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Redefining electro-acoustic: Applying techniques from electronic music to the composition of Pivot, an acoustic work for percussion quartet

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ABSTRACT

Redefining Electro-acoustic: Applying techniques from electronic music to the composition of *Pivot*, an acoustic work for percussion quartet.

There are a number of characteristics that distinguish acoustic and electronic music. The most apparent difference is the nature of their sound sources, but there is also substantial variation in the compositional process and in the techniques available to composers of each medium.

The history electronic music extends from two traditions: Western Art Music and popular music. During the 20th Century, composers and popular musicians alike took advantage of the many advances in electronic equipment technology to create new styles of music. The development of electronic instruments and recording equipment offered new sounds and provided new methods for the creation and distribution of music.

Working strictly within the framework of a single medium potentially restricts the possibilities available to a composer. By analysing techniques found in electronic music and incorporating them into acoustic composition, one can expand the creative tools at their disposal. The goal of this dissertation is to contextualise the field of study, examine a range of techniques from electronic music, and to suggest ways they can be applied to acoustic music composition, with reference to existing works and my original composition, *Pivot*.

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Many thanks to Cat Hope for her guidance throughout the duration of this study and over the last few years. I would also like to acknowledge the other staff at the Western Australian Academy of Performing Arts that have helped me during my time there. Finally, thankyou to my family and friends for your ongoing support.

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1. INTRODUCTION

This paper investigates the possibilities offered to acoustic music composition by elements of electronic music composition. The discussion will refer to my original composition, *Pivot* (2007), which has been created in parallel with this dissertation. For the purposes of this study, electronic music will be defined as sounds that are "electrically produced or modified" with electronic instruments and / or equipment.[1] On the contrary, acoustic music is created entirely with acoustic instruments – those which produce sound without the need for electric amplification[2] such as piano, violin, marimba, or the human voice, et cetera. Audio recordings produced with the intention to faithfully reproduce acoustic music performance will also be categorised as acoustic music, even though they exist on an electronic medium. These two distinct areas take on a number of forms which will be discussed throughout the dissertation.

On several occasions prior to the commencement of this study I observed a number of differences between my own electronic and acoustic compositions which extended beyond the obvious distinction in the nature of their sound. In each medium, the process of generating ideas relies on the composer's creative ability to utilise the tools and techniques available to them. Consequently, the resulting material itself varies in its outcome: ranging from stark contrasts, for example using electronic devices to play passages that are physically impossible for a human performer; to more subtle differences like the rigid accuracy of computer playback compared to the natural fluctuations of live, acoustic performance. Structural elements within electronic music and the processes of development (on both a macro and micro level) also show a significant departure from common methods in my acoustic music composition. Thus, it is in the interests of the composer to investigate these differences in order to find ways to adapt the techniques in a new context.

Electronic music composition was an exciting prospect for musicians of the early 20th Century. As advances in technology spread, composers were quick to use them in music, with increased volumes of music being written for tape, electronic instruments and mixed ensembles. Works for instrumental performer and tape started to emerge soon after the development of electro-acoustic music in 1949.[3] Examples of such works include *Orphée 53 (1953)* by Pierre Schaeffer (1910-1995) and Pierre Henry (b. 1927), and *For Marimba and Tape* (1983) by Martin Wesley-

[1] Thom Holmes, *Electronic and Experimental Music,* 2nd ed. (New York: Routledge, 2002), 5-12.
[2] "acoustic." Dictionary.com (Accessed October 2007) <http://dictionary.reference.com/browse/acoustic>
[3] Peter Shapiro, ed. *Modulations: A History of Electronic Music* (New York: Caipirinha Productions, 2000), 5.

Smith (b. 1945). Current equivalents can also provide the accompanying material on digital media such as CD or for computer playback, as demonstrated in *Grab It!* (1999) for tenor saxophone and pre-recorded soundtrack by Jacob Ter Veldhuis (b. 1951).

A personal interest in both acoustic and electronic music led me to consider merging the two styles in my own work. But rather than directly fusing them, I have investigated the techniques based in electronic music composition and applied them to scored acoustic writing. This opens up possibilities to extend one's compositional vocabulary and bring new influences into the development of a purely acoustic work, while still maintaining a firm link with aspects of electronic music.

There are several cases of composers imitating electronic timbres acoustically, as mentioned below, and it is easy to comprehend the initial attraction to experimenting with electronics. "Many composers became interested ... [in] a source of new sounds [while] others were looking for control,"[4] both of which were a success, achieved by exploiting the new technology at the time. However, the specific reasoning by the individual for recreating these sonorities within acoustic music is an area requiring further investigation. In the case of Karlheinz Stockhausen (b. 1928), acoustic imitation of electronic distortion and ring-modulation effects became a frequently used technique in his later works.[5] Many works by Iannis Xenakis (1922-2001) emphasise the spatial relationship between sounds – a common practice in electronic music. He also generated data on computers in order to implement his stochastic method (the process of using mathematical probability and statistical laws to distribute mass "random" events)[6] in his acoustic compositions. Though Xenakis did not want the listener to be aware of these techniques, thus their function was purely as a vehicle to convey his music on a larger scale.

Composing in the electronic domain can allow a direct transmission of a musical statement without the need for performers, which was extremely liberating for composers.[7] But even so, a large proportion of active composers return to acoustic music, which in itself says something about the ongoing significance of acoustic music in Western Music. The purpose of this dissertation is to contextualise the field of study, explicate a range of techniques that electronic music composers have at their disposal, and to suggest ways that they can be applied to acoustic music composition, with examples from existing works and my original composition, *Pivot*.

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[4] Eric Salzman, *Twentieth-Century Music: An Introduction,* 2nd ed. (New Jersey: Prentice-Hall, 1974), 143.
[5] Robin Maconie, *The Works of Karlheinz Stockhausen* (London: Oxford University Press, 1976), 147-148.
[6] Iannis Xenakis, *Formalized Music* (Bloomington: Indiana University Press, 1971), 9. Quoted in David H. Cope, *New Directions In Music,* 5th ed. (Dubuque: WM. C. Brown Publishers, 1989), 353.
[7] Salzman, 140.

2. BACKGROUND

The history and development of electronic music is split into two main categories. The first falls under the tradition of Western Art Music, emerging from the Romantic era and entering the melting pot that was the 20th Century and beyond. Composers generally maintained an academic approach to their composition in this area, and stylistically the music took on many new approaches. The second category is electronica, which began to emerge in the 1970s, following on from the developments in rock and pop music in the fifties and sixties. Bands and musicians had begun using electronic elements in their line-up, eventually arriving at its natural conclusion with entirely electronic-based groups and the conception of club genres like House and Techno. There are many cases of artists or stylistic directions that blur the distinction between these two areas but largely these two categories are sufficient.

2.1 The Academic

In 1907, Italian composer Ferruccio Busoni (1866-1924) wrote *A Sketch for a New Aesthetic of Music*. A few years later, futurist painter and composer Luigi Russolo (1885-1947) published his own manifesto entitled *The Art of Noises*. Both of these texts declared their respective writers' visions of the future in music. Now 100 years on, their dreams of a rich palette of sonorities encompassing mechanical noises, pure electronic music and alternate tuning systems have all become a reality. The evolution of electronic music would not have begun without the many pioneers throughout the 20th Century that helped advance their musical vision. One of the most significant points during this time was the advent of *musique concrète*. Pierre Schaeffer and Pierre Henry met in 1949 and established the *Groupe de Recherche de Musique Concrète* (GRMC). They began creating music on magnetic tape, experimenting with recorded sounds and ways to manually manipulate and arrange them using multi-track tape recorders.

> *Schaeffer and Henry's constructive transgression was to act on the knowledge that tape materialized music into a solid, concrete object. In its plastic form, music could be interfered with – reversed, sped up, or slowed down, measured in inches, laid out on a slab, and dissected at will. The artistic moment no longer occurred in the written manuscript, nor with the physicality of performance, but became distributed within the manipulation of stock and found sounds, a process resembling film editing.* [8]

[8] Shapiro, 14.

It is interesting to note that most current multi-track recording software is fundamentally linked to the original concepts of tape alignment and manipulation (see Figure 1). These programs still provide a strong visual aspect to the arrangement of sound clips, but any physical interaction with the medium itself has been replaced by editing on a computer screen. Although far more advanced in terms of overall functionality, this type of software allows the user to perform all of the above tasks at a much quicker rate.

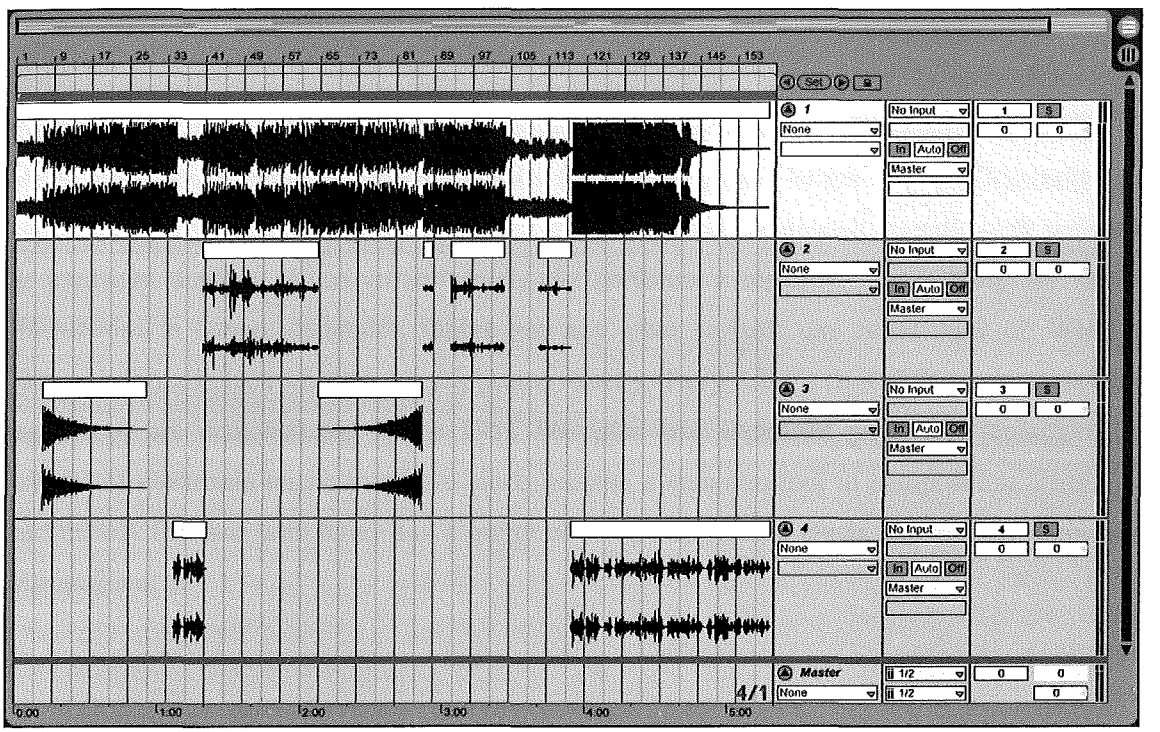

Figure 1. Computer software program Ableton Live. This example shows four horizontal channel strips, each with different audio material that has been "cut up" and arranged in a similar fashion to magnetic tape.

