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TECHNIQUES FOR RETRO SOUND DESIGN

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TEKNIIKKOJA RETROÄÄNISUUNNITTELUUN

Viimeisen parin vuosikymmenen aikana tapahtuneen tietotekniikan kehityksen rinnalla on kehittynyt myös vahva esteettinen mieltymys menneiden vuosien teknologian tuottamaan estetiikkaan. Tämä ilmiö näkyy muun muassa siten, että eri medioita pyritään tietoteknisillä menetelmillä muokkaamaan sellaisen vaikutelman aikaansaamiseksi, että media olisi tuotettu tai toistettu jollain aiemmalla teknologialla. Nykyään esimerkiksi digitaalisia valokuvia voidaan käsitellä muistuttamaan analogisia valokuvia virheineen ja kulumineen. Vastaavalla tavalla videokuvaa voidaan vanhentaa tai siihen voidaan lisätä esimerkiksi VHS-kasettien kohinaa ja häiriöitä muistuttavia artefakteja. Tässä opinnäytetyössä tutkittiin retroestetiikkaa digitaalisten pelien näkökulmasta ja retroäänisuunnitteluun keskittyen.

Opinnäytetyön alussa esitellään lyhyesti retroestetiikan teoriaa ja käsitemäärittelyjä sekä esimerkkejä peleistä, joissa hyödynnetään retroa jollain tapaa. Loppuosa opinnäytetyöstä käsittelee kahta käytännön äänenkäsittelytekniikkaa, joilla voidaan luoda retroäänisuunnitteluun sopivia ääniä ja tehosteita. Tekniikat toteutettiin Reaperissa eli digitaalisessa audiotyöasemassa hyödyntäen sen mukana tulevia liitännäisiä. Työssä käytettiin myös kahta kolmannen osapuolen luomaa liitännäistä.

Ensimmäisessä tekniikassa muokattiin liitännäisketjulla matemaattisesti ”puhdasta” ääniaaltoa muistuttamaan vanhojen tietokoneiden luomia värittyneitä signaaleja. Tämä tekniikka toimi hyvin, ja sen avulla karkean kuuloinen puhdas ääniaalto muuntui esteettisesti miellyttävämmäksi ja ”retrommaksi”.

Toinen tekniikka perustui graafiseen spektrimallinnukseen, jossa ääniaalto luodaan maalaamalla kuvioita, jotka syntetisaattori tulkitsee maalattujen pisteiden koordinaattien perusteella tietyksi taajuudeksi värisävyn ilmaisemalla amplitudilla. Tämä tekniikka toimi hyvin formantteja matkivien äänien tuottamisessa sekä erilaisten vanhoissa peleissä käytettyjen mekaanisten äänien matkimisessa.

Lopuksi opinnäytetyössä todetaan, että äänisuunnittelussa olisi parasta ottaa huomioon esteettinen teoria, sillä sen avulla voidaan luoda etenemissuunnitelma sille, millaisia tekniikoita ja teknologiaa äänen tuotannossa ja käsittelyssä olisi parasta käyttää.

ASIASANAT:

digitaaliset pelit, musiikkiteknologia, nostalgia, retro, äänenkäsittely, äänisuunnittelu, äänitekniikka.

BACHELOR´S THESIS | ABSTRACT

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TECHNIQUES FOR RETRO SOUND DESIGN

The development of the aesthetics of retro technology has developed at the same time as computer and media technologies have advanced further during the last few decades. This phenomenon can be observed in different fields of media activities. For instance, digital photographs are processed to resemble analog photography with its technological limitations and artifacts. In the same manner, digital video is processed to have the same sort of artifacts and noise introduced by VHS cassettes. In this thesis, retro aesthetics was researched from a sound and video game design perspective. The objective was to develop audio production techniques for retro sound creation.

The beginning of the thesis introduces the theory of retro aesthetics with explanations for analytical concepts. Digital game examples using retro design are examined. After the theoretical part, the thesis introduces two sound design techniques which are used to create sounds suitable for retro sound design. The techniques were realized using the Reaper digital audio workstation and its plug-ins. Two third party plug-ins were used as well.

The first technique is an effect chain which is used to modify a mathematically “pure” wave into resembling the more colored or distorted waves produced by old hardware. This technique worked well and converted the harsh pure sound into a more aesthetically pleasing and retro styled sound.

The second technique was based on graphical spectral modeling synthesis in which a sound wave is created by painting shapes which the synthesizer interprets as certain frequencies according to the coordinates of the dots in a shape and as certain amplitudes according to the hue of the dot. This technique functioned well with producing formant like sounds and in producing different kind of sounds resembling mechanical sound effects used in old digital games.

The conclusion states that a sound designer should be conscious of the theory of aesthetics he submits to. A theory should be used to create a road map for the design which is then used to decide which sort of techniques and technologies are best suited for the targeted style.

KEYWORDS:

Audio processing, digital games, music technology, nostalgia, retro, sound design, sound engineering.

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ABBREVIATIONS

DAC	Digital-to-analogue converter.
DAW	Digital audio workstation.
EEL	Extensible embeddable language.
FM	Frequency Modulation.
IDE	Integrated development environment.
Lo-fi	Low fidelity.
OPL	FM Operator Type L.
SID	Sound Interface Device.
VST	Virtual Studio Technology.
VSTi	Virtual Studio Technology instruments.

1 PREFACE

The thesis aims to research audio engineering techniques to be used in creating retro or nostalgic sound design in digital gaming and similar purposes. Popular culture is known to have a distinct branch of design which is usually called retro design. Retro design refers to design elements of the recent past which in popular culture usually refers to preceding decades. Thus, retro is approximately something made during a person's or a person's parent's lifetime.

Digital gaming is a young branch of popular culture which began its growth in the 1970s and the 1980s. These first decades produced memorable games which could be said to form the first games of a digital games canon. The sounds, graphics, characters, gameplay, levels etc. from these games have become symbols of the early history of digital gaming. Therefore, that contemporary retro design pays homage to these classics of gaming.

However, contemporary retro design does not actually need to refer to the classics precisely. In retro design it is usually enough to create an illusion of a previous age. This is what can be called the imagined past. The imagined past consists of symbols which, when consumed successfully, create associations, which the receiver believes to be representations of the actual past. It is thus enough in retro design, to find a technique, which somehow refers to the actual past while using design styles and production techniques from contemporary design.

This thesis examines I use different "retro studies" as a theoretical framework to understand the theoretical aspect of retro design and how the meaning of retro is created by the developers and the players. The theory will guide the practical part of my thesis in which I will research two production techniques which are suitable for the creation of retro sound design. The research question for the practical part is "how to create retro sound design without emulation?". I will introduce examples of retro design in recent digital games before the practical part of this thesis.

2 ANALOGUE NOSTALGIA

The concept of retro was introduced into popular culture in the early 1960s (Guffey 2006, 12). The idea of creating retro design or using retro elements in contemporary design has been a part of 20th century popular culture. Retro especially refers to design styles of the recent past and is a phenomenon found mostly in and related to popular culture.

Analogue nostalgia is the admiration of past technologies and the aesthetics associated with them, Schrey (2014, 28) argues that analogue nostalgia embodies a return to the seventeenth and eighteenth centuries' fascination with ruins and its fragmentary aesthetics. This early fascination led to the construction of artificial ruins. This phenomenon is comparative to the fascination shown towards the aesthetics of early digital games, pixel art and chip sounds. In the same manner, this fascination with previous technology and games has led to the creation of numerous amounts of games resembling games of the past. The hit game Hotline Miami is examined as an example of “artificial ruins” of the gaming world in the example part of this chapter.

Marks (2002, 152) describes analogue nostalgia as a retrospective fondness for the problems of decay and generational loss that analog video posed. Digital video does not have these problems so video artists fond of the aesthetics of decay began to add noise, color imperfections and other signs of analogue noise deliberately to their art. Although these methods have been used to make digital art resemble past mediums, the adding of noise etc. has become an aesthetic or technique which does not necessarily have any nostalgic motivation behind it.

One example of analog nostalgia is Instagram which gives the users the choice to use vintage filters, film scratches, polarization effects etc. to create the illusion of an analogue medium. Caoduro writes (2014, 68) that a trend in digital photography emerged around 2010, when amateur and professional photographers began intentionally modifying their digital pictures with discoloration, technical faults and signs of aging or other defects. The problems of old technologies became deliberate aesthetic styles of today.

Digital imitations of analogue technologies pose the question of authenticity. In audio production, analogue noise is difficult to reproduce digitally since analogue technologies usually present unpredictably fluctuating noise and signs of decay of the physical medium itself to the product. This question is especially important in the Commodore 64 music culture where it is disputed whether the music from games and demos is different if listened on an actual Commodore 64 computer, thus producing the analogue imperfections of its sound chip, or if it is enough to listen to emulated sound. This discussion entails the fact that the production of these sound chips was far from perfect. The manual to the Plogue chipsounds VST (2015) mentions that the on-board filters in the Commodore 64 varied a lot even between weeks of manufacturing. Thus, decisions concerning the sound emulation have been made and an completely authentic emulation is impossible in this case.

For some, emulation is just not enough, as can be seen and heard in the Stone Oakvalley's Authentic SID Collection, which is a complete collection of SID music recorded on actual Commodore 64 computers. The collection presents several recordings of every tune to cover all the official variations of the sound chip. At the moment of writing the collection held 744 305 recorded files (Oakvalley 2017).

2.1 Restorative and reflective nostalgia

Nostalgia can be observed in retrogaming practices such as: collecting old hardware, creation of emulators, appreciation of classic titles and remaking them for new platforms (Garda 2013, 2). Boym (2001, 49) distinguishes between restorative and reflective nostalgia. Restorative nostalgia manifests itself in total restoration of monuments of the past (e.g. emulators) while the latter lingers in the dreams of another place and another time, thus being essentially the imagined past. Nostalgia is not the property of the object itself but rather it is generated in our innerly experienced relation with it. This does not imply that nostalgia is a highly personalized emotion, because it often reflects collective memories of a certain generation or subculture.

According to Garda reflective nostalgia restores nothing. It refers to an individual experience, is linked to the process of cultural remembrance, and is relied on to understand the cultural phenomena of longing towards the bygone eras. Reflective nostalgia does not necessarily demand personal memories of the past and can be based only on the collective memories about this period that are transmitted by the media. (Garda 2013, 4).

Not all past technologies and techniques are equal in nostalgic value. For instance, the chiptune sound has become a symbol of antiquated digital games whereas early frequency modulation synthesis has not. Yamaha Corporation's OPL2 chip was used in sound cards such as the AdLib and Sound Blaster, which were both market leaders during the first part of the 1990s, nonetheless this technology and its sound has been mostly forgotten and emulated games from this period use the FM sound only if the game does not support sample-based synthesis.

The sample-based techniques of the 1990s found a new life in sample-based digital audio workstations which are continuations of the music trackers of the 1980s and 1990s which used digitized samples of instruments in the creation of music. Some early music trackers for the IBM PC type computers had the ability to send messages to the OPL2 chip. The popularization of VST technology however has made dedicated synthesis chips obsolete. There is a demand for the SID chip from the Commodore 64 but a similar demand for authenticity has not been born around the OPL2 although it being the most used chip of its time. Interestingly enough, the Plogue chipsounds VST used in this thesis models the dynamic sample playback rates of the Amiga Paula sound chip and its volume limitations to play low quality sampled sounds authentically. The omission of OPL2 from nostalgic representations reveals how subjective reflective nostalgia is.

On a more general level, certain genres and elements of the past have not become parts of retrogaming. For instance, text based adventure games, although very popular in the 1980s, are not part of the retrogaming culture or at least in the reflective nostalgia part of the scene. Some games have become symbols of the imagined past (Pac-man, Super Mario) but other commercial hits of the time (Dragon's Lair, Tapper, 1942, Paperboy) have not although they are surely known in the hard-core gaming community.

For practical use in audio design, the distinction between reflective and restorative nostalgia presents several design choices. Design using reflective nostalgia is targeted especially for modern audiences. The design choices must use the current collective ideas of nostalgia and omit elements which are not associated with the past although they actually existed in the time which the design tries to resemble. For instance, using sounds resembling the OPL2 chip too much might not be understood as retro design, or they might be interpreted as having less value since the sound of that chip has not entered the popular imagined notion of the past.

