in the time of that sonorous space. Enriched with the abilities of memory and cognition, we can interpret and (re)organise that discourse as music and we are often contingent to an outcome that is not always proportionate, or superposed, to any past.

Let us re-approach that the system we are interacting with manifests into more than a mere pseudo-automaton, but rather, into a vessel, the use of which turns into a process for a self-reflective creativity. A delicate and clear way to address the essence of this creative process was put by the pioneering electroacoustic composer Eliane Radigue, in a 2006 interview with Institut für Medienarchäologie (IMA), where she described the outcome of her work as a "mental mirror" of herself (Radigue, 2006).

Tudor referred to his setup components as "his friends" (Austin, 1989). Truth comes often from the voice of comedy. Yet, I tend to prefer the notion of the 'self' as Radigue states — despite not being specifically referring to feedback — as the organisation, and therefore the result, of such musical systems can be considered as an output of ourselves being invested in the expression of music.

1.4. Engaging (within) the circuit

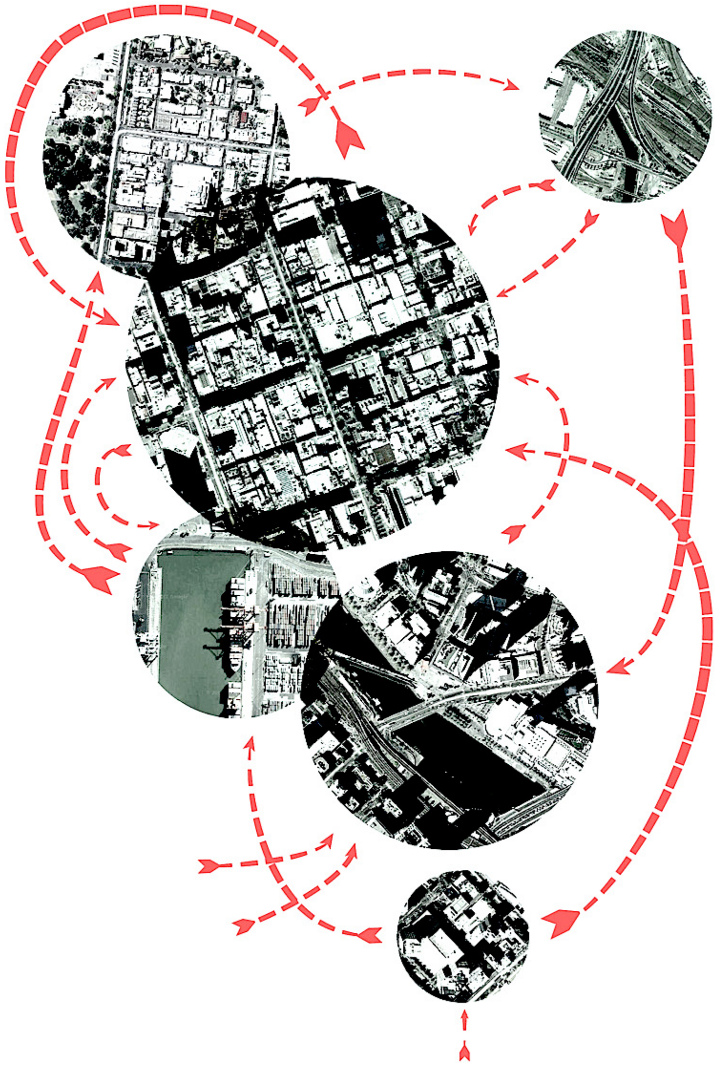
In order to reflect on my musical interactions complex, dynamic and often nonlinear systems through the course of two years in this artistic research, I will allude to an analogy made in reference to the psycho-geographical concept introduced in 1956 by Guy Debord, the *dérive.* Encountered in the socio-political theory and practices of Situationist movement, the dérive was a strategy for re-exploring urban surroundings, beyond limiting the reference points through a map based on a compass.

The individual(s) undertaking the dèrive were involving themselves in an attentive focus on the inherent characteristics of the observed environment, in that case the urban landscape. This journey would not be planned beforehand, but would rather unfold in accordance to the observed situations that would 'stream' before the senses of those exploring these pre-determined fields, re-shaping them while they "let themselves be drawn by the attractions of the terrain and the encounters they find there" (Debord, 1958). The encounter with this idea posed the thought that while playing with a musical feedback system I could, in a similar manner, consider myself to engage into a musical dérive.

Through the invocation of a system's various characters whilst performing with it, the effort would focus in continuously morphing the resulting sonic 'terrain' that would envelope me. A performative attention given to the output is the act of shaping it while the compositional process occurs (Gunnarsson, 2018). This regards the process where listening becomes coupled to action's drawn based on the output of the. Aiming to bring out a synergetic potential is always relative to the performative engagement of the user. In other words, in the case of playing along with a self-sustainable dynamic system, the user can also dynamically alter roles. Via an observational stance, where the attention is focused on attentive listening to the output, a compositional intention is informed which then manifests in an physical coupling to the system through actions as perturbations, or structure shifts, on the system in dialogue. Participating by re-shaping has, in turn, an effect to the overall behaviour of the system that streams back to the perception of the experimenter.

During the instances where the relations of the inter-connected components change, is where the effort was placed to bring into the foreground hidden potential of the system; the use of the system essentially gets altered. An example can be the case of the 'no-input mixing board'; created as a mixer, shaped into a idiosyncratic synthesiser. The system is then extended into new behaviours that would otherwise remain dormant, and this could be an important characteristic for musical expression, since it suggests a challenge and a platform for experimentation. On the user's behalf, this interaction often necessitates a strive for fluency and experience achieved through practice.

To reach that fluency, the approach of the user could be brought in an 'equal footing' to a system; to address it as a dynamic entity that is communicative because it is observed as such by another dynamic — albeit more complex — entity, instead of their dialectic being rigidly reduced into an overly strict set of commands and parametrisation that solely function on serving and promoting a sense of order and the assertion of control. A musical practice approached as a dèrive*,* as exploring and re-contextualising a given system, is inviting for a non-hierarchical stance while interacting. This amalgam of playfulness and curiosity could be loosely conceived as a method in order to further develop an awareness over the practice itself, and therefore of ways of coupling with our extensions in sound.



A dérive map from David Mutch's *Drift, (*Mutch*,* 2011) .

1.5. In and out (or findings in 'getting lost')

So what could I extract as to where to choose to stand when interacting with sonic complexities of our own devise? Are we observers, experimenters, operators or users? Are we merely governors and controllers? All these terms have been also used here thus far; but are they adequate to describe the human agency during process of creating music with complex systems? Perhaps a thought can be that we might be fluctuating through *all* of the above roles, but the importance lies in how we approach our time with such systems at any undertaken musical practice.

In *Cahier M*, the great Dick Raaijmakers distinguishes two entities present in electronic music. In summary, they are:

> ~ the *composer*, as the organiser and choice-maker among infinities.
> ~ the *inventor*, as an instrumentalist, the dreamer of unheard sounds, a modern centaur; as half engineer and half musician.
> (Raaijmakers, 2000, pp. 13-19)

By slightly 'stretching' the above distinction we could perhaps redefine the human agent as an *inventive composer;* content with accepting the organisation of surprising discoveries among those 'infinities'. We can try to reach this hybridised role through what the term 'modern centaur' aims to express.

I find Raaijmakers' metaphor to that mythical beast to be a very clever way to address a dichotomy that often entails an electroacoustic music artist. Due to the electronic music's contingency to technology and to the required knowledge on many of the general principles and physics of sound (within all the levels it might be regarded; synthesis, computation, diffusion, registration and reproduction), to be on this 'balance act' — or better yet, this fluctuation — between the artistic and the scientific might become somewhat of a dutiful task, a form of asceticism. Nonetheless, I have — as many others interested in practicing similar means of creating and thinking about electroacoustic music must have too — often experienced both frustration and delight whilst considering how to operate within this double-sided prism of "inventor and composer", as Raaijmakers poses. This is still a new field that I find myself concerned with — this research project being a stepping stone upon developing such an artistic practice where an idea that can be unthreaded through the sciences to find an application for the arts — so it seems as somewhat of a pseudo-natural problematic to be posed with. I shall continue this speculative stream for only a little bit more, adding that perhaps at times the coupling of these two counterparts — half engineer, half musician — manifests into an even more 'twisted' and tormented being; a *modern minotaur,* dwelling within the 'infinities' that musical interaction brings forth, whilst seeking to choose all the 'unheard' thought to be dreamt of: always familiar, yet never known.

Gladly, we can praise the artistic counterpart; it relieves the path through music from being an aimless wandering, making it a product of an engagement into an expressive act realised through the intention to shape, to compose and to learn about sound as music, and thus the world around us.

We can now try to close the loop back to the previous analogy of the musical dérive. The auditory result that streamlines from this musically interactive meandering can be conceived to cradle and express all these different coupled isles: people and machines interacting engulfed within a self-exploratory creation through listening to our acts; as one and as a complex whole.

Within this dynamical coupling, the human, both actor and observer, instantiates a variability of the machine's output, and in turn is affected by the use and. Why shouldn't then a technological system devised for music be designed upon exhibiting similar notions and characteristics, where its resulting products are the epiphenomena of the dynamic relations among its components — with the user included among those? First Order Cybernetics was invested in the observation of a system, with the human agent decoupled from the overall system behaviour. Second Order Cybernetics closed that loop, by including the human as a vital part of the processes observed. Distributaries of these ideas infiltrated music performance as well, as can be seen from the way artists like Tudor and Nakamura mention their approach their interaction with their feedback-based setups; in a friendly and a subdued manner, respectively.

Thus, reflecting upon these ideas began to inform a personal stance of addressing musical interaction and composition; by giving space to the system to play with my aims and often change them. I wished explore and express and explore again through a recursive process; what Radigue refers to as the "mental mirror". This does not suggest that everything was left to chance or a lack of interest for understanding. As Heinz von Foerster said:

> "The compliment to necessity is not chance, it is choice! *We can choose who we wish to become when we have decided on an in principle undecidable question*."
> (von Foerster, 2003).

Over the course of this research I tried to approach music with an 'equalised mirroring' that invited curiosity, through which I wished to develop a musical self. In a more pragmatic sense it can be argued that *control* is there. Yet, I aimed to forget it as a prerequisite and to not view its presence as the linchpin for creating musical systems; if anything, when it came down to playing, I longed for the balance to emerge from a sound-based interaction, provided I approached a instrument or system as an equal, with all its intricacies and traits. Upon the idea that "intentions should lead to methods that help one those intentions" (Gunnarsson, 2012, p.14), I opted to add an influx where the intention can be the method itself; in this case, a mutual exchange of energy — or coupling.

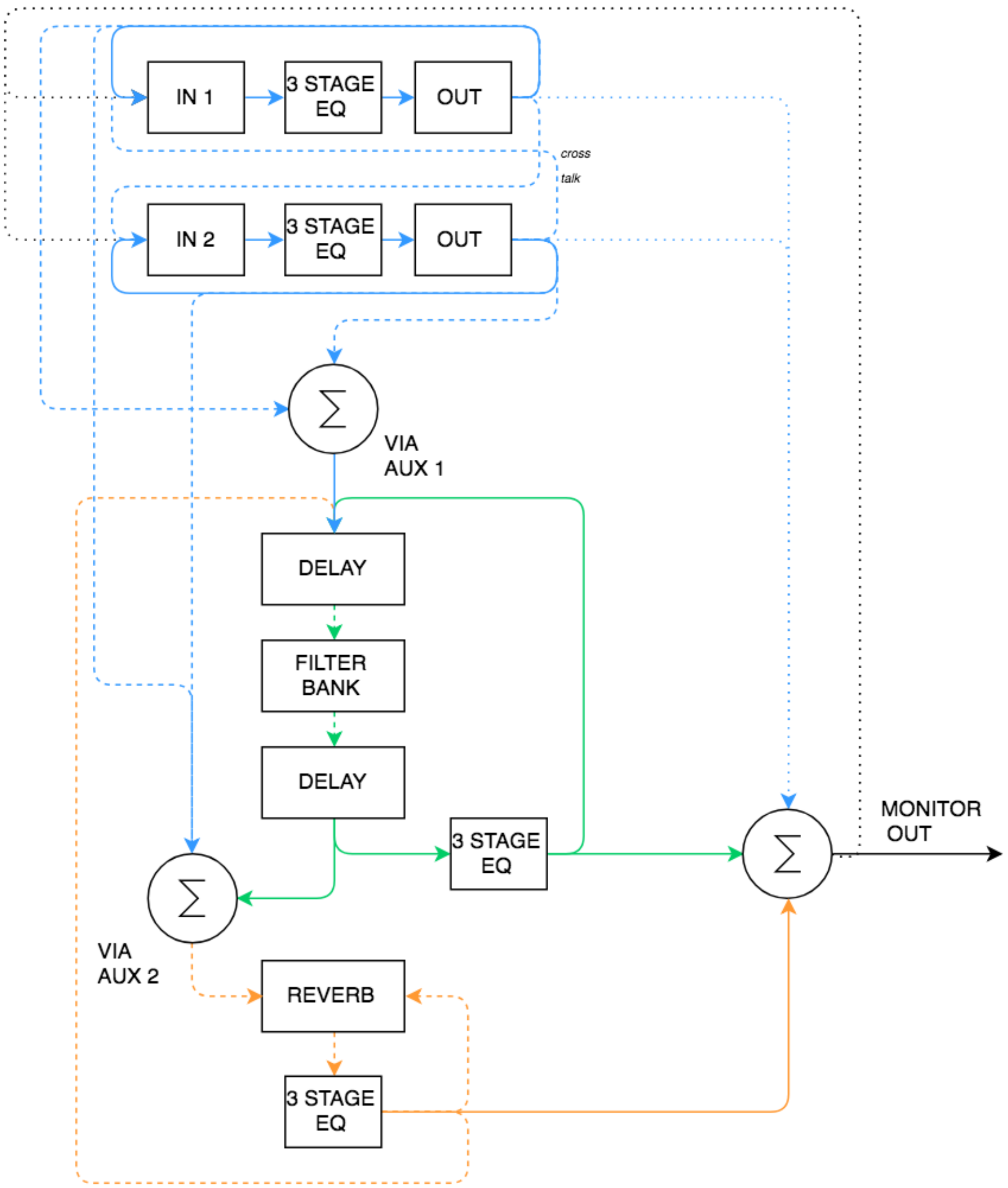
Detail from -*Taurus*, a 1986 comic (based on Jorge Luis Borges' The House of Asterion), with texts by Yorgos Gotis and illustrations by Nikolaos Loupis. (own photo)

2. Implementations: causes and effects of the aforementioned ideas

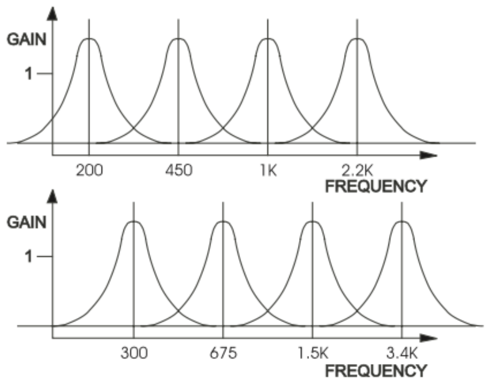
2.1. The 'no-input mixing' technique as a point of departure

Practicing on variation based on the 'no-input mixing board' technique for live electronics was the gateway to the topics that unfolded in this research project. This was undertaken as a means to devise and play with analogue feedback, both as a means of using it for live and studio performance and composition.

A crucial factor was that it could be seen as a relatively efficient way to develop a more informed approach while on the path to learn analogue modular synthesis; the equipment utilised for this setup was already in possession, used for previous practices through the electric guitar. This seeded the notion that through feedback the use of a tool such as a mixing board transformed into a complex synthesiser.



One of the variations on the 'no-input-mixer' setup.



