Creative Music Production

Professional Project Preparation

Mo Sung Du

What place do Analog Hardware EQs and Compressors have in modern studio environments?

A Creative, Commercial & Technical Comparison

26/04/24

Peter Meighan

Declaration

I hereby certify that the material, which I now submit for assessment on the programmes of study leading to the award of BA(Hons) in Creative Music Production, is entirely my own work and has not been taken from the work of others except to the extent that such work has been cited and acknowledged within the text of my own work. No portion of the work contained in this thesis has been submitted in support of an application for another degree or qualification to this or any other institution.

I have used the IADT library referencing guidelines (available at https://iadt.libguides.com/referencing) and/or the appropriate referencing system recommended in the assignment guidelines and/or programme documentation.

I understand that the IADT regards breaches of academic integrity and plagiarism as grave and serious.

By signing this form or by submitting material for assessment online, I confirm that I have read and understood the IADT Academic Integrity Policy (available at https://iadt.ie/wp-content/uploads/2024/03/Academic-Integrity-Policy-V1-2024.pdf).

Signature of Candidate

26/04/24

Date

Contents

Abstract

Over the past few decades, audio has been rapidly transferring from the analog domain to digital. The digital domain brings with it new technologies and workflows that vastly expand mix engineers' possibilities. Despite this, some engineers still insist on holding onto analog tools for their desired sonic capabilities and creative advantages. With the advancement of software technology, the question remains whether plug-in emulations are at a standard that the trained ear can hear the difference. If not, is there still a need for hardware processors used in modern studios as they downsize, with artists and engineers deciding to mix in reduced studio home setups?

This study aims to investigate these questions through three main subcategories: Technical, Commercial and Creative analysis. The chosen equipment will be put through a series of tests measuring multiple parameters. These results will coincide with results gathered from a blended quantitative and qualitative questionnaire, providing clarity on the subject. Research questions from this questionnaire include: can engineers hear the sonic differences between hardware and software, does affordability factor into engineers' preferred mix method, and are there any creative arguments that can made for mixing in analog?

The conclusion drawn from this study is that the mix of engineers interviewed could not hear the sonic differences between the hardware and software processing units. Valid arguments were made in relation to the creative advantages. However, the affordability of plug-ins outweighed the hardware’s creative advantages, with 100% of participants stating they mainly used plug-ins for mixing. In addition to this, the majority of participants agreed that plug-in workflow is much more efficient. The results concluded that plug-in emulations are at a high enough standard to replace their hardware counterparts sonically, especially in conjunction with their financial advantages.

Introduction

In the modern world, the current shift is stepping into the uncertainty of the era of artificial intelligence. This holds true in the audio world, but before this, the primary crossover in audio was between the analog and digital domains. Nowadays, a studio seldom works solely on an analog system; most will incorporate computers, digital effects, and digital control surfaces, among other digital devices. The birth of Digital Audio Workstations (DAW) has given rise to a generation of innovation; one of the main features of this has been the creation of audio plug-ins (Wilmering 15). Audio plug-ins can be viewed in two ways: firstly, they can be emulations of traditional analog effects such as the 1176 or LA-2A. Secondly, as a fresh conception, creating unique effects that only exist on computer-based systems such as Plug-In Alliance's DS Tantra 2 (Wilmering 16). With such an emphasis on digitally emulating traditional hardware, the question arises whether these plug-ins have reached the standard where they can live up to the qualities of hardware that many engineers desire.

The overall focus of this project is to investigate whether plug-ins are at a level where they can substitute analog hardware for the trained ear. This study aims to unravel what attracts users to analog hardware instead of using their plug-in emulations. This study will contrast the changes in audio signals pre- and post-processing to help better understand the effects of plug-ins and hardware on a signal.

This study will include a series of pre-meditated steps. Firstly, secondary research will be carried out as a literature review, using other studies and various sources to help better understand this topic. Next, recordings of original material will take place to avoid any legal infringements that may arise from using copyrighted music. Recording original material also allows for more control when creating the mixes, permitting a fairer comparison. These mixes will then be presented to professional audio engineers alongside questions using a blended approach. The data gathered from the professional engineers will hopefully shed light on whether they can hear the difference between analog hardware and plug-ins, answering whether there is a need for hardware effects in the modern audio world.

Please note that in the context of this paper, analog hardware relates to the processing units being examined. These include SSL 4000 G Series Channel Compressor, SSL 400 G Series Channel Equaliser, Universal Audio 1176 LN Rev A and Empirical Labs Distressor.

Literature Review

Introduction

Many arguments have been made regarding the debate of analog hardware and virtual emulations; some argue for analog's tonal qualities, while others argue for plug-ins, stating that they are to the same standard (Sage Audio). These arguments are generally subjective, with people providing these statements based on beliefs rather than facts. This project aims to gather data to clarify if professionals can hear the differences that claim to make analog superior. The focus of this section is to carry out secondary research on the topic of study. It is divided into two discussions; the first is an argument for digital audio and effects, summarising how emulations are created and why users and manufacturers are drawn to them. The second section gives evidence for the advantages of analog hardware effects, discussing the technical and general reasoning behind their use. This groundwork provides a clearer understanding of both digital and analog domains. This investigation will ultimately grant a more in-depth study into the field of analog hardware and virtual plug-ins.

Digital Audio/Plug-ins

With the ascent of digital audio, audio plug-ins rose to prominence, gaining popularity with many audio engineers often switching to work primarily in their DAWs. Simply put, digital audio is an audio signal in the digital domain. Digital audio works off a system called pulse code modulation (PCM), which utilises a process called sampling. Sampling measures frequent intervals using a discrete manner to represent the audio signal. Figure 1.1 represents how PCM works, with the x-axis depicting time and the y-axis showing voltage (Watkinson 3).

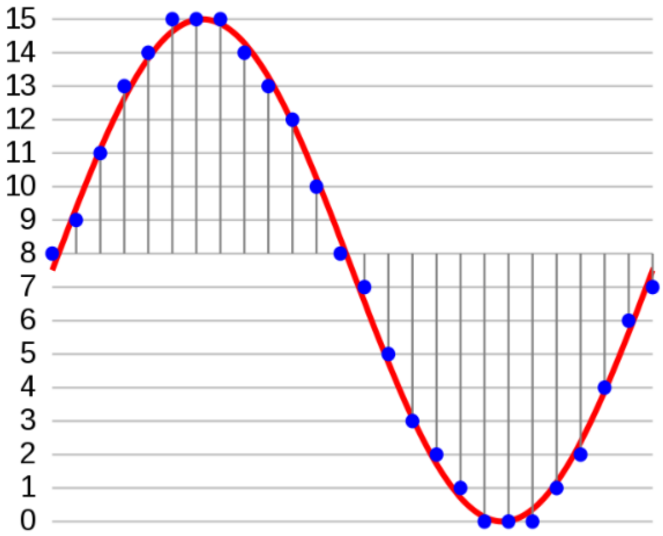


Figure 1.1 *Analog signal (red line) sampled as digital audio using PCM.*

('G.711' (2023, October 21). In Wikipedia. https://en.wikipedia.org/wiki/G.711).

Watkinson (9) states that there are two main reasons to use digital audio:

a) The quality of reproducing a well-engineered digital audio system is independent of the medium. It depends only on the quality of the conversion processes and any compression scheme.

b) The conversion of audio to the digital domain allows tremendous opportunities that were denied to analog signals.

Within the digital domain exists an area of digital effects as hardware and software. Zölzer describes digital audio effects (DAFX) as boxes or software tools that modify an input signal based on sound control parameters, producing an affected output signal (1). Zölzer also mentions that audio effects can be categorised into a list of perceptual attributes:

- Loudness
- Time
- Pitch
- Spatial hearing
- Timbre

Understanding these aspects is vital for the virtual recreation of analog hardware. For example, if one understands that loudness is perceived sound intensity over time, then this can be recreated computationally using time and frequency integration of the energy in critical bands (8). Digital Signal Processing (DSP) engineers use the transfer function (the relationship between the input and outputs) of a device to base their code on (Lambert).