Design based on restorative nostalgia seems to be tricky. The most authentic design would use the actual old hardware and should be listened on that as well. This would limit the audience severely to the “authenticity scene”. Sounds made with emulators are so close to the authentic sounds that in practice there is no difference. However, the old hardware introduced limitations to compositional structures as well. Usually the composer had only three or four channels available and no possibilities to use any effect processors or such to enhance the sound. For instance, echoes had to be made by playing the echoed tone twice in the available channels. Thus, if the composer wanted to use echoes he or she had to sacrifice space from the channels which then modified the structure of the composition. These limitations led to creative solutions such as using highly fast arpeggios to play chords, which then released space for other elements as the arpeggio could be played just in one channel. These fast arpeggios are especially associated with music made with the Commodore 64.

True restorative nostalgia based design would try to submit to these limitations and use the same structural solutions which the original composers used. In practice, it is very easy to step out from strict authenticity. For example, if a game wanted to play a sound effect at the same time as the music was playing, usually this was made by playing the sound effect on one channel which was, for instance, the channel used to play bass and percussive sounds. The sound effect would then mute the bass and percussive sounds from the music for the length of the sound effect. Removing these features introduced by hardware limitations by using more channels than was actually available, the design takes a step away from true authenticity. In practice then, if true authenticity is not the design goal, choices should be made which then render the design to be more of the reflective kind.

The strict interpretation is then that if the design is not made with actual old hardware or if the emulation does not consider all the features introduces by limitations, then the design uses reflective nostalgia in practice. It is up to the designer to create the audio in such way that if he or she wants the design to resemble true authenticity, it must take into account the public perception of the (imagined) past and therefore introduce elements from the imagined past and the authentic past in a balanced way.

2.2 Examples

The next section describes some of the reflective or restorative design approaches found in modern games.

2.2.1 Hotline Miami

Hotline Miami (Dennaton 2012) is a retro inspired top-down shooter video game that received critical acclaim at its release and has become a cult game since (Figure 1). The developer's blog entry on announcing the game reveals the thematic of the game quite clearly:

> It's a surreal orgy of violence and neon lights. We wanted to make a bit of a tribute to the violent action flicks released during the 80s (although with less cheesy one liners). (Söderström 2012)

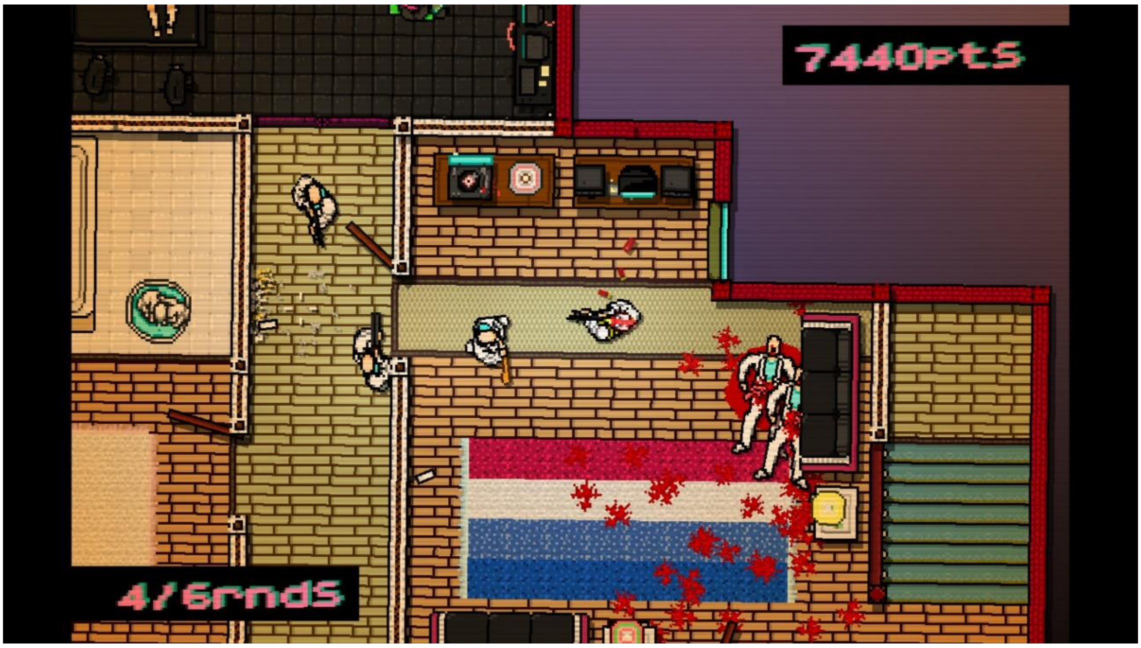

Figure 1. Screenshot from Hotline Miami (Eurogamer 2012).

Other sources of inspiration the developers source (Matulef 2012) are the neo-noir movie Drive, a documentary about drug trade in Miami called Cocaine Cowboys and the original Miami Vice tv-series from the 1980s. Dennis Wedin, one of the developers, especially underlines the music from the movie Drive. One can hear this quite directly if one compares the Chromatics' song "Tick Of The Clock" (2007) from Drive's soundtrack with M.O.O.N.'s "Hydrogen" (2011) from Hotline Miami's soundtrack. "Hydrogen" sounds like a dance remix of "Tick Of The Clock". Drive in itself is a retro motion picture referencing some sort of imagined 1980s. Thus, it is clear that the conscious intent of the developers was to create a game version using the same sort of pseudo nostalgic 1980s.

Lehtonen and Virtanen (2016) describe the music of the game as synthwave which is a modern music genre which deliberately references the music from the 1980s although not trying to actually be like the music of that period. Lehtonen and Virtanen perceive Jasper Byrne’s “Miami” (2012) song from the game soundtrack as conjuring up memories of Jan Hammer’s “Crockett’s Theme” (1984).

The author of this thesis does not have the same perception but it is noticeable that the song is some sort of fabrication of a 1980s song which easily conjures up these associations with actual songs from the 1980s. The same could be said of all the aesthetics in the game. It resembles something from the 1980s but is not quite like anything actual made in that period.

These associations are brought by references, which are vague enough to hit some resemblances to actual past things. For instance, the use of clearly artificial synthesized sounds is perceived to be “eighties-like”, although the melodical, harmonical and song structures of the fake 1980s songs do not really sound like the actual popular music from that period. In actuality then, Hotline Miami references elements from popular culture which are very recent. The game is a success in creating a false sense of nostalgia. It is the epitome of reflective nostalgia where the aesthetics are built of elements which are purely reimaginations of past styles.

2.2.2 Doom

Doom (id Software 2016) is a first-person shooter video game and a reboot of the original Doom franchise, which was created in the 1990s. This game is part of the “rebooting craze” of the 2010s during which many significant game franchises of the 1990s have been rebooted. For instance, Tomb Raider (2013), Mortal Kombat (2011), Shadow Warrior (2013), Wolfenstein (2009), XCOM: Enemy Unknown (2012) are reboots of famous game franchises from the 1990s.

In general, reboots do not try to create “artificial ruins” resembling the past but some sort of faithfulness to the originals is usually considered during development. These faithful elements in reboots are the nostalgic nods to players old or experienced enough to know the originals. Doom interestingly uses restorative elements as well as reflective elements although some elements are not necessarily meant to be nostalgic but simple reimaginations of past gaming elements to fit modern audiences and design styles.

Marty Stratton, the executive producer of the rebooted Doom, states in an interview (Takahashi 2016) that the development team tried to find the “DNA of Doom” by examining the original Doom games. This “DNA” translates to the essential gameplay and design elements that audiences consider to be the “Doom experience”. I will point out some of the more nostalgic references to the original games next.

The clearest references are the tiny hidden “classic” areas which are exact copies of parts of the levels in the original games (Figure 2). These areas use the exact same graphics the originals used. The sound of a door opening is an exact copy from the originals as well. Otherwise, the enemies in these areas and other sounds are from the rebooted version which the player is playing. These references are not the imagined past but concrete ruins of the past inserted into a modern context. The areas are like mini museums inside the game.

Figure 2. “Classic area” in Doom (Rao 2016).

The next reference type is an interesting one. The player can find collectible dolls from most levels in the game. If the player picks up a doll inside the game, the doll plays a short fragment of music from the original Doom’s first level. There are two different versions of this fragment. Most dolls play a version which do not contain the actual sounds of the 1990s games but a chiptune cover of the melody. The other version sounds like a digitally distorted version of the melody played with a synthesizer sound or perhaps a guitar.

One could argue that the chiptune sound mimics real toy dolls' cheap lo-fi speakers but the author cannot help but wonder if this is more related to the fact that when the original Doom was launched the most common sound card was the AdLib compatible Sound Blaster. Most people first heard the music as synthesized with the plasticky FM synthesis discussed previously in this thesis.

In this author's opinion, the choice to use the chiptune style in the dolls is a clear indication of the value of the chiptune style as a symbol of past video games and maybe unworthiness of the sounds of the OPL chip. The chiptune style in the dolls renders this reference essentially as the imagined past since the originals did not use that style and neither did the majority of games from that period. The chiptune style was essentially an antiqued technique at that point of gaming history.

The soundtrack of Doom includes many references to the original three Doom games picking up different musical elements from here and there. However, the new songs are not new versions of the old songs. Instead, the new songs seem to use the original songs as either starting points or inspiration for original music. Thus, the new songs include references to old while not trying to be overtly nostalgic or retro. This type of approach does not seem to try to arouse any particular nostalgic feeling in the audience but it tries to stay faithful to the original material thematically.

As these examples show, Doom uses different types of references in creating a continuum from the original franchise to the new game. Some of these references are clearly meant to be nostalgic while others seem to be using the originals as source material without the intent of being nostalgic but staying faithful.

2.2.3 Contemporary games for antiqued platforms

The subject of this section is somewhat controversial when considered from the perspective of nostalgia or retro. There exists a discourse on whether for e.g. pixel art is a retro style or if retro and old graphics are a part of a larger whole called pixel art. Pixel art can be seen just as an art style which is not meant to be nostalgic (Byford 2014). This argument is quite strong since nobody considers oil painting to be a retro style, for instance.

We present these games as at least partly being in the category of restorative nostalgia since the games uphold the actual platforms to which the reflective type of nostalgia refers to. There cannot be any more authentic references to past than these games except the games from the original eras of these platforms. To give examples, there are still new games being developed for the Commodore 64, ZX Spectrum and the Nintendo Entertainment System. Websites like Indie Retro News follow the development of different game projects for antiqued gaming platforms.

The three examples show three different design styles. Hotline Miami belongs to the completely imaginary retro design which resembles the actual past in a vague way which still manages to create an illusion of some actual past. Doom uses explicit references and reimaginations and is not retro or nostalgic per se but gives the player a few straightforward nostalgic moments. Games for antiqued platforms can be seen as restorative nostalgia or just games for old platforms in which the retro element comes from the platform and its limitations itself and might not be any intentional purpose of the game developer.

The next chapter will move to the practical part of this thesis in which we examine two techniques in creating sounds resembling past platforms.

3 SIMULATING RETRO SOUNDS IN REAPER

The first technique uses a chain of effects in manipulating a mathematically pure square wave into something resembling an imaginary past device. Next, we will introduce the software used in this thesis and the plug-ins used in the first technique.

3.1 Reaper

Reaper is a powerful and highly customizable digital audio workstation. For sound design purposes it offers several useful features and tools. Reaper uses ReaScript which is a feature that allows the user to edit, run and debug scripts within Reaper. With ReaScript the user can write full-featured extensions to Reaper. Most of the effects included with Reaper can be edited in the ReaScript IDE which then allows the user to tweak the code of the effects to suit his purposes.

ReaScript supports three programming languages EEL, Lua and Python. Extensible Embeddable Language (EEL) is an open source, C-like language which is intended for real-time systems with cycle rates in the kHz range, such as musical synthesizers. Lua is an efficient popular language designed for embedded use in applications. Python is another famous language but its performance is not as good as EEL or Lua (Reaper 2017) but it provides larger libraries, code examples, tutorials and such which might render it easier for the beginner to use.

For analytics, Reaper includes tools such as a spectrograph spectrogram meter, frequency spectrum analyzer meter and an oscilloscope meter. Spectrogram is a visual representation of the spectrum of frequencies of sound or other signal as they vary with time (Wikipedia 2018a). The user can also select to see the waveform as a spectrogram (Figure 3) which then allows spectral editing which is a highly useful feature for mimicking the waveforms produced by different old computers. Spectral editing is done to a recorded waveform. The spectrogram meter shows the spectrum of a live sound (Figure 4). Fourier transform can be used to generate a spectrogram as is done in part four of this thesis.