Frequencies of the filter bank (Moog Music Inc., 2004) .

What became gradually apparent was a growing preference for open feedback systems and techniques for subtractive synthesis. Using the main feedback signal generated from connecting the mixer's inputs to the outputs was scoped as way to further process the complex and rich signal that was produced. Yet, I did so by feeding a portion of it to several other signal paths, as I find the 'dry' feedback signal overbearing, both in an aesthetic and a technical manner. When closed in that loop the main signal generated is highly distorted and most importantly its gain level tended to overtake everything else being monitored as output. This choice, started transforming the use of the mixer back again to its original function; as a platform for interaction. Its main feedback loop was still used but not as the main 'voice' of the system.

The time I dedicated in exploring the compositional-performative potential of variations on a 'no-input mixing board' system paved the way for inquiring what the were within these interacting feedback signals. Could these phenomena, if studied, be purposefully (mis)used for musical creativity? During that time, I tried to experiment with opening the mixing board setup to external signals. This involved driving the main feedback signal with function generators, which yielded instances of detuning especially when the signal was coupled to the self-oscillation of the filter bank (seen in the 'green loop').

To a certain extent, the particular variations based on that system later seemed limited in succeeding to developing a performative fluency with the system, to support a will for that 'equal footing'.

On the one hand, the output of the system did have the ability for a wide range of behaviours — from indeterminate poly-rhythms (sound example 1, video example 1) to rich sustained textures. After a year of interacting with variations on that system in live group improvisations and studio experimentations, I gradually felt a hinderance on furthering a user-system coupling that kept me musically excited; my practice somehow seemed to start becoming 'normalised'. Most importantly, it would always seem to contain a black-box type of problem which I wanted to overcome, especially as far as coupling was regarded.

On the other hand, its role in shaping later ideas and implementations as well as introducing me to notions such as those mentioned in chapter 1, was detrimental.

Some brief conclusions and motivations for the projects that followed I could extract from the 'no-input' days were:

1. The central position the presence of a mixing board would play in my practices, both in studio and live use.
2. The inspiration in designing and using networks based on devices with multifaceted applications as a result of their coupling in feedback; i.e. the mixer turns to a synthesiser, a filter bank into a series of coupled resonators.
3. The desire to play with such systems where the sonic unpredictability and nonlinearity would be a destination to be striven for by having a more informed approach for feedback than the one the 'no-input mixer' could provide at the time.

The above led a research path that later manifested in implementing a van der Pol oscillator analogue, described in following chapters.

2.1.1. The *pyrwatærra* etudes (2017)

Tracklist:

||: *Reprise / Okayeano / Borderscape Reprisal / Respiral / Epitaph/ Respire* :||

Reprise: 0' - 4.40',
Okayeano: 4.40'- 9.20',
Borderscape Reprisal: 9.20' - 16',
Respiral: 16' - 22', (ft. Amir Bolzman and Giuliano Anzani)
Epitaph: 22' - 27.20',
Respire: 27.20',

To close the 'no-input-mixing board' chapter, I will mention here some of the musical results of this practice. A series of etudes were realised, composed by material derived form experimentations with this system. These individual pieces were later combined into forming a larger body of works that could also be listened to as unified whole (sound example 2). It could moreover be looped, its end-piece being the first half of the first.

Each smaller study was an example of experimenting on a specific idea. For example, the last/first piece *Respire/Reprise* was the result of modulating parameters of the filter bank through computer-generated stochastic patterns, converted into control-voltages, while the centrepiece was composed in the Analogue Studio based on a system loosely modelled after the 'no-input mixer' setup, with the addition of controls derived form a step-sequencer. I will mention here in more detail the second piece of this series, as it had a larger impact on later projects:

Okayeano (2016)

The main idea behind creating this study piece was that of layering through *memory*. This involved a limited series of improvised performances with a duration of approximately 5 minutes for each take. The material was composed in two environments:

1) a configuration of a 'no-input mixing board', delay lines and a resonant band filter, and
2) a variation on external perturbation of the aforementioned *tape delay amplitude-modulated feedback patch* (see chapter 1.4) as taught in the Voltage-Control Techniques lectures.

The term "memory" here regards a performative and improvisational 'sound memory discharge'; each recording would provide a basis for the next — in other words, an overdub technique without listening directly to the previously recorded material whilst playing the next layer. It was conceived more as a practice or game, through which it could be possible to build a 'muscle-memory' and fluency with the two systems at hand. The process was conceived as:

~ First, an improvisation of five minutes was recorded with the mixer system.
~ Immediately after, ,and without having listened to the first recording, a second improvisation was to be recorded, influenced in its unfolding by the fleeting memory of the first.

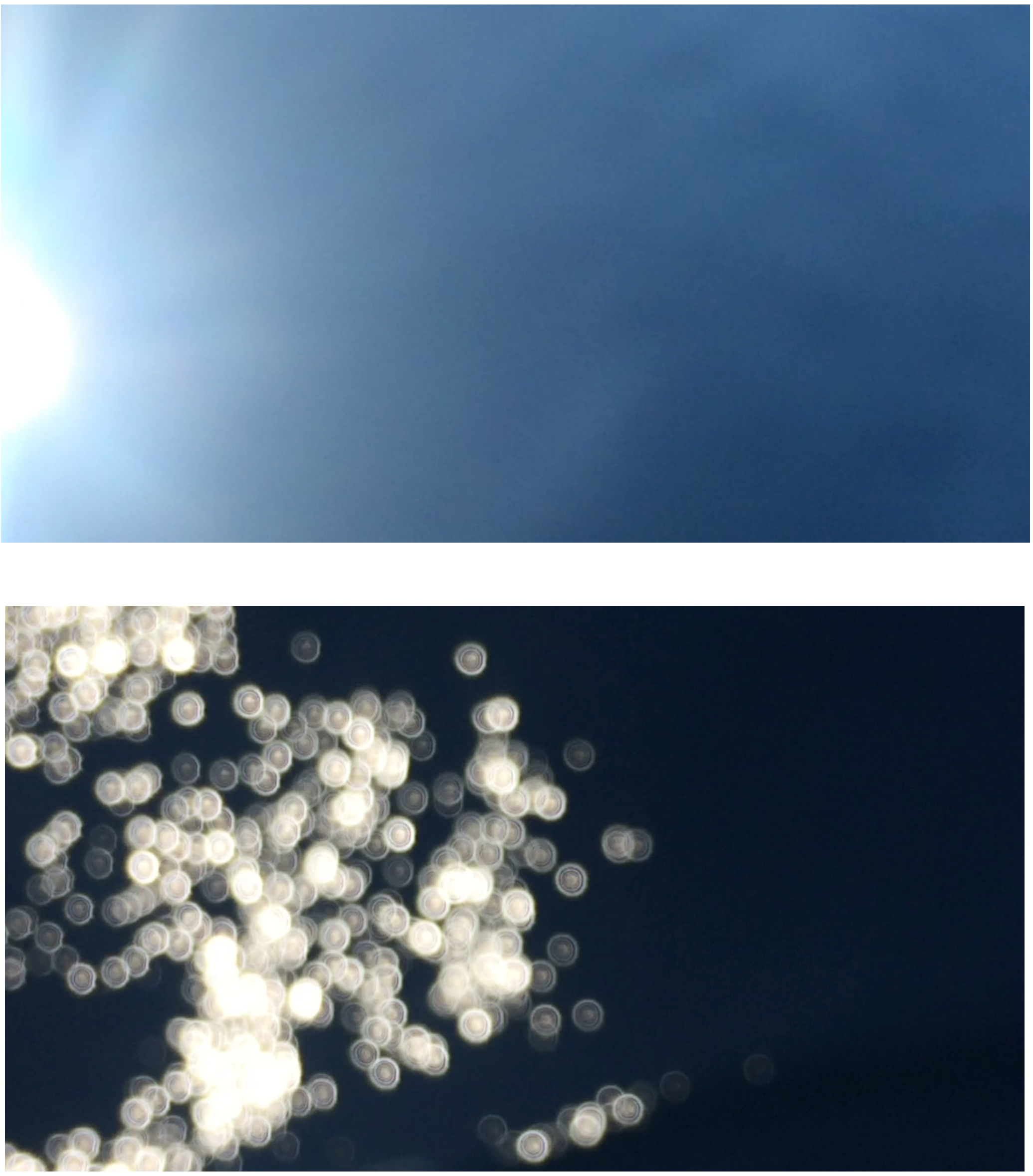
I wanted to play upon this gradual sound-memory discharge and to use it in order to observe the extent to which I could loosely guide a correlation between the superimposed session recordings.

The foundations for this study piece would start to arise by superimposing the two takes, with a curiosity to observe where they complemented each other and where not. Interestingly enough, they fit well together during most of their duration and they spectrally complemented each others sonic events; they left 'space' for each another when played back simultaneously. The same approach was to be followed whilst recording in the studio, but the task to maintain a memory would be proportionally harder to the amount of time — often numerous days — passed, discharging gradually and thus loosening further each later recording to unfold in an even more displaced way from the previous ones.

Another significant element in both systems — 'no-input-mixer' and Analogue Studio feedback patch — was an experimentation on force driving: for the mixer-system, a square wave oscillator was variably driving the feedback system with alternating frequency. For the studio system, impulse voltages were fed into the tape delay.

In the first case, the external oscillator entrained the coupled feedback signal into amplitude modulation — this is primarily evident in the first minutes of the piece. For the tape patch, the randomised impulses had an unexpected result. Due to their non-periodic nature, and perhaps to the design of that specific quadraphonic patch, the emerging material resembled dense masses of short events, similar to underwater sound of a wave crashing. After all the material was collected, superimposed and listened to it became evident that even though it was an enjoyable and playful process to follow, this approach still ended up implicating the composition if no action was to be taken post-recording, especially in moments of 'memory-loss' that led to a 'cluttering' of sonic streams.

Several months later, the same approach was followed this time the next layer was a five minute continuous video, shot on board a transit ship close to the island of Ithaca in the Ionian sea. For the filming of this single-take video (video example 2), the temporal evolution of sounds within the piece was loosely guiding variations in the angle of the camera capturing the water surface where the sunlight was reflecting. I hypothesised that his could find correlation when coupled to the sound material. Indeed, when placed together the two media combined somewhat delicately, having moments of synchronised 'cross-narrative'. In this, nonetheless, might significantly play a role an innate tendency to detect, decode and correlate patterns and events presented. A thought raised was whether these loosely independent streams of narration might be forcing correlations, entraining the perception of each along the other's path.



Still shots from the video part.

This experiment posed important observations as to ways of creating an audiovisual work where sound material — in the cases presented here, made with feedback systems — and video (de)couple dynamically. It thus proved as a starting point for adopting a method of composing the music to accompany a short film by cinematographer Alcaeus Spyrou, as described in the next chapter. This playful practice opened up notions of how to work with the way either of the media could be made in order to complement each other without a continuously rigid, or even 'enslaved', relationship; layering the audio as a narrational stream that could dynamically find moments of correlation and synchronisation with the video.

2.2. The soundtrack for the film *Anina (2017)*

Premise

In February 2017, cinematographer Alcaeus Spyrou embarked on a week-long round-trip journey on board a commercial cargo ship. The journey's route would involve stops in various ports on the coasts of the North Sea, before returning back to its initial point of departure, the Hook of Holland near Rotterdam, Netherlands. The overall displacement was close to nil. Yet, what was the point of interest that drove the theme of the film, and therefore of the music, was the journey itself and its documentation in an essay documentary playing upon images of the landscape and infrastructure of commercial cargo shipping industries that operate in service of "our access to excess" (Spyrou, 2017).

Directionality and intentions

When Spyrou's journey closed its circle, I luckily had the opportunity to preview some of the filmed shots and to briefly improvise with a small set of Euro-rack modules upon them. The result seemed promising, and we decided that the main task for the sound design would be to create a feeling of *displacement* for the viewer; that is, to try and attach an accompanying soundscape that would delicately shift between synthesised sounds and sound recordings of the filmed locations. This was to be created upon the finished video result. An inspiring source for thoughts was Michel Chion's writings in *Audio-Vision: Sound on Screen*, where he suggests that the sound is an unconfined element that looks for its position by relating to what is occurring in the visual realm unfolding in parallel, although contained in its pre-existing frame. He adds that the viewer is continuously reassessing the sonic events' placement according to what is different in that which is seen (Chion,1994, pp.66-94). Thus, I considered my preview of some of the filmed events as an initial stimulus that could loosely guide my composition and classification of sounds that could be used. It was a second and inverted stage of the 'game' I played in *Okayeano*; this time, the visual layer came first, briefly but would return to establish itself upon the sonic. Instead of coupling the video *to* the sound, now *the sound had to dynamically couple with the video*.

Whilst waiting for the video part's completion, I recorded and catalogued experiments and improvisations with coupled self-oscillating filters and other feedback patches based and processed on a modular synthesiser. The 'no-input mixer' setup was also used, occasionally, in conjunction to provide complex sustained tones.

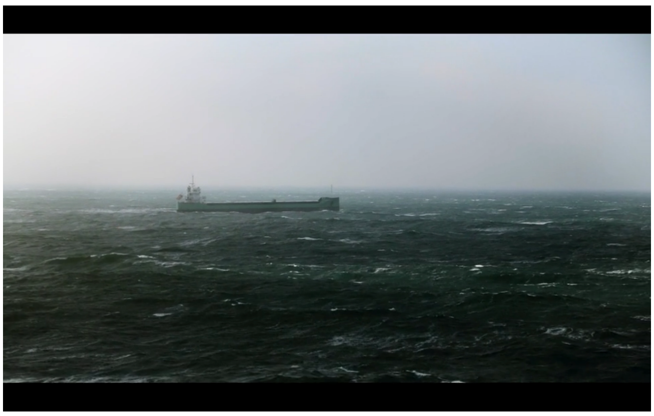
Having a brief idea of what the actual video shots looked like — despite if the ones I had seen would be finally used or not — helped in having a sense of the images' theme and characteristics. Upon receiving the first sketch of the video, the task was to shape the sound so as to loosely follow the visual activities. Certain moments did call out for a more synchronised coupling; still, the montage was quite powerful, yet eloquent in its changes. The whole twenty minute-long video did give me the impression of having distinct episodes, either classified by the locales depicted or by the dominant colours of the shots used. So, I tried to build upon those. For example, the first third — approximately around 7 minutes from the beginning — of the film, can be considered to establish the premise of the story told. I considered the middle part to be a depiction of the ports' nocturnal activities, where the 'mechanic' and the 'vivid' merge in an pseudo-automated 'waltz'-like choreography of labour. I tried therefore to use material that fit that theme. These were primarily created in the Analogue Studio, shortly before receiving the video, with a system that was not designed or intended to give materials for the film. What I aimed to do at the time with that patch was to create a self-playing audio and control feedback system that would be instantiated via a single manual trigger and then would play on based on scaled triggers that would start slow ramp voltages controlling amplitude modulators connected to several filters placed in feedback. At the time, I was only recently introduced to Roland Kayn's music, so I was troubled in designing a a system where I would take a step back and observe what occurs. Its results, prior to their use in the film, did not excite me that much, as I firstly realised my preference in being invested playing with a system, thus treating it as an instrumental extension of expressivity and whose output contains the moments of my interactions with it. Still, listening to its sounds come gradually back and forth reminded me of a breathing-like process, much like to the motion of the waves.

Another important factor that added guidance on the composition of the music was that Spyrou had included his own mix of sounds he recorded in the locations he visited. He created a track that would, intermittently 'come and go' where he deemed his image required it. I used this so as to 'wrap' my composition around this track, viewing it as an axis where everything else can be linked to. However, several of these sound recordings needed to be 'supported' — or even replaced at times — by Foley sounds, which I had to recreate based on their respective shots in the film. Some of those, I chose to synthesise so as to enhance that initial aim for creating a 'displaced' atmosphere for the viewer, thus leaving an open suggestion that what might be depicted or heard at a given moment during the film could not be what it sounds or seems like.