One of the main struggles of creating emulations is when the original hardware contains non-linearities. These non-linearities are reactive, continuously modifying the output signal based on the circuit's internal state, ensuring that each product reacts slightly differently (Zölzer 101). If a sin wave is sent through a linear system, the sin wave will be outputted with a varied amplitude. In contrast, if a sinusoid is sent through a non-linear system, the outputted signal will deliver a sum of sinusoids, i.e. harmonic distortion (Zölzer 102). In order to test hardware containing non-linearities, DSP engineers develop test signals that will expose them; as each model has different characteristics, they must also have separate test signals (Lambert). For this project, this approach will not be viable; a black-box approach will be adopted when comparing plug-ins against hardware.

A third advantage can be mentioned when discussing plug-ins, specifically concerning the benefits of the digital domain. This is affordability. It is evident that plug-in emulations are significantly cheaper than their hardware equivalents. This is down to basic economics; the engineering, support, and office overhead costs are similar in both fields, but when it comes to plug-ins, there are exceptionally few manufacturing costs compared to assembling and maintaining hardware equipment. Plug-in manufacturers can sell an infinite number of specific plug-ins without ordering parts or assembling equipment. This allows them to jump in price ranges erratically. Users often see plug-ins jump from a couple of hundred down to forty/sixty euros. These affordable prices have provided access to users of every level (Inglis).

Analog Hardware

With virtual effects rising in popularity, the question remains whether there will be a place for hardware in the future. It may seem difficult to see why, with the current accessibility and affordability of plug-ins. However, arguments can be made in favour of hardware. Pakarinen (1) states that " there is still room for improvement in sound quality and model adjustability if the virtual analog models are to act as substitutes for the original analog devices." According to Zölzer (5), from the viewpoint of a DSP engineer, analog technology can be categorised in the following chronological order:

- Mechanics/acoustic
- Electromechanics
- Electromagnetics
- Electronics

It is the imperfections and sporadic behaviour of these processes that draw users to hardware technology. Traditionally, analog equipment uses a process called magnetic coupling due to the electromagnetic behaviour of transformers within the products. This process creates harmonic distortions and other non-linearities. Additionally, transformers can reduce transients, 'naturally' balancing audio signals and boosting specific frequencies. In addition to transformers, active gain stages, tubes, and op-amps can add similar characteristics to a signal. Audio engineers are also drawn to the analog domain due to its ability to carry out peak clipping. Good quality analog to digital (A/D) converters will handle clipping with plenty of headroom before undesirable distortion becomes noticeable (Sage Audio). On the contrary, digital systems create digital clipping, which is much more noticeable since it produces unnatural anharmonic distortion through aliasing (Robjohns).

According to Pakarinen (1), when trying to measure and understand the changes hardware makes to an audio signal, there are two main testing methods: the black and white-box. In summary, the black-box method only considers the external behaviour; the DSP engineer attempts to re-create the hardware based on its input and output relationship, ignoring its internal state. On the contrary, white-box testing sets out to replicate the internal operation of the hardware. The linear and time-invariant hardware systems are easily analysed through the magnitude and phase responses, the relationship between the input and output of a signal. In contrast, non-linear and time-variant systems have proven to be much more challenging to measure, e.g. compressors and saturation effects. This must be considered when conducting research, as measuring non-linear systems like compressors will be essential for a fair comparison.

Upon further discussion of this topic, Pakarinen (2) lists various measuring techniques. One method that may be considered to help legitimise this study is the *Sine Analysis* technique. This method involves inserting a sinusoid signal with a fixed frequency and amplitude through an analog or virtual system and analysing the ensuing spectrum. The advantage of this practice is that it is a simple process, and the results are easily interpreted. The one limitation is that it only provides information on how the system reacts at one static sinusoid, ignoring the system's dynamic behaviour. This handicap should not be an issue as the *Sine Analysis* will only be acting as support to the main project.

Sampling Methods

In relation to sampling methods, there are two main avenues: convenience sampling and purposive sampling. The first of these techniques involves using convenient participants for the researcher. These respondents are chosen at random. The limitation of this method is that it is regarded to have a high degree of bias. (W.Edgar and O.Manz). The second of these techniques incorporates a selective group of respondents chosen for their specialised knowledge in the field of research. Purposive sampling is used vastly in qualitative research of information-rich studies. The goals of this method are to reduce variation and simplify analysis (Palinkas et al.).

Conclusion

In summary, arguments can be made for both preferred methods; both have advantages and disadvantages. Evidently, there is a claim that hardware is more sonically desirable, whereas plug-ins have more accessibility and economic advantages. Despite this, it is still unclear whether plug-ins outweigh the need for analog hardware and if professionals can hear the difference in sonic value when blind tested. This section has defined the desirable elements for both themes, providing analytical techniques for testing different effect types, permitting a more accurate re-creation of the analog mix for a less biased comparison.

Methodology

Introduction

As mentioned in previous sections, this research aims to compare analog hardware and their plug-in emulations to unravel whether plug-ins are at a point where they negate the need for analog processors. In the modern age, are there still advantages to using hardware? How much of a factor is the affordability of plug-ins? These questions are more prevalent than ever with the advancements of computers resulting in many highly regarded mix engineers like Richard Furch downsizing and predominantly transferring to in-the-box workflow, yet still opting to hold onto specific pieces of hardware for their sonic qualities. (FreeDawkins).

This research will be carried out in two parts. Part one includes a practical element involving recording and creating identical analog and digital mixes. Each element of these mixes will be analysed in detail using various tools, e.g. frequency analysers. Part two will involve presenting these audio examples to participants alongside a series of qualitative and quantitative questions for analysis.

Project Plan

Firstly, a decision on what effects to compare was made. The studio utilised was Sun Studios in Dublin. Due to studio limitations, the hardware processors chosen were the SSL 4000G Channel EQ, SSL 4000G Series Channel Compressor, 1176 LN Rev A and Empirical Labs Distressor. From research, the 1176 and Distressor are commonplace in Irish studios; studios researched include Cúan Studio, Blackgate Studio, Hellfire Studio and Black Mountain Studio. The compressors in question cover FET and VCA compressors, while the Equaliser in question is a parametric model. In relation to emulations, plug-in manufacturers were chosen on their merit and high regard within the industry, based again on the research of Irish studios. Examples of this research can be seen in Appendix Figures 2.9 and 3.0. Universal Audio emulations were used for the 1176 LN Rev A and Distressor, while Plugin Alliance’s (PA) bx_console version of the SSL 4000 G was used to replicate the SSL audio processors.

As a means to test this equipment, a plan was devised to compare them creatively, commercially and technically. Regarding the audio used to conduct the analysis, a digital and analog full-band mix was compared alongside individual elements of the mix in a blind test. The band used were the five-piece indie rock band Arabú. Recordings were live-tracked over the duration of a twelve-hour recording session in Sun Studios. No audio was processed pre-tape, leaving all processing to post. Instruments tracked included a four-piece drum kit, two electric guitars, bass and vocals. Recordings and analog mix were through an SSL 4000 G Series Console. Please refer to appendix figure 2.8 for microphones used.

Sine Analysis Method

Test signals were sent through these effects to measure their outputs. Test signals included a 10-second 20Hz – 20Khz logarithmic sweep to test for total harmonic distortion (THD) on compressors across the whole frequency spectrum, a single 16-second sinusoid with an abrupt decrease in volume to test compressors' attack and release times. The first of the tests was chosen based on Pakarinen’s (2) discussion on Sine Analysis, while the second method is based on *Analysing Effects* by Eric Tarr. (1). Sine Analysis was carried out for two purposes.

A) To compare the analog and digital equipment to see how the processors altered the audio.
B) To accurately measure attack and release times to ensure that both hardware and software versions of the processors were matching ensuring accurate replication.