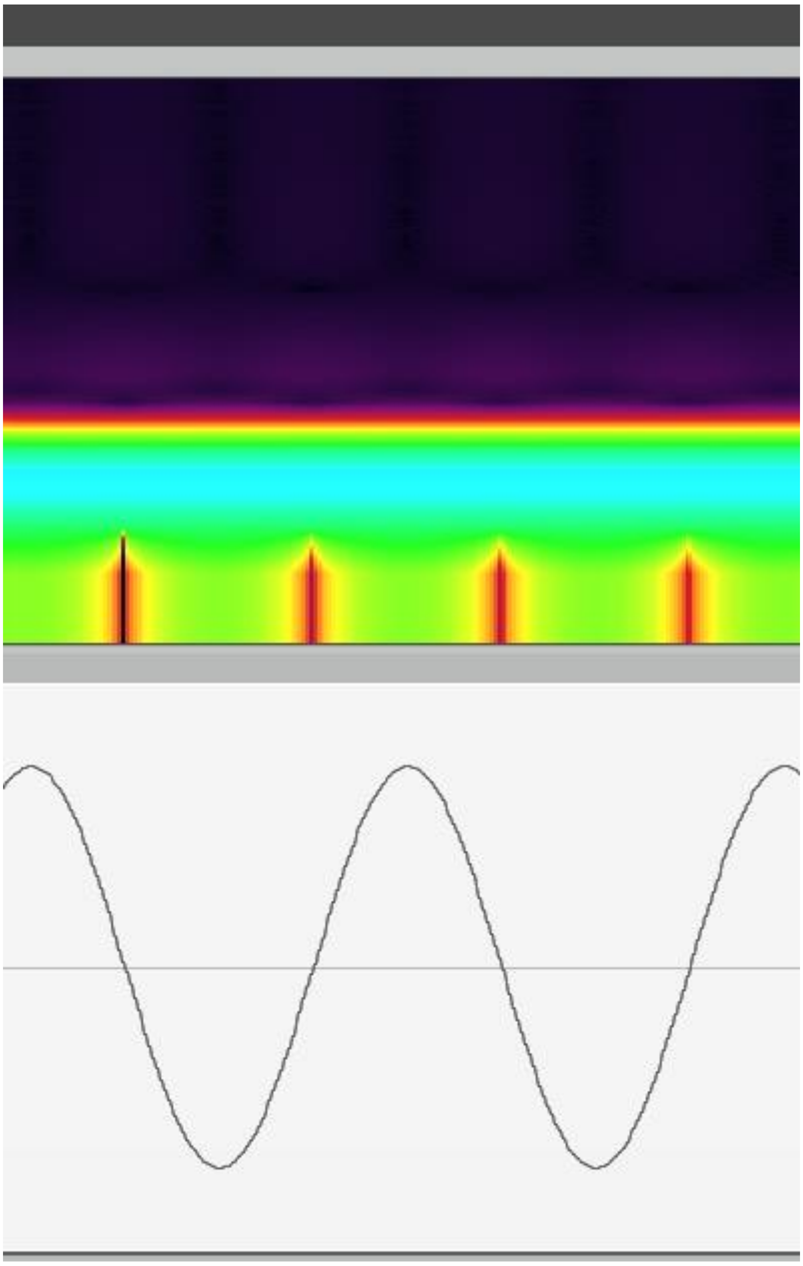

Figure 3. A spectrogram and a wave envelope of a 440 Hz sine wave.

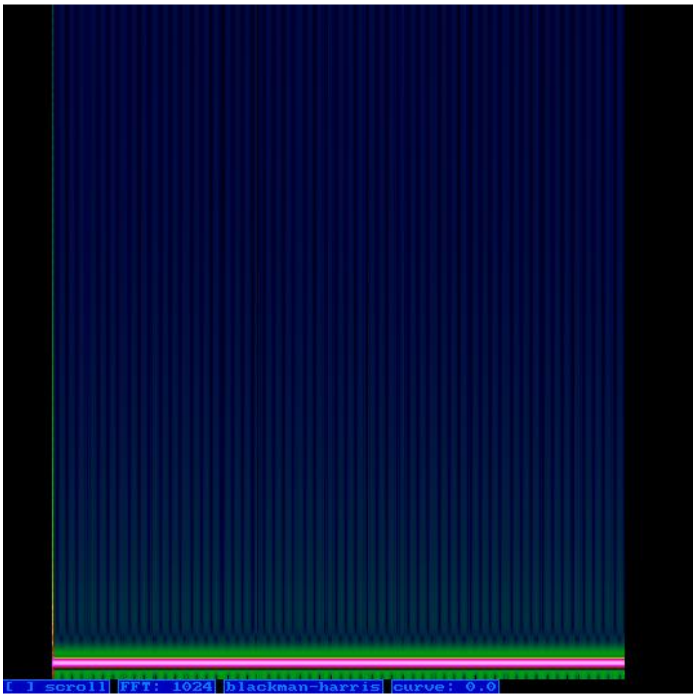

Figure 4. Spectrogram of a 440 Hz tone drawn by the Spectrograph Spectrogram Meter.

A spectrum analyzer measures the magnitude of an input signal versus frequency within the full frequency range of the instrument (Wikipedia 2018b) as shown in Figure 5.

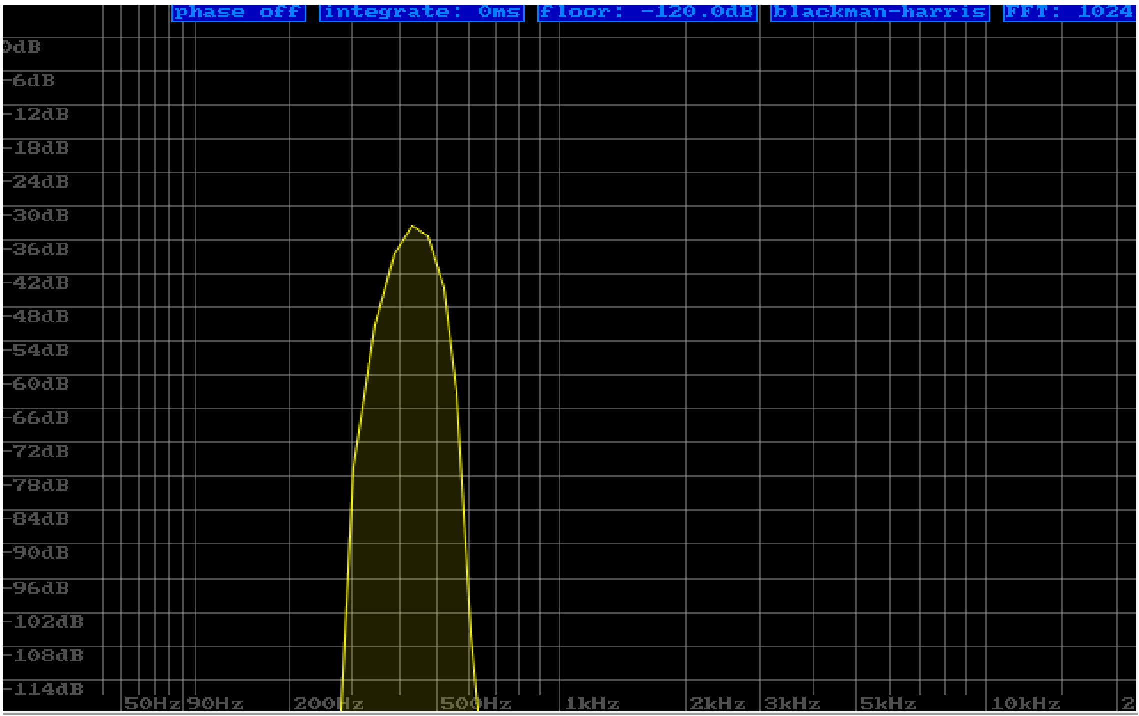

Figure 5. Spectrum of a 440 Hz sine wave in the frequency spectrum analyzer meter.

Finally, an oscilloscope is used to observe the change of an electrical signal over time. The observed waveform can be analyzed for such properties as amplitude and frequency. (Wikipedia 2018c). A 440 Hz tone in the Oscilloscope Meter is shown in Figure 6.

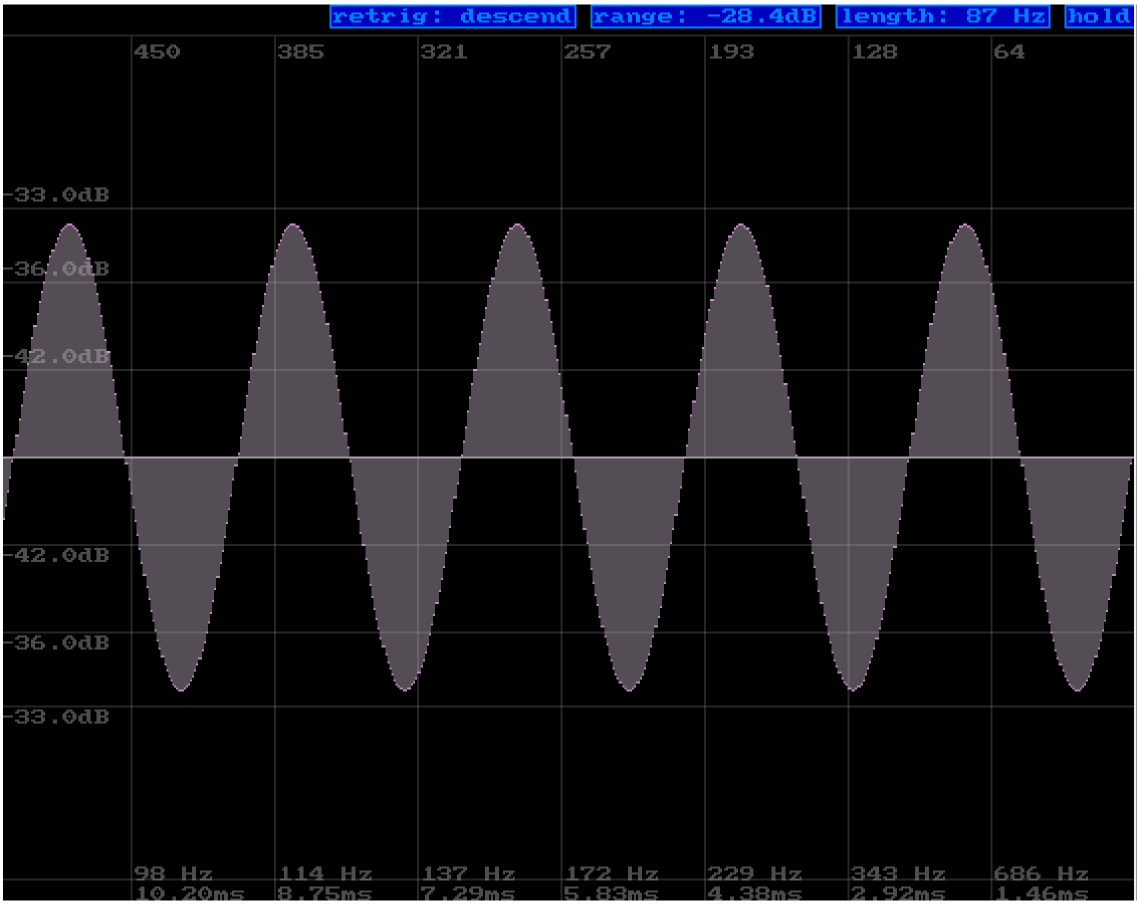

Figure 6. 440 Hz tone in the Oscilloscope Meter.

3.2 Plogue chipsounds & Plogue chipcrusher

Plogue chipsounds is a software synthesizer that simulates the behavior and sounds of more than ten integrated circuits of the 1980s. Chipsounds uses both samples and synthesis in its goal to achieve perfect emulation (Plogue 2016). In this thesis, Plogue chipsounds is used to generate a reference signal.

Plogue chipcrusher is a vintage DAC emulator, a speaker simulator and a noise machine. It can be used to simulate the audio output of old telephones, old samplers, old computers etc. This VST is used to filter the generated signals. For additional authenticity, Chipcrusher can be used to add recorded noise from different computer and video game systems such as Atari 2600, Commodore 64, Intellivision I, Nintendo Entertainment System and Sega Master System.