This project was one of equal collaboration. Still, the film was initially intended as the final project for Spyrou's Bachelor studies, so I wished to offer him my best effort. One of his few — yet not adamant — requests was whether I could create a sense of closure after that desired displacement, especially when the film reaches its final moments. Indeed, the last minute of the film can be scoped as another 'episode' where the visual scope comes out of the premise introduced in the beginning and the tales encountered during the main body of the journey. This, along with its particular way of ending, brought into mind a recording of an improvisation session made with fellow student, Max van der Wal. In this session, due to errors, or 'accidents' in the recording interface connection to the computer our recording suffered from abrupt artefacts and 'glitches', that just so happened to be very well timed with the music being played.

Out of curiosity, I tried this recording for the final minutes of the piece and, quite surprisingly, it seemed to have moments of such close synchronisation that might even seem intentional — this reminded me of the previous audiovisual experiment in *Okayeano*, and Spyrou was very enthusiastic about how it worked with the image thus we decided to use it.

I received some mixed criticism from various people whom had watched the final result; for some it seemed too detached and different from the overall music, while for others it worked as intended to. Personally, I learned from appreciating both points of view. Yet, I must admit that for this case, I was content with what it came out to be as a creative journey (video example 3).

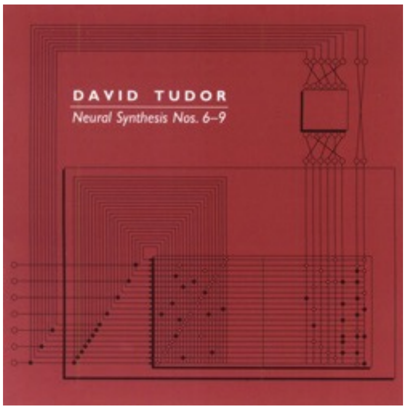


Still shots from the film.

2.3. Arrivals, interactions and departures : matrices in performance with feedback

Central urges in this project were to compose (with) systems by placing a variability over the way components exchange energy over-time, and to then interact with what emerges from these inter-connections. Especially in the case where the components are self-oscillating, meddling with the dynamics on the points where they interact could heighten the instability intrinsic to these condition-sensitive systems. An efficient means to interact with these relations could be to place their connections upon a matrix.

Most notable for his use of patch matrices in his complex networks of feedback is David Tudor. Interacting with his infamous setup, a table brimming with commercial effect units and hand-built electronic devices, Tudor employed the use of a matrix mixer in order to make complex feedback networks with his devices. For two of his works he used more advanced patch matrices. On his series of pieces titled *Neural Synthesis Nos. 6-9 (1995)* "a broadband matrix of analog and digital signals" (Lovely Music Ltd., 1995) was the cornerstone of that particular complex setup (see left picture below). He also had used a custom built patch matrix mixer for his 1966 performance piece *Bandoneon! (a combine)* to connect sound to several outputs or electronic devices (Bonin, 2006).



Tudor's *Neural Synthesis Nos. 6-9* CD-cover (left) (Lovely Music Ltd.)
and the custom-built matrix used in *Bandoneon! (a combine)* (right) (Bonin, 2006)

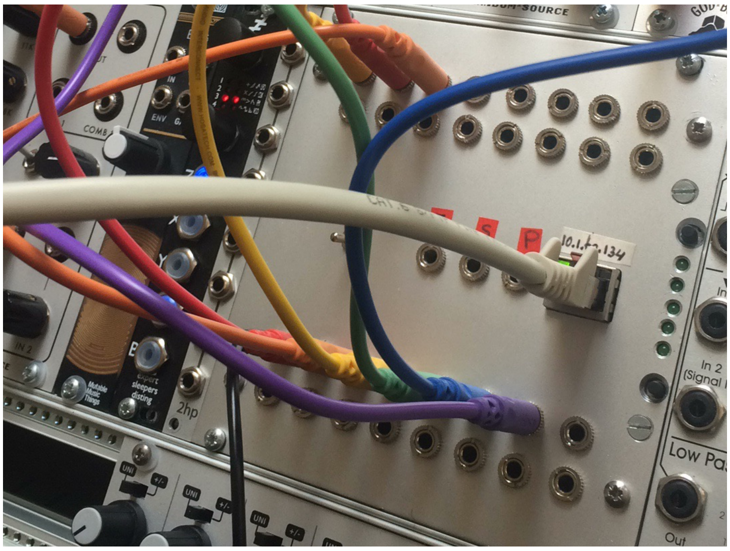
Another inspiring example in the context of live electronics performance with a modular synthesiser setup that includes a programmable patch matrix, is that of Thomas Ankersmit. Over the course of this research, I attended several of his performances; all of them were unique experiences. What impressed me most was the variability in the way he would traverse between sonorous fields that were all impactful and rich but also shared managed to share a cohesiveness — despite his use of "radical cut-up juxtapositions" (Ankersmit quoted in Haanstra, 2006).

He makes this way of interaction possible through a real-time programmable patch matrix. I also found to resonate with more on his approach:

> [..]the kind of sounds I'm most interested in are happening at the edge of control; the "dirt" in the signal. You can't really control that dirt. [..] I use a matrix mixer to switch between patches and I built a little interface that basically lets me circuit-bend the machine without opening it up. So those are ways to mess with the sound more dynamically.
> (Ankersmit quoted in Fischer, 2012)

During the initiation of this project, another research project in the Institute of Sonology was reaching its completion; the *CompLex* (van den Broek, 2017), a computer-aided switch matrix-mixer for analogue signals. It is an interface of 16x16 inter-connecting inputs/outputs. It offers the possibility to programme and store configurations via a dedicated Max/MSP software that drives the on/off switching of the connections. Furthermore, the device has the ability to be voltage-controlled.

One of my initial impressions was the potentiality for experimenting with coupling on analogue feedback systems via this device. With this practice came the effort of 'translating' into a grid a thus far intuitive workflow of patching devices together. This has a learning curve overcoming the tendency to place all the connections on the matrix interface and then experiment with their organisation; to obtain the insight, via practice, of choosing which would be the components' connections more worthy of variating was found to be far more efficient.



Lex van den Broek's *VC-SPG (CompLex),* (own photo).

The construction steps[1] and the final product of these extensions into what is now dubbed as the *SimpLex,* are presented below:

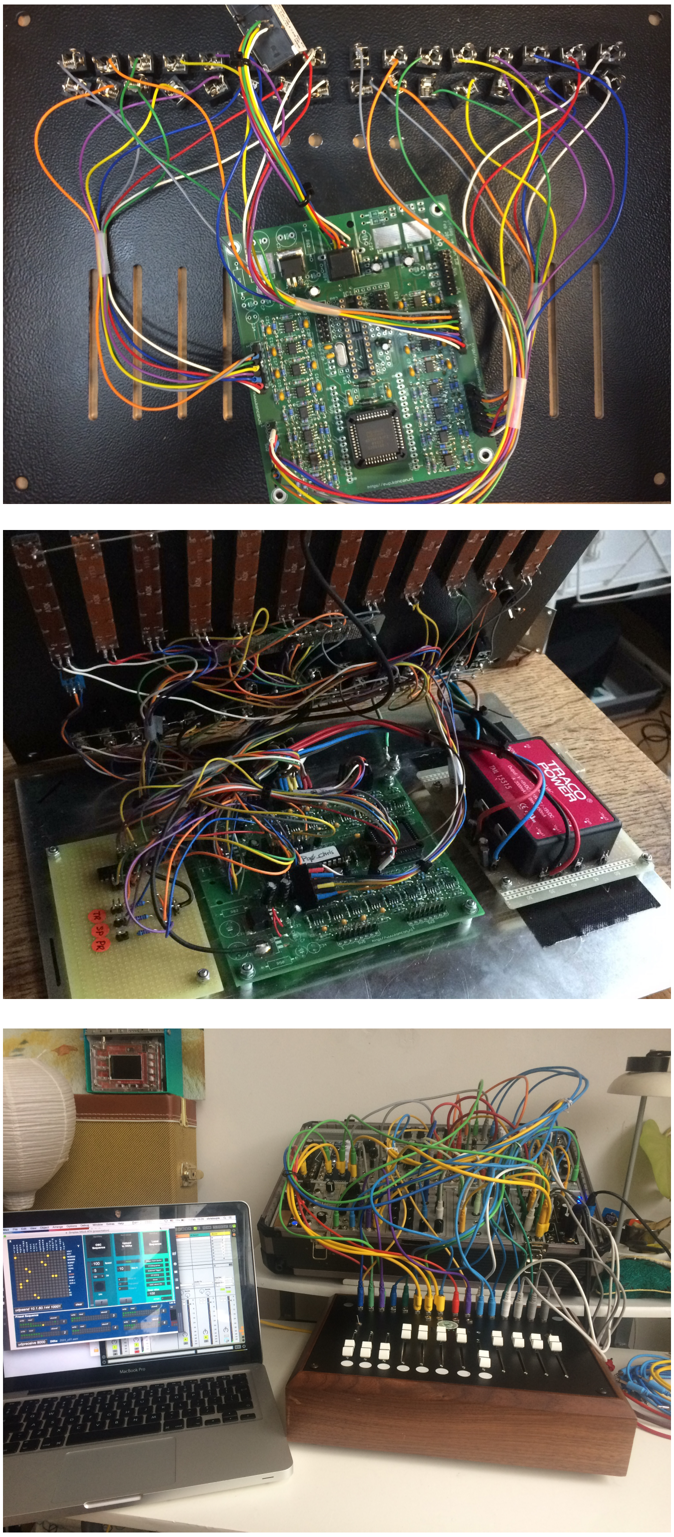
From top left to bottom right (clockwise):

(1 & 2) Soldering the PCB.

(3) Milling the front panel.

(4) The front panel ready for wiring.

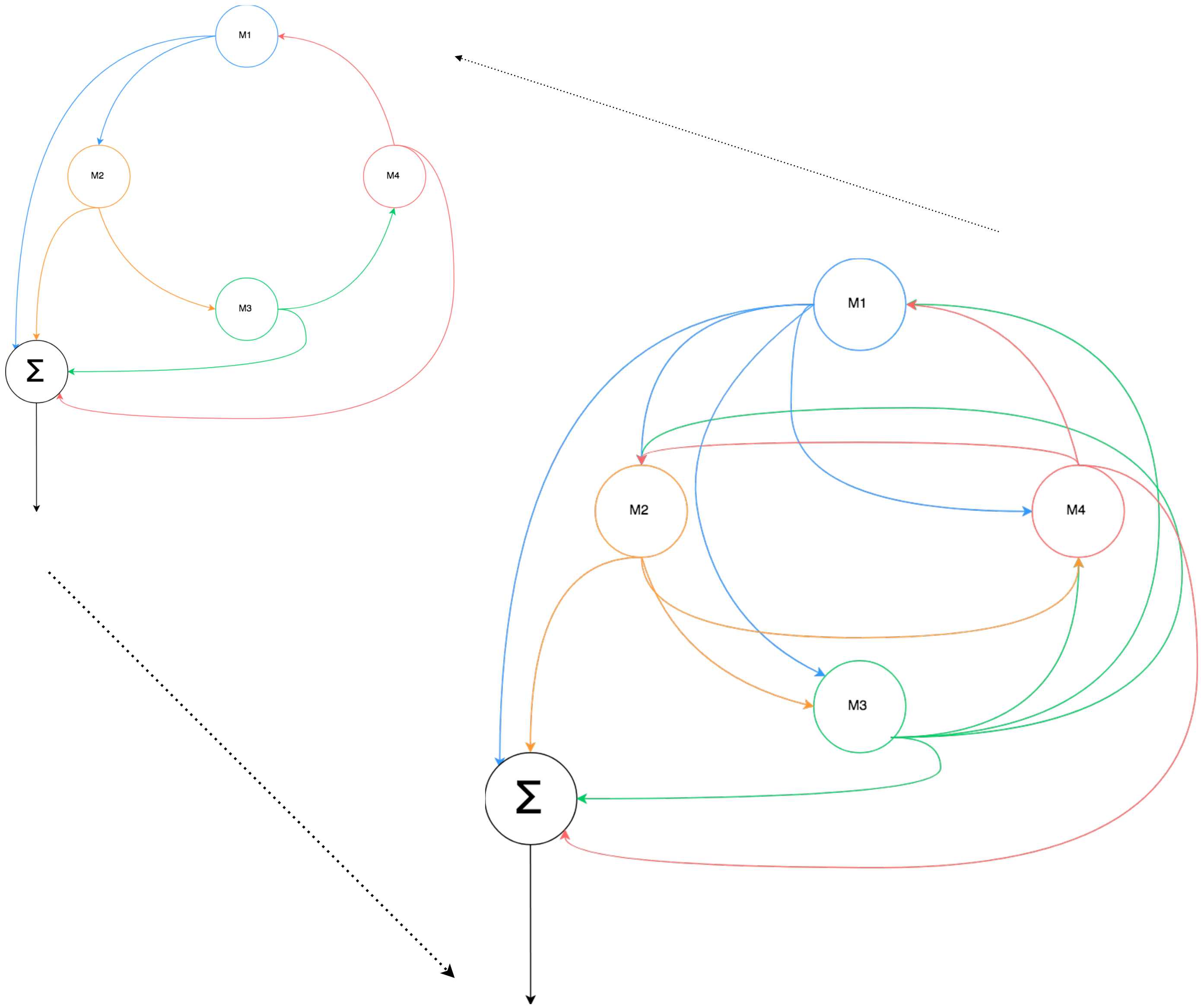
[1] Lex van den Broek's guidance and support were crucial to this implementation.



(Top) Components wired and attached on the panel. (Middle) A look into the guts of the device. (Bottom)The final product in its natural habitat.

Thus far, I have used the *SimpLex* as part of my modular setup mostly within the practice of a live electronics improvisation group, *Miloš Cathals,* initiated together with three other fellow Sonology students. A platform for experimentation developing individual projects and instruments that would be placed in close interaction, this project's central idea was the inter-connection of all individual systems in a circular path. In initial iterations, each system would communicate with its adjacent ones — on left hand-side the input and on the right, the output.

Including the *SimpLex* in this context, made available to experiment further on different ways and speeds the network of individual systems can be configured. Additionally, it offers the ability to similarly approach the processing of analogue signals incoming to my system, though separate processes that can be dynamically cross-coupled via the software matrix interface.



Changing couplings in time (and system level).

2.4 The van der Pol oscillator for music

Note: The topics and implementations discussed in this chapter are the products of a fruitful and cherished collaborative group research path taken along with Sonology staff members, Peter Pabon and Lex van den Broek. Without their continuous support, enthusiasm and efforts, my urge to make music with the van der Pol oscillator as an analogue modular synthesis device would have been quite harder to accomplish; it might have stagnated and disappeared in thin air. I truly thank them for this very exciting and educating experience.

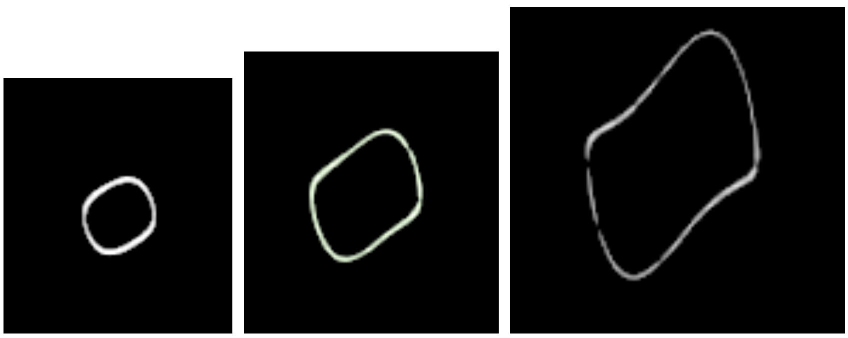
2.4.1 Background and Overview

Balthazar van der Pol (1889-1959), was a Dutch physicist whose work focused in on the fields of radio signals, vacuum tubes and electrical oscillations (Ginoux, 2014, p.2). He is mostly known for his second-order differential equation:

$$x'' - \mu(1-x^2)x' + x = 0$$

This equation describes a self-sustaining oscillation with a non-linear damping. Van der Pol described a self-sustained triode circuit with this equation (Ginoux, 2014); it is also known as the van der Pol equation and the nonlinear oscillating model it governs bears his name.