Melda’s MultiAnalyser (MMA) was used to measure the change in spectral content, while pro tools meters were used to catalogue the inputting and outputting signal levels. Daw of choice was Pro Tools due to accessibility in Sun Studios and its ability to create test tones using Pro Tool's native plug-in Signal Generator.

Digital Mix

Regarding the digital mix, each track was processed through a PA's bx_console SSL strip emulation followed by the appropriate audio processor. Firstly, the mix was carried out following references provided by the band. Once the mix was complete, the previously mentioned test signals were passed through the plug-ins and printed onto a new track. By printing the track, it was possible to measure the attack and release times of the compressors accurately. This was done for each instrument, and spectral analysis was performed using melda. In addition, the compressor's settings for gain reduction and input levels were also recorded for analog replication.

Analog Mix

In preparation for the analog mix, duplicates of the original tracks were created alongside corresponding SSL return tracks to print the processed signals. The test signals mentioned were passed through the hardware to ensure all effects were working. This ensured that each track outputted the same information as the digital emulation, and settings were adjusted accordingly where needed. In relation to the SSL EQ, the settings were first set identically to the emulations. MMA was used as a real-time analyser (RTA), analysing both curves and dials and adjusting accordingly until both curves were homogenous. The settings were set to the same points as the software equivalents regarding compression. The inputting signal was adjusted using clip gain to ensure the same gain reduction (GR) level was being carried out in both the software and hardware processors. Test signals were then sent through to measure the response recording attack and release time as well as Total Harmonic Distortion. These results would be later utilised to either support or disprove whether participants could hear a difference between the analog and digital files. With these variances between hardware and software documented, it was possible to adjust the analog processors accordingly when carrying out the analog mix ensuring an accurate recreation.

Data Analysis Method

The primary research for this paper was executed using interviews/questionnaires, which took place in Sound Training College's mixing suite, allowing for a non-biased controlled environment. Playback was through a Behringer UMC 1820 and Genelec 1032C stereo pair and a low-frequency emitter (LFE). Participants were provided a Pro Tools session containing individual track stems and a section of the full mix. The test was blind, so subjects were not provided information on whether stems were digital or analog. In an effort to further randomise the test, participants were provided with multiple instruments from which they could choose. The audio files were zoomed out during testing to prevent participants from visually analysing the waveforms.

A questionnaire was provided alongside the Pro Tools session containing questions in relation to the creative, technical, and commercial advantages and disadvantages. This questionnaire aims to answer the following research question:

- Can engineers hear the difference in total harmonic distortion?

- Do the hardware processors in question hold any creative value over their digital counterparts?

- How much does affordability affect engineers' decisions on what tools they use?

- Are plug-ins at a standard that negate the requirement of their analog equivalent?

The interview results were used in conjunction with the technical analysis to clarify these research questions.

The questions were designed using a blended approach using both qualitative and quantitative methods since the results were to be based on subjectiveness regarding certain areas and defined variables for others. A qualitative approach is best when the "reality cannot be measured – it exists as perceived by people and by the observer " (Cleland). The quantitative approach measures identified variables, i.e. harmonic saturation (Niada).

As mentioned, participants were provided with multiple tracks of separate instruments to diversify the selection and further randomise the testing, preventing bias due to only one instrument being tested. In addition, participants were requested to repeat the same questions regarding a full mix with all elements. This provided a comparison in the context of a completed mix.

Sampling Techniques

Because this field of study is extremely specialised, participants were selected based on their ability to hear and understand the terminology being used. As a result, a small selective sample size was used based on their knowledge and skillset to help legitimise the results. This sampling method is known as Purposive Sampling (Palinkas et al.) Participants included professional studio and live mix engineers and final-year audio engineering students. The student population of participants was selected based on their high academic performance and previous work.

Conclusion

The main goal of this project is to investigate whether analog hardware processors are still necessary for modern studio environments. The questions that stem from this title include: can audio engineers hear the difference between hardware processors and their software counterparts? Is financial difference a factor in their decisions? Does faster workflow with plug-ins play a part? If any, what advantages are there to using hardware? Are plug-ins at a standard to negate the need for hardware units?

Analysis

Introduction

As mentioned, this research aims to investigate whether there is still any need to use hardware analog effects in modern studio environments. The project examines and compares the main areas in relation to this question: technical, creative, and commercial. The technical analysis consists of audio test data in conjunction with participant data. The creative and commercial data is based on a qualitative method, which will be discussed in more detail in the discussion section of this paper.

In reference to the literature review, Pakarinen (1) claims that plug-ins have not yet reached a level sonically where they can replace the original hardware. However, this paper was written in 2010, and with the advancement of technology, this statement may not hold true. These results will reveal the current state of this field of study. In addition to this, the sonic qualities are not the only reason for audio engineers' preferred methods; affordability and creative functionality affect these decisions heavily. This chapter investigates and presents the results found based on these three main themes.

Demographic

As this is a niche area of study, subjects have been selected on specific requirements. Participants were required to be knowledgeable in this field. As a result, all participants were either professional audio engineers or in their final year of studying audio engineering. All participants were required to have operated in studio environments and have used analog hardware effects and software plug-ins. All candidates were selected for their proximity to Dublin City so that they could attend the interviews in person at Sound Training College, Dublin, which ensured a controlled, non-biased listening environment. The ages of participants ranged from 20-40 years old and included mixed genders.

Technical Results

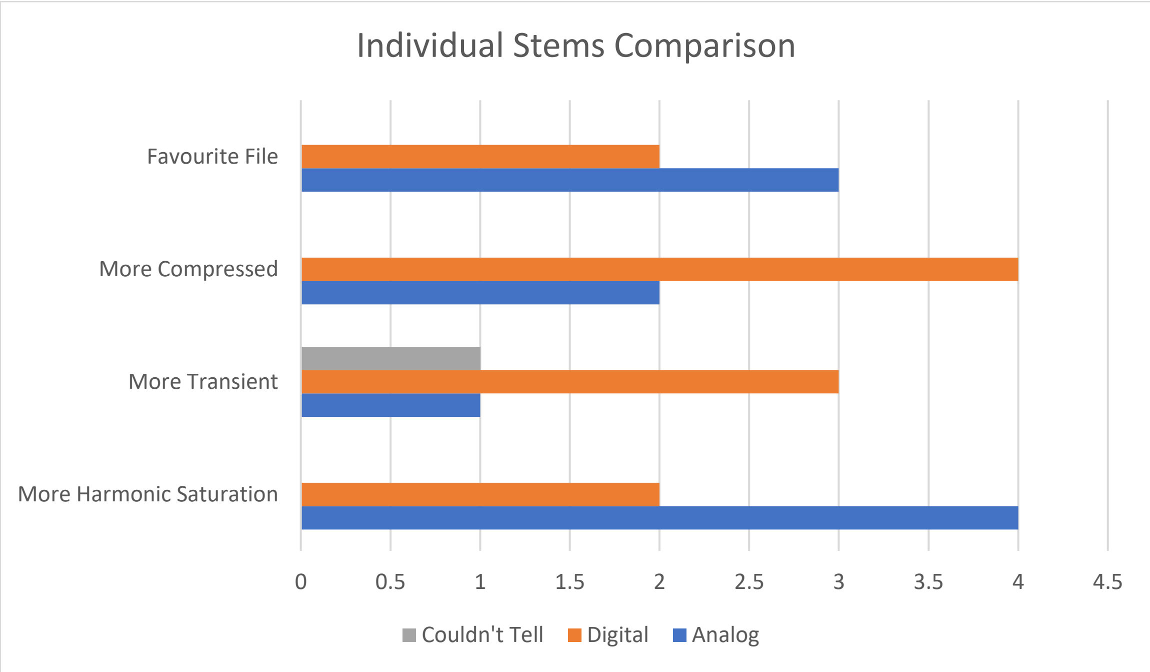


Figure 1.2 *Individual Stem Comparison*

Bass

Sine Analysis: Attack times for digital and analog 1176 LN compressors range from 700 - 800µs. Release times are also at 500 – 600ms. Please refer to Appendix Figure 1.1. Analog compressor adds a lower harmonic at 100Hz and an upper harmonic at 2057kHz. Both harmonics range between -55db to -45dB. Refer to appendix figure 1.2.