Experiments with tape music took place in large studios. "Composers such as Pierre Boulez, Karlheinz Stockhausen, Oliver Messiaen, Darius Milhaud and Edgard Varèse were making pilgrimages to the [GRMC] studio in order to produce sounds they were unable to achieve anywhere else."[9] Tape composition and electronic sounds were spreading worldwide, and slowly began to infiltrate mainstream culture. The 1958 World Fair in Brussels featured the premiere of *Poème Electronique* (1958) by Edgard Varèse (1883-1965), and *Concret PH* (1958) by Xenakis, both intricate works of concrete music. *Poème Electronique* was played back over 425 loudspeakers, filling the Philips Pavilion with an aural landscape that almost possessed a physical presence.

[9] Shapiro, 14.

"After the [mid] 1950s, the character of new European music began to change drastically. Totally controlled serialism ... gave way to a new idiom based on transformations of densities, colours and texture."[10] There was a definite shift of focus away from traditional elements like melody and harmony, and instead timbre and textural development took centre stage. Krzysztof Penderecki (b. 1933), Varèse, Xenakis and György Ligeti (1923-2006) were all advocates of this style. Ligeti is well known for his orchestral work *Atmosphères* (1961), and the textural approach to his music is sometimes called sound mass composition, which removes the emphasis of individual notes and instead focuses on overall shape.[11]

Further explorations into the unique characteristics of electronic music revealed the ability to create loops which could be repeated exactly for any designated length of time. Originally this was achieved by constructing tape loops but today it is easily replicated digitally with software or hardware devices. When an instrumentalist performs a repetitive figure there are subtle fluctuations in tempo, dynamics, timbre and any other variable one could think of. When a pattern is looped electronically it is duplicated exactly. Terry Riley's (b. 1935) experiments with tape loops are demonstrated in the 1961 *Mescalin Mix*. Extended loops and repetition are aspects of electronic music that have since become a common tool in composition. This was particularly the case with Riley and a group of composers whose music has become known as Minimalism.

It's Gonna Rain (1965) and *Come Out* (1966) are two early works by Steve Reich (b. 1936) that fall under the category of Minimalist or process music. These two tape pieces use a technique that Reich called phasing. His discovery of the technique came about by accident when he was playing two copies of the same tape loop simultaneously. Reich noticed that the loop was gradually shifting in and out of time with itself due to the discrepancy in playback speed between the two tape players.[12] The truly relevant thing about Reich is that the series of pieces following *Come Out* applied phasing to acoustic music. *Piano Phase* (1970) is a work for two pianos or marimbas that placed new demands on the performers in order to recreate his phasing technique. It required one player to gradually speed up while the other remains at a steady tempo.

Unusual ensembles of acoustic and electronic instruments not only pushed boundaries in sound, but in many cases increased demand on a performers' extended technical ability (as was the case with Reich's phasing) and added pressure on composers to achieve notational clarity.

[10] Salzman, 172.
[11] David H. Cope, *New Directions In Music,* 5th ed. (Dubuque: WM. C. Brown Publishers, 1989), 55.
[12] Holmes, 253.

Below is a score example from Stochkausen's *Mixtur* for orchestral groups, sine-wave generators and ring modulators. Note the use of long glissandi and the reference to specific frequencies instead of note pitches in the sine-wave part (bottom and middle stave).

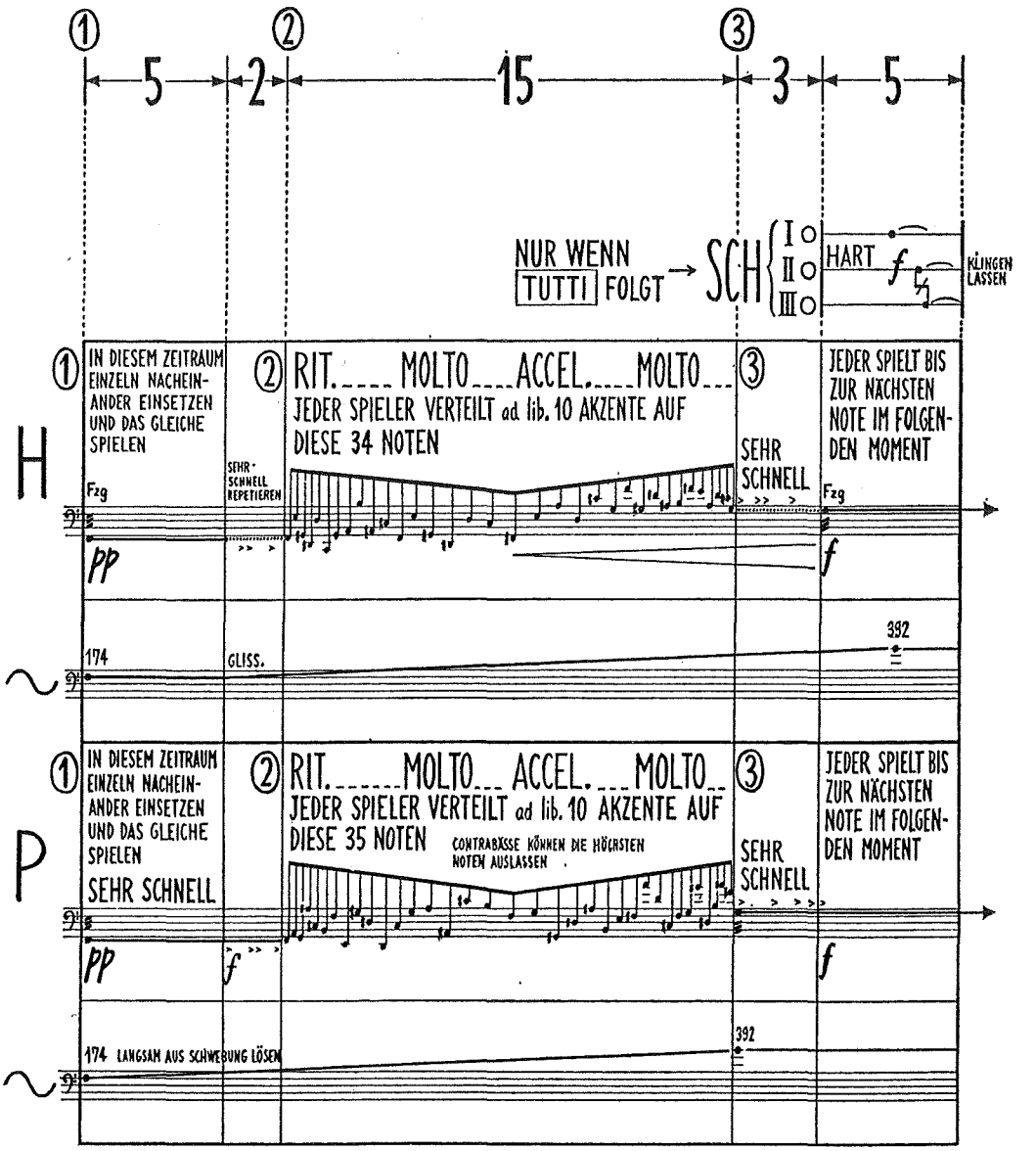

Figure 2. A score excerpt from *Mixtur* by Stockhausen. Note the use of long glissandi and reference to specific frequencies instead of note pitch in the sine-wave part (bottom and middle stave). © Oxford University Press, 1976.

2.2 The Dancefloor

The social revolution of the late 1960s introduced people to new experiences with a fresh attitude towards life, and it was accompanied by a soundtrack of new music. Many nations were undergoing a period of change in relation to the political and cultural ideals of the public, and

the youth generation at the time played a key role in this. Perhaps the most significant event in this regard was the Vietnam War, which was met with resistance from the Baby Boomer generation. Increased social awareness, activism and rebellion was paired with a culture that generally endorsed keeping an open mind – a positive outlook that brought many new musical and cultural ideas into the subconscious of popular culture. It was around this time that tape and synthesisers made their way into the realm of rock music, sending electronic music off on another tangent. The commercial success of minimalist composers such as Steve Reich, La Monte Young (b. 1935), Terry Riley and Philip Glass (b. 1937) also had a large impact on popular music during this time. Glass himself considered Pink Floyd's *Dark Side of the Moon* (1973), with its innovative use of synthesisers, to be a landmark release that was "one of the best examples of minimalism in rock."[13]

Coming to prominence during the seventies in Germany was a genre known as Krautrock. Bands like Can, Faust, Neu! and Kraftwerk took a step back from the overtly technical virtuosity of progressive rock and instead took a more experimental approach, resulting in music with a futuristic feel.[14] In part influenced by movements such as Minimalism and the avant-garde,[15] Krautrock often favoured synthesisers and electronic textures over electric guitars, which were formerly the emphasis in rock music. Kraftwerk "was the group that really bridged the gap between rock and electronic dance music."[16] Their line-up consisted purely of electronic instruments, which even extended to vocals when modified with a vocoder to create a robotic sound. Kraftwerk had many significant releases, including *Trans-Europa Express* (1977) and *Computer World* (1981), and they were a major influence of the Techno movement.