The van der Pol oscillator has been a topic widely studied in the domains of nonlinear systems in physics and theoretical mathematics. Van der Pol himself was said to be highly enthusiastic on his equation, and in a series of lectures in France he aimed to generalise it by stating that the equation could describe many natural phenomena; for that, he was received with scepticism from his peers (Ginoux, 2014). Yet, one aspect he did not probably consider was that his discovery could be used for the creation of music. The aim in this chapter is to present and discuss how it could also be more widely adopted in the domain of electronic music, particularly as an analogue electronic circuit for modular synthesis.



XY plots of the van der Pol phase plane over time,
exhibiting its wave-shaping ability — from sinusoid-like to ‘wilder’ oscillations.
(Corron, 2006)

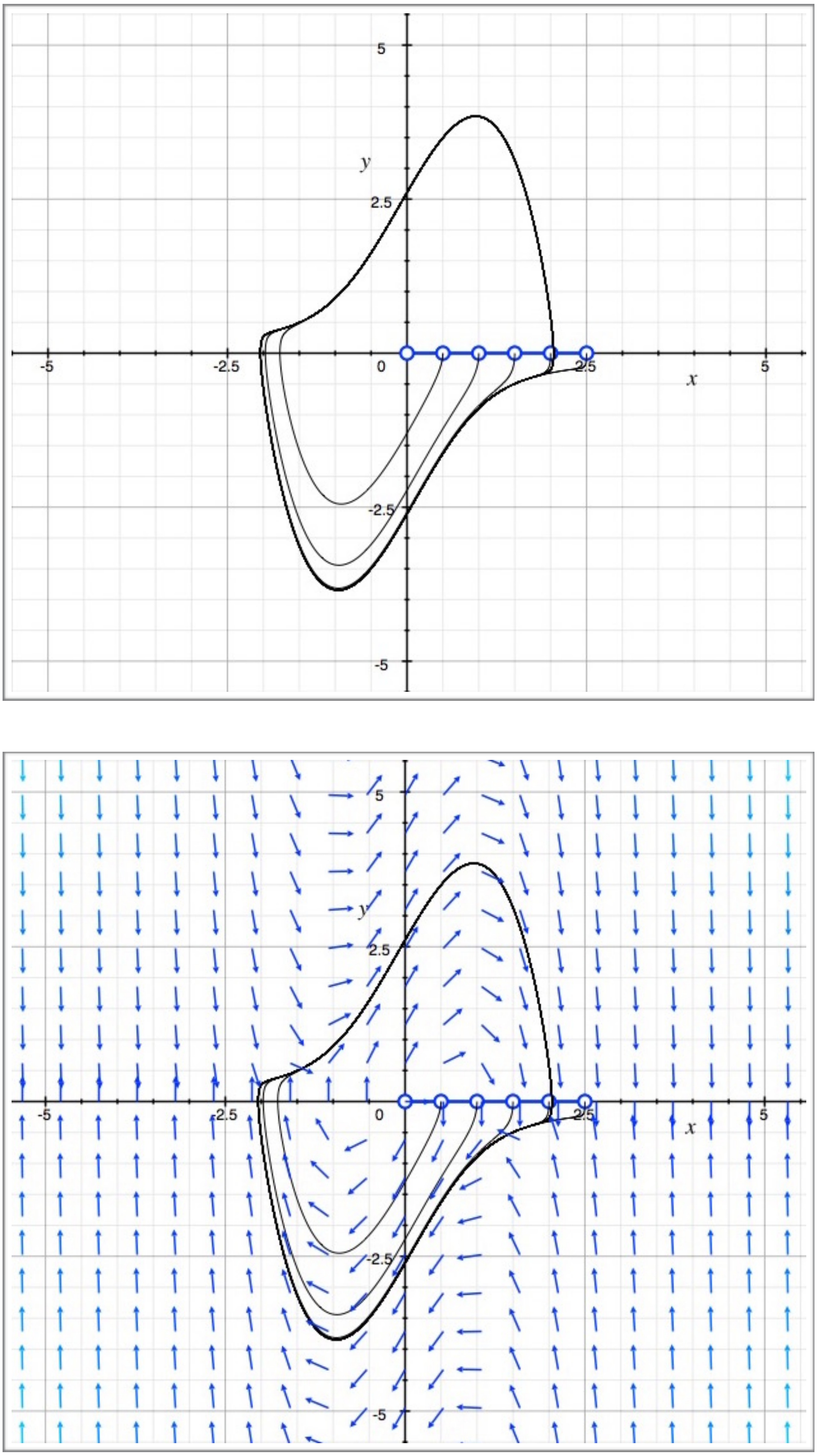


Fig.1. The phase plane plotting (top) ande vector field of the equation (bottom), made in Apple’s Grapher application, in 2018.

2.4.2 Motivations and aims

The motivations and aims behind the undertaking of implementing a van der Pol oscillator as an analogue electronic circuit can be traced to its nonlinear response characteristics.

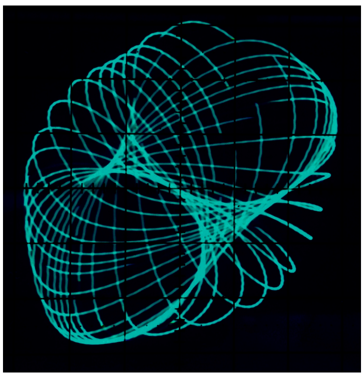
As those presented in chapter 1, the main characteristics of nonlinear systems (limit cycle, subharmonic and harmonic response to input, jump resonance and multiple equilibrium states) are also exhibited by the van der Pol oscillator. Additionally, the van der Pol is a system that often exhibits chaotic behaviour; its initial conditions are also delicate in external perturbations that could lead it to

My initial hypothesis was that some of the phenomena observed in the 'no-input mixer' system were of similar nature; i.e. the detuning of interacting signals for specific frequencies could suggest that mode-locking occurred. The fact that these instances contributed to an element of surprise in my interaction with the instrument, as well as moments where they added character to the sonic output motivated me to look further into the principles of coupled systems in order to apply them as a technique for synthesising sound.

Dedicating time in looking for music-, or sound-, oriented findings brought me to a paper depicting the coupling of acoustic oscillators (Fischer, Bergweiler & Markus, 2013), where the authors measured the deviation of the coupling strength through variating the distance between two organ pipes; this would be perceivable as a slight detuning in the observed frequency and seemed of similarity to detuning occurrences observed in my ‘no-input mixer’ setup. I was interested in using a system where this phenomenon would be possibly *found* more often and to be more open in educating my use. Landing on the van der Pol and its inherent ability to mode-lock to external signals was an exciting ‘eureka!’-like moment.

In the domain of analogue modular synthesis, I deemed that this oscillator model was still musically under-explored. It is often the subject of study in the domains of theoretical mathematics and physics, but I could not locate it in terms of a musical dimension. A dedicated model of the van der Pol oscillator for modular synthesis did not seem to be widely used or acknowledged, while other types of complex and nonlinear models are gaining recognition in the field (Fritz, 2018).

Another important factor in motivating me to use it was that I viewed as a step-forwards in my musical setup, compared to my previous use of a feedback system such as the ‘no-input mixer’, as it was It was, therefore, judged as a promising platform in experimenting on its nonlinear properties which could be utilised musically.



XY plot of two coupled van der Pol oscillators, (own photo).

2.4.3 Paths

The following implementations were carried out in order to test and to further examine how to bring the potential of the van der Pol oscillator into an analogue electronic device oriented for electronic music:

I. Digital simulation in the Max/MSP environment,
II. Model with analogue computer in the Willem Twee studios in Den Bosch,
III. Model in the Analogue Studio at Sonology with the existing equipment,
IV. Dedicated voltage-controlled analogue electronic circuit; this task - as a final aim - was running in parallel, continuously being informed and reassessed by findings during the experiments, trials and errors in the rest of the above domains.

The primary target was indeed the voltage-controlled module; the previous steps were implemented in order to inform and prepare the process of design and interfacing of it, via simulation in the first two cases and the ability to experiment on a voltage-controlled patch model in the Analogue Studio.

Each implementation presented issues that required consideration. The modelling in each environment did exhibit similar qualities that the oscillator is known for, yet decisions and refinements had to be made in order to maintain those that gave the most interesting musical results. The common point that arose along all of those paths as the most demanding task to tackle was the correct scaling of the system in order to maintain the oscillation within a range of behaviours that were true to the equation. Essentially, they all related to the following principles underlying the design of the system:

1. The organisation of the components should promote an interactive environment — that is, with other devices and the user.
2. The internal scaling of the model should correspond to the interfacing of its parameters.
3. Its potential should always be defined within their musical functionality.

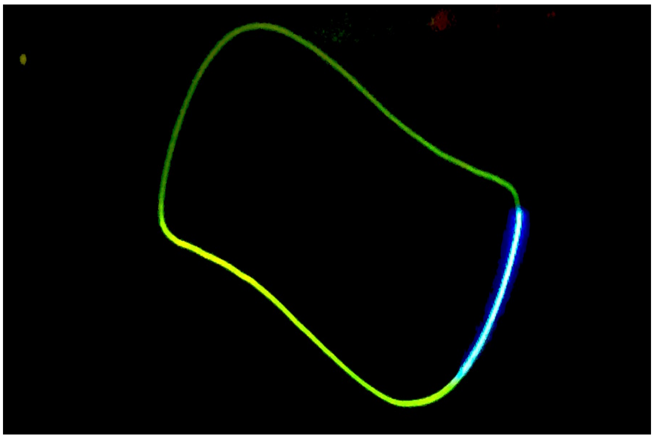
I. Digital simulation

During initial research into the theory and history of the van der Pol oscillator, the first consideration — prior to deciding on implementing an electronic analogue — was the its behavioural and sonic potential. In order to preview those, pre-existing digital simulations in programming environments commonly used for the production of electronic music, such as Max/MSP. This greatly informed the design and ways of scaling the analogue circuit whilst it was in development with Pabon and van der Broek. I personally did not end up using it for composing music, as I was content with experimenting with an analogue model patched in the Analogue Studio.

II. Model on an analogue computer

It was rather fortunate to have the chance to model the van der Pol oscillator on a Hitachi analogue computer during a visit to the Willem Twee Studios, in Den Bosch. The workflow of setting up a van der Pol patch on an analogue computer is requires rather meticulous work. Additionally, it requires a certain amount of time to get become accustomed to the way the individual devices need to be set up. Hans Kulk, one of the administrators of the Willem Twee studio and an analogue computer enthusiast, has invested a lot of effort in acquiring and maintaining this device. He was of tremendous help during this implementation.

As a system analysis device, the analogue computer offered the means to study and observe solutions to this differential equation in regards to its variables' integration over time. The ability to stop and run the program at specific moments in time sets it apart from the way an analogue system would operate in an environment such as the Analogue Studio or in electrical circuit. By being able to be studied discretely in time, the simulation constructed on the analogue computer could be regarded as a 'middle ground' between the digital software program's disseminative abilities (Collins, 2016) and the idiosyncratic physicality of its implementation in the analogue domain.



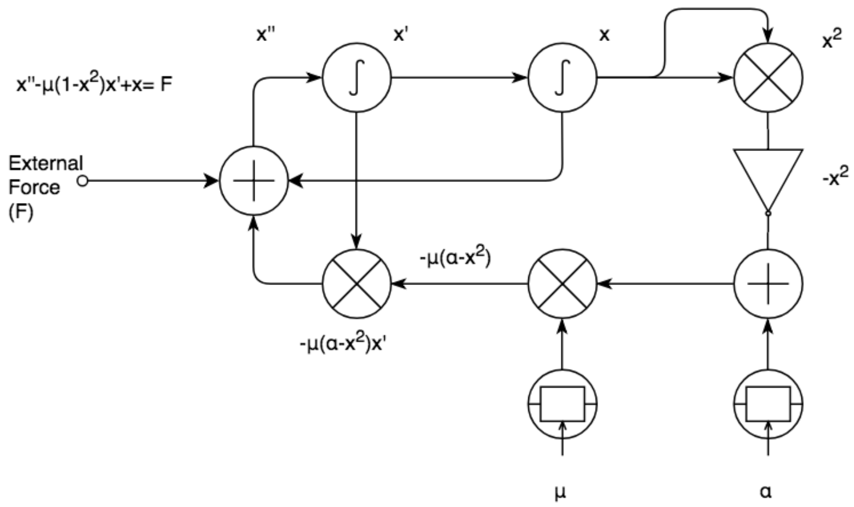
The XY output of the analogue computer model plotted on the *Willem Twee* studio oscilloscope.

To conclude on that step, the analogue computer program was scoped as a valuable step in further understanding the van der Pol oscillator as a system. This informed, in extension, the approaches and techniques used in analogue computation, which I deem as inspiring for future experiments in analogue modular synthesis.

III. Model in the Analogue Studio

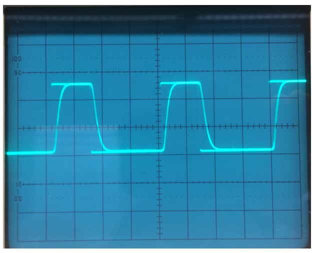
Implementing the van der Pol equation as a patched model in the Analogue Studio offered a large valuable insight to each potential, especially due to being able to work with it in the environment where most of this project's work had taken place. The fact that the individual modules used had the ability of being able to be voltage-controlled provided a fruitful platform for experimentation.

The first image below describes the signal flow for an electronic van der Pol analogue, while the second depicts the way the equation is being shaped along the patch.

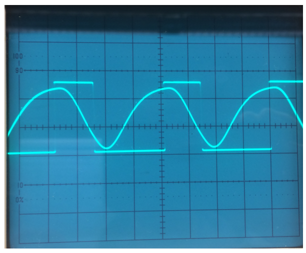


The steps in modelling an analogue of the equation.