Spectral Analysis: Both graphs are identical, with no more than a 1-2 dB difference at 40Hz and 1-2kHz. Refer to appendix figure 1.3.

Violin

Sine Analysis: Regarding the 1kHz tone test, the SSL Channel Compressor attack times, both software and hardware compressors match at 1ms, and the release times also match at .3 - .4ms. Please refer to Appendix Figure 1.4. Upper second harmonic present from 100Hz – 200Hz during sweep test. Please refer to Appendix Figure 1.5. Attack time for both analog and software Distressors is between 1-2ms. Release times also match at around .8-1s. Please refer to Appendix Figure 1.6. A Second Order Harmonic is visible at 2Khz on the analog signal but not the digital one. Please refer to appendix figure 1.7. Analog signal also let through a much larger transient. Sweep test on the Distressor shows Second Order Harmonic Distortion (SOHD) and Third Order Harmonic Distortion (TOHD) until 200Hz on the digital signal, peaking at -30dB. The analog signal then shows SOHD from 2-17kHz, peaking at -35dB. Please refer to appendix figures 1.8 and 1.9.

Spectral Analysis: Curves from SSL Channel EQs match accurately, with a few exceptions. A 2dB increase at 400Hz, 500Hz and 850Hz in relation to the analog signal and inaudible frequency content not removed by the filter affecting the range of 20 – 35Hz. Please refer to Appendix Figure 2.0.

Guitar 2

Sine Analysis: For the single 1kHz sinusoid test, the analog and digital signal on the Distressor's read at 2ms. Both release times are at 2ms. Please refer to appendix figure 2.1. SOHD occurs a 2Khz at the same -42dB on both signals. Please refer to appendix figure 2.2. Regarding the sweep test, a decreasing second and third order harmonic is present until 500Hz; after that, only the second order harmonic remains. This SOHD has a gradual increase in volume from 1kHz onwards. The analog signals' Second Order Harmonic averages 2/3dB above the plug-in version while the fundamentals remain at the same level.

Spectral Analysis: As shown in appendix figure 2.3, the SSL Channel EQ curves accurately match with minimal disparity. The only divergences are from 70 Hz, which is below -40dB, and between 8 – 20kHz, again under -40 dB.

Vocals

Sine Analysis: As shown in Appendix Figure 2.4 1kHz test, release times for both signals are in the range of .8 – 1 second. Both have similar attack times of 20μs. SOHD 2kHz tone at -40dB is only present on the analog signal; no additional harmonics are present in the plug-in version. Please refer to Appendix Figure 2.5. Regarding the sweep test, no additional harmonics were found in the software version; on the contrary, a Second Order Harmonic is present across the whole spectrum, and a lower 100Hz harmonic emerges when the signal reaches 5 – 20kHz. Please refer to Appendix Figure 2.6.

Spectral Analysis: As shown in Appendix Figure 2.7, the SSL Channel EQ curves conform to the same contour shape with a few exceptions. 100Hz tone is present in the analog signal, which is most likely due to a default in the 1176 LN compressor. Any other deviations average a 1/2dB differential.