The underground club scene was also taking a firm hold – occasionally achieving mainstream success with hits such as the disco classic *I Feel Love* (1977) written by Giorgio Moroder (b. 1940) and performed by Donna Summer (b. 1948). The distinctive characteristic of this song was its entirely synthesised backing as opposed to regular disco instrumentation which combined typical band instruments (electric guitar, percussion, piano et cetera) with synthetic elements. At nightclubs, DJs would beat-match and mix records in order to create seamless transitions between tracks, allowing non-stop music all night. The turntable itself began to be treated as an instrument in its own right. Christian Marclay (b. 1955) and Grandmaster Flash (b. Joseph Saddler, 1958) are two disparate examples of 'turntablists,' who have manipulated vinyl records to create new compositions. One of the first mainstream releases to feature scratching (an effect created by manually dragging a record back and forth) was *Rockit* (1983) written by

[13] Mark Prendergast, *The Ambient Century*, 2nd ed. (London: Bloomsbury, 2003).
[14] Shapiro, 27.
[15] Christoph Cox and Daniel Warner, eds. *Audio Culture: Readings In Modern Music – Glossary* (New York: Continuum, 2004), 412.
[16] Shapiro, 33.

Herbie Hancock (b. 1940) and his band,[17] which was a commercial success. However, turntablism is usually associated with hip-hop, in which DJs would isolate a drum 'break' from a record and loop it in real time for rappers to rap over.[18] When these break-beats where substituted for drum machines such as the Roland TR-808, electro music was born.

Stylistic developments in the field of electronic dance music were moving at an extremely rapid rate. Two of the most significant club genres to come out of the eighties were House and Techno.

> *"During his residence at* [The Warehouse in Chicago], *DJ Frankie Knuckles discovered that his crowd ... enthusiastically responded to the electronic feel of tracks like Summer's "I Feel Love." As a result, he began to augment his ... records with the more rigid beat of a cheap drum machine; the dancers responded with remarkable intensity. Legend has it that this combination of disco with drum machines and reel-to-reel tape edits became known as house music after people kept asking record stores for 'the records they played at the Warehouse.'"*[19]

Juan Atkins (b. 1962), Derrick May (b. 1963) and Kevin Saunderson (b. 1964) were producers that began experimenting with their own variation of House music, taking influence from Kraftwerk and electro-funk artists such as George Clinton (b. 1941) and Afrika Bambaataa (b. 1957). The result was a "mechanical, minimalist, dystopian, and futuristic"[20] sound now known as Detroit Techno. Pulsating kick drums and driving percussion were put side by side with cold, thick sound-scapes. Ironically, if the drums were removed the atmospheric textures bared a striking resemblance with Ambient music – a term coined by Brian Eno who described it as being "able to accommodate many levels of listening attention without enforcing one in particular; it must be as ignorable as it is interesting."[21] Eno was interested in using the recording studio as a tool itself rather than simply a means to capture and reproduce live performances. This was a concept integral to the approach of dance music producers.

Composers and musicians of Western Art Music typically study at music institutions, whereas House and Techno musicians were often self-taught, sharing knowledge with friends and using cheap equipment to create music. Probably the single most important piece of electronic equipment in electronic dance music history is the Roland TB-303 synthesiser. Produced in 1982 for a period less than two years, the TB-303 was designed as a replacement for a real bass

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[17] Herbie Hancock, *Future Shock*, Columbia CK 38814, 1983, compact disc.
[18] Shapiro, 219.
[19] Shapiro, 75.
[20] Cox and Warner, 416.
[21] Brian Eno (1978). *Music For Airports* [CD liner notes], quoted in Mark Prendergast, *The Ambient Century*, 2nd ed. (London: Bloomsbury, 2003).

player. Initially it was a failure, but a few years later House and Techno producers starting buying and using them in their music; the result was a phenomenon and Acid House was born. The 'acid' prefix referred to the squelchy, resonant synth lines of the 303 whose parameters were tweaked in real time while it looped a repetitive pattern of programmed notes.[22] The 303, alongside Roland drum machines the TR-808 and TR-909, have become staple sounds in electronic dance music. Acid House had its biggest impact in the late 1980s when rave culture was at its peak.

As the new millennium drew nearer, the two camps of electronic music continued developing in new directions. Experimental tangents evolved from Ambient-influenced 'chill-out' music by artists like The Orb and Aphex Twin. A style now known as Intelligent Dance Music (IDM), became known for its complex drum programming and haunting melodies. Aphex Twin and Autechre both pushed this stye to its limits and introduced truly experimental compositions to the world of electronic dance music. The line between 'high' and 'low' art forms continuing to dissolve, testament to the influence of Postmodernism. *Rossz Csillag Alatt Született* (2005) by Venetian Snares is a perfect example of this – it combined frantic, programmed percussion sequences typical of the IDM genre with avant-garde classical instrumentation.[23]

New electronic music has become increasingly difficult to classify, resulting in further blurring of the boundaries between these seemingly disparate traditions. Interactive electronics works use live performers and computer software which has been written to play an active role in the outcome of the music. Western Australian composer Lindsay Vickery (b. 1965) has written many pieces in this area, such as *Hey Jazz Fans!* (2003) and *Scratch* (2004). Performances involving the use of a laptop computer are often criticised in both academic and dance music circles. Audiences sometimes feel "*cheated*, because the laptop musician *appears* to be simply playing back soundfiles stored on their hard drive."[24] This has promoted exploration into new ways to interact with computer technology with the aim of treating it more like a musical instrument than an office tool. It may be the case that society requires genre names and classifications in order to fulfil consumers' 'needs', but it is true in some cases that electronic music of the present day is accessible to followers of both the academic and dance-floor traditions.

[22] Unknown. "Roland TB-303 Bassline." Vintage Synth Explorer (Accessed October 2007) <http://www.vintagesynth.com/roland/303.shtml>

[23] Cameron Macdonald. "Venetian Snares: Rossz Csillag Alatt Született: Pitchfork Record Review." Pitchfork Media (Accessed October 2007) <http://www.pitchforkmedia.com/article/record_review/22951-rossz-scillag-alatt-szletett>

[24] Kim Cascone, "Laptop Music – Counterfeiting Aura in the Age of Infinite Reproduction," (2003): 5.

2.3 Technological Developments

A large number of major advances in electronic music have been the direct result of the adaptation of new technology as it is introduced. This notion also extends to acoustic music: brass instruments were developed due to the Industrial Revolution; but for the purposes of this study, this section will only focus on the technological developments that made an impact on electronic music.

In 1877, Thomas Edison invented the phonograph which signalled the beginning of the recording age and the mechanical reproduction of music.[25] Records were responsible for bringing music into the homes of consumers which changed people's conceptions of music. The first electronic instrument, the telharmonium, was developed in 1906 by Thaddeus Cahill. It was by no means a portable instrument, but a very significant discovery nonetheless. Other inventors were developing their own instruments with notable examples the Theremin in 1920 and the Ondes Martenot in 1928. Lee DeForest also made significant contributions - the vacuum tube in 1906 and the electronic oscillator in 1915, which were integral elements of the amplifier and synthesiser respectively.

The next recording medium to be developed was magnetic tape – originally in 1928, but improved upon by the German company AEG in 1935 when they developed the first tape recorder.[26] Tape had an immense impact on electronic music. It was central to the *musique concrète* movement and also found its way into popular music. The techniques involved with tape composition remain just as relevant to modern electronic music composition (as discussed above with reference to Figure 1). Synthesisers were an equally important development, making pure electronic music composition possible. RCA and Moog Music were companies that developed instruments in the 1950s and 60s that potentially allowed limitless possibilities in sound design; composers of academic and popular music responded with enthusiasm.

Microchips and nanotechnology were refined in the mid-seventies, which laid the foundation of digital synthesisers and more powerful computers. In 1979, an Australian company developed the Fairlight CMI – a digital synthesiser that was one of the first commercial products to include digital sampling, which is the process of compiling and using audio data that is stored digitally. Dedicated samplers followed, which became a very resourceful tool for producers, particularly

[25] Shapiro, 4.

[26] Kristine H. Burns. "History of Electronic and Computer Music Including Automatic Instruments and Composition Machines." Electro-acoustic Music, Dartmouth College (Accessed October 2007) <http://eamusic.dartmouth.edu/~wowem/electronmedia/music/eamhistory.html>

in the genre of hip-hop. Music production was shifting towards the digital realm, and this was echoed by the medium for music reproduction and distribution with the introduction of Compact Discs in 1982.

As previously mentioned, the Roland TB-303, TR-808 and TR-909 were landmark pieces of equipment that shaped the sound of dance music. The irony is that these instruments were not used as originally intended, but in a creative way that propelled electronic dance music to new heights. Analogue synthesisers and other early devices used control voltage (CV) in order to 'communicate' and stay in time with each other. A significant step forward for digital and computer music was the introduction of MIDI (Musical Instrument Digital Interface) in 1984. There was now an international standard protocol that allowed greater flexibility and control within electronic music production.

Computers were first being used with musical applications in the mid 1950s, but early models were large and difficult to program. Thirty years later, around the same time that CDs were introduced, personal computers were becoming more widespread and available at a cheaper price. This trend is still evident in the present day, with faster and more powerful computer components become available at an increasing rate. Laptop computers removed the problem of portability altogether. The interactivity of programs such as MAX MSP, originally conceived in 1986 by Miller Puckette, would make it an indispensable tool for live laptop musicians. MAX uses a modular interface and custom software modules that are useful in the studio but also for real time interaction with a performer.

Multi-channel playback was used for performances of multi-track tape works (e.g. *Poème Electronique* at the 1958 World Fair) and in surround sound cinemas, but popular configurations such as 5.1 surround sound have only recently become a common consumer product. The Digital Video Disc (DVD) format was developed and introduced in the mid 1990s and is a useful media for distributing 5.1 audiovisual experiences. Two contrasting examples of DVDs with a focus on music are *Electronic Music, Vol 1 – La Legende d'Eer* (2005) which presents a multi-track electronic masterpiece by Xenakis, and *DE9 | Transitions* (2005) – a 96 minute, hybrid DJ mix by Minimal Techno DJ / producer Richie Hawtin (b. 1970) presented in 5.1. The invention of electronic instruments and new recording mediums opened up new possibilities in sound design, new methods for construction and deconstructing music, and new ways to listen.