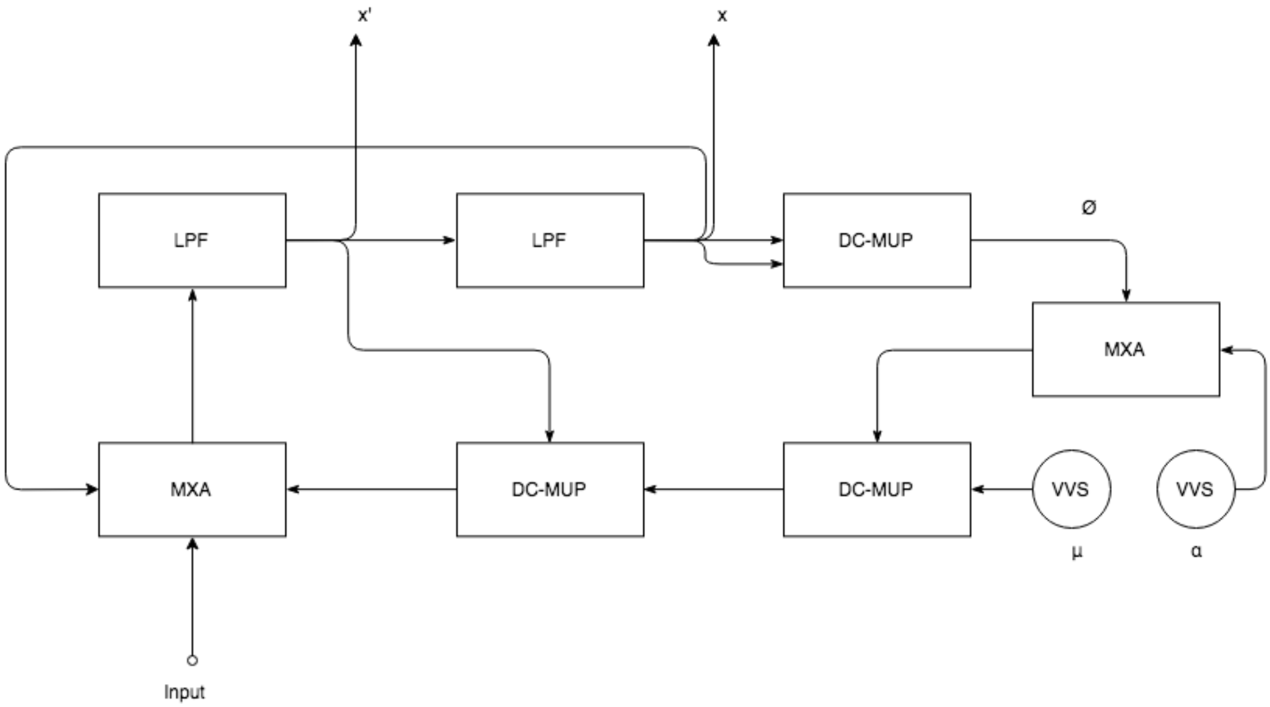
One of the most important steps is that of the ‘double integration’, and one needs to make sure the integrators — in this case, two low-pass filters — are set to the correct initial conditions. The two filters are connected in series and a function or noise generator is fed into the input of the first filter via a mixer module (MXA). The function generator’s and the second integrator’s outputs are then connected on to two channels of the oscilloscope. Once that is done, the rest of the patch can proceed as shown. it is advised that each step is monitored on the scope in relation to the external input. The multipliers should be set in DC-mode (DC-MUP) as the signal after the integration is a DC signal — similar to the product of amplitude followers. The second of the external potentiometers (VVS) is analogue to the μ factor.



The output of the double integration of a square wave as input; first (left) and second (right) integrator output monitored on the oscilloscope against the incoming signal.



When the initial conditions of all components are set the system will start to self-oscillate. To monitor accordingly, the oscilloscope should be set into an XY-plane mode, with the two channels being connected to each filter’s output. The system can be monitored through various outputs, depending on the application it is intended for. The first integrator outputs the first derivative x’, or velocity. The second integrator gives the oscillation displacement (x). The output of the mixer connected to the first integrator is equivalent to the acceleration (x’’) or force (F).

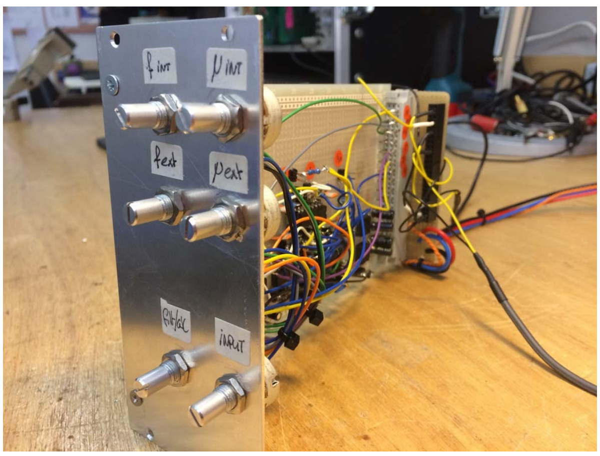


A van der Pol model in the Analogue Studio

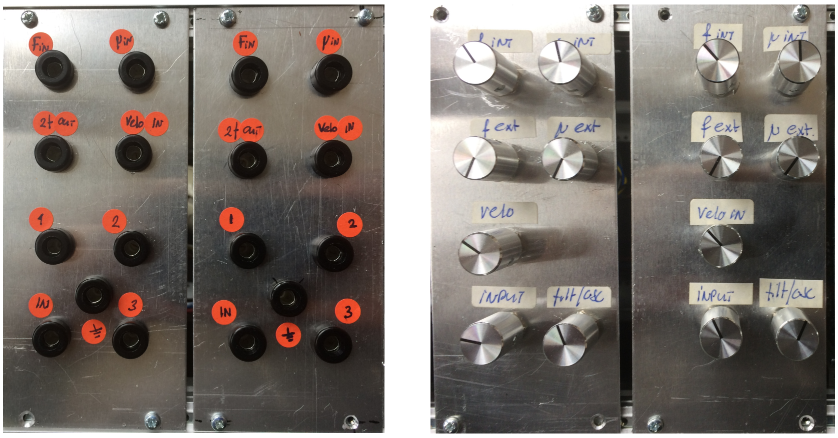
IV. Dedicated voltage-controlled analogue electronic circuit

The entire effort to study the van der Pol equation was directed towards the implementation of the oscillator as an analogue electronic device, designed to interact with other signals and systems. I started by basing a construction on a solder-less breadboard found through an already existing implementation (Corron, 2006). This didn't prove fruitful, although it helped in pointing out that the path towards a correctly scaled system would be a demanding one to get through. This required several iterations of trial and error.

Eventually, after several attempts and discussions with Peter Pabon and Lex van den Broek over the design, a prototype started to form; a result of their expertise and determination, I must add.



The first prototype of the
voltage-controlled van der Pol (VC-VDP).



The interfaces of the prototypes.
The connections (left) were placed in a separate panel to make the access to the controls (right) easier.

Thoughts on first trials with the van der Pol oscillator as a musical device

A first consideration was that the van der Pol oscillator analogue does not ‘leap’ immediately *in* distortion — as compared, for example, to the extreme levels of the signals from a ‘no-input’ mixer system. For a delicate range of the μ factor

The most important point I could stress on is that the cases where the system is externally driven can provide the most interesting musical results[2]. In general, its interaction with other signals and devices is truly captivating; its ability to dynamically synchronise, or mode-lock, to external perturbations is one of its most important and musical traits. This invites exploration; in the presence of periodic signals in its input the van der Pol will exhibit some areas where it ‘locks and follows’ the incoming signals frequency, while in others it will ‘drop out’ and start to produce an output that could remind of complex amplitude modulations — such as the product of ring-modulation — and frequency division (sound example 3).

This suggests that the user is more challenged in figuring out the nonlinearities of the van der Pol oscillator’s responses as results of it ‘open-ness’, instead of those it might exhibit as an *isle.*

From this observation, the idea of including a ‘special’ option on the dedicated module was brought forth. Specifically, part of the van der Pol electric analogue constructed with modern day electronic components is the topology of a state-variable filter. This suggested that the final module could be designed so as its use can drift, or ‘shift’: from a multi-mode filter-type of device into a complex nonlinear self-oscillating unit.

To translate this into the module, a potentiometer was added allowing for a dynamic ‘mix’ between the two states (picture below in green).

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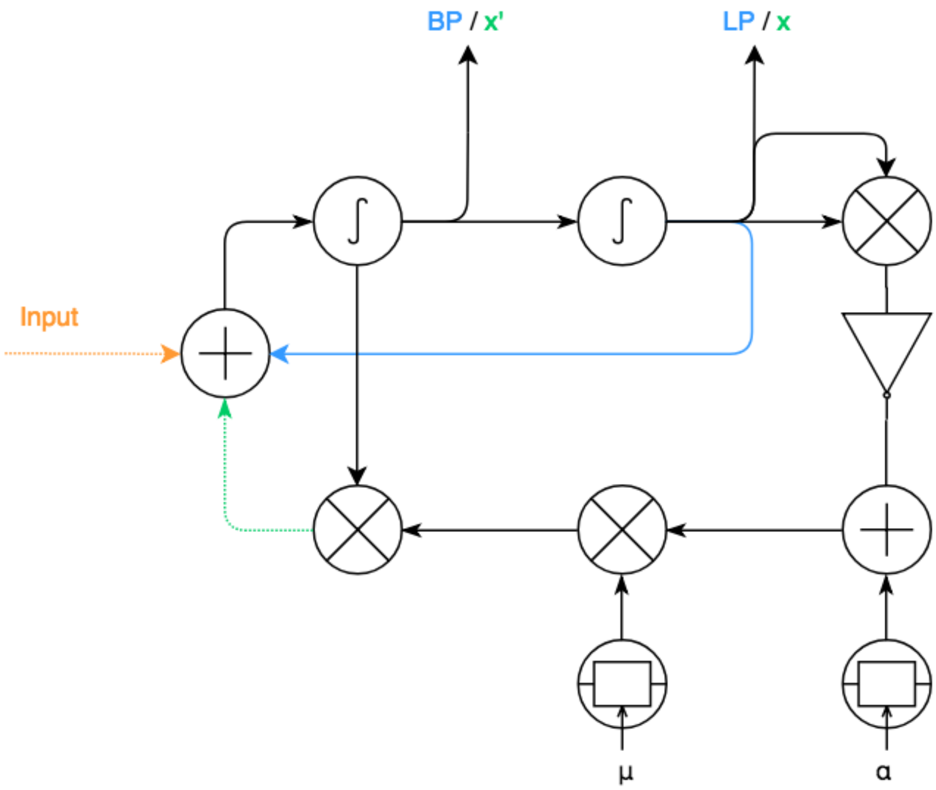
[2] Chapter 3 includes indicative examples (audio & representations) of some of the module’s results



The van der Pol analogue's *isles.*

This way, the user can decide the use of the device; I have to note that interesting behaviours can be yielded when this 'state mix' attenuator is in it middle range. Combining this with a dynamic interaction of external signals can push the module to 'jump' in and out of self-oscillation. An additional function that can be separately used is made possible via a parallel output in the multiplication section; this provides the rectified version of an incoming signal, doubled in its frequency. Thus the system can find many uses according to each user's compositional needs. This provides extensive experimentation in complex system designs.

Furthermore, the device in its current state is still subject to further improvements. To return to the initial principles that guided the implementation:

1. The organisation of the components should promote an interactive environment — that is, with other devices and the user; this manifested into making the van der Pol an open system, that is also variable in the ways it can be used (e.g. 'state mix' knob, 'rectifier' output)
2. The internal scaling of the model should correspond to the interfacing of its parameters; this still requires fine-tuning, but overall the module is operating in a 'healthy' range of voltages.
3. Its potential should always be defined within their musical functionality; this is subjective to a certain extent, as it depends on individual use. For this project, the addition of the 'state mix' reflects the idea of systems that are open to be coupled and variable in the use they can find in one's musical setups.

3.Variations & Techniques in the Analogue Studio

The main motivation for implementing a van der Pol oscillator was to explore its musical potential as an analogue electronic circuit for modular synthesis. This was undertaken by experimenting firstly on the analogue model patch and later on the dedicated module bank within the Voltage-Controlled Studio of the Institute of Sonology. The ability to modulate various parameters of the individual components that comprised the model suggested two things:

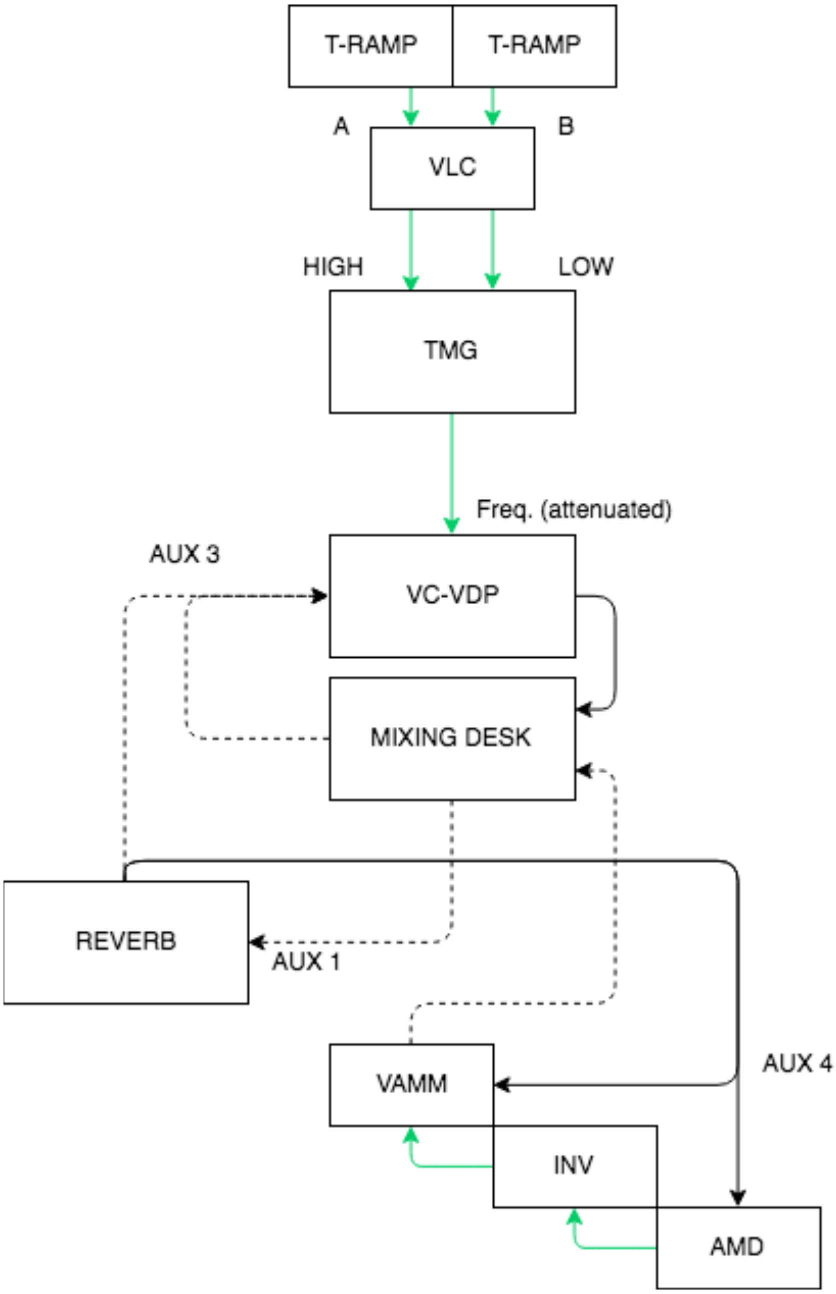
1. That the oscillator as a patch network of devices built for sound production would be open for variations and thus illuminate some of the inner workings of the equation model. This could inform the interfacing and points of interaction of the dedicated module under development, in parallel.
2. That it would be possible to experiment in coupling it with more van der Pol oscillator models, to the point that the studio equipment available would allow it; creating a single oscillator would occupy several studio modules. Experimenting on placing the oscillator to interact with other devices was the primary objective for this research project, since it was already evident by trials in the digital simulation that when driven, coupled and further utilised in sound processes, many of its 'hidden' attributes could be explored further.
3. Sound material as a result of these experimentations would emerge and therefore give way to possible fixed media compositions, as well as an initial indication of its synthesis potential and, possibly, problematics. This would, as well, be informative for the design of the dedicated modules.

It is important to note here that the flexibility in the way signals and devices can be routed and inter-connected in the studio — a result of a fantastic mixing board and the custom patch panel — was crucial in encouraging creativity in coupling the van der Pol oscillators.

Once again the presence of a mixing board was the centrepiece for interactions, both for signals and myself as the human agent in the systems. In this chapter I include several signal flow patches of those variations; the plethora of them where realised with the patched model, while some included the first three dedicated module prototypes. These are indicative of a portion of what can be realised, as they are the result of one person, with my biases and possible errors; it is highly likely that the use the modules might find in other hands will shed light in even more creativity.