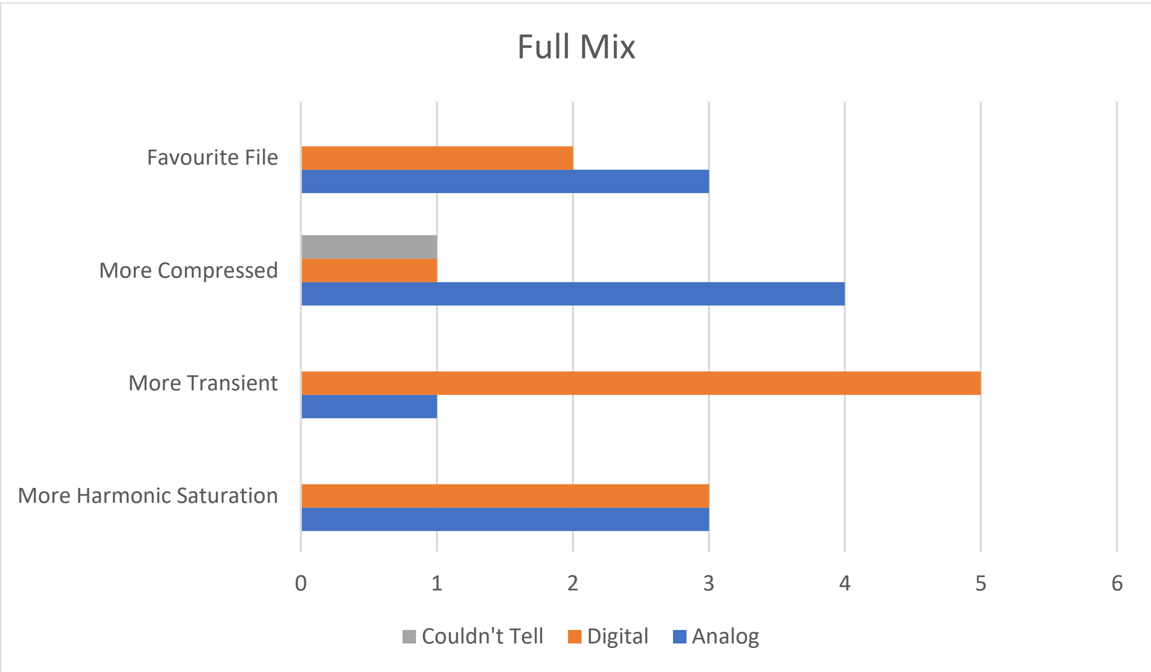


Figure 1.3 *Full Mix Comparison*

General Result

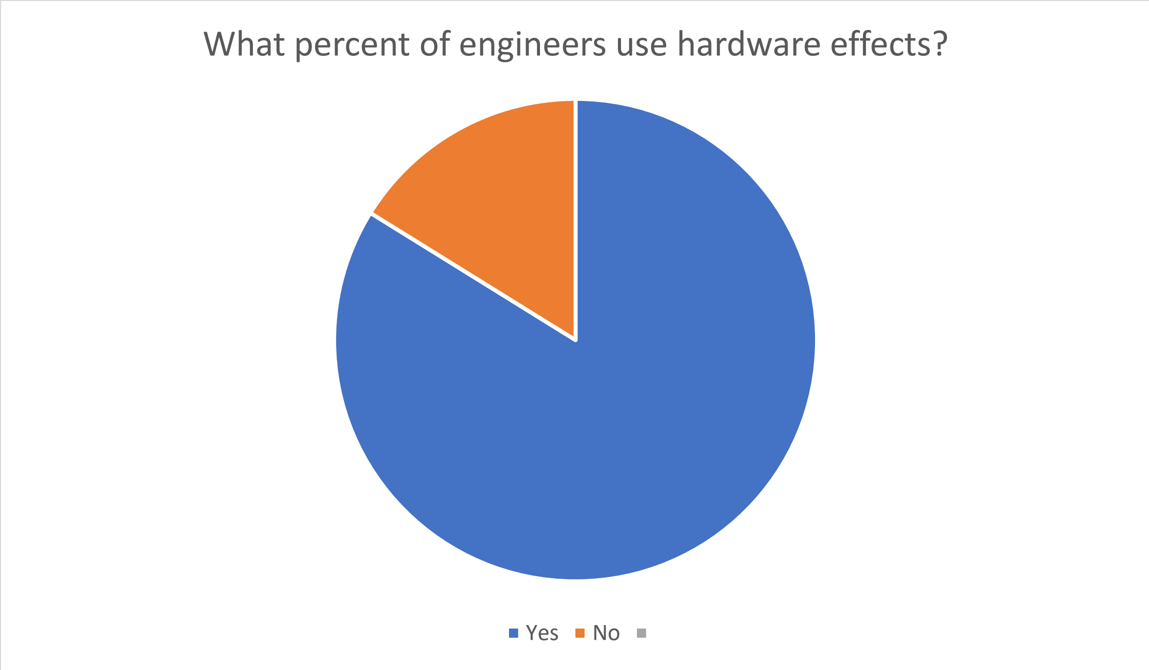


Figure 1.4 *Percentage of Engineers That Use Hardware*

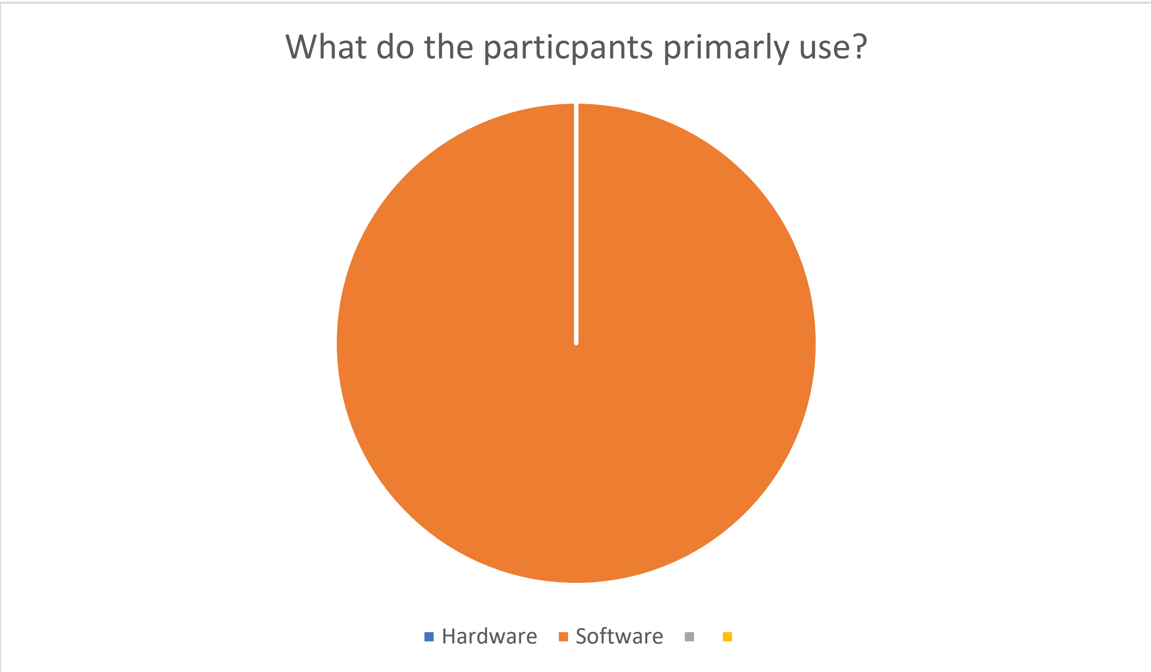


Figure 1.5 *Do Engineers Predominantly Use Hardware or Software?*

Creative Results

Five out of six engineers state that they prefer using hardware over plug-ins. They claim that a physical connection helps psychologically, connecting their ears to what they are mixing. They also declare that hardware's tactile functionality yields better and faster results. All engineers believe that hardware forces them to trust their ears more and that hardware has fewer options, causing users to get more out of less. One participant stated that plug-ins that offer RTAs are great for learning how to use the tool, but that leads to engineers mixing based on what they see rather than hear.

Despite these arguments in favour of hardware use, every engineer agrees that plug-in speed and practicality play a significant role in their decision to use plug-ins. They find that they can finish a mix faster with software plug-ins. One engineer said they use plug-ins in the early stages and then run through the hardware equivalents when ready to print. Another argument for plug-ins was the ability to have multiple instances of the same unit affecting the track.

When asked whether they prefer to run EQ and compression pre or post-tape when tracking, the majority said they prefer to run post-tape. Which means they can do most of their processing with plug-ins in post.

Commercial Results

When asked whether plug-in prices factored into their decisions to use plug-ins, 66% of participants said yes, stating they use discounts and sales. All subjects admit to plug-in discount sales encouraging their purchasing decisions, with half of the participants declaring that they try only to buy during these sales. Despite this, only 33% of engineers say plug-in bundles influence their purchasing choices, while the remainder purchase individual plug-ins. In relation to hardware investments, 100% of participants stated that they would be inclined to purchase hardware if pricing was not an issue. Last year, only 50% of participants purchased hardware, whereas 83% of participants purchased plug-ins.

Additional Comments

The statements below were optional additional subjective comments stated by the participants:

- "*The consumer will not know the difference. Producers get pedantic about this stuff. I feel hardware is a luxury but not a necessity; while I do feel there can be a difference, I do not think it is worth it. And it's the way the world is moving…towards in-the-box mixing.*"

- *"I think in the grand scheme of things, the general consumer cannot tell the difference on whether hardware or software was used. It is very much an audiophile debate."*

- *"I think hardware will always have a place in the audio industry. While it can certainly be replicated in plugins, I think there is an innate quality to analog hardware that will always be desired by engineers and producers. The hybrid format has been adopted by everyone and I don't see a massive change in that occurring any time soon."*

Discussion

Introduction

This section will analyse and interpret the findings gathered from the technical analysis and research interviews. The main question under scrutiny is what place analog hardware processors have in modern studio environments. This question will be answered under the technical, commercial, and creative subcategories. These headings aim to provide a clear, non-biased argument for analog and software from which a conclusion to this question can be drawn.

Technical

As mentioned by Sage Audio in the literature review, mix engineers are drawn toward analog hardware for their tonal qualities and the non-linearities they add to audio. From the results shown, it is evident that additional harmonic distortion was added to specific signals; these extra harmonics were predominately seen within the hardware signals, reinforcing Sage Audio's statements. Most of these harmonics were below -40dB, which raises the question of whether this saturation is audible to the human ear. As shown in Figure 1.2, 66% of participants perceived the analog hardware example to contain more harmonic saturation. Figure 1.3 relates to the results gathered from the full mix; 50% of participants claimed that the hardware mix sounded more saturated. These percentages are sufficient enough to claim that participants could hear the harmonic saturation.

Despite these claims, when asked to describe what they were hearing, participants stated characteristics that were not true. For example, they described the guitar as "analog has less low midrange, and digital has more upper harmonics" in accordance with Appendix Figure 2.3; this statement is false; the spectral content is identical. A similar statement can be said for the bass files; participants state, "The hardware file seems to sound a little chunkier than B", as shown in Appendix Figure 1.3; this statement is also inaccurate.

Could participants really hear the differences in the audio files? Based on the statistics collected, it is evident that participants could not hear the difference based on the specific parameters investigated. However, when asked which file they preferred, most participants chose the hardware mixes. This shows that listeners may be inherently drawn towards the effects of analog hardware. The analog hardware was predominantly shown to have more harmonic saturation added to the signal, which can be seen on the Melda MultiAnalyzer in the screenshots provided in the Appendix. However, there was not overwhelming support for the analogue stems; from this, it can be drawn that participants could not clearly hear the difference between the hardware and their software counterparts, meaning plug-ins are produced to a standard where there is no definite audible difference.

Creative/Commercial

From the creative and commercial analysis, the consensus is that participants use plug-ins out of practicality more so than out of desire. 100% of the participants claim that they prefer to mix with hardware. They state that hardware's physical touch and tactile functionality produce better results. In addition, all participants declare that hardware units compel engineers to listen more with their ears, ultimately resulting in better mixes. Whereas, software plug-ins can lead to more visual mixing, causing engineers to rely on analysers. They also state that analog effects tend to have fewer options, which forces users to focus on what they can get out of the processor rather than switching from plug-in to plug-in. They also mentioned that workflow with analog processors is a healthier way to mix as it forces engineers to print tracks in contrast to the digital age of infinite options.