3. TECHNIQUES IN ELECTRONIC MUSIC

When writing acoustic music, a composer is forced to make decisions about a range of technical issues within the limitations of any given instrument/s in order to construct a piece of music. A composer of electronic music also has to choose from a range of sound sources, instruments, the means by which they want to create their work and an extensive list of effects and techniques which are not available to composers of acoustic music. This chapter serves as a means to explain some of the tools available to an electronic musician. Although there are many aspects to electronic music composition, I have selected areas that relate to the composition of *Pivot*, and organised them into four categories – compositional devices, delay effects, other sound effects and mixing processes.

3.1 Compositional Devices

3.1.1 Sequencing

A sequencer is a device that can be used to compose electronic music. They are devices that send messages electronic instruments, allowing the user to programme patterns for playback. Sequencers can be software or hardware based, and come in a variety of forms.

- *Digital Audio Workstation (DAW)*
  DAWs are all-in-one programs that include sequencing capabilities alongside multi-track recording and other MIDI and audio tools. E.g. Pro Tools, Cubase.

- *Tracker*
  Common amongst music for written for computer games. The data in trackers is entered using numeric and hexadecimal systems and is shown along a (commonly vertical) timeline (see Figure 3, below).[27]

- *Step Sequencing*
  Data is entered into step sequencers using a grid of usually sixteen notes, or steps, which loop continuously to form a pattern. Individual patterns are programmed independently and then linked together to create a larger piece of music.

[27] Unknown. "Tracker." Wikipedia (Accessed October 2007) <http://www.wikipedia.com/Tracker>

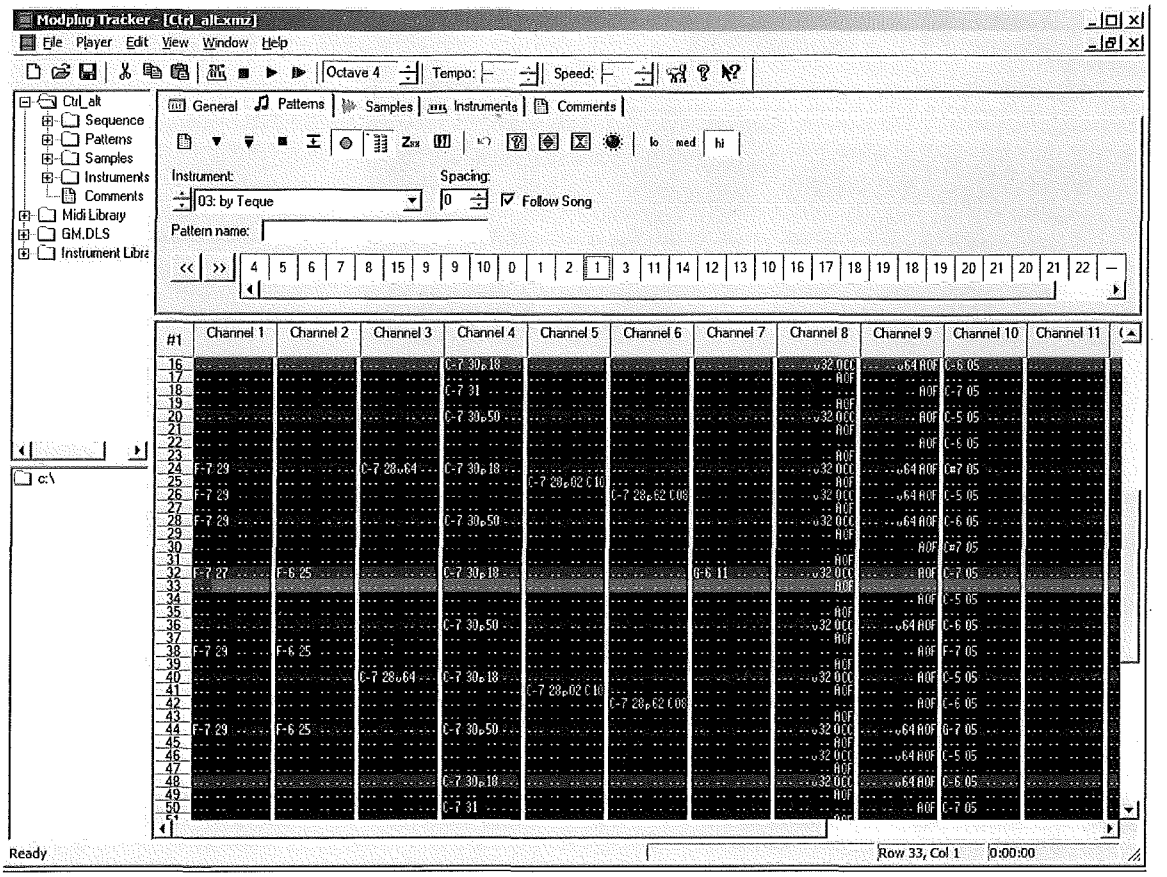


Figure 3. A screenshot from the popular tracking program Modplug Tracker. The vertical channels represent different sounds or elements which exist on a timeline that moves from top to bottom.

Of these three types, I have chosen to focus on step sequencing for the purposes of this project. I own two electronic instruments that use this method – the Elektron Machinedrum SPS-1 (a drum machine) and Nanoloop, a software cartridge that runs on a Nintendo Gameboy console allowing music composition using the native synthesiser onboard the Gameboy.

The Machinedrum's onboard step sequencer has the ability to programme patterns up to thirty-two steps in length. This is done by entering rhythms into the grid of sixteen square buttons along the bottom of the interface (see Figure 4). For example, to program a bar with four crotchets you would enter the data as seen in Figure 5.

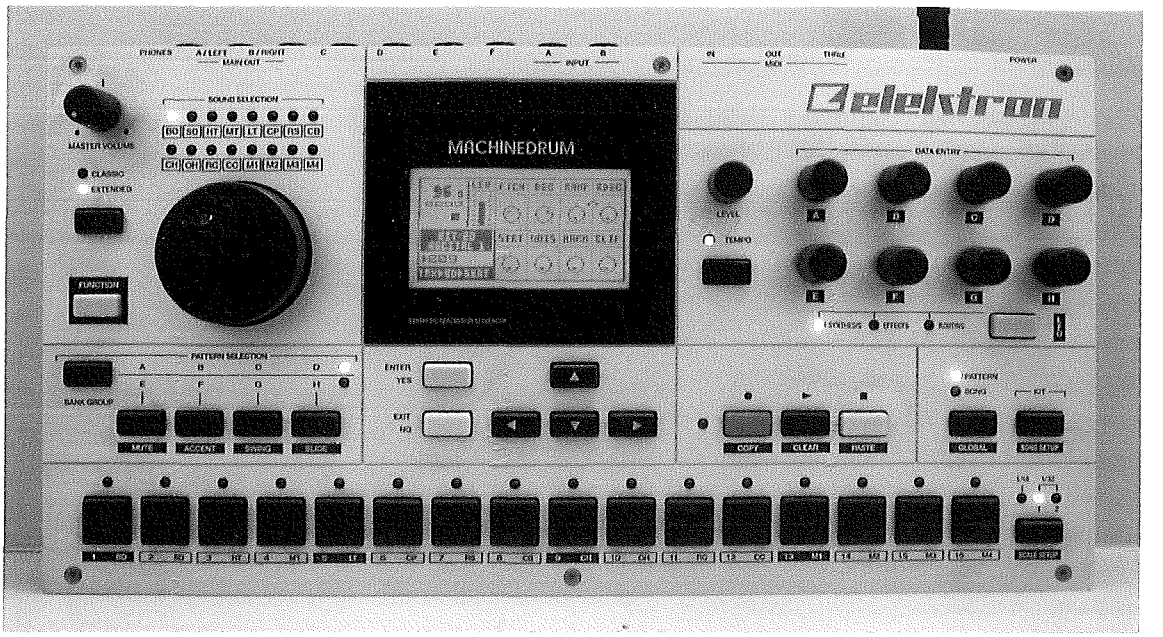


Figure 4. The Elekton Machinedrum SPS-1. The row of sixteen buttons along the bottom is used for entering pattern data, while the other knobs and buttons control various functions and sound parameters.

Figure 5. The highlighted box is surrounding the step sequencing element of the Machinedrum. The lit up LEDs indicates a note has been entered on that step. This particular pattern represents a single bar 4/4 with four straight crotchets.

To further demonstrate, Figure 6 represents the following rhythm:

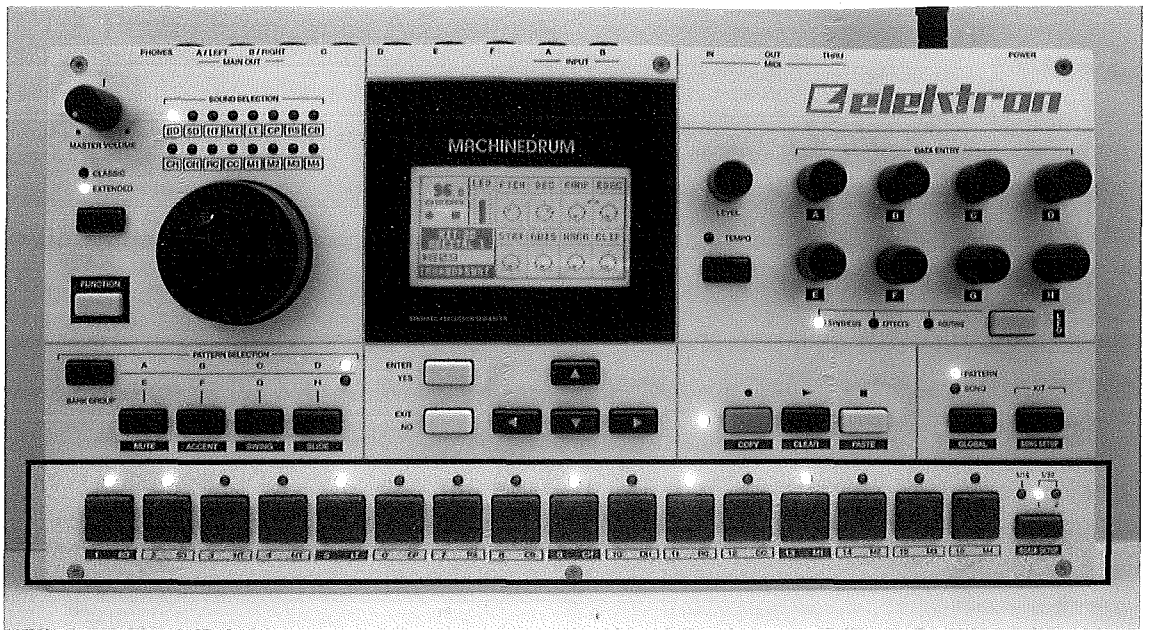


Figure 6. This example demonstrates a simple rhythmic pattern in the step sequencer.