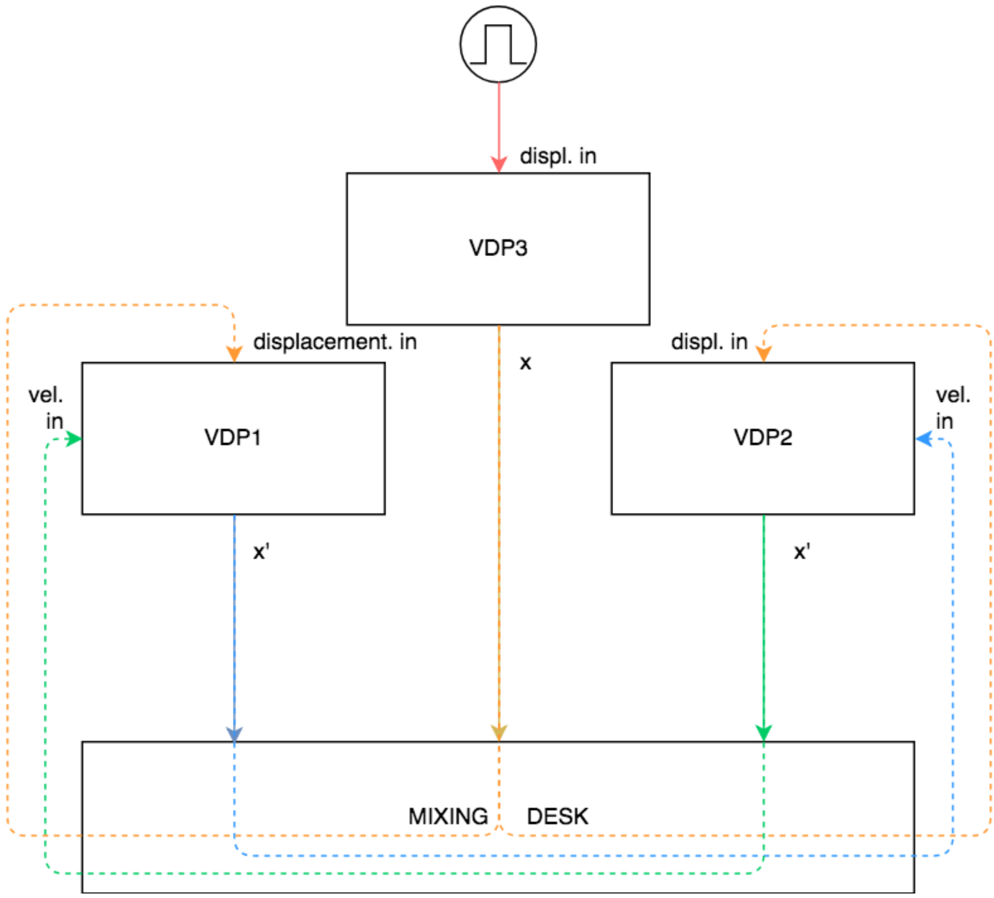
The systems depicted further are a few indications of variations to be accompanied with sound examples. In almost all of the examples the element of human interaction and improvisation was of high importance in the resulting output; each system's output was a result of it being approached as resembling an instrument. As with the signal flow charts and patches present in previous chapters, what are depicted are the possible routings where variability was possible (indicated by dashed lines); these depict the possible points of interaction with the given system, conceived as the dynamics of coupling strength levels for the individual components. Lastly, the majority of the sound material from these improvised rehearsals and experiments with these systems are used in a fixed media piece titled *Archétypa,* which is described in the following chapter.

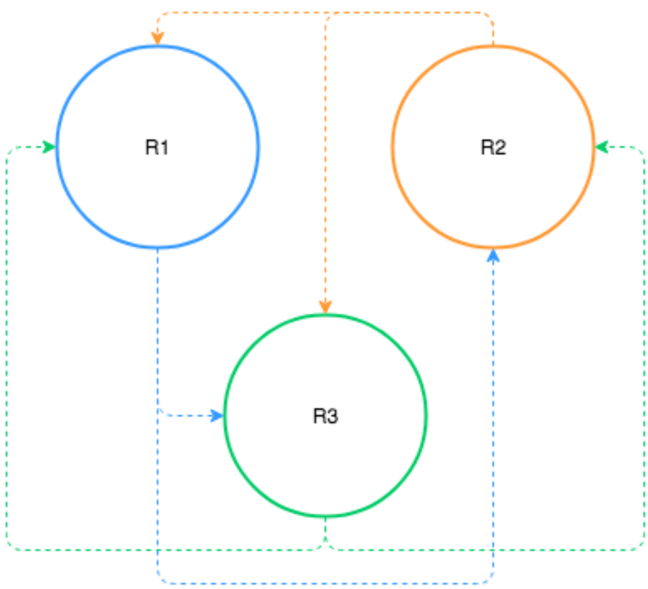
Variation 1: Stochastic frequency micro-modulation ('Falsetto')



Voltage control on the frequency of the van der Pol from Tendency Mask Generators (TMG) seemed to resemble a falsetto-like sound output (sound example 4) . Tending to the μ factor and a self-regulated Reverb-based feedback network resulted in a brass-like timbre (sound example 5).

Variation 2: Driven cross-talk — 'Triads'

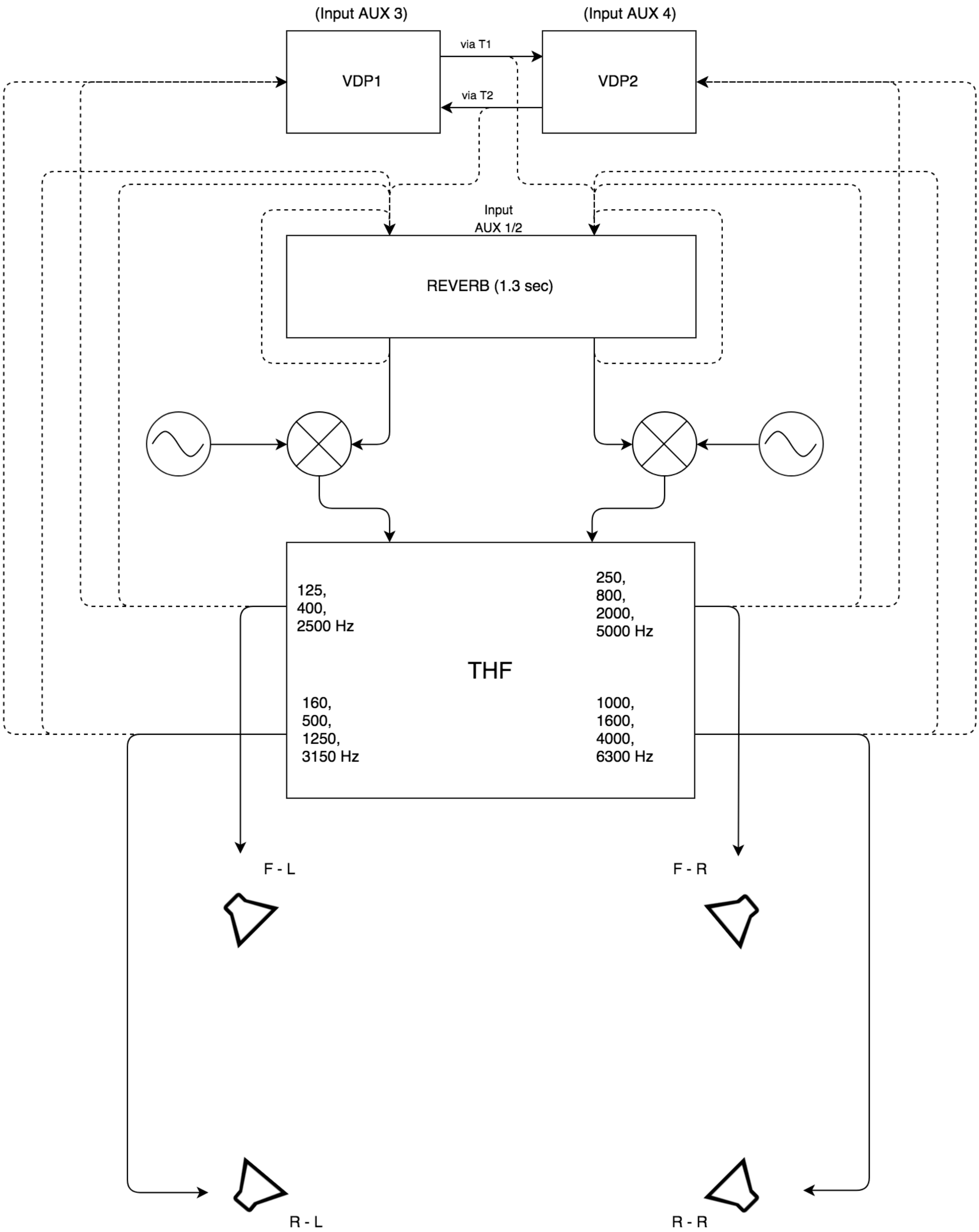




The accompanying sound excerpt (sound example 6) included the routing of the coupled van der Pol system (top) to a feedback network of reverb units (left).

The matrix on the studio's mixing desk provides the possibility for a large combination of routings. The user can control the variability of the connection levels through the mixing desk; this made the interface of interaction resemble a 'no-input mixer' approach, replaced with the 'voicing' from the van der Pol oscillators.

Variation 3: Juxtaposing two mutually coupled oscillators — 'Poly-rhythms'



The sound excerpt from this recording is based on performing the levels of this system, with the addition of experimenting on phase inversions of the signals before they fed back to the system. This created very interesting 'cuts' in the rhythm, briefly desynchronising the oscillations.

(sound example 7)

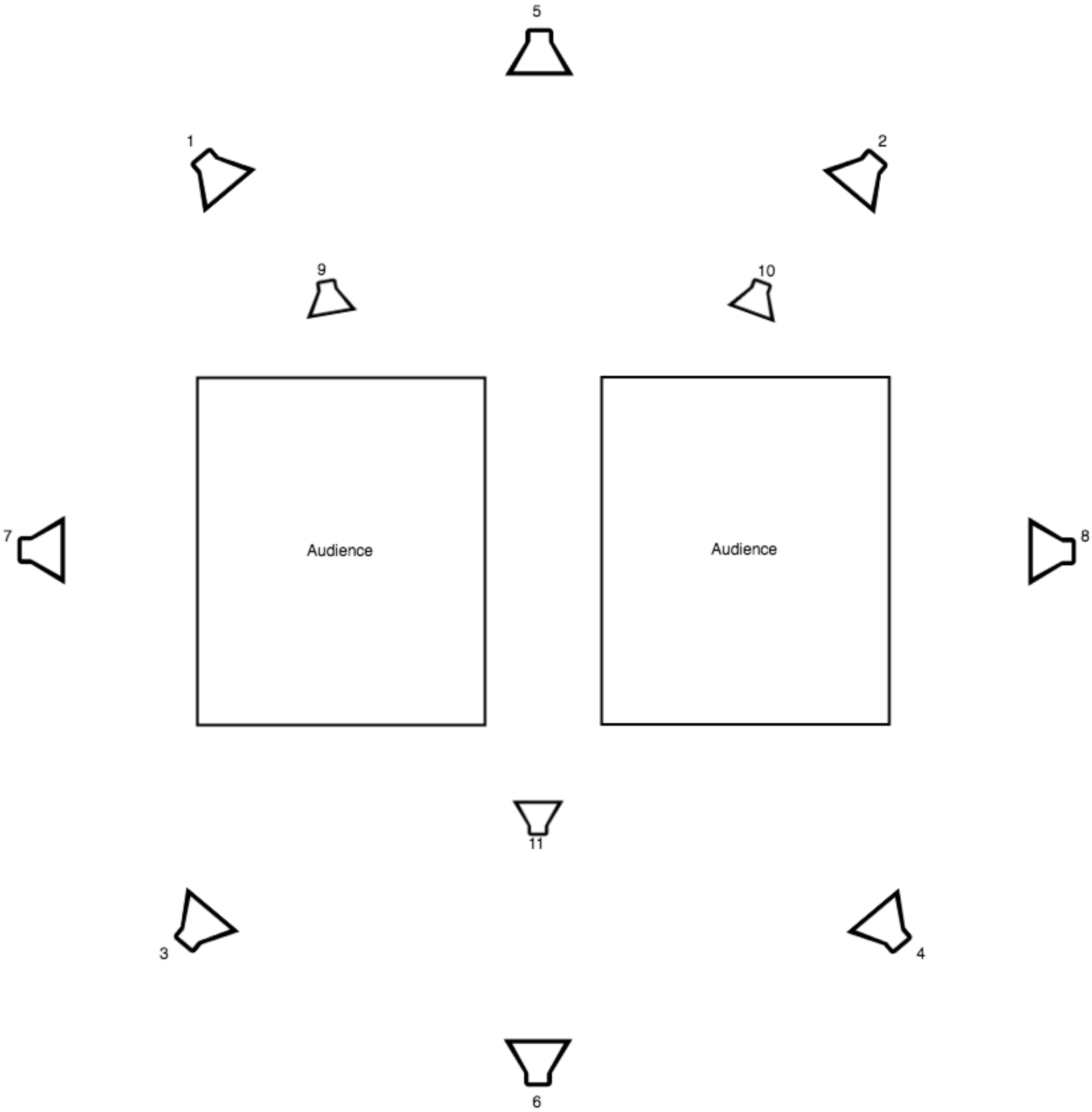
Variation 4: 'Forced, ringed, delayed & filtered'

This experiment was a variation on a synthesis model first designed by Jaap Vink, and later expanded and passed on by Kees Tazelaar in the Voltage Control Techniques lectures. I was curious to combine the general architecture and to replace the included oscillators with driven van der Pol oscillators — with the addition of a control-voltage derived from amplitude following to gradually change the oscillators' frequency based on the activity of the output. This resulted (sound example 8) to the van der Pols' detuning due to dynamically shifting their mode-locking on the input signal and thus extended the richness of the output's motion. Another variation done here was the replacement of the tape recorder as a delay line to three voltage-controlled Bucket Brigade Delays (BBD) placed in series. I added tendency masks on the time delay controls in a notion that this could resemble a crude model of a tube with a indeterminate variable waveguide.

4. Works

i*solarchy (2018)*

As mentioned previously, several material derived from the aforementioned van der Pol variations and experiments in the Analogue Studio are to be used for the composition of a tape piece titled *Archétypa.* A second piece created with various electroacoustic feedback techniques under the title *Vassal States.* The two pieces are composed though different approaches; one is closer to a 'montage' of the various recordings resulting from experimentations based on the van der Pol oscillator, while the other is based on a series of sound transformations of a short synthesised sequence as the original material. At the time of writing this dissertation the pieces are yet to be finalised; nonetheless, they are intended to accompany this dissertation in the final examination concert, and together form a diptych entitled *isolarchy.* The two parts have the freedom to be independently played. However, my intention is to also have the ability to place them adjacently in order to shape a compound-piece. My estimation here is that the two pieces can complement each other despite the differences in the techniques used in each work. Here, I will mention them inversely as to their playback positioning. This due to *Archétypa* being the result of experimenting with the van der Pol oscillators that were described in the directly previous chapter.



A sketch of the diffusion configuration for the *isolarchy* piece.
The circular eight channels are to be set higher on a vertical axis than the inner triangular configuration, which is aimed to create a ‘dimension’ perceivable as closer and more impactful for the audience.

3.1. ***Archétypa (2018)***

Working in the Analogue Studio with voltage-controlled models of the van der Pol equation has provided several recordings as results of variations on coupling van der Pol oscillators in larger systems. Over the course of this past year, through experiments and variations — including the ones depicted in the previous chapter, I have been collecting and creating a catalogue of sounds to be used for the composition of this piece. This approach will be closer to a 'montage', treating the recordings as sound objects that are classified based on their phenomenological traits. I intend to approach this composition as a next step after making the soundtrack for the short film, Anina. In this case, the difference will be that the image will not be there; the recordings are informally conceived as 'filmed events' or episodes that will be placed in time for a narrative to appear. The central theme for the piece emerged from what the recordings — or episodes — suggested upon first listening; *conflict and collaboration*.