Despite these advantages of using hardware processors when mixing, 80% of participants use plug-ins for the majority of their mixing. This is due to the practicality of plug-ins. Reasons provided include the software's ability to load multiple instances of the same unit, faster way to carry out specific processes, and the ability to use presets, as well as user presets. Another major factor is plug-in affordability. One benefit of plug-ins is the ability to buy plug-ins at substantial discounts. As Inglis *(Sound on Sound*) mentions that plug-ins are able to sell for such prices due to their low manufacturing/upkeep costs and the ability to sell an infinite number of the same product. It is evident that these lower prices directly affect their decisions, with 100% of participants stating that plug-in discounts influence their purchasing decisions. In addition to this, 100% of engineers said that they would use more hardware if pricing were not an issue; due to production costs, hardware affect prices will remain where they are, creating a strong argument in favour of plug-in use.

Conclusion

As Pakarinen (1) mentioned in 2010, "There is still room for improvement in sound quality and model adjustability if virtual analogue models are to act as substitutes for the original analogue device". From the blended qualitative and quantitative technical analysis, it is evident that the participants could not confidently hear the difference between the hardware and software versions. This supports the idea that modern plug-ins are at a standard that accurately emulates their hardware counterparts, showing that the quality of plug-ins has significantly progressed since 2010.

From the results gathered, it is evident that the affordability of plug-ins is a significant factor regarding plug-in use. The price difference between hardware and software emulations is significant, especially with plug-in manufacturer's constant sales. Users can get the software version for a fraction of the hardware price. For example, from research, analog 1176 LN Rev A is roughly €2,500 while UAD 1176 Classic Limiter Collection on sale is €42.00. Please refer to Appendix Figures 3.1/3.2. These price differences provide a strong argument in favour of the use of plug-ins over hardware, especially with the high closure of recording studios (Skinner). Financially, it does not make sense for engineers to buy hardware when the software versions are accurately reproduced for a fraction of the price.

From the creative results, it is clear that engineers would mix with hardware processors in the ideal environment with unlimited time and resources. However, more often than not, engineers are under strict time and financial limits, with labels and bands trying to record for the lowest cost possible. This is where plug-ins outweigh hardware; the speed of plug-in workflow allows engineers to finish projects in a much shorter time frame, allowing them to take on more projects and increase their income. As well as this plug-in portability allows engineers to mix on the go wherever they are.

Limitations

Due to uncontrollable variables, limitations arose during this process. Please find a list of limitations below:

1) Due to availability, multiple participants had to withdraw from the study; many of these participants were professional senior live and studio mix engineers, and their input would have significantly helped support these results.

2) Due to the studio in use and available software emulations, the number of audio processors was limited. Further investigation into more effects would have helped diversify this study.

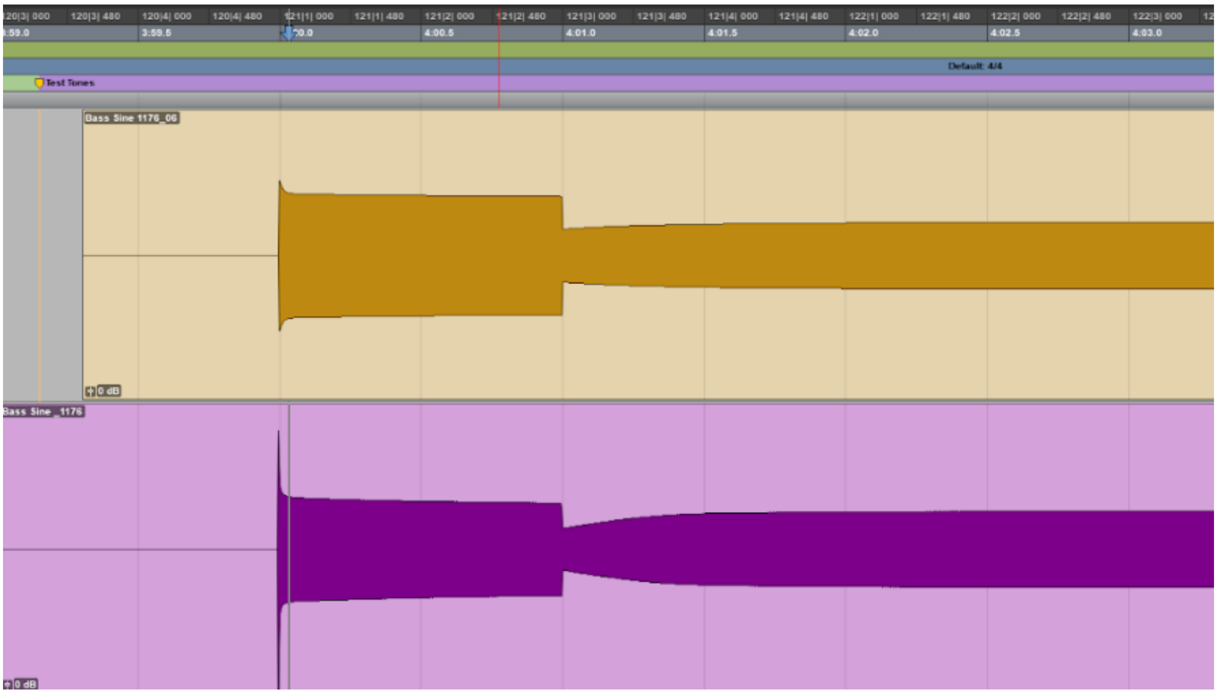
3) Due to a lack of financial support, the commercial section of the study was affected. Statistic studies on plug-in sales were impossible as access to these analytics was in the price range of €3000.

Conclusion

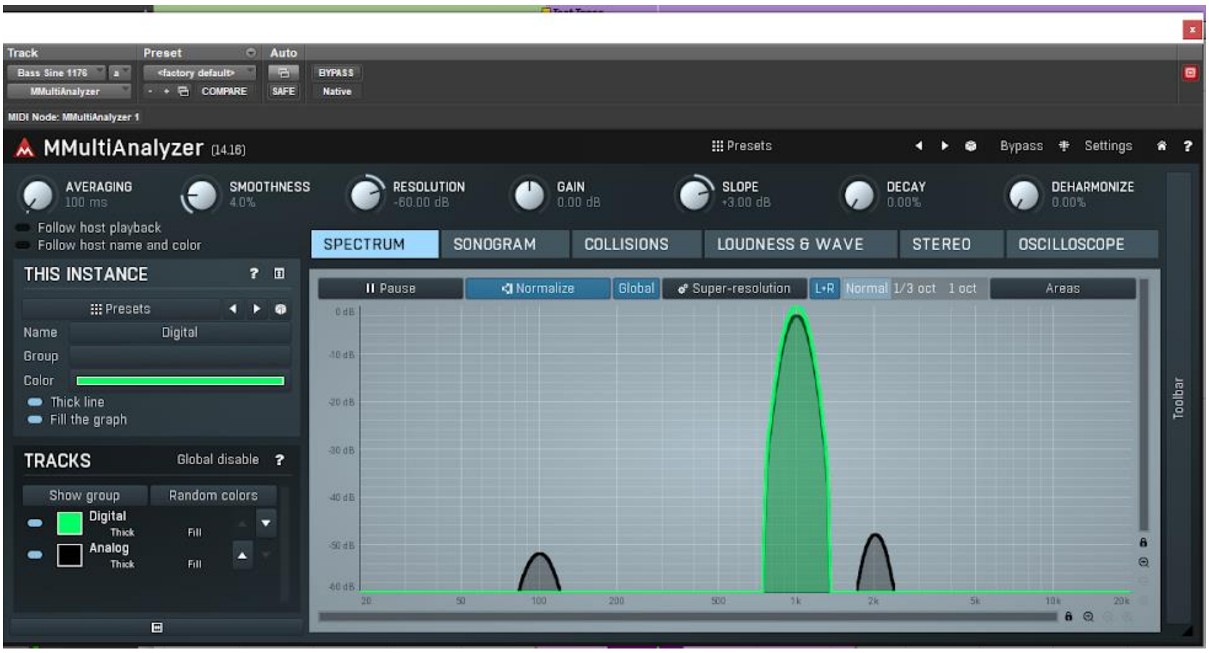
In summary, it is evident that plug-ins hold a notable advantage, especially for beginner and intermediate engineers, as they allow users to access the majority of pieces of hardware through their emulation. Hardware is a luxury that is great to have, but in practical everyday use, plug-ins make more sense. They do not require additional hardware or routing and are easily transported from place to place, studio to studio. From the technical analysis, the sonic differences were slightly audible to the trained ear, but these differences will go unnoticed by the untrained ear.