The sequencer of Nanoloop works by the same principle as the Machinedrum but has a slightly different interface. Instead of a single row of sixteen steps, it has a four rows with four steps each (see Figure 7). Both of these step sequencers have features which allow more complex information to be stored. Each individual note that is entered on any 'step' within the pattern can also contain data that controls pitch, sustain, volume, filter settings and more. Both sequencers also allow variable pattern lengths, which opens up the possibility to have loops of different lengths playing over each other.

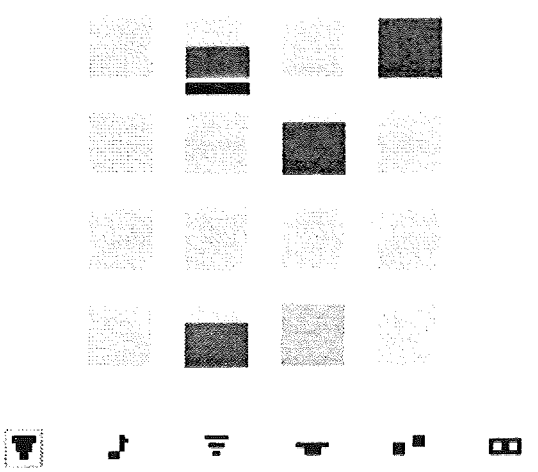


Figure 7. The step sequencer for Nanoloop. The symbols along the bottom represent different variables, from left to right: volume, pitch, filter, sustain, offset and panning. The blacked-out squares on the grid contain note data. © Oliver Wittchow, 2007.

3.1.2 Pitch / Frequency Adjustment

In most acoustic music, the concept of pitch is generally thought of in relation to the notes of the equal-temperament scale. However when it comes to electronic music it may be wise to re-evaluate this understanding with reference to a more scientific definition of frequency. Frequency refers to the number of cycles, or vibrations that occur per second, which we perceive as pitch.[28] For example, A440 refers to a waveform travelling at 440 times per second, which we hear as the note A. When working with electronic music, whether digitally or with tape there is an intrinsic relationship between pitch, frequency and speed / rate. This is best experienced if you were to alter the playback speed of a recording, and is an accurate representation of pitch as frequency.

3.2 Delay Effects

Time-based effects are some of the most common and versatile tools in electronic music. They are created by repeating an input signal once or multiple times to produce a variety of results, from a very quick repetition to a longer echo effect. In analogue electronic music, this was achieved by creating a tape loop of the original signal which would then be played back moments later. However, modern digital effects pedals and software allow it to be replicated digitally. The length of time between the original signal and the repeated signal determines which category of delay effects it falls into.

3.2.1 0 – 50 milliseconds

Three different effects full under this category, each of which provides versatility to alter the harmonic character of a sound. These effects rely on two copies of the same signal being played at very close intervals, which are perceived as part of a single sound rather than a distinct echo.

- *Phaser*
  Phase shifting involves mixing the raw input signal with a duplicate signal sent through a filter that creates notches in the frequency spectrum. The filter can be gradually or rapidly modulated which results in phase-cancellation. Typical parameters include modulation rate & depth, centre frequency (around which filter notches are centred), feedback amount and dry / wet balance.

- *Flanger*
  Once a delay is introduced in the above process, the effect is called a flanger. Flanging deals with an offset signal between around 1 and 20 milliseconds, and produces a much

[28] Holmes, 15.

more metallic sound, also with the use of frequency notches. Typical parameters include modulation rate & depth, delay time, feedback amount and dry / wet balance.

- *Chorus*
  Involving delay times up to about 50 milliseconds, chorus is another variation on the above effects. This time the delayed signal is slightly detuned which produces a rich, layered effect. The detune amount can be modulated at different rates and depths to allow subtle variations in sound. Chorus effects can also be produced by flangers; therefore the typical parameters are often the same.

3.2.2 > 50 milliseconds (Echo)

When the signal delay time reaches a point where the human ear perceives multiple instances of the input sound, the effect is known as echo and is often just referred to as 'delay.' The integral parameter for this effect is the delay time, which ranges from shorter times (effectively creating a flanger effect) up to several seconds long. Other parameters include feedback, to create multiple echoes, and the ability to modify of the frequency content of the delayed signal, e.g. placing a filter on the delayed sound to dull the high frequencies.

3.3 Other Sound Effects

3.3.1 Filter

Filters are modules that sculpt the frequency content of a sound. They act as a tone control and can be used to remove or enhance particular frequencies. The two most common filter-types are low-pass and high-pass filters. The former reduces high frequencies while the latter removes the 'bass' from a signal. Typical parameters include cut-off frequency (the frequency at which the filter slope begins) and resonance. Figure 8 represents a low-pass filter with various resonance settings.

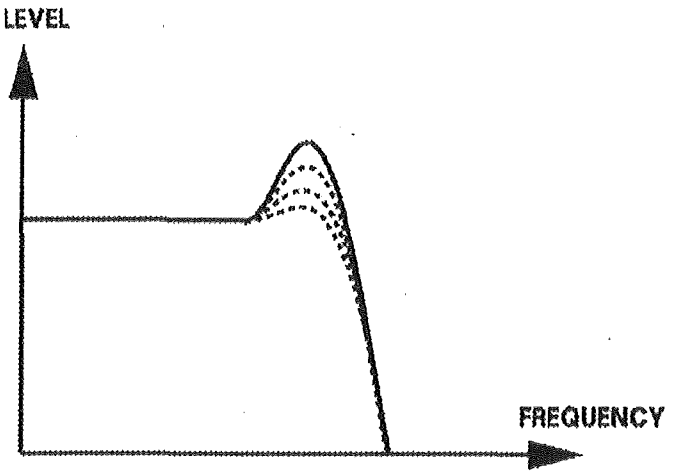


Figure 8. Diagrammatical representation of a low-pass filter. The level peak on the right-hand side denotes the cut-off frequency, above which other frequency content is removed. The dotted lines indicate different resonance settings. © Elektron ESI AB, 2002.

3.4 Mixing Processes

3.4.1 Spatialisation

> *"A turning point in* [John Cage's] *artistic life occurred when he entered a soundproof anechoic chamber and heard two sounds. The high one, he learned, was his nervous system in operation, the lower his circulatory system. The experience taught Cage that there was no such thing as silence; there were only intended and non-intended sounds."*[29]

Spatialisation refers to the positioning of sounds in a space, including definition across a horizontal plane and perception of depth. Environmental sounds are inescapable, as witnessed by John Cage (1912-1992) in the example above, and thus people are surrounded by sounds their whole life. One could argue that spatial effects are therefore a natural part of reality, whether people pay attention to them or not. When recording was first developed, the technology only allowed one channel of playback resulting in monaural sound (mono). This was later developed into stereophonic (or stereo) sound which utilised two channels at once, and opened up possibilities for recording engineers and electronic musicians in the realm of spatialisation.

In stereo recordings, the position of a sound between the left and right speakers is known as panning. When combined with the use of an echo unit, an effect commonly called "ping-pong"

[29] Richard Crawford, "United States of America (I.3) – 20th Century," *Grove Music Online* ed. L. Macy (Accessed October 2007) <http://www.grovemusic.com>

delay can be created. This creates the effect of a sound bouncing back and forth between the two speakers.

Reverb is another spatial effect that recreates the natural phenomenon of reverberation which can create the perception of depth or distance. When a sound is produced in any space it is followed by a series of 'reflections' as the sound bounces off the surfaces in the area until it is eventually absorbed and dies away. Different spaces and different materials respond differently to these reflections, for example: tiles are far more reflective than carpet. Reverb is useful for giving different sounds their own space in a mix, or for pushing things into the background.

3.4.2 Feedback

Most people's experiences of feedback have left them with sore ears from a loud squeal that occurred when a microphone is directed at the speaker it is connected to. This sudden burst of sound is the result of the output signal (from the loudspeaker) being fed back into the input (the microphone) which has a cumulative effect that is the demonstration of a positive feedback loop.[30] This is also a common effect in rock music when the signal from the guitars' electric pickups is sent through the amplifier and back into the pickups et cetera. A common variation in electronic music is the send the signal of a delay unit back into itself to create a unique, morphing delay. David Lee Myers (b. 1949) is an electronic musician who uses feedback as a mixing aesthetic. Myers "feeds electronic circuits back onto themselves to create interference noise that he can then mix, filter, and shape using audio processors."[31] He creates electronic music in this way without the use of any signal generators. Robert Ashley (b. 1930), another composer that specialises in feedback describes it as "the only sound that is intrinsic to electronic music."[32]

[30] feedback. Dictionary.com (Accessed October 2007) <http://dictionary.reference.com/browse/feedback>
[31] Holmes, 29.
[32] Robert Ashley. 1982. Interview with Thom Holmes, 8 September. Quoted in Holmes, 27.

4. METHODS OF APPLICATION

Most of the aforementioned effects have a trademark sound, beneficial in that they are able to serve a particular purpose, so when a composer is searching for that specific sound they will know where to look. The downfall of this is that the effect may be recognised too easily and consequently become superficial. In order to avoid this happening, one must be creative in the application of such effects; to experiment with new ways to exploit the technique, which is indeed the goal of this research. The approach is to explore ways that transform the tools of electronic music to serve a functional purpose in a different medium altogether. This section will discuss possible ways to apply these tools to acoustic composition in my own, and other composers' works.