3.3 Effect chain for simulating retro sounds

This technique works best if used with a synthesizer which generates mathematically pure simple waveforms. A mathematically pure waveform is a waveform which is created solely from a formula for a periodic waveform. A pure sine wave is shown in Figure 3-1.

Old hardware usually colored the waveforms in different ways either by design or by accident and by limitations of the hardware. The intention of the effect chain is thus to modify the pure waveform so the result will resemble retro sounds in analysis and sound believable to the listener.

To create the pure sounds, ReaSynth VSTi, which is included with Reaper, is used. For creating the reference sounds Plogue Chipsounds is used. First, analyze the differences between a pure square wave and a pulse wave with a 50% duty cycle (which is the same thing as a square wave) created by emulating the sound of a Commodore 64. The differences between envelopes and spectrograms are shown for the sounds in Figure 7. The tone used in these examples is middle-C or C4.

As can be seen in Figure 7, there are clear differences between a pure square wave and a wave generated by hardware emulation. The pure square wave exhibits more energy at all frequencies (blue represents the highest amount of energy here) and sounds harsh. The emulated wave is filtered on some frequencies and sounds more pleasant. More dramatic differences can be seen when the sounds are shown in the frequency spectrum analyzer.

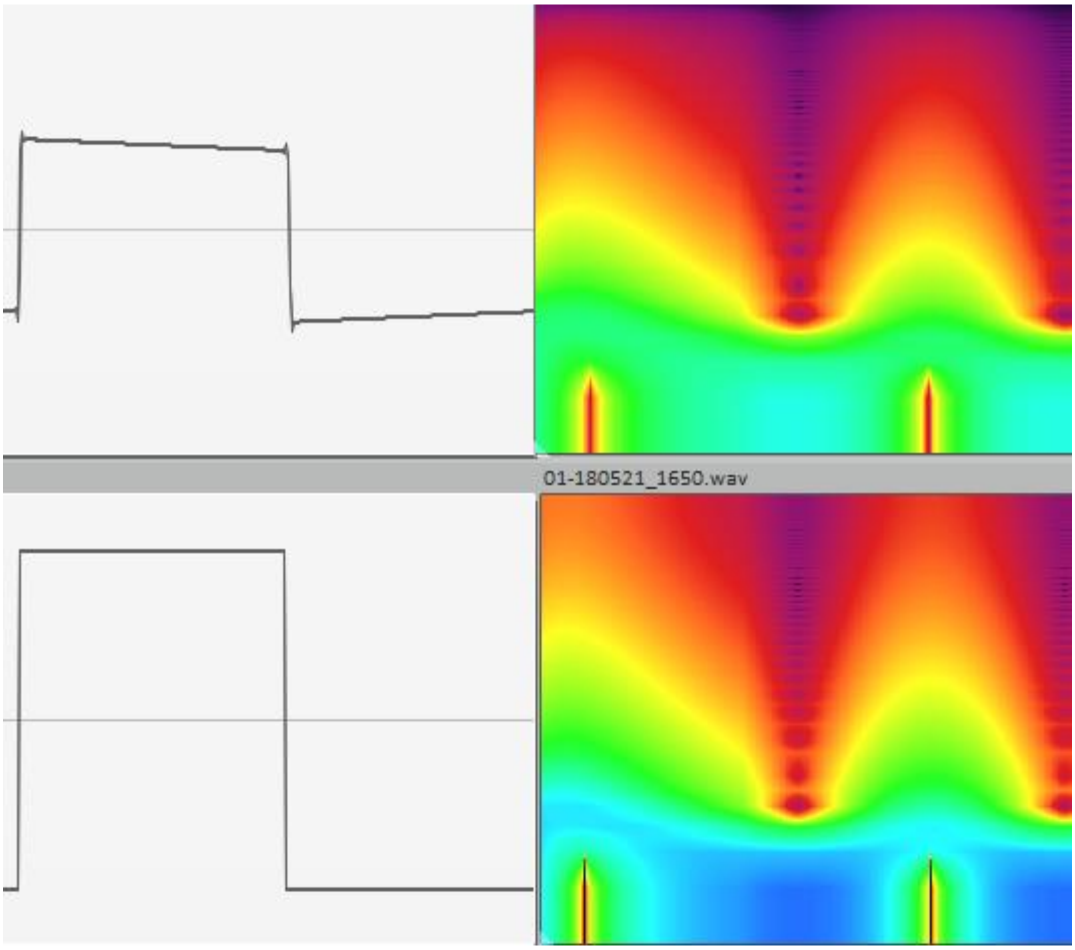

Figure 7. Differences between a pure square wave (below) and a square wave generated with emulation (top).

Figure 8 shows the frequency spectrum for the emulated square wave and Figure 9 for the pure square wave. The pure square wave shows a harmonic pattern and a constant decrease in amplitude when going further up in the frequency axis. The emulated wave shows a similar harmonic pattern but differs in the total amount of frequencies present. A clear attenuation of higher frequencies can be seen in the emulated wave, resembling a low-pass filter, although no low-pass filter is in use.

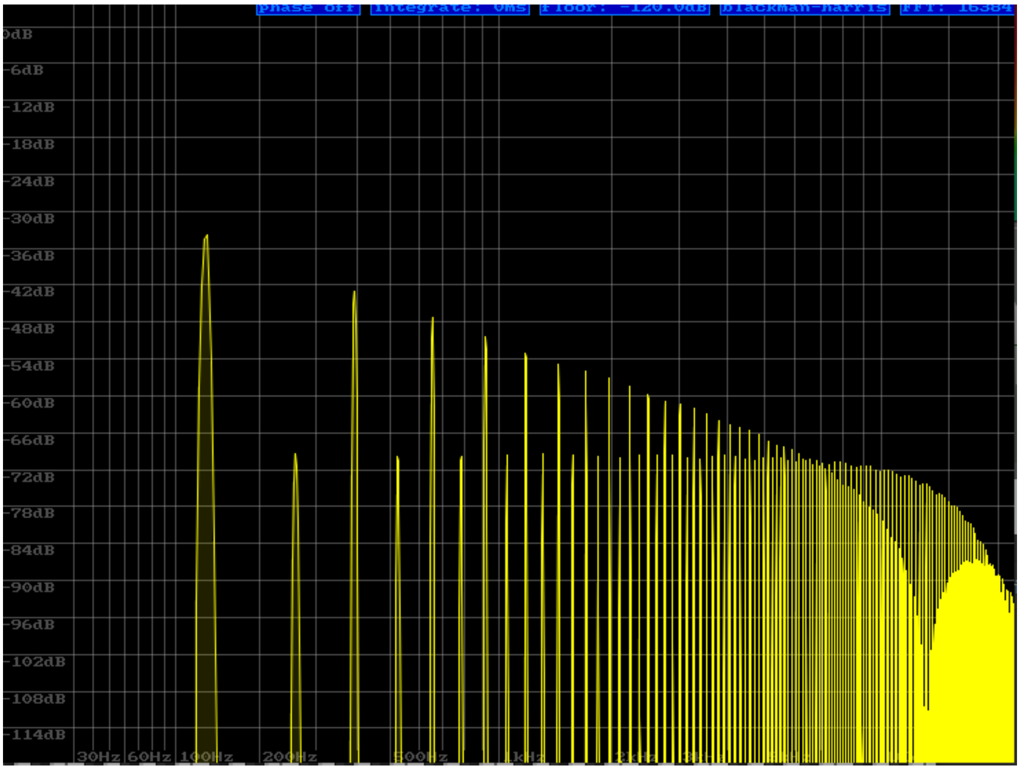

Figure 8. Frequency spectrum for the emulated square wave.

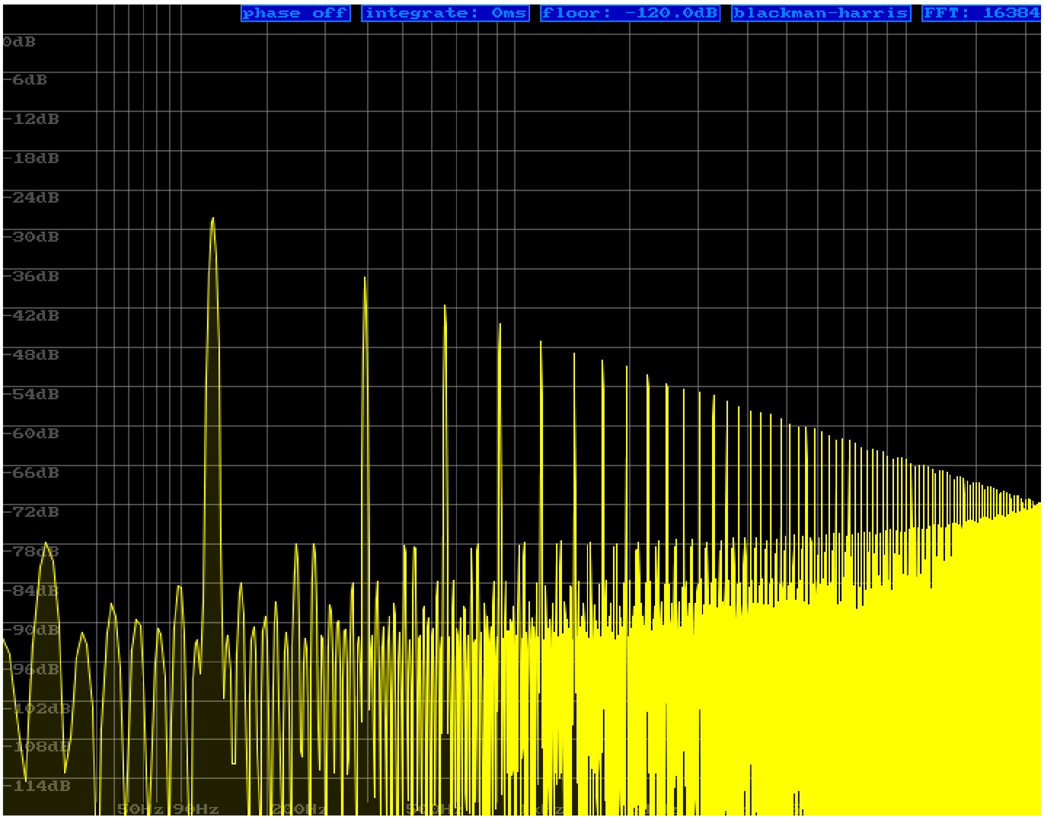

Figure 9. Frequency spectrum for the mathematically generated square wave.

The next section will introduce the effect chain which will allow a designer to modify a mathematically pure wave in such way that it will resemble imaginary hardware. In the process, techniques used to further modify the signal to allow the designer to control the final color of the sound more precisely, are introduced.

First, we present a list of the effects included in the chain with their functions. All the effects are included in Reaper except the Chipcrusher.

ReaFir: frequency subtraction.

Graphical Waveshaper: complexity addition and further shaping of the wave.

Paranoia mangler: addition of noise and distortion, bitcrushing and resampling.

Saturation: analog warmth addition.

ReaComp: compression and transient addition.

ReaEQ: harshness filtering.

Chipcrusher: DAC and speaker simulation.

ReaFir is used to remove the mathematical purity from the waveform. Select “subtract” for mode and “precise” for edit mode. This setting allows the user to edit the frequency content of a simple waveform in a surgical manner, resulting in a more complex and aesthetically more interesting sound. Figure 10 shows an example subtraction envelope. The filter is amplitude dependent but its level can be changed to fit the incoming signal. An average FFT size is suitable for the purposes of the effect chain.

Figure 11 shows the resulting wave envelope and Figure 12 the resulting frequency spectrum. The sound is now more complex, mellow and pleasant. The high frequencies are filtered from the sound and the higher mid frequencies are somewhat attenuated. The designer can attenuate the sound as he pleases and a more dramatic and concentrated subtraction can bring forth interesting timbres.