The decision on what to use depends on the individual's preference and style, but overall results favour software plug-ins over their hardware equivalents. The top engineers in the world have the accessibility and freedom to use whatever they wish. However, for everyday engineers working in average studios, plug-ins carry out the majority of the workload, helping smaller engineers mix records to a professional standard at an adequate pace.

Appendix

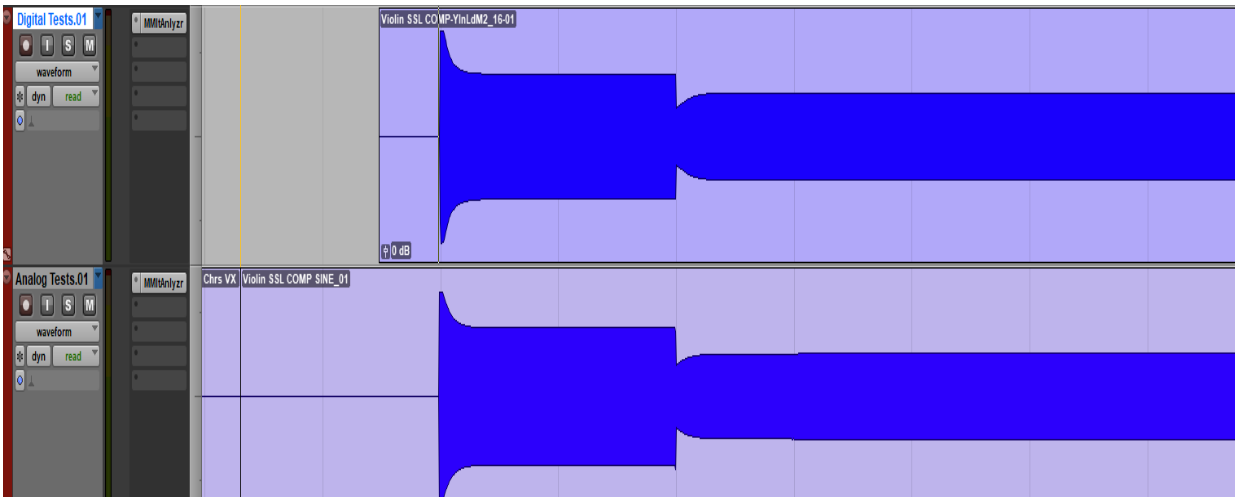


Appendix Figure 1.1 *Bass 1176 Sine Analysis Attack & Release*



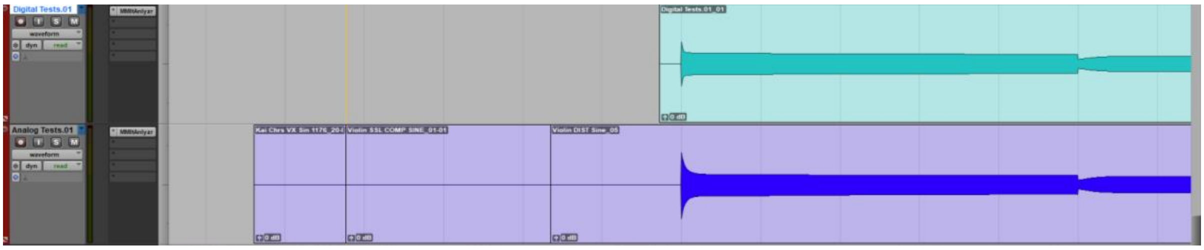
Appendix Figure 1.2 *Bass 1176 Total Harmonic Distortion*

Appendix Figure 1.3 *Bass SSL Channel EQ Comparison*

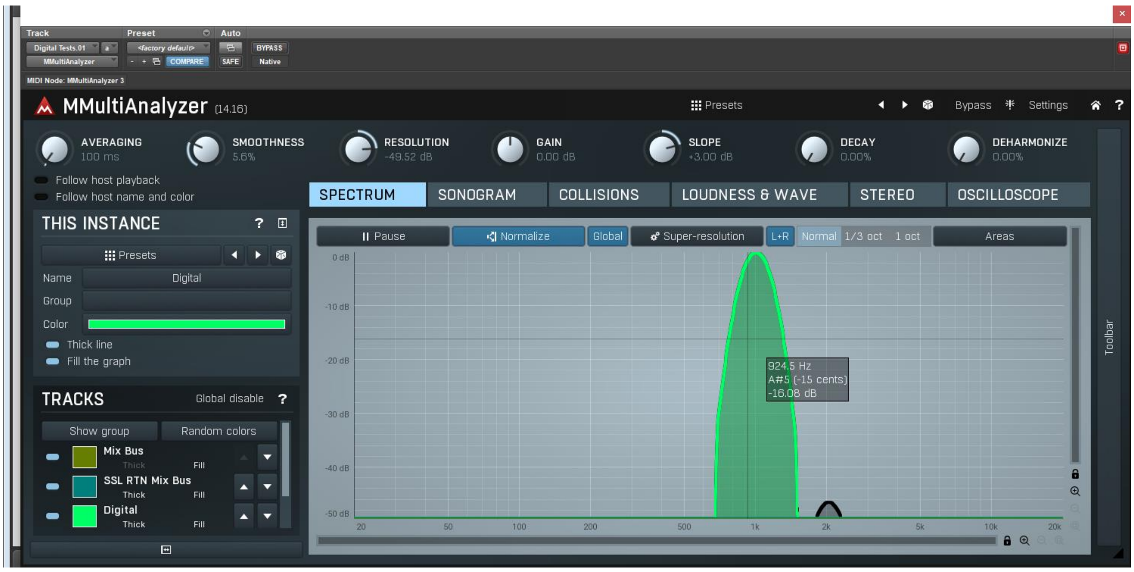


Appendix Figure 1.4 *Violin SSL Channel Compressor Attack and Release*

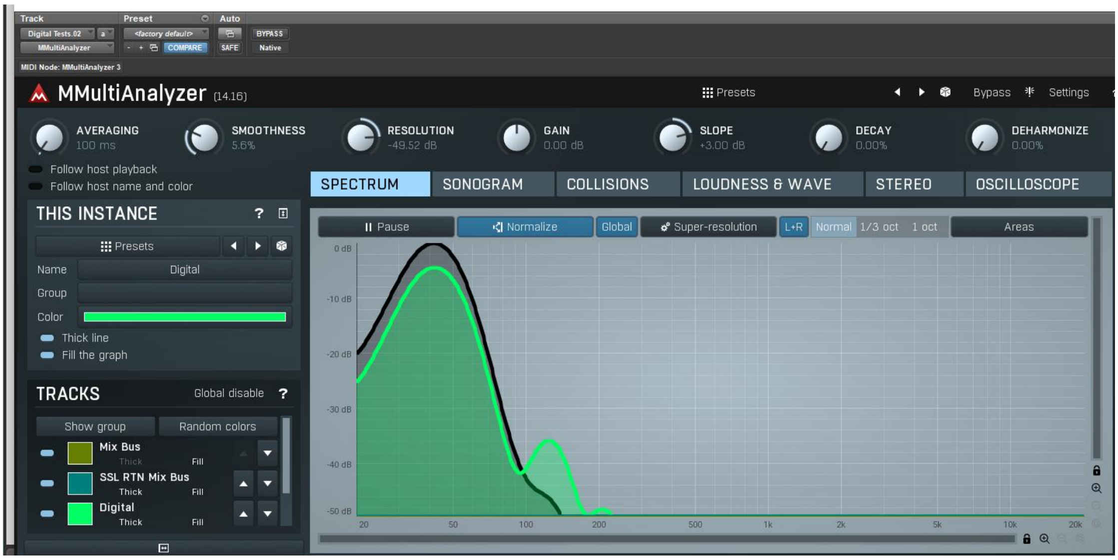
Appendix Figure 1.5 Violin SSL Channel Compressor 100-200Hz Second Harmonic