4.1 Step Sequencing Pitch and Time Relationships

The role of step sequencing in the composition of *Pivot* was primarily as a means of generating material for further development. Certain features of the native step sequencers in Nanoloop and the Machinedrum have also been emulated. Multi-channel patterns were programmed into these two devices and then modified by trial and error (not in a random sense) until a satisfactory result was reached. The feature that lent itself most to experimentation was the ability to use different length patterns on each channel; for example, one part loops an 8-step pattern while another repeats a 5-step pattern. Evolving cross-rhythms and textures could be produced in this manner, similar to the tape loop compositions of Terry Riley and Brian Eno.

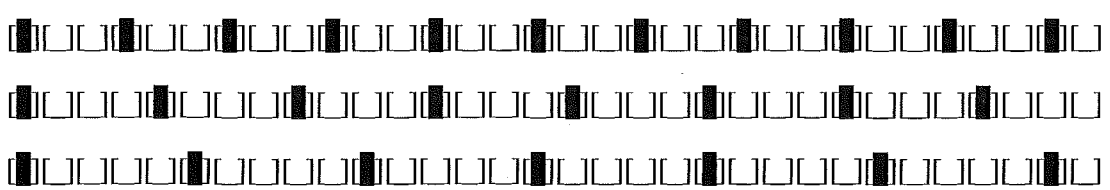


Figure 9. Overlapping loops of 3, 4 and 5 steps as part of a 32-step pattern.

Figure 9 demonstrates three parts cycling at different loop lengths. This example uses straight rhythms, but the concept can also be applied to simple or complex rhythmic motives of different lengths. The following example is taken from the first movement of *Pivot*. The instrumentation is two marimbas with four performers, i.e. one player per stave. The treble parts use 3-semiquaver patterns while the bass parts use 5-semiquavers.

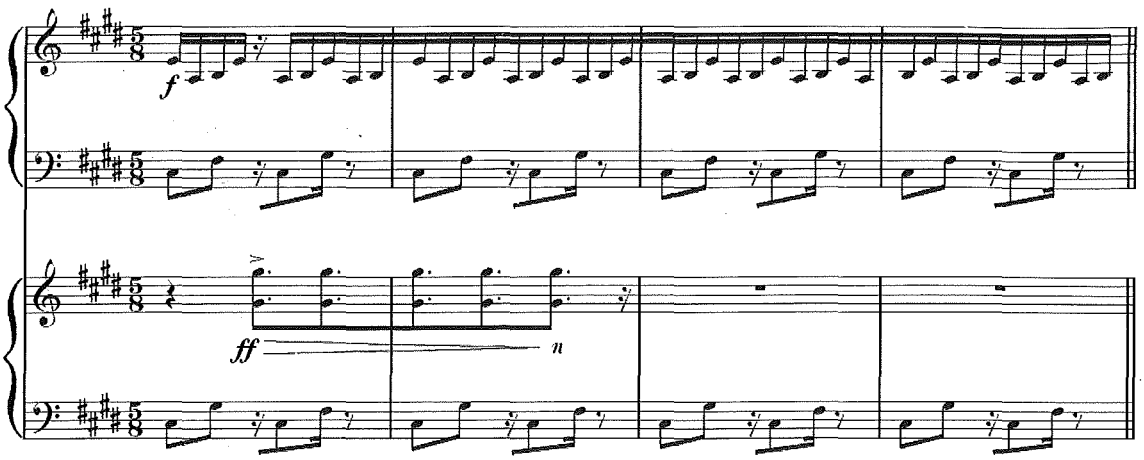


Figure 10. A short excerpt from *Pivot, Movement 1.*

Over the duration of the composition of *Pivot* I had built up library of patterns to choose from which became building blocks of the piece. These individual 'cells' usually acted as starting points but also as a glue to unite the work. Some patterns were directly similar whereas others were linked via a common 'shared' pattern which effectively acted as a pivot point to move between the two. This actually comes back to the process chaining successive patterns together in a step sequencer. Working with step sequencers is limiting in this way because the structure can become overly segmented. The advantage of applying the concept to acoustic composition is that further editing and variation can be implemented in order to create a better sense of flow (see Figure 11 for a visual representation). Most, if not all of the patterns could be composed without the use of a step sequencer though they may not seem 'natural' to some composers. The objective was to use a different cognitive process to normal, freeing oneself from a habitual framework or practice.

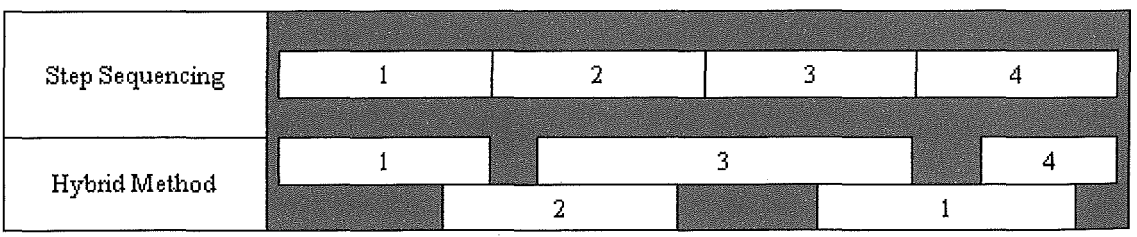


Figure 11. Different patterns (represented by number) can be overlapped using the hybrid method to create smoother transitions between sections.

There is one strong example of a unique musical voice that used a method of sequencing to create acoustic music. Conlon Nancarrow (1912-1997) was a composer most well known for the music he wrote for player piano – an upright piano that uses a mechanism to automatically

playback music from a pre-prepared paper strip known as a piano roll.[33] Nancarrow used this system to his advantage, writing many pieces that would be impossible to perform otherwise. His works are rhythmically focused and construct independence of voices, often through the use different tempi simultaneously. "A later piece was a canon with a tempo ratio of 60 to 61."[34] Canonic devices based on tempo can be combined with the traditional use (with intervallic relationships) by referring to the pitch / speed relationship inherent in electronic music. This technique is then applicable to regular motivic development, not just for use in a canon.

When a recorded passage is played back at one octave above its original pitch, the resulting passage sounds twice as fast. This is due to the mathematical relationship of the interval, which in the case of an octave is 1:2. To clarify: A440 has a frequency of 440 Hz. The frequency of the note one octave higher is 880 Hz, therefore the ratio of the two notes is 440:880 or 1:2. Other consonant intervals also have "simple frequency ratios, such as ... the 5th (2:3) [and] the 4th (3:4)."[35] Thus, if the recorded passage was to be played at its original pitch and a fifth above at the same time, the result will have a polyrhythmic connection of two against three. Figure 9 is a simple example of how this might look on an acoustic score.

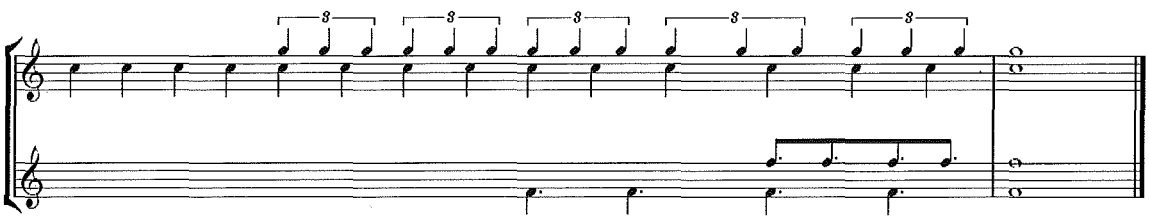


Figure 12. An example of simple polyrhythm created by transposition involving the pitch / speed relationship inherent in electronic music.

The speed change as a result of transposition is usually an undesired effect within electronic music, because the producer may want to change the pitch of a sample without altering its duration or harmonic quality. This effect applied in the acoustic medium provides a basic extension of traditional transposition techniques, whether applied to basic rhythms or more complex phrases.

[33] "Player piano." Reference.com. *Columbia Electronic Encyclopedia.* Columbia University Press. (Accessed October 2007) <http://www.reference.com/browse/columbia/playerpi>

[34] William Duckworth, *Talking Music: conversations with John Cage, Philip Glass, Laurie Anderson, and five generations of American experimental composers – Conlon Nancarrow,* (New York: Da Capo Press, 1999), 43.

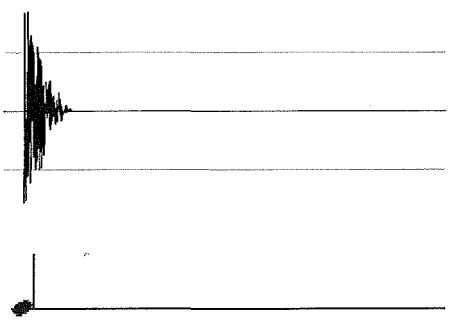
[35] Charles Taylor and Murray Campbell. "Sound." *Grove Music Online* ed. L. Macy (Accessed October 2007), <http://www.grovemusic.com>

4.2 Delay Effects

Of all of the effects covered, delay is one of the most frequently used electronic effects in compositions with acoustic and electronic elements. There are countless works for a performer with delay pedal, such as *Fabian Theory* (1984) and *Hinchinbrook Riffs* (2003) by Australian composer Nigel Westlake (b. 1958). Steve Reich used a delay technique without the use of any electronic equipment, though it was a secondary result of his phasing technique. In the case of *Piano Phase*: the two performers begin in unison until one of them speeds up, gradually shifting out of phase with the other until they slip back into time one semiquaver ahead. At this point the two performers are essentially creating a tempo-synchronised delay of one semiquaver. The accelerating part then moves ahead again to form a delay of one quaver between them, and so on. Below are some examples of different delay parameter settings, with visual representations of their respective waveforms and suggestions of how they might be notated on a musical score. Note that example 4 refers specifically to percussion, using a buzz roll.

1. The raw signal – a short percussive note / noise.
2. Medium delay time with multiple echoes.
3. Faster delay time with multiple echoes.
4. Very fast delay time, possibly with an audible pitch.

1.