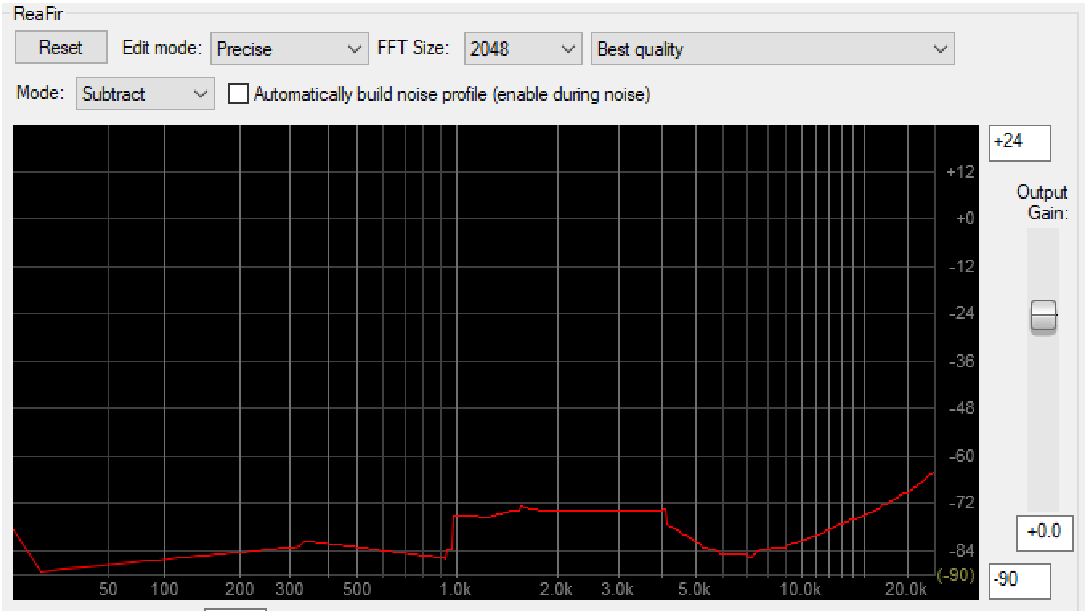

Figure 10. An example subtraction made with ReaFir.

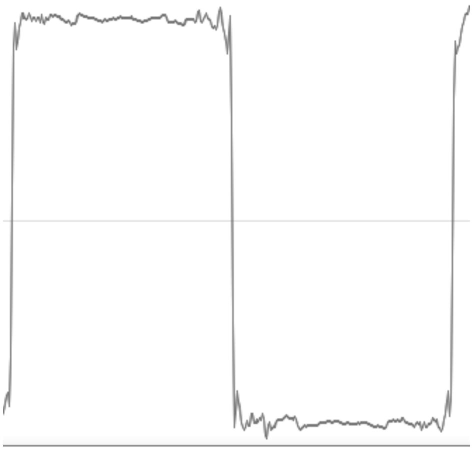

Figure 11. Resulting wave envelope after subtraction.

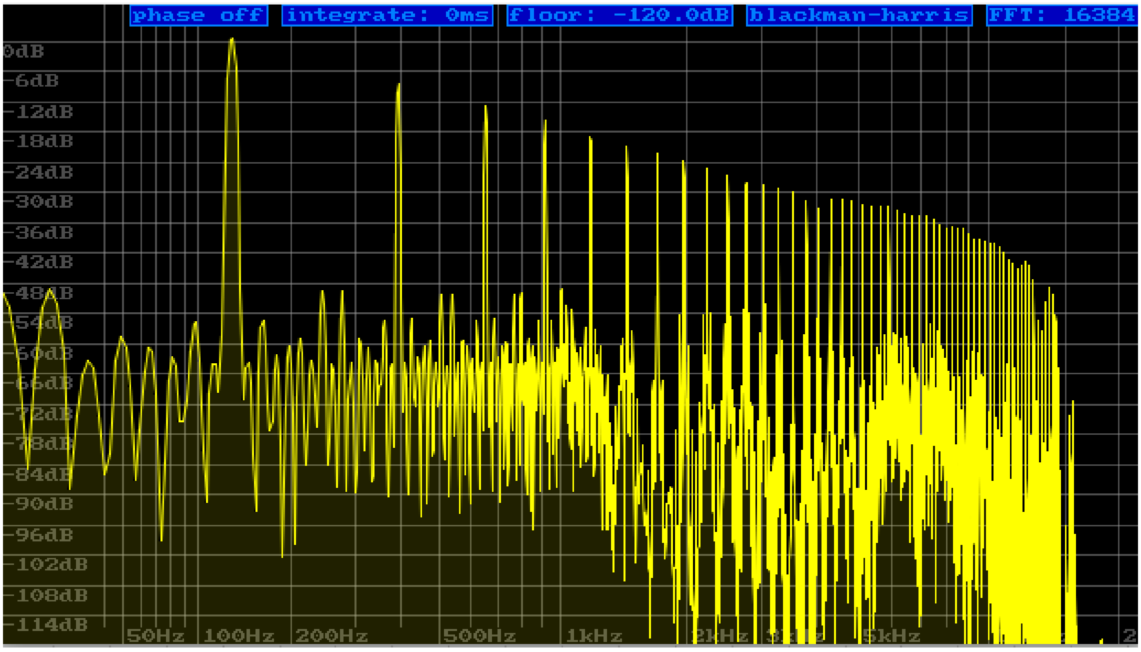

Figure 12. Resulting frequency spectrum after subtraction.

Waveshaping is a distortion synthesis which alters the shape of the waveform to create more complex spectra with large numbers of high frequency harmonics (Wikipedia 2018d). The Graphical Waveshaper provides a graphical user interface to draw a shaping function which is added to the output signal. Figure 13 shows the shaping function (magenta), original wave (dark magenta) and the resulting wave (green).

There are problems associated with waveshaping which should be noted. The sound created by waveshaping tends to be harsh. This can be countered by increasing the oversampling setting. The effect is amplitude-dependent so changes in, for instance, in the amplitude of the synthesizer will alter the waveshaping effect.

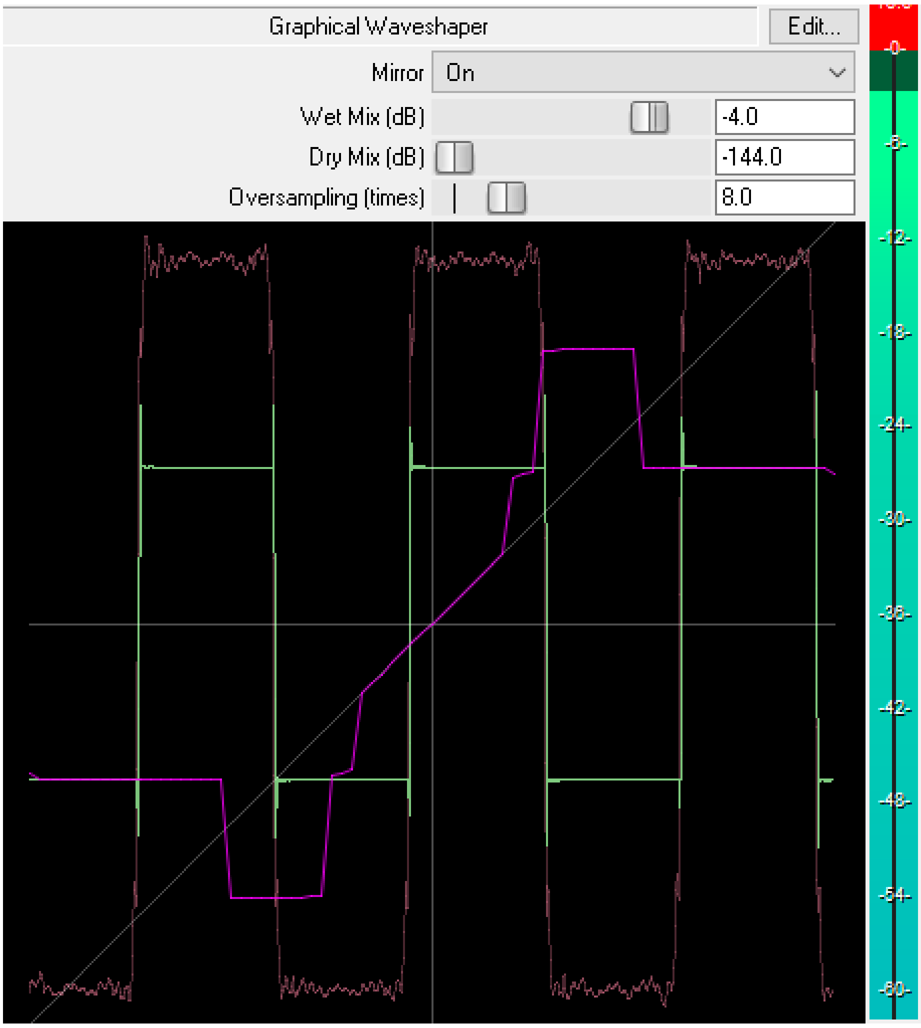

Figure 13. Graphical Waveshaper.

“Paranoia mangler” (Figure 14) is an experimental effect which combines several different effects to “mangle” the waveform. It is used in the effect chain to add subtle lo-fi noise and color to the sound to increase the resemblance to cheap hardware but without degrading the sound too much.

With the “Bad resampler” setting the user can add subtle noise and undulations to the sound. The “Bitcrusher” reduces the resolution of digital audio data which can then be used to add crunch to the sound. A setting called “Thermonuclear War” manipulates the bit pattern of the data. The final effect of this setting is highly dependent on the source material so a suitable amount of this setting is a matter of testing. Finally, there is a post-processing filter with settings named as “Love”, “Jive” and “Attitude”. These can be used to add or reduce harshness, for instance. Experimentation should be done with this plug-in to achieve useable results.

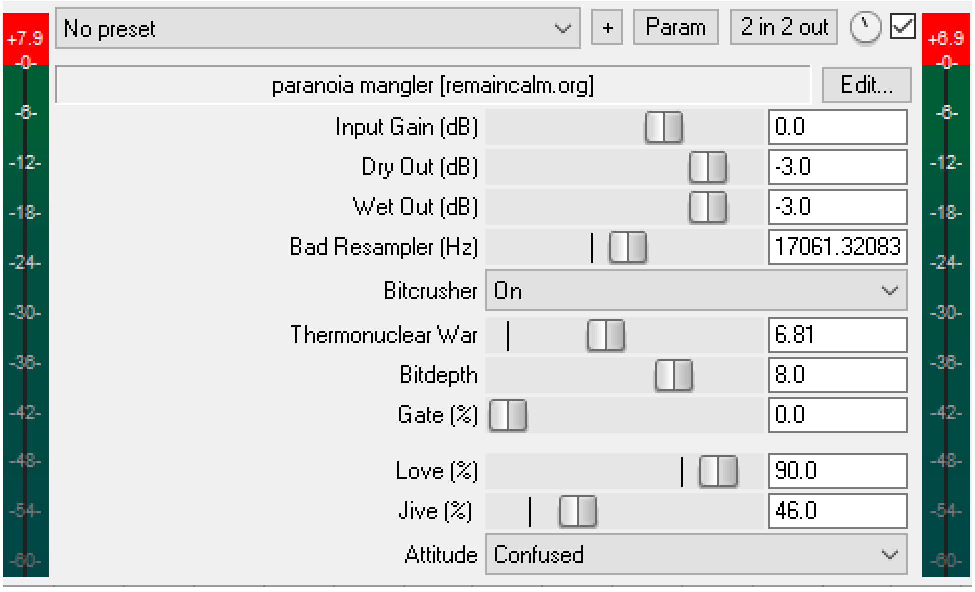

Figure 14. The Paranoia Mangler.

Saturation (Figure 15) is a simple effect which adds harmonic distortion to the sound which is usually felt as a “warm” sound. This effect can increase the “roundness” of the sound which makes it more pleasing to the ear. Harmonic distortion is encountered in magnetic tapes and this plug-in can be used in simulating the “warmth” of compact cassettes for instance.

Figure 15. Saturation effect.

ReaComp is a dynamic range compressor (Figure 16). Compression is used to reduce the volume of a loud sound or amplify quiet sounds thus reducing or compressing an audio signal's dynamic range (Wikipedia 2018e). In this effect chain, compression is used to create transients to the sound and compress it after the transient. Short attack and release times with a somewhat high compression ratio around 5:1 will create a short amplitude spike when a tone begins to play. Transients are essential elements of acoustic instruments' wave envelopes so by adding them the sounds will become more instrument-like which might help in adding pleasantness and rhythmicality to the sound if needed. Compression is not the only technique to add transients though but these techniques are not discussed in this thesis.