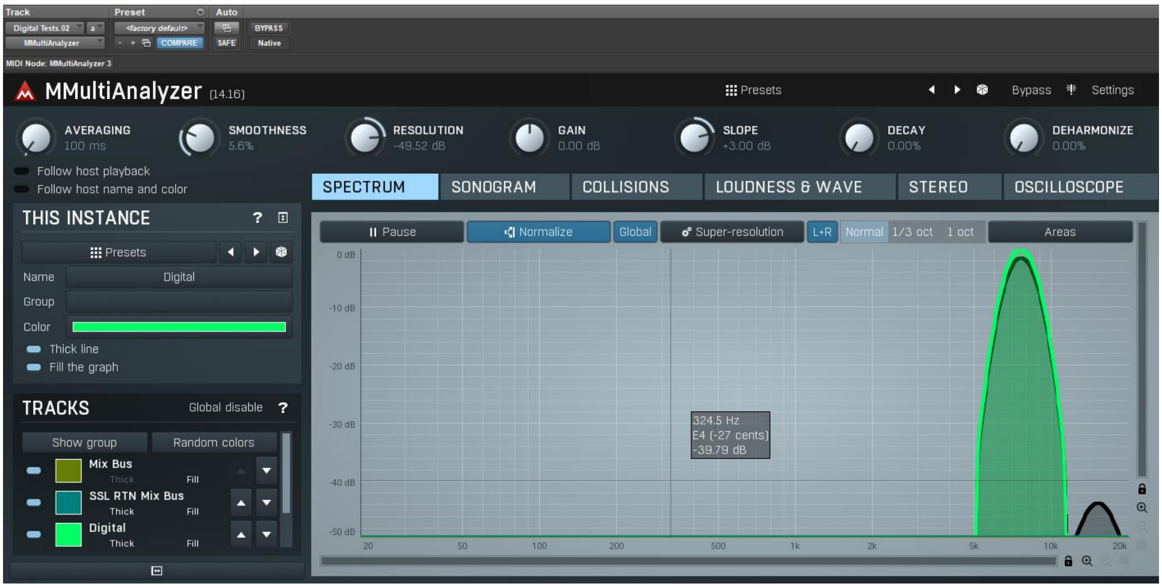
Appendix Figure 1.6 Violin Distressor Attack and Release



Appendix Figure 1.7 Second Harmonic on Analog Distressor

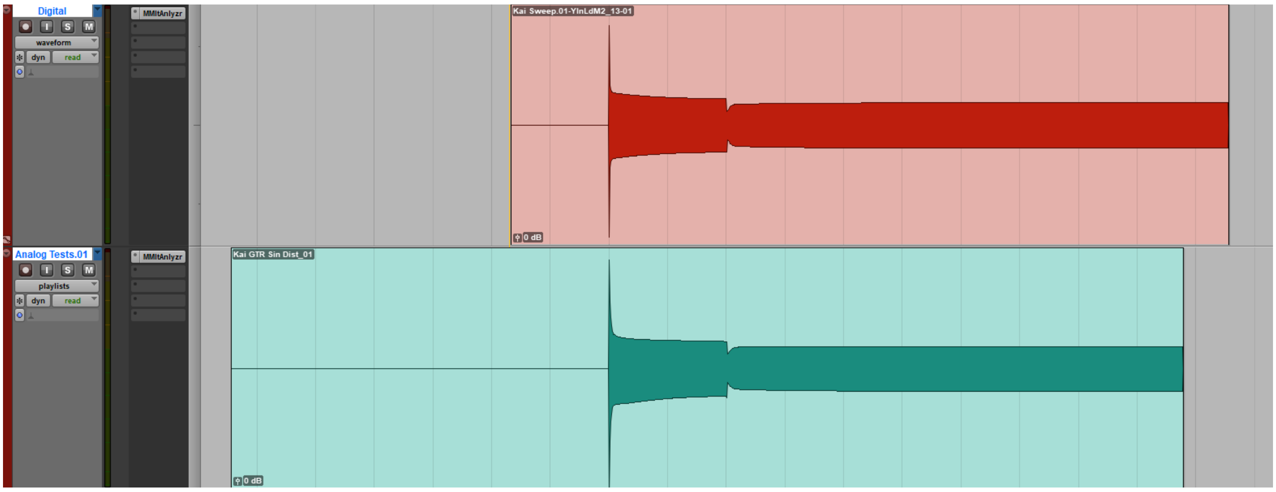


Appendix Figure 1.8 *Digital Signal Harmonic Distortion*



Appendix Figure 1.9 *Analog Signal Harmonic*

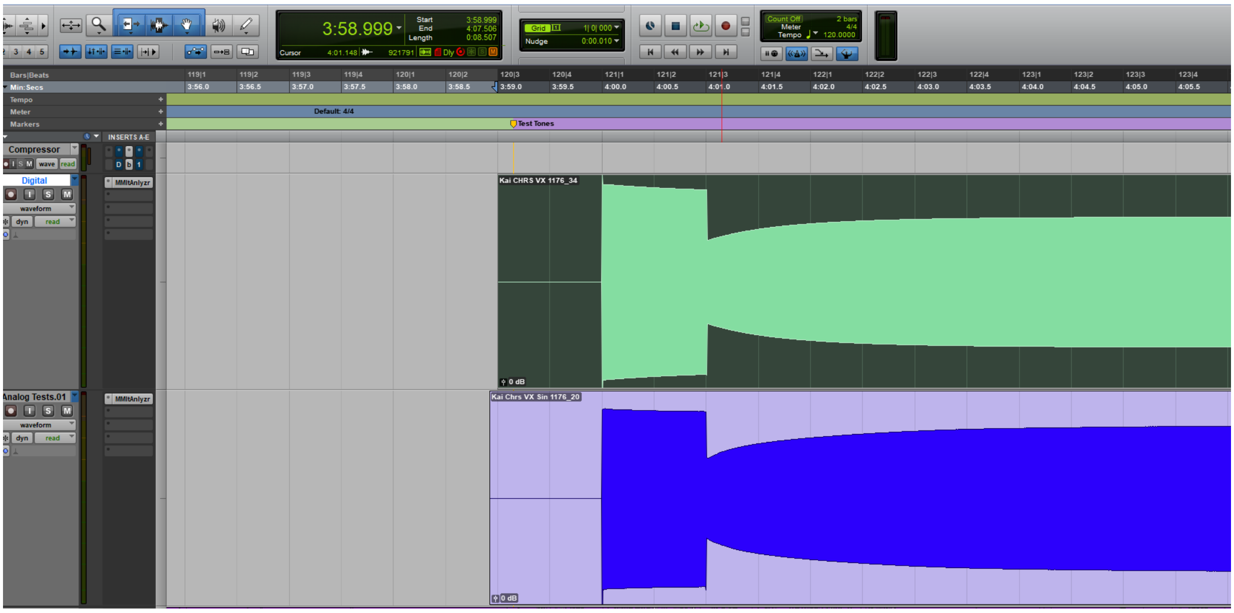
Appendix Figure 2.0 *Violin Spectral Comparison*