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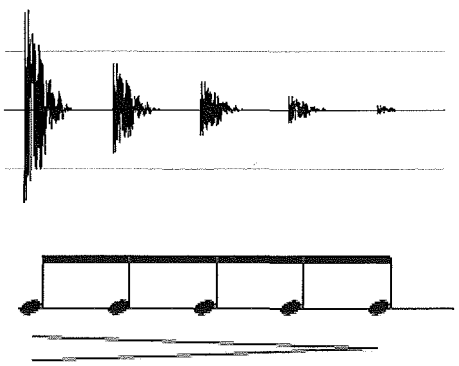

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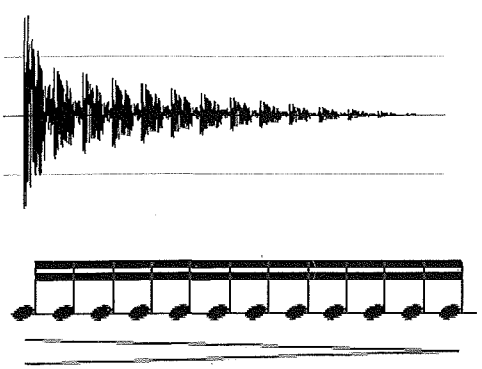
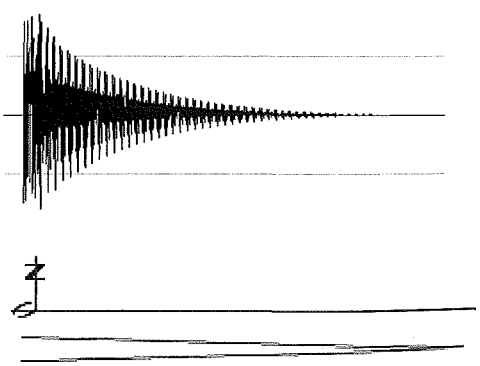


4.



Tempo-synchronised delay would be of the greatest value to many composers. The methods as used in *Pivot* are not primarily based around loops that become offset, but rather apply delays selectively to certain notes and passages. Figure 13 is an excerpt from Movement 3 of *Pivot*, which demonstrates delay and elements of spatialisation, mostly the use of 'ping pong' delay as explain in section 3.4.1. The middle stave (vibraphone) would be situated in the centre of the performance space with the outer parts (marimbas) placed on extremities of the stage. In bar 3, the vibraphone plays an accented Bb, which is then passed back and forth between the marimba parts at a delay rate of three semiquavers. A similar thing happens in bar 7 except the delay is 6 semiquavers. In a way, the marimbas operate as a selective delay pedal for the vibraphone.

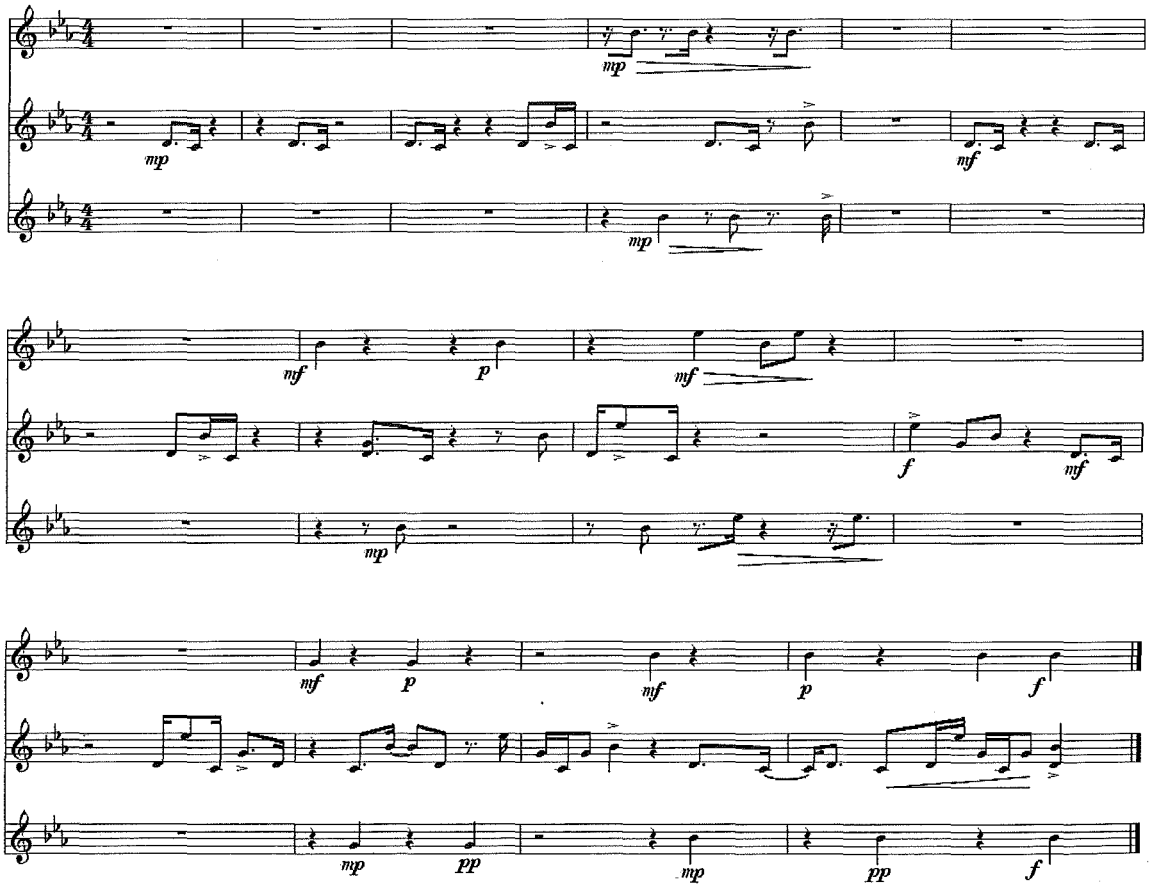


Figure 13. An excerpt from *Pivot, Movement 3* which applies delay effects to acoustic writing.

Delay effects with shorter times (phaser, flanger and chorus) do not translate quite as well, and generally require acoustic imitation. Recreating the effect requires two sound sources that are almost identical, and works best with sustained sounds. This can be done by bowing the same note on a vibraphone resulting in a phasing effect caused by the interference of the two waveforms, for example.

4.3 Spatialisation

Spatialisation has never been exclusive to electronic music, with early examples in acoustic music dating back to the 1500s with the use of antiphony or *cori spezzati* – "literally [meaning] 'broken' choirs, that is, choirs spatially separated from one another."[36] Its use also became quite widespread during the 20th Century, particularly amongst composers that were also writing electronic music. Stockhausen's *Mixtur* involves setting up five orchestral groups around the audience[37] creating a surround sound effect. In the quest for total serialisation, spatial position was even set rows by Stockhausen, Anton Webern (1883-1945) and Olivier Messiaen (1908-1992).[38] While listening on headphones while score-reading *Pléïades* (1979) by Xenakis, certain spatial effects should come to one's attention. The part on upper stave of the score is audible in the left ear while the lower stave in the right, with the other parts spread between. Xenakis' writing creates moments where the music swirls from side to side as if it were a single instrument moving around on stage. This is achieved by being aware of an instruments spatial position on stage during the compositional process. In *Pivot*, the instruments are located on the outer extremities of the stage, and effects like ping-pong delay (as demonstrated in Chapter 4.2) and gradual panning movements are emulated.

Reverberation is a natural effect in all acoustic spaces. Concert halls sound very "wet" while small, carpeted rooms may sound "dry." Forming the sustained, wet sound regardless of what the acoustic are of a space can be done by either sympathetic vibration or simple imitation.

> *"The property of sympathetic vibration is encountered in its direct form in room acoustics in the rattling of window panes, light shades and movable panels in the presence of very loud sounds, such as may occasionally be produced by a full organ. As these things rattle (or even if they do not audibly rattle) sound energy is being converted into mechanical energy, and so the sound is absorbed."*[39]

This concept can be applied to instruments as well. A common example is the sympathetic vibration of the snares on a side drum (when left turned on) when a tuba or bass drum plays. A suggestion as to how this may be applied musically to percussion, is to activate the sustain pedal on a vibraphone and force vibrations by striking notes loudly on other pitched instruments until a desired result is achieved. In *Pivot*, a reverb trail is imitated by softly bowing a vibraphone note at the same time a louder note is struck on a different instrument.

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[36] James G. Smith. "Chorus (i) – The Baroque." *Grove Music Online* (Accessed June 2007) <http://www.grovemusic.com>
[37] Cope, 63.
[38] Erich Auerbach, *Images of Music* (Köln: Könemann Verlagsgesellschaft, 1996), 70.
[39] Ronald Lewcock, Rijn Pirn and Jürgen Meyer. "Acoustics (I.3) – Resonance, reverberation and absorption." *Grove Music Online* (Accessed October 2007) <http://www.grovemusic.com>

4.4 Mixing & Other Effects

4.4.1 Filter

High-pass and low-pass filter characteristics can be easily applied to tuned keyboard percussion instruments such as the marimba and vibraphone. The basic acoustic principle of these instruments is that they use a variety of vibrations to produce their sound. The wooden or metal bars, when struck, vibrate in various ways: along their entire length, in halves, thirds, quarters, and so on (see Figure 14).[40] By hitting the in specific points along the bar, different overtones can be emphasised. Striking close to the edge of the key will produce a brighter sound with less bass content, giving the effect of a high-pass filter, especially when using a hard mallet. While striking close to the centre will give much more bass response and emphasis of the fundamental frequency of that note. Notation of these changes is shown in Figure 15.

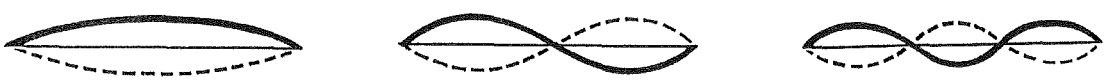

Figure 14. Different modes of vibration produce different overtones. © Oxford University Press, 1970.

Figure 15. Notating the change of striking position on the bars of a keyboard percussion instrument. © W.W. Norton & Company, Inc., 1980.

Applying a low-pass filter to a sound will reduce upper frequencies, which gives the illusion of distance. Filtering, to a certain extent, can also be considered as a spatial effect in this regard, because depth is an element of spatialisation. *Pivot* achieves these filter effects with percussion instruments by using the above notation method, and by specifying the use of different mallet types. For example, a slow low-pass filter sweep is recreated by using progressively harder or softer mallet-heads.