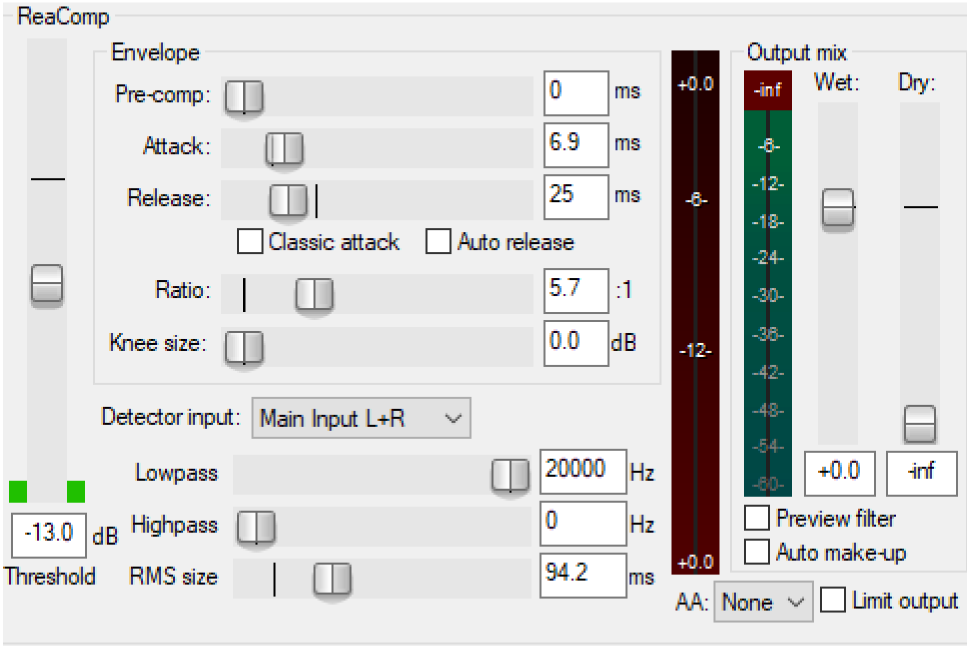

Figure 16. The ReaComp compressor.

ReaEQ (Figure 17) is an equalizer. Equalization is the process of adjusting the balance between frequency components within an electronic signal (Wikipedia 2018f). In the chain, we use equalization to round off the highest frequencies to remove some of the harshness introduced by previous effects in the chain.

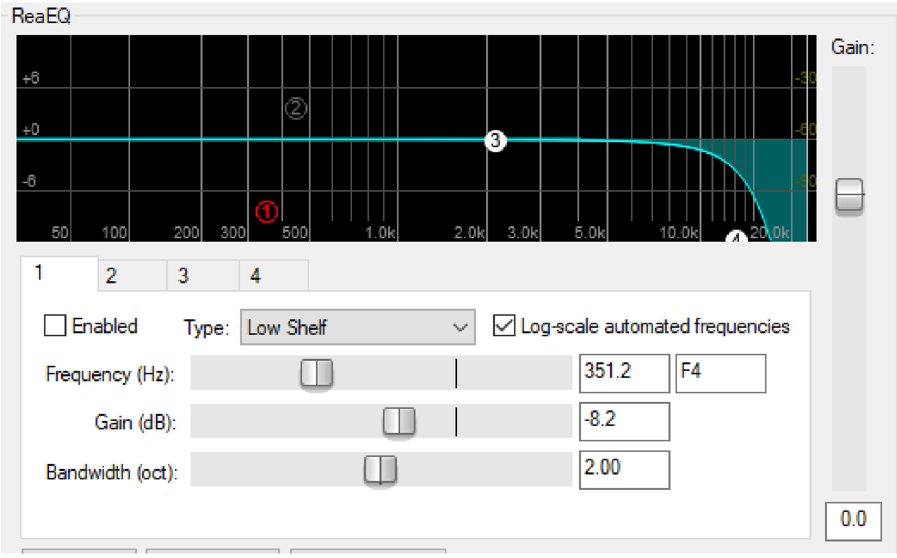

Figure 17. ReaEQ with a low shelf filter to attenuate the highest frequencies in the sound.

Finally and optionally, the Chipcrusher plug-in is used to add DAC elements to the sound. In this example I use the YM3012 preset which does not sound too harsh. YM3012 was a digital-to-analog converter made by Yamaha Corporation which was used, for instance, in several arcade system boards by SEGA and in arcade games of the 1980s.

The wave envelope and the spectrogram of the sound now resemble the reference sound generated with Commodore 64 emulation as shown in Figure 18. The sound is more complex and "musical" than in the reference, as can be seen from the wave envelope and from the frequency spectrum of the sound (Figure 19). This is acceptable since the objective was to create an illusion of a retro device.

This effect chain is best used in creating samples for instruments. Many of the effects are altered by changes in amplitude and for this reason it is better to record clips of the tones in different amplitudes and different wave types separately and create an instrument from the clips in a sampler. The effects should be attuned according to the amplitude and characteristics of the sound.

The order of the effects can be changed. For instance, it produces a different kind of sound, if the waveshaper is placed before the requency subtraction. Experimentation produces the best results.

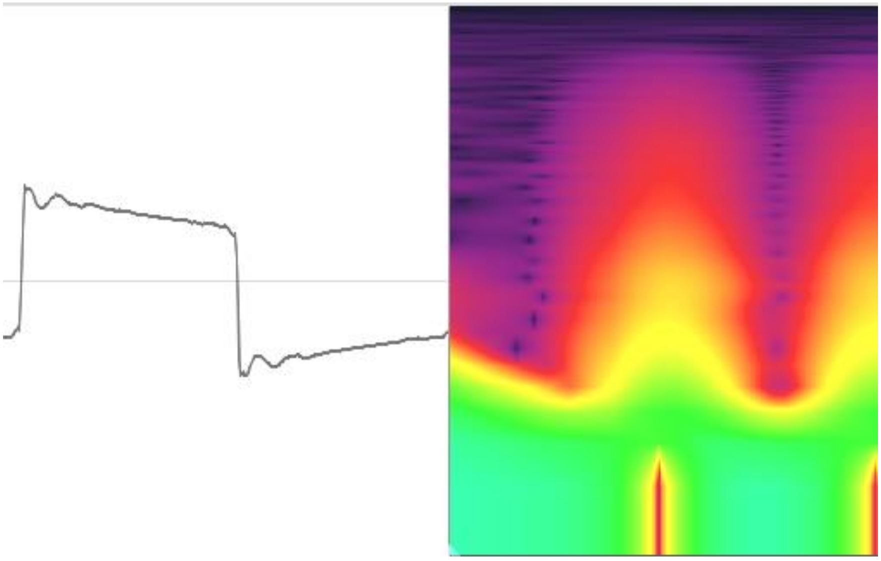

Figure 18. Wave envelope and spectrogram of the sound after being processed by the effect chain.

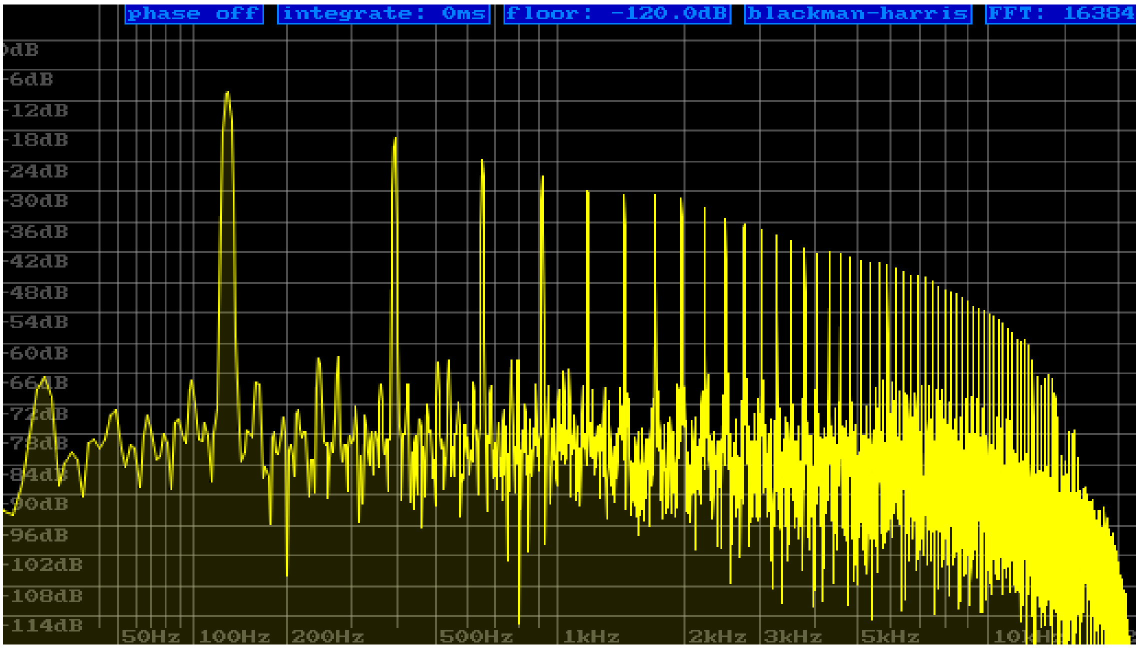

Figure 19. The frequency spectrum for the final sound.

4 SPECTROPAINT SPECTRAL MODELING SYNTHESIS PLUG-IN IN SOUND EFFECT CREATION

4.1 Spectropaint spectral modeling synthesis plug-in in sound effect creation

In this section we will use Spectropaint – Graphical Periodic Spectral Synthesis plug-in to create retro style sounds. Spectropaint is an open source effect included with Reaper.

Spectral modeling synthesis considers sounds as a combination of harmonic content and noise content. Harmonic components are identified based on peaks in the frequency spectrum of the signal, normally as found by the short-time Fourier transform. (Wikipedia 2018g).

Short-time Fourier transform is a Fourier-related transform used to determine the sinusoidal frequency and phase content of local sections of a signal as it changes over time. The changing spectra is plotted as a function of time. (Wikipedia 2018h).

The user can create sounds with Spectropaint by painting frequencies and their amplitudes. Painting can only be done in freehand which hinders the usability of the plug-in. Fortunately, the user can edit the source code of the plug-in which is licensed under the GNU Lesser General Public License (GNU LGPL). Before going to the creation of sound effects, we increase the usability of the plug-in by adding more controllability and features.

4.2 Additional code for improving the usability of Spectropaint

The following code snippets are added to Spectropaint to increase control over painting which then allow the user to design sounds more precisely. First, we will add two sliders to allow the exact control of pressure and brush size.

Pressure affects the amplitude of the painted frequencies. The amplitude is represented as a brown yellow color gradient. Lower amplitudes are shown as shades of brown and higher amplitudes as shades of yellow. Black represents zero amplitude and white represents maximum amplitude. In its original state, Spectropaint adds “volume” every time the user paints on the “canvas”.

In the original version, brush size is changed by clicking the buttons 8 and 9 in the user interface. One click increases or decreases the size by one. This cumbersome procedure is replaced with a slider controller.

```
slider6:0.08<0.001,1,0.001>pressure
slider7:1<1,32,1>brush size
```

Next, we add two variables into the `@init` section. `Add` variable is used as a Boolean (all variables in EEL are double-precision floating point) to indicate whether the user wants the painted amplitudes to add to existing amplitudes in the canvas or to replace them with the value in the pressure slider. `Invert` variable is used to change the sign of the pressure value. This allows the user to decrease the amplitudes by painting, whereas originally only addition was possible.

```
add = 0;
invert = 1;
```

To allow the user to switch between states in the previous variables we use the buttons already present in the user interface but which are not used for anything. This code is placed into the `@block` section.

```
(trigger&(2^1)) ? (add = 1);
(trigger&(2^2)) ? (add = 0);
(trigger&(2^3)) ? (invert = 1);
(trigger&(2^4)) ? (invert = -1);
```

In the `@gfx` section we will do modifications to the existing code. First, we change the code to use the `add` variable. The original code is shown as code comments in the snippets.

```
//g_dir = g_dir? 0.08/brush_size : -0.3;
g_dir = g_dir? (add == 0? pressure : pressure/brush_size ) : -0.3;
```

Next, we modify the code in which the addition of intensities takes place. The `invert` variable is inserted here as well.

```
//loop(brush_size,
//g_vx >= 0 && g_vx< img_w && g_v >= img_buf && g_v < img_buf+img_w*img_h ? (
```

```
//g_tmp = g_v[] + g_dir;
//g_v[]=g_tmp<0?0 : g_tmp>1?1:g_tmp;
//);
loop(brush_size,
          g_vx  >=  0  &&  g_vx<  img_w  &&  g_v  >=  img_buf  &&  g_v  <
img_buf+img_w*img_h ? (
          add == 0?  g_v[]= g_dir :
           ( g_tmp = g_v[] + g_dir * invert;
           g_v[]=g_tmp<0?0 : g_tmp>1?1:g_tmp; );
```

Finally, movement controllability is increased by adding the ability to lock movement on the axes. By holding the ctrl-key pressed down, painting is allowed only on the y-axis. Likewise, by holding the shift-key pressed, painting is allowed only on the x-axis.

```
//g_lx += g_dlx;
//g_ly += g_dly;
mouse_cap&4 ? 0 : g_lx += g_dlx;
mouse_cap&8 ? 0 : g_ly += g_dly;
```

4.3 Examples made with Spectropaint

In this section we will examine three example sound effects created with the improved version of Spectropaint. The examples include vowel sounds, laser beams and computer noise.