At this time, the piece is still to be finalised, so few things can be analysed here. What I can state is that my interest is to see how this piece will contrast — both in its creative process and in the way the result will work — against its counterpart, *Vassal States.* when placed adjacently in this diptych-piece, *isolarchy.* Specifically, *Vassal States* (as described in the next chapter) was created based on a series of transformations of a single sequence of original material, and therefore was more abstract in terms of theme and semantics. Thus, the juxtaposition of the two might operate in a way that the two pieces will either conflict, and thus each will 'lose' in their operation, or collaborate to a synergetic result that brings both to a better place.

3.2. ***Vassal States (2018)***

The construction of this piece is based upon a temporal trajectory through a series of transformative processes which the chosen original material is fed through; the form of the piece arises from the derived material.

As initial material, a minute-long recording was chosen based on the following criteria:

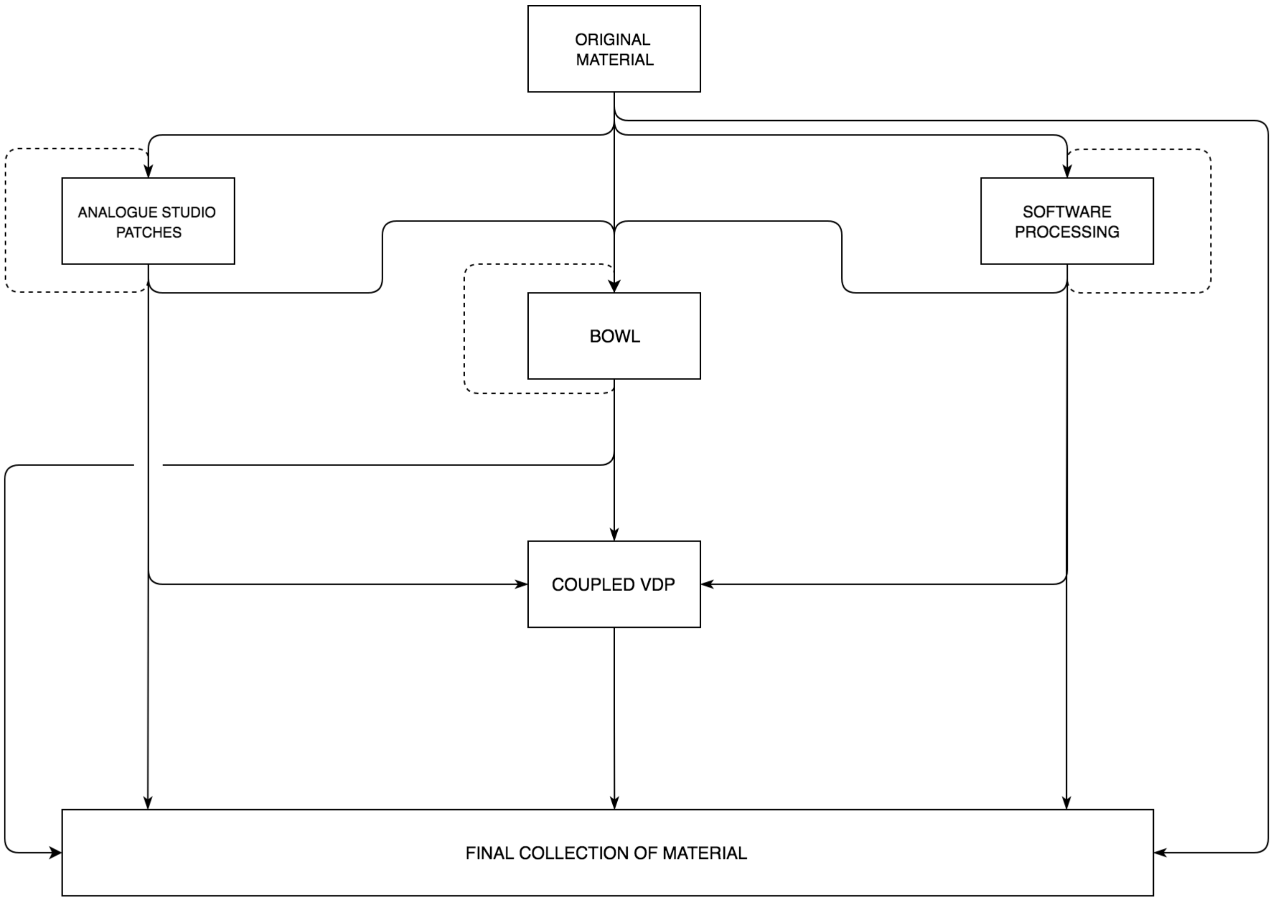
~ Short duration,
~ Identifiable transients,
~ Rich spectral content.

The above were taken into account in order to guide the approach for designing the transformation systems. The choice of selecting an initial recording that involves highly gestural and identifiable sonic events brought a challenge into the process of transforming it beyond recognition. In the cases of transformations where this residual 'shadow' of the original content remains, it can create an underlying connection throughout the piece as the listener is navigated through the series of transformations, sometimes familiarising between them and other times not. The title of the piece refers to this 'residual history' and its influence on the transformation states.

Choosing a recording close to the borders of noise gave the ability — or challenge — to extract various resonances with subtractive synthesis. Specifically, it was decided beforehand that the task for the transformative process would be to place several 'spectral foci' on the initial material, thus 'zooming-in' the way individual resonances would translate in the movement of the original sonic gestures. Configurations where the signal would flow through while perturbing resonant bodies were chosen as the main transformation guideline. Iterating this process with each generation of derived material would enhance the resonant character increasingly along each passing — a process inspired by the technique famously used by Alvin Lucier in 1969 piece, *I am sitting in the room* (Lucier, 1969). Lucien's piece is a landmark in electroacoustic music, for it delicately reveals the impact a resonant space has by transforming his original speech recording through several iterative playback and recordings in the 'room'. In my opinion it is one of the ultimate 'feedback pieces' due to its ingenious way of slowing down and magnifying the process of acoustic feedback in time and space.

The first series involves systems in the Analogue studio, where the combination of resonant filter banks and reverb units model a *synthetic* and exaggerated resonant 'space'. A second transformative branch would start from exciting a *physical* resonant space, namely a Tibetan singing-bowl, with the original material via the use of piezo-electric microphones attached as transducers on the bowl. A third branch involves transformations made in Digital Audio Workstation software. I wanted to see how these three 'families' of derived material could, when placed together, bring an element of displaced familiarity where the acoustic properties of the transformations could suggest one another.

After feeding the original material from each of the three branches, the resulting transformations were also processed via the van der Pol modules, which were set on the verge of self-oscillation, to provide an extra generation of material that could operate as 'adhesive passages' between material from each of the three transformative branches. This could give the ability to temporally intersect each transformation technique with material of similar timbral characteristics, thus trying to enhance a continuity along the piece.



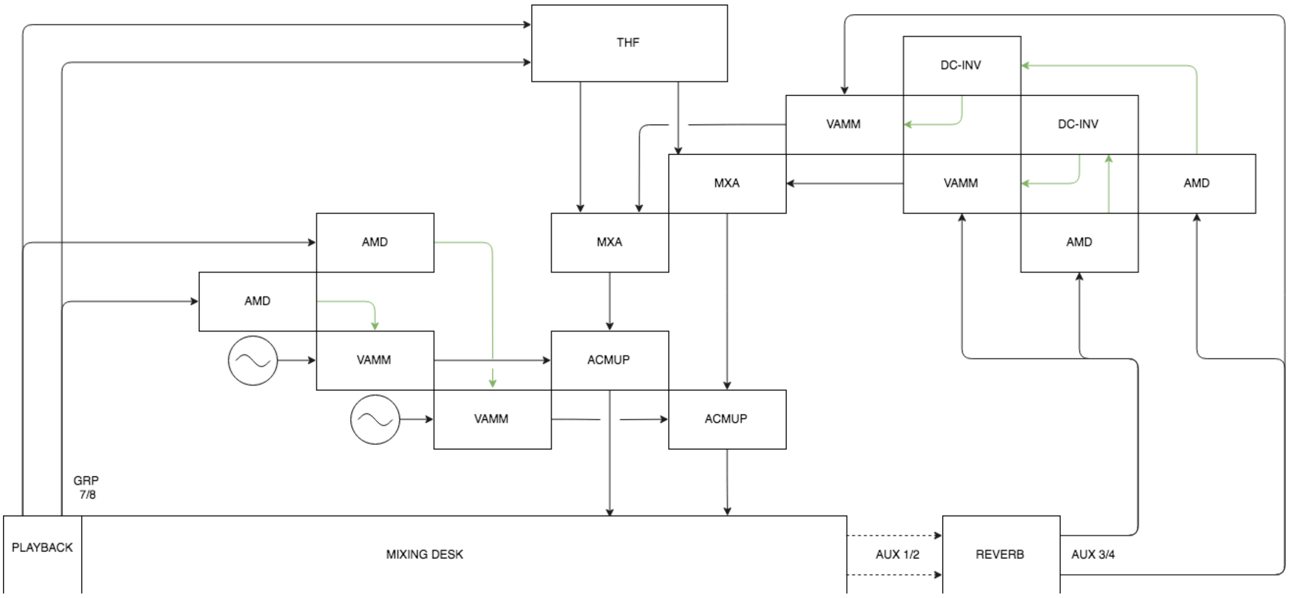
The transformation tree.

Transformation techniques

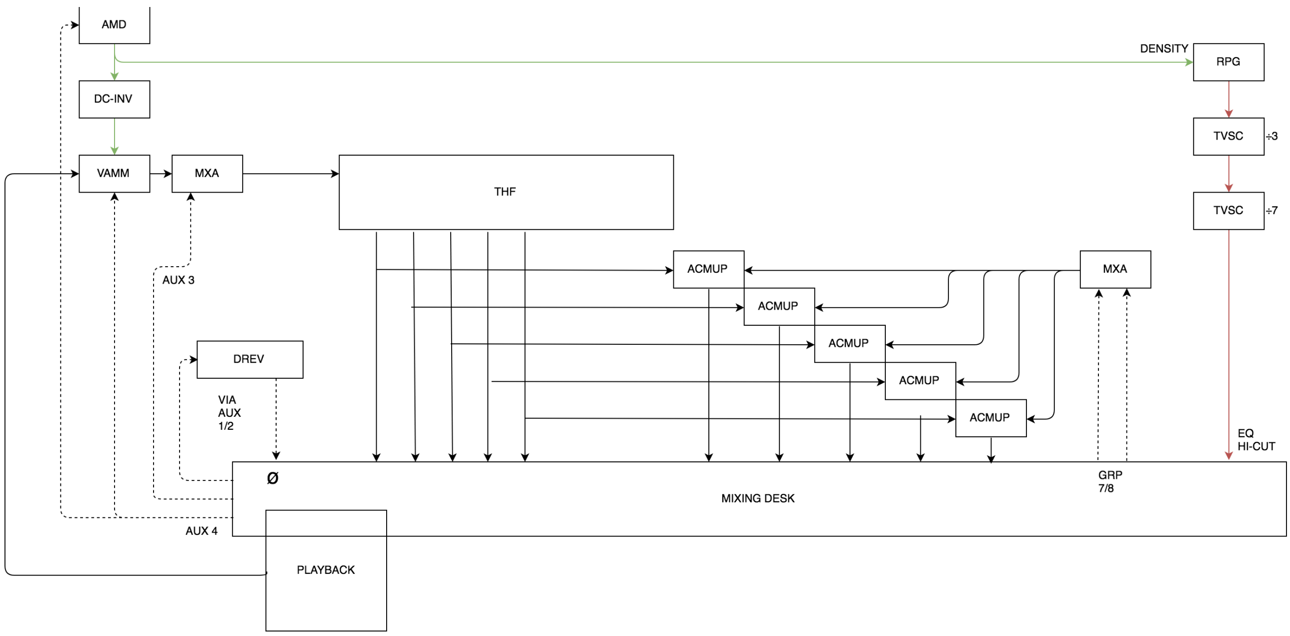
I. Analogue studio

The first transformation was to slightly 'add colour' by ring-modulating the filtered frequency bands of original material, which was fed into the Third Octave Filter (THF). Its custom interface invites creativity in the way those filter bands can be associated with the input and the output of the device, via a matrix panel with pin connections, similar to those incorporated on EMS synthesisers. The two-channel input of the filter necessitated that the process would be repeated for the individual tracks of the original sequence. Once complete, this process would be iterated, each time with a different frequency for the modulator in order to give slight variation in the timbre of the transformed material.

The modulators' frequencies were chosen in three registers — high, mid and low ranges of the spectrum — for the first, second and third iteration, respectively. The difference between the two function generators' frequencies would increase as their range would decrease. The modulators were fed into the multipliers through amplitude following of the original material and these two ring-modulated signals were connected to the mixing desk from where they would return in the input of the system.Through different settings on the parameters of the equaliser stages on the mixing board's stereo channel output of the reverb unit, the timbral character of the transformation could be dynamically enhanced while listening to the system output, bringing out resonances which could be increasingly exaggerated in each next transformative process.



First analogue transformation system.



Second analogue transformation system.

The three sets of material derived from the first patch were processed through a second patch of similar approach, albeit with some variations that lead to totally different results. Here the regulation of feedback was mostly manual. An addition of a complementary patch of slow random pulses, with a density inversely proportional to the amplitude of the system, was connected to a channel on the mixing board to excite the self-oscillation when activity in the output was low.

II. ‘Bowl’ Transformations

For this series of transformative processes a set of contact microphones was attached on a Tibetan singing bowl, serving as transducers through which the original material and other transformations were played back, thus causing the bowl to resonate. The recordings that were derived were themselves played back through the bowl, in a manner similar to the transformation patches created in the Analogue studio.

The aim was to bring out, and exaggerate, the resonant frequencies of the bowl along the amplitude modulation that the material prescribed. transients would eventually give way to sustained tones.

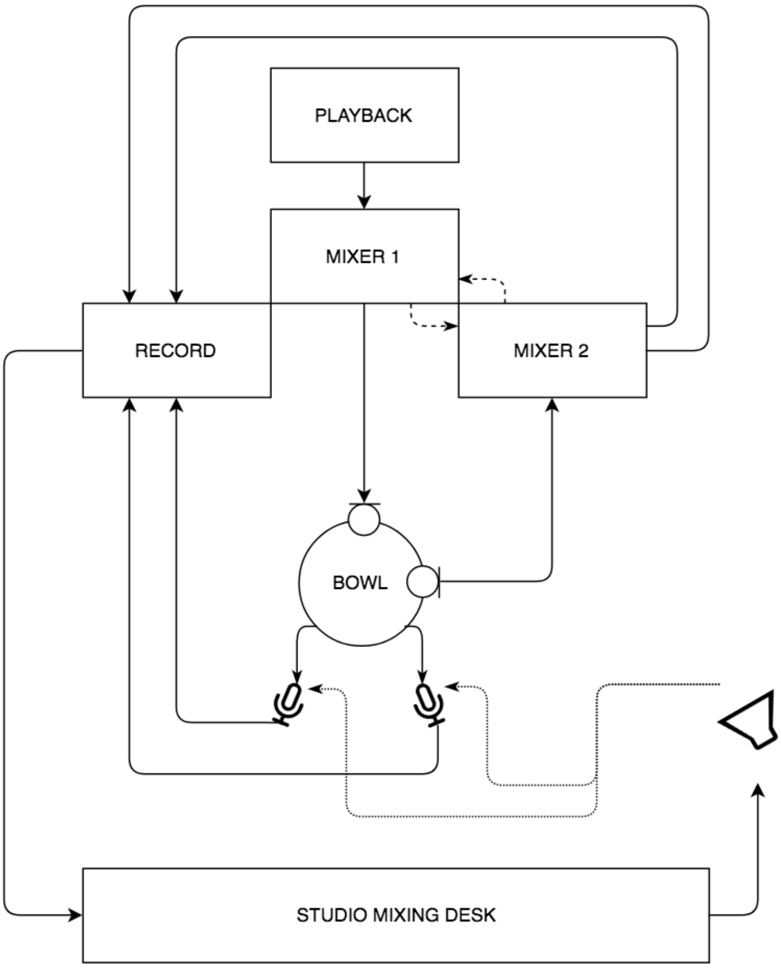
In the case of the first series of transformations, the ‘room’ was conceived as modelled in the studio patch, whereas through the technique mentioned here, the resonant ‘room’ was the singing bowl. Another aspect that was considered and put to the test was the extent to which the two different spaces chosen - the electrical and the physical - would yield outputs that could be juxtaposed in the final composition and the perceptual or aesthetic effect this would have.