[40] Reginald Smith Brindle, *Contemporary Percussion: Chapter 5 – Factors Influencing Timbre* (London: Oxford University Press, 1970)

4.4.2 Feedback & Creative Routing

The approach to feedback by David Lee Myers was to treat an audio mixer as an instrument in itself, using creative routing paths in order to create something from nothing. Certain sections of *Pivot* were constructed with this idea in mind, creating "signal" paths which suggest ways to develop material. The diagram in Figure 16 was a preliminary step in composing parts of the third movement of *Pivot*.

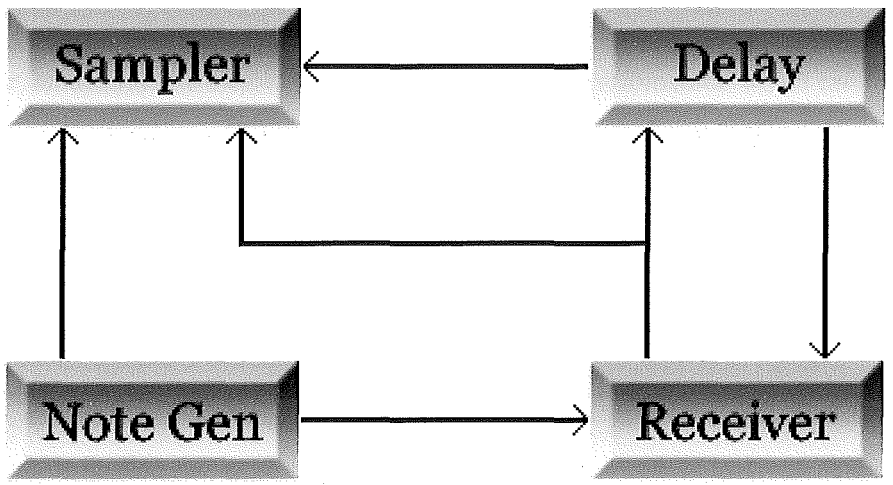

Figure 16. A 'signal' flow diagram used for developing material.

The boxes represent separate players, each allocated a function. Material is initially generated by the 'Note Generator' (performing patterns written on Nanoloop and the Machinedrum's step sequencers) and then transferred to other players for further development according to their assigned function. A feedback loop occurs between the 'Receiver' and the 'Delay,' sending material back and forth. The role of the 'Sampler' is to occasionally grab small fragments of what is currently being played, and to repeat or transform them in a variety of ways, e.g. transposition, with or without tempo adjustment. This process occurs as a predetermined event (i.e. written into the score) or is left open for improvisation at assigned moments.

5. CONCLUSION

The development of audio recording and electronic technology has undoubtedly had a permanent impact on music. Records, tape, CD and now computer hard disc music playback has given worldwide accessibility that was previously unthinkable. "Nearly every serial composer who worked with electronics returned to live music with some modification of his older approach."[41] This verifies the importance of both acoustic and electronic styles. Electronic music has worthy qualities that influenced a change in approach to acoustic composition. There is, however, an undeniable element of live, acoustic music performance which cannot be simply reproduced or replaced by a recording; certainly not for the performers themselves. For many composers, electronic music provides an outlet by which they can achieve an immediate result without any blurring of interpretation. To that end, electronic music provides the ultimate potential for producing an accurate communication of a musical idea; but that does not necessarily make it an ideal solution.

In the pursuit of finding the most suitable compromise, *Pivot* was created in a single medium – that of acoustic music. I genuinely feel that adapting techniques from electronic music allowed me to approach my acoustic music composition in a fresh and engaging way. Hopefully the ideas presented in this dissertation will also offer something to others, and no doubt I will continue to develop them myself as I feel this area has scope for much deeper research.

[41] Salzman, 143.

6. BIBLIOGRAPHY

Auerbach, Erich. *Images of Music*. Köln: Könemann Verlagsgesellschaft, 1996

Bois, Mario. *Iannis Xenakis, the man and his music: a conversation with the composer and a description of his works*. London: Boosey and Hawkes, 1967

Burns, Kristine H. History of Electronic and Computer Music Including Automatic Instruments and Composition Machines. Electro-acoustic Music, Dartmouth College (Accessed October 2007) <http://eamusic.dartmouth.edu/~wowem/electronmedia/music/eamhistory.html>

Burrows, Terry. *Total Guitar Tutor*. 2nd ed. Carlton Books, 2000

Cascone, Kim. 2003. Laptop Music – Counterfeiting Aura in the Age of Infinite Reproduction.

Cope, David H. *New Directions In Music*. 5th ed. Dubuque: WM. C. Publishers, 1989

Cox, Christoph, and Daniel Warner, eds. *Audio Culture: Readings In Modern Music*. New York: Continuum, 2004

Crawford, Richard. "United States of America (I.3) – 20th Century" *Grove Music Online* ed. L. Macy (Accessed October 2007), <http://www.grovemusic.com>

Dictionary.com. *Dictionary.com Unabridged (v 1.1)*. Random House, Inc. (Accessed October 2007) <http://dictionary.reference.com>

Duckworth, William. *Talking Music: conversations with John Cage, Philip Glass, Laurie Anderson, and five generations of American experimental composers*. New York: Da Capo Press, 1999

Elektron ESI AB. *Machinedrum SPS-1 User's Manual*. Gothenburg: Elektron ESI AB, 2002

Emmerson, Simon and Smalley, Denis. "Electro-acoustic music." *Grove Music Online* ed. L. Macy (Accessed June 2007) <http://www.grovemusic.com>

Gann, Kyle. "Nancarrow, (Samuel) Conlon." *Grove Music Online* ed. L. Macy (Accessed September 2007), <http://www.grovemusic.com>

Hancock, Herbie. *Future Shock* [CD], Columbia CK 38814, 1983.

Henck, Herbert. In *Piano Music: Conlon Nancarrow, George Anthiel* [CD liner notes]. München: ECM, 2001.

Holmes, Thom. *Electronic and Experimental Music*. 2nd ed. New York: Routledge, 2002

Lewcock, Pirn, Meyer, Hutchins, Schelleng, Richardson, Woodhouse, Martin, Benade, Campbell, Rossing, Sundberg. "Acoustics." *Grove Music Online* ed. L. Macy (Accessed September 2007) <http://www.grovemusic.com>

Macdonald, Cameron. Venetian Snares: Rossz Csillag Alatt Született: Pitchfork Record Review. Pitchfork Media (Accessed October 2007) <http://www.pitchforkmedia.com/article/record_review/22951-rossz-csillag-alatt-szletett>

Maconie, Robin. *The Works of Karlheinz Stockhausen*. London: Oxford University Press, 1976

Neuhaus, Max. In *The New York School: Nine Realizations of Cage, Feldman, Brown* [CD liner notes]. Milano: Alga Marghen, 2004.

Nordwall, Ove. 1969. György Ligeti. *Tempo*, no. 5 (Spring) (Accessed September 2007) <http://www.jstor.org>

Oliveros, Pauline. 1995. Acoustic and Virtual Space as a Dynamic Element of Music. *Leonardo Music Journal*, vol. 5 (Accessed August 2007) <http://www.jstor.org>

Peterson, George, and Steve Oppenheimer. *Tech Terms: A Practical Dictionary for Audio and Music Production*. Hal Leonard Publishing Corporation, 1993

Philip Glass, Official Website. Recordings – Music In 12 Parts (Accessed October 2007) <http://www.philipglass.com/html/recordings/music-in-12-parts.html>

Prendergast, Mark. *The Ambient Century*. 2nd ed. Bloomsbury, 2003

Reference.com. *Columbia Electronic Encyclopedia*. Columbia University Press. (Accessed October 2007) <http://www.reference.com>

Rose Knudsen, Gerhard Behles, Jakob Rang, Robert Henke and Torsten Slama. *Live Version 4.1.1 Reference Manual*. Ableton, 2004

Salzman, Eric. *Twentieth Century Music: An Introduction*. 2nd ed. New Jersey: Prentice-Hall, 1974

Shapiro, Peter, ed. *Modulations: A History of Electronic Music*. New York: Caipirinha Productions, 2000

Smith, James G. "Chorus (i) – The Baroque." *Grove Music Online* ed. L. Macy (Accessed June 2007) <http://www.grovemusic.com>

Smith-Brindle, Reginald. *Contemporary Percussion*. London: Oxford University Press, 1970

Steve Reich, Official Website. From New York to Vermont: Conversation with Steve Reich. Rebecca Y. Kim. 2000 (Accessed October 2007) <http://www.stevereich.com/articles/NY-VT.html>

Stone, Kurt. *Music Notation in the Twentieth Century: A Practical Guidebook*. New York: W.W. Norton & Company, Inc. 1980.

Taylor, Charles and Campbell, Murray. "Sound." *Grove Music Online* ed. L. Macy (Accessed October 2007) <http://www.grovemusic.com>

Unknown. Effects Explained. Harmony Central (Accessed September 2007) <http://www.harmony-central.com/Effects/effects-explained.html>

Unknown. Roland TB-303 Bassline. Vintage Synth Explorer (Accessed October 2007) <http://www.vintagesynth.com/roland/303.shtml>

Unknown. Bibliography. Steve Reich Official Website (Accessed October 2007) <http://www.stevereich.com>

Unknown. Timeline. Vintage Synth Explorer (Accessed October 2007) <http://www.vintagesynth.com/local/timeline.shtml>

Unknown. Tracker. Wikipedia (Accessed October 2007) <http://en.wikipedia.org/wiki/Tracker>

Venetian Snares, *Rossz Csillag Alatt Született* [CD], Planet Mu ZIQ111CD, 2005.

Vickery, Lindsay. Works Program Notes. Lindsay Vickery (Accessed October 2007) <http://homepage.mac.com/lvickery/lvpgmnotes.html>

Westlake, Nigel. List of Works. Rimshot Music (Accessed October 2007) <http://www.rimshot.com.au/listofworks.htm>

Wittchow, Oliver. *Nanoloop 2.2 Manual*. Germany: Oliver Wittchow, 2007

Xenakis, Iannis. *Aesthetic in Music Series, No. 2: Arts / Sciences: Alloys – The Thesis Defence of Iannis Xenakis*. New York: Pendragon Press, 1985.

Xenakis, Iannis. *Electronic Music* [CD liner notes]. New York: EMF Media, 1997.