4.3.1 Vowel sounds

This example shows how to create a vowel like sound using formants. According to Wood (2005), a formant is a concentration of acoustic energy around a particular frequency in the speech wave. Formants occur at roughly 1000Hz intervals and each formant correspond to a resonance in the vocal tract (Wood 2005).

A frequency spectrum visually represents formants as peaks. Wood (2005) gives two examples. The spectrum on the left show the formants for the voiced vowel [i] and on the right, is the spectrum for the voiceless fricative [s].

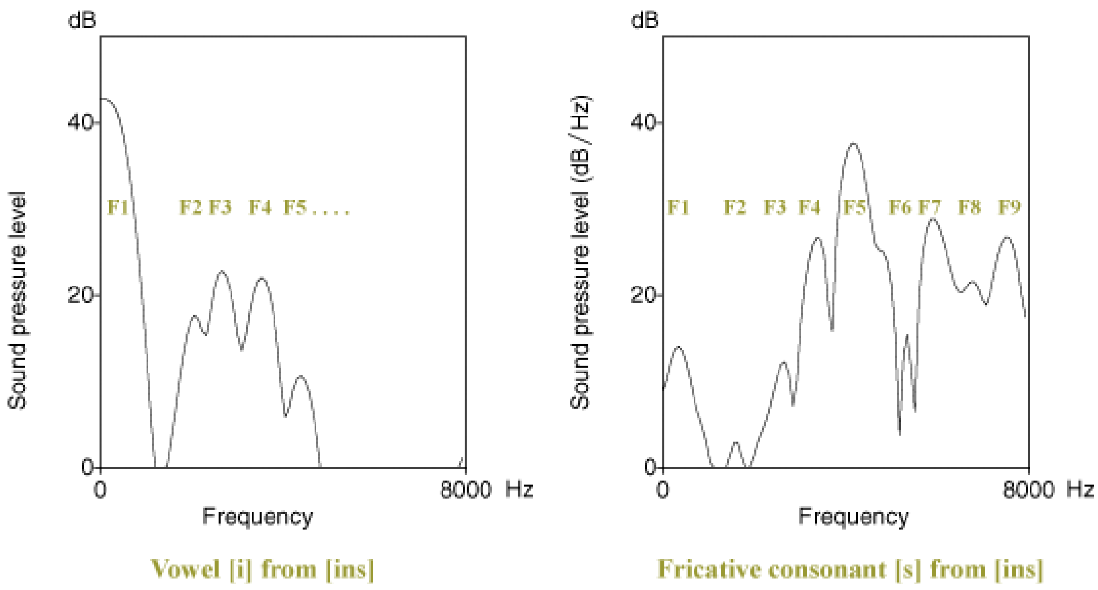

Figure 20. Frequency spectra for [i] and [s] (Wood 2015).

To create a vowel like sound, the painted frequencies must correspond roughly to the formants in a vowel. The “mode” setting must be changed to “fill” since this mode adds harmonic frequencies around the painted frequency. The “sine” setting in “mode” would only add the painted frequencies and nothing else but since formants are peaks in a spectrum, it is appropriate to use “fill” to add realism to the sound. Lower “FFT size” values should be used as well as they create a more voice-like sound.

The painted example is shown in 21. The formants have more energy than other frequencies which are used to add color to the sound. The spectrum is shown in Figure 22 from which the formants can be clearly seen. Additional information for the exact formants for each vowel are available, for example, at Wikipedia (2018i).

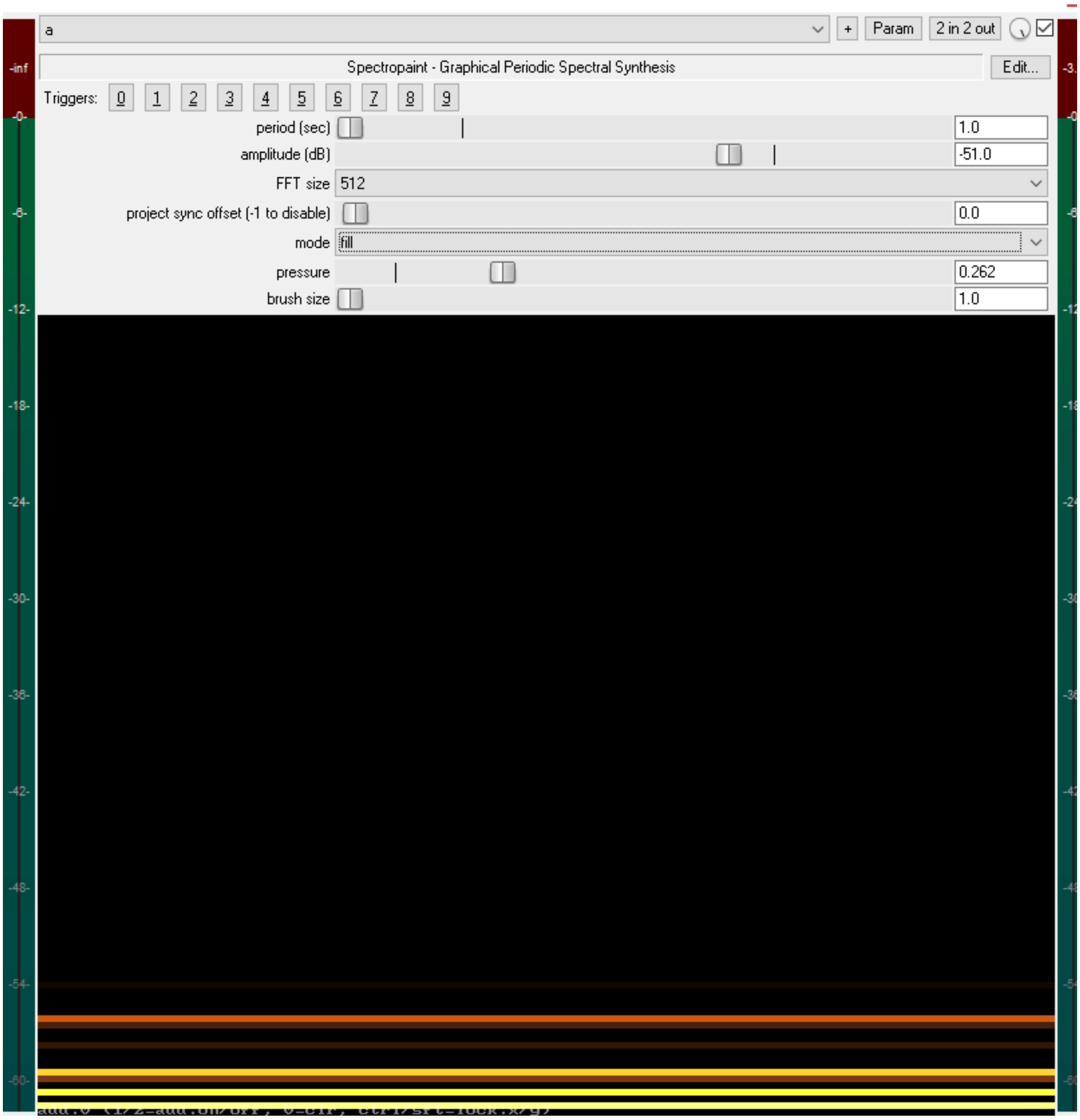

Figure 21. A vowel sound.

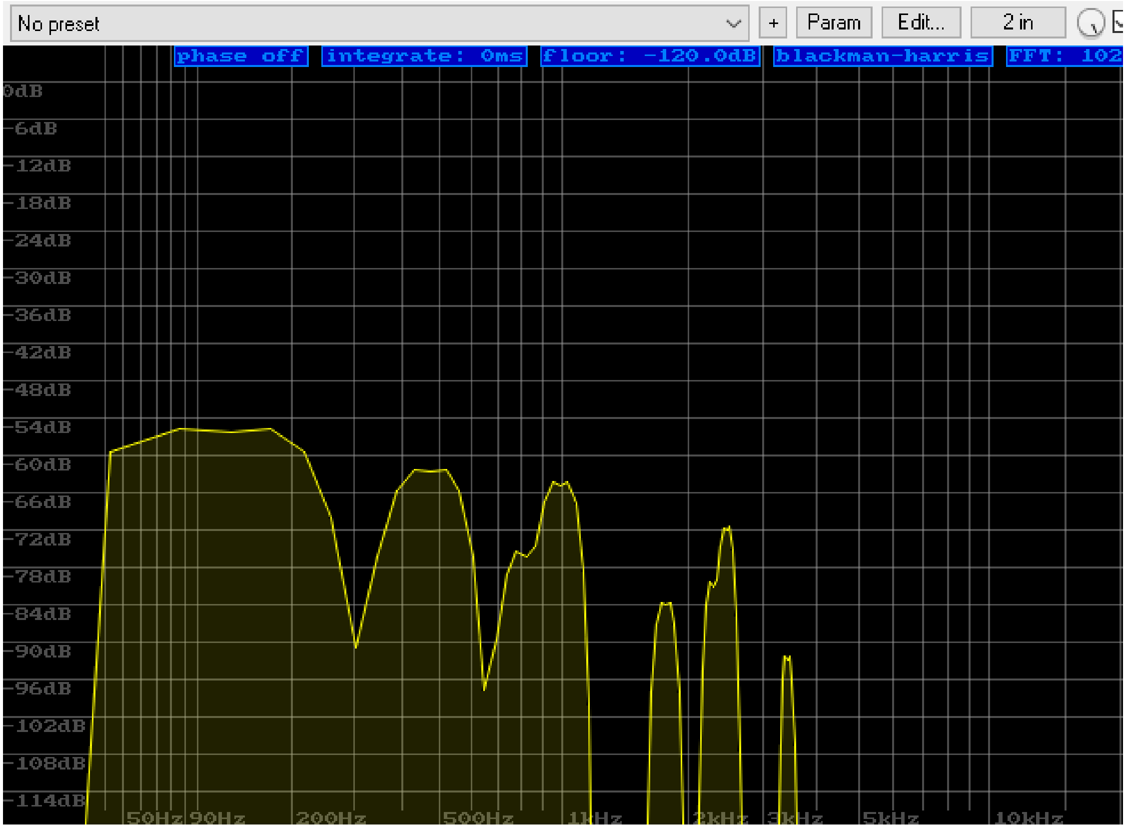

Figure 22. Spectrum of the vowel sound.

4.3.2 “Laser beam” sound effect

For this effect we paint downward sloping lines or curves. The “mode” setting is set to “sine” in this case. Figure 23 shows alternately the spectrograph for a sound with a transient and a sound without it. The sounds with the transient have a snap in the beginning which can be seen from figure 24.