First stage: ‘Mixing-Bowl’ system

As an initial set up for playing back the original material and exciting the bowl, two small mixing boards were used. The first mixer was connected to a contact microphone, operating as a transducer, connected to the auxiliary output. The original tracks were played back both as a summed output and individually.

The first setup for the recordings with the feedback mixers and the bowl.

Close-mic recordings enhanced the registration of the bowl's resonant space

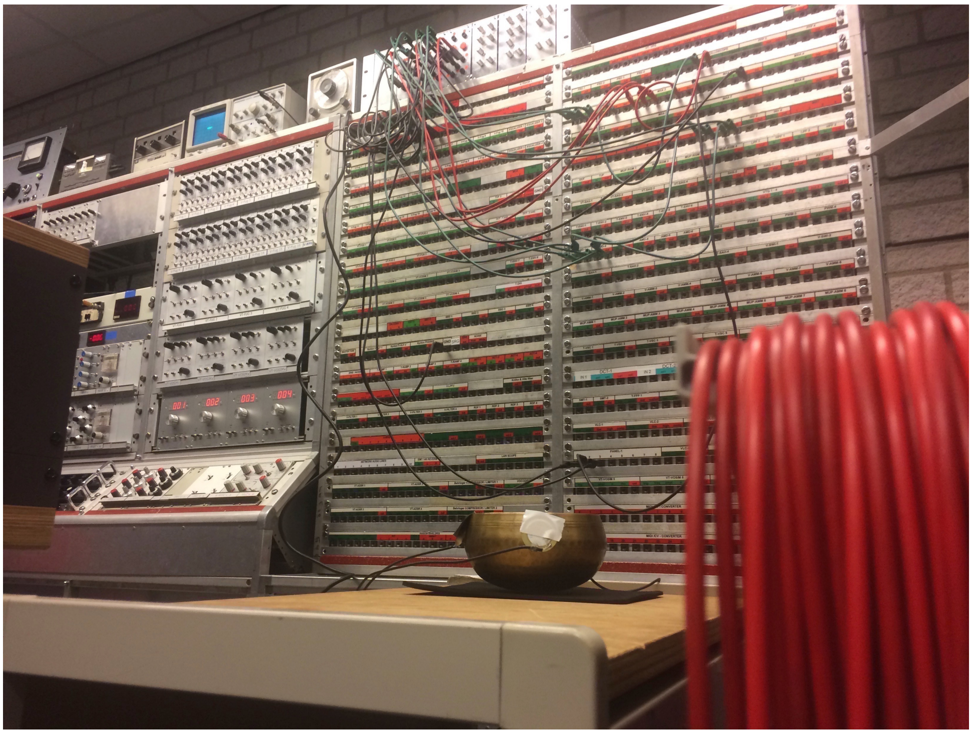


The signal flow of the first bowl session setup.

The result of this experiment was radically different from what anticipated; this was welcomed. The configuration of the two coupled mixers made possible to 'stress' and make interferences between the signals entering the bowl — among which, first were the original material — and thus creating short intermittent transients of the bowl being 'pinged'. The recordings were thought to be interesting if made into a highly rhythmical section that would contrast the rest of the more textural transformed material.

Second stage: 'van der Bowl' in the Analogue Studio

Several material from the first stage of the 'bowl-transformation' were then further transformed back in the Analogue Studio, in a similar 'bowl-setup' that also involved the three van der Pol oscillator prototypes.



The second setup in the Analogue Studio.
On the top of the panel, the van der Pol oscillator bank.

Here, the bowl was connected in a similar manner to the first stage, receiving the playback signal from a bus channel via the mixing desk and the connection panel. Two contact microphones were again placed in order to transmit its vibrations back to the mixing desk, being recorded in two channels. These signals were in parallel fed as input signals to two of the van der Pol oscillators, which were mutually coupled via their 'velocity' inputs and outputs. A third van der Pol oscillator was connected to the mixing desk, from where it was dynamically mixed in the 'force' inputs of the other two oscillators.

Voltage-control signals as products of frequency and amplitude following of the resonating bowl were inversely modulating the frequency and μ factors, respectively, on each of the coupled oscillators. These modulating signals were attenuated on the interface of the oscillators, in order to create micro-fluctuations on their respective parameters. Nonetheless, the first attempts were not as satisfactory to the needs of this transformation task, since the voltage-controlled oscillators would assert their distinct character over the bowl-processed material in a very intense way. For the purpose of this stage it was a too drastic effect to begin with. To deal with this, the oscillators were set unto the threshold between self-oscillation, through the coupling level of the lower-level *isles* in the van der Pol, to colour of a resonant 'tail' in the decay of the bowl's excitation by the incoming sounds. The process,would be iterated for selected results, thus exciting the 'resonant space' further each time, as done in the previous approaches.

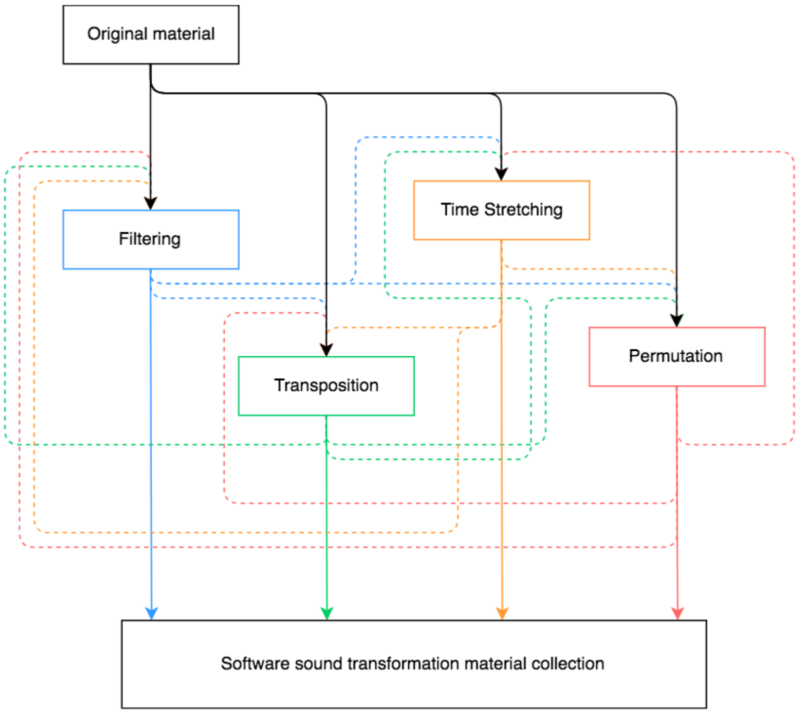
The playback material also involved selected recordings from all other previous stages, in an effort to obtain recordings which could later be used throughout the piece so as to give a sense of 'foreshadowing' through the piece.

Software Transformations

For this series of transformations, that were made in parallel to the previous hardware-based processes, the original sequence was firstly filtered in a DAW environment. Specific frequency bands were selected: 92 Hz, 130 Hz, 164 Hz, 246 Hz, 293 Hz, 374 Hz. These correspond to the notes F#2, C3, E3, B3, D4 and F#4, respectively, and shape the chord:

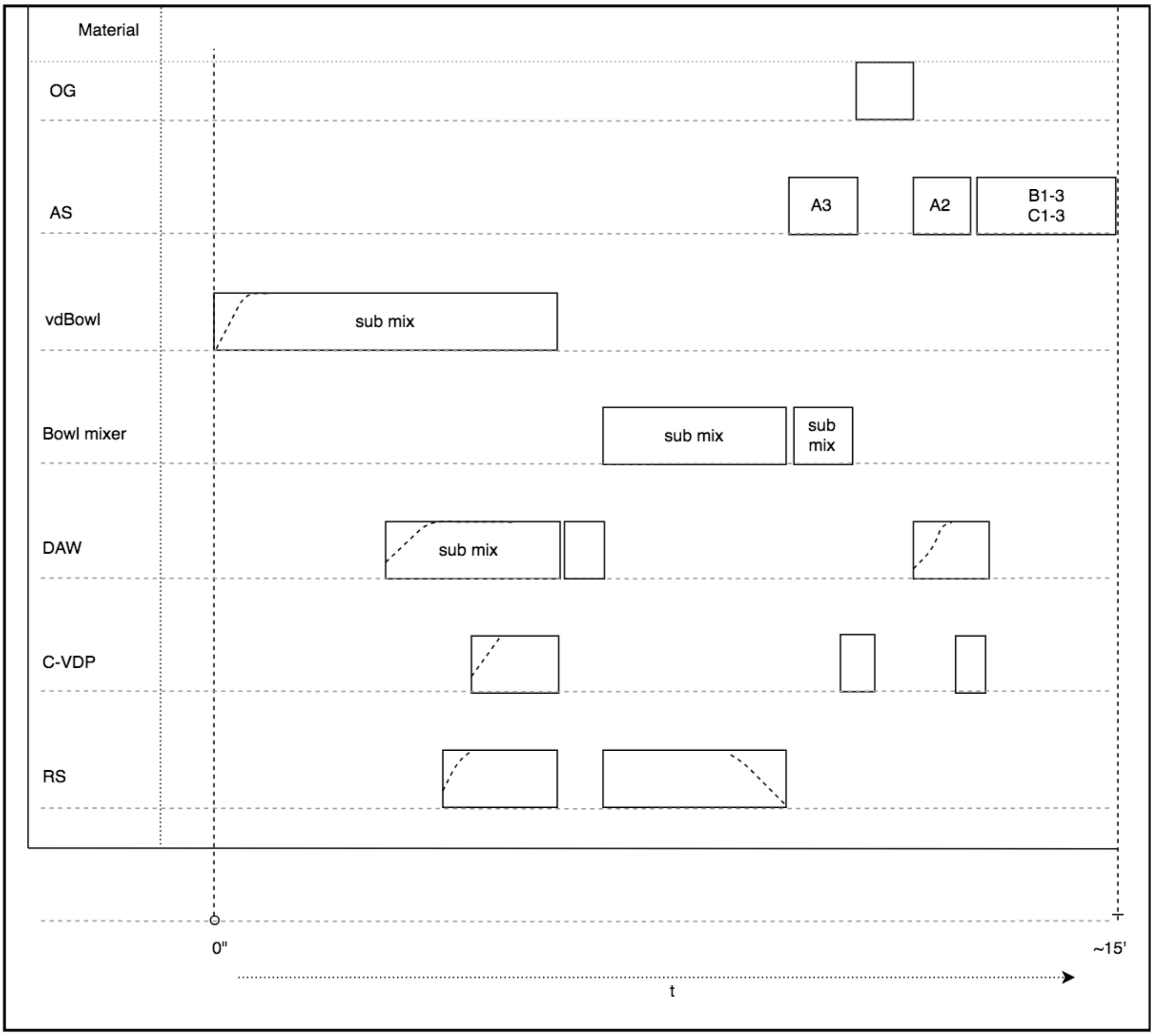
Cmaj7(9,#11)

Due to the multitrack original material, each track was filtered through one of the above frequency bands, thus creating 'legato' variations on the chord that are based on the amplitude variation of each track, bringing a different note, or more of them at times, to the foreground. Further transformation techniques were used as seen below:



The software transformations' tree.

Walkthrough in time



A sketch for the final form.

The main idea for shaping the way the material would be placed in time was to loosely create the impression of a 'zoom-in' from the physical space — of and around the Tibetan bowl — into the more abstract space of the electrical circuits that were perturbed — represented by the derived material of the analogue transformations[3]. This transition occurs gradually by introducing the first iterations of the analogue transformations, then maximising the tension when the original material (OG) are finally uncovered, close to the final minutes of the piece. The ending sequence is the superposition of the final iterations of the analogue transformations, where the resonances are in their most exaggerated state.

[3] Note: The sequences named 'RS' in the picture above, are material transformed in a variation of a four-track random spatialisation patch taught by Kees Tazelaar in his lectures Voltage-Controlled Techniques, in the Analogue Studio of the Institute of Sonology. Each block regards the layered material occurring in parallel, and it was included with the intention of adding specific moments of 'spatial' tension through the final 11-track diffusion configuration.

Conclusions

This artistic research project has provided me with a large input for developing further as an electronic musician. What started out as an urge to learn about feedback — as explored in 'guerilla' techniques such as the 'no-input mixing board' — and to turn my use of it in less of a case of a 'black box' problem. I hypothesised that this could be done by finding more about the physics of coupling as encountered in electronic systems and to apply it as a technique for synthesis and by extension to a philosophy underlying my works. This suggested that I should figure out what stance I wished to hold along the systems I would be using, the way to interact with them and to get inspired by the ways other notable musicians and composers thought about this. Nonetheless, this is a vast topic branching out from music to technology and I cannot say that I have covered it enough yet; of course this is as dynamic as we are and is bound to evolve along my musical practice.

Practically, this theoretical part of my research has culminated in several devices of which I will now invest my time to make the input I was given into musical and artistic output. The Analogue Studio and the van der Pol oscillator projects — I would say the central ones to this research — offered me the chance to work alongside great people and mentors and to learn from them. I believe there are still fruits to be harvested from the van der Pol module; my hope is that more people in the Institute will be interested in using it as time passes. I believe I will be using it for long.

The idea I would like to stress on here is that the most important outcome of this research is not the closing of a circle; although I leave with a relatively more informed approach on electronic music this is not something that is ever bound to be complete. I am eager to 'spiral' down in this field.

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This journey would have been harder without Miloš. To my parents, family and friends I owe everything; I humbly and wholeheartedly thank them for their unconditional support and love. Finally, I need to thank my dearest Andriani for always being there to support, inspire me and to give me strength.

Post Scriptum

XI. This art has accomplished nothing, except to show us the confusion in which most of us find ourselves already. It has frightened us, rather than making us quiet and peaceful. It has shown us that we all live on different islands, only the islands are not far enough apart for us to stay solitary and untroubled. Someone on one island can pester someone on another, or terrorise him, or hunt him with spears—the only thing no one can do to anyone else is help him.

XII. There is only one way to journey from isle to isle: dangerous leaps in which more than one's feet are endangered. The result is an eternal hopping back and forth, with accidents and absurdities, for it sometimes happens that two people jump toward each other at the same time so that they encounter each other only in midair and after taking all that trouble they are just as far apart, one from the other, as they were before changing places.

XIII. This is by no means strange, because in actual fact the bridges to each other we cross so beautifully and festively are not in us, but rather behind us, exactly as in the landscapes of Fra Bartolomeo or Leonardo. Life truly does gather to a point in individual personalities. But from peak to peak the footpath runs through broad valleys.

(Rilke, 1898)

Appendix : Contents of the accompanying DVD

Sound examples

1. Music for Frustrated Commuters.wav
2. pyrwatærra (2017) [stereo mix].wav
3. Driven VDP.wav
4. Falsetto.Wav
5. Brass.wav
6. Triads [stereo mix].wav
7. Poly-rhythms [stereo mix].wav
8. Forced,Ringed,Delayed & Filtered.wav

Video examples

1. Wildlife/Music for Frustrated Commuters.mov
2. *Okayeano* (2017) [4 channel audio].mov (interleaved multitrack audio only available through download)
3. *Anina (2017) [1080p]*.mp4

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