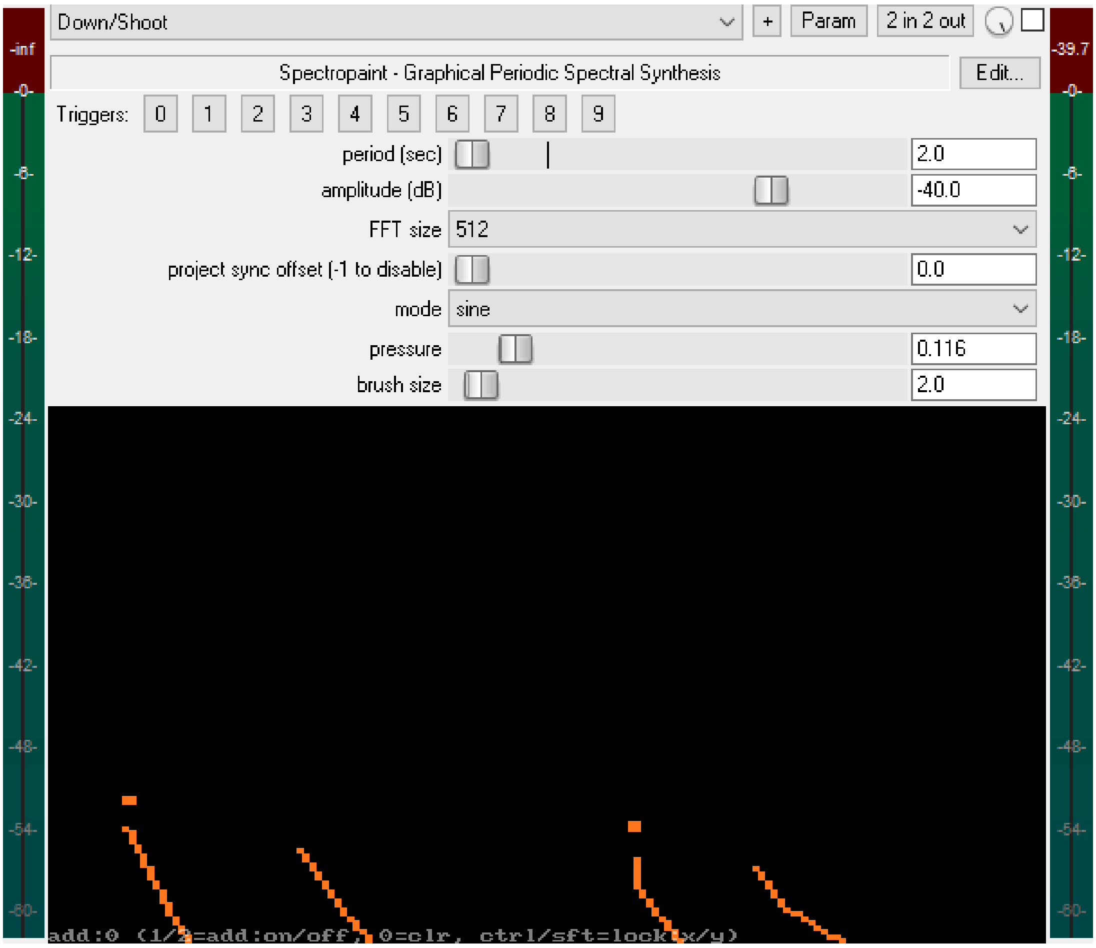

Figure 23. Laser beam effects.

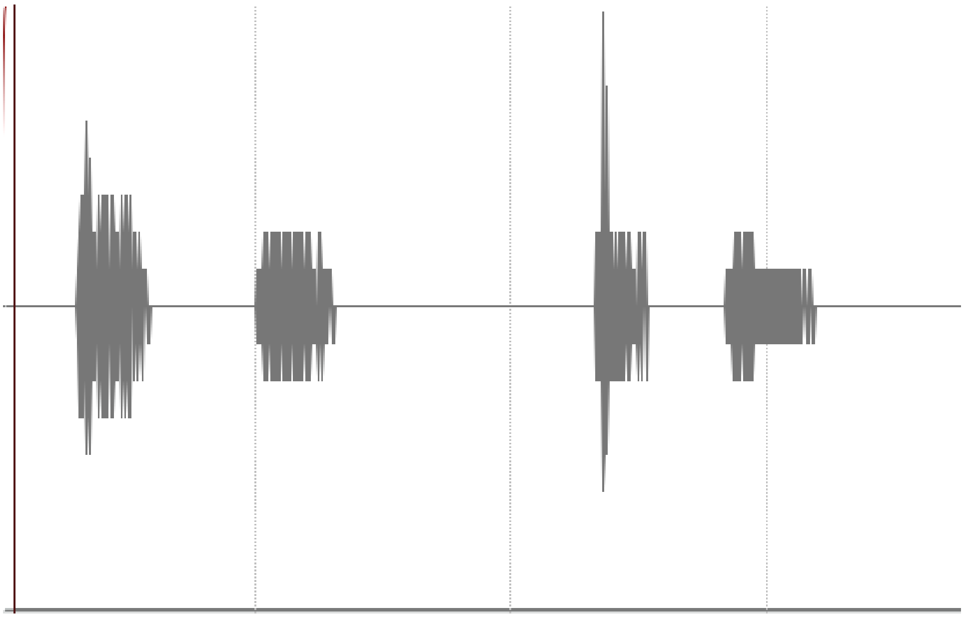

Figure 24. Wave envelopes of the laser beam sounds.

4.3.3 Computer noise sound effect

This sound effect is a stylized imitation of the noises emitted by old computers and disk drives and other such devices. The graph is painted with blocks and dots as shown in 25. The blocks represent different mechanical parts as their activation or deactivation create sudden changes in the spectrum of the sound. The dots with high intensity create a screeching effect.

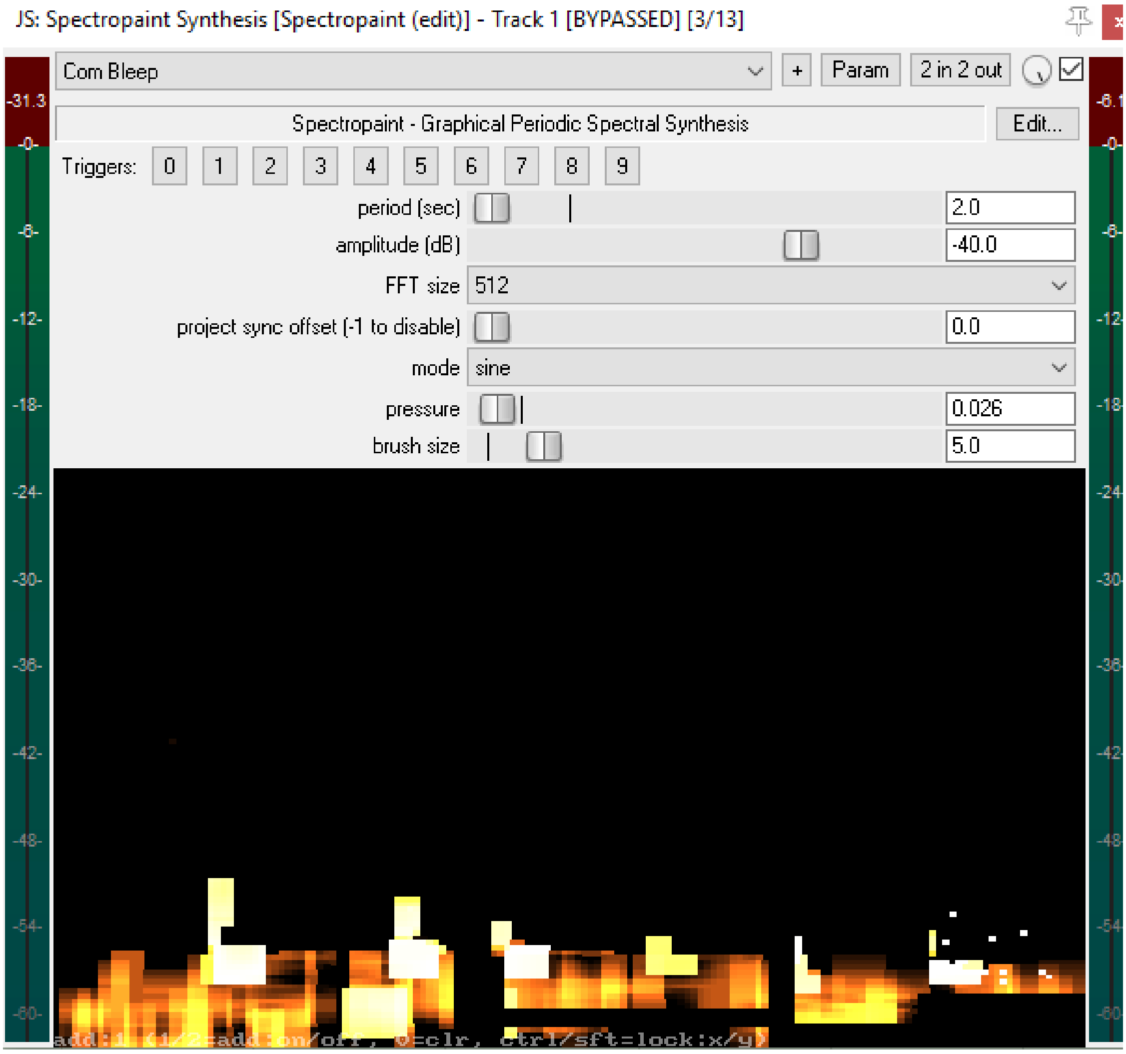

Figure 25. Computer noise sound effect.

This sound is followed by the Chipcrusher plug-in which is used to filter the sound with models of old DACs and computer speakers. For this example, I use the “C64 digi”-preset which distorts the sound heavily and converts it to have a very cheap, retro machine-like feeling. For post-processing I use the “PC2 top of case”-type filter which processes the sound to sound like it was coming from inside a computer. The chipcrusher settings are shown in 26.

Figure 26. Chipcrusher settings for computer noise sound effect.

The effect of post-processing is visualized with spectrograms in Figure 27. On the left the sound is shown without post-processing and on the right with post-processing. It can be seen how the selected post-processing type filters especially low frequencies and retains mid frequencies. In both cases, the resulting sound sounds like there was something horribly wrong with the computer. In this example, there is a lot of variation happening during the length of one sound. For practical use, several different sounds should be made with this technique.

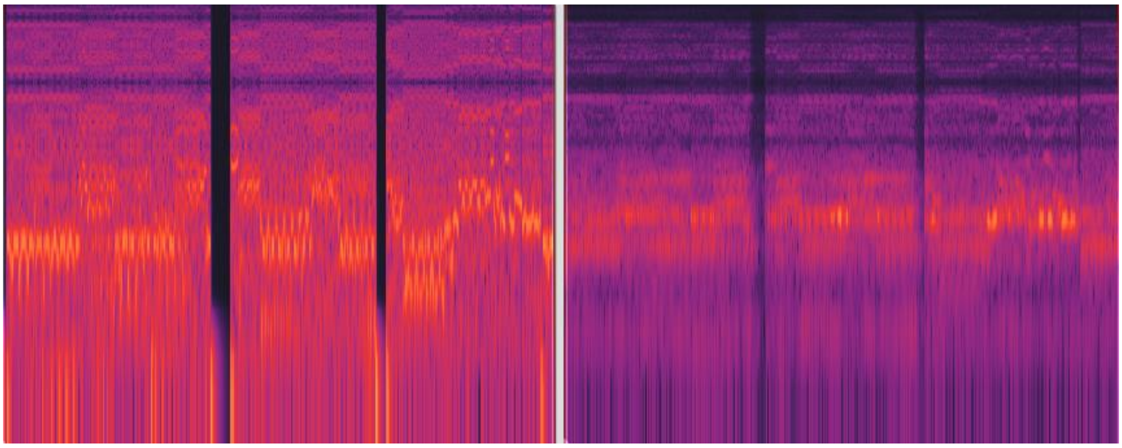

Figure 27. Spectrograms of the computer noise effect.

5 CONCLUSION

In this thesis we have studied retro aesthetics and have created two techniques which allow a designer to create retro sound design. First, we wrote about the differences between restorative and reflective nostalgia and examined these concepts by studying how they are manifested in video games.

Next, we researched two techniques which allow a sound designer to produce retro sounds belonging to the category of reflective nostalgia. The first technique was an effect chain which modified a pure mathematical simple wave into a more useable and retro sounding wave. The second technique used was the graphical spectral modeling synthesis which was used to produce formant like sounds as well as retro sound effects.

As in all aesthetical pursuits, there is no exact criteria for a successful technique. The examined techniques are used to imitate retro sounds in a way described in the thesis as reflective nostalgia. The final verdict concerning the successful “retroness” of a sound design differs from listener to listener. The created example sounds were not tested with a test audience and thus their effectiveness remains unknown. Test sessions would be necessary to improve these techniques although the scope of this thesis does not cover true emulation.

There is no end in researching new production techniques in sound design. Instead of pointing to a technical direction, the author’s recommendation for sound designers or game designers in general would be to think about the theoretical side of aesthetical choices in a more conscious manner. Design always includes aesthetical choices and those choices influence the engineering part of the production. Conscious thought on aesthetics will provide the designer more precise ideas on the actual techniques and technologies he should use or create in producing the targeted result. Engineering is only the practical part in sound design. Aesthetics is the roadmap which guides the engineering process and allows the designer to produce appropriate sound design.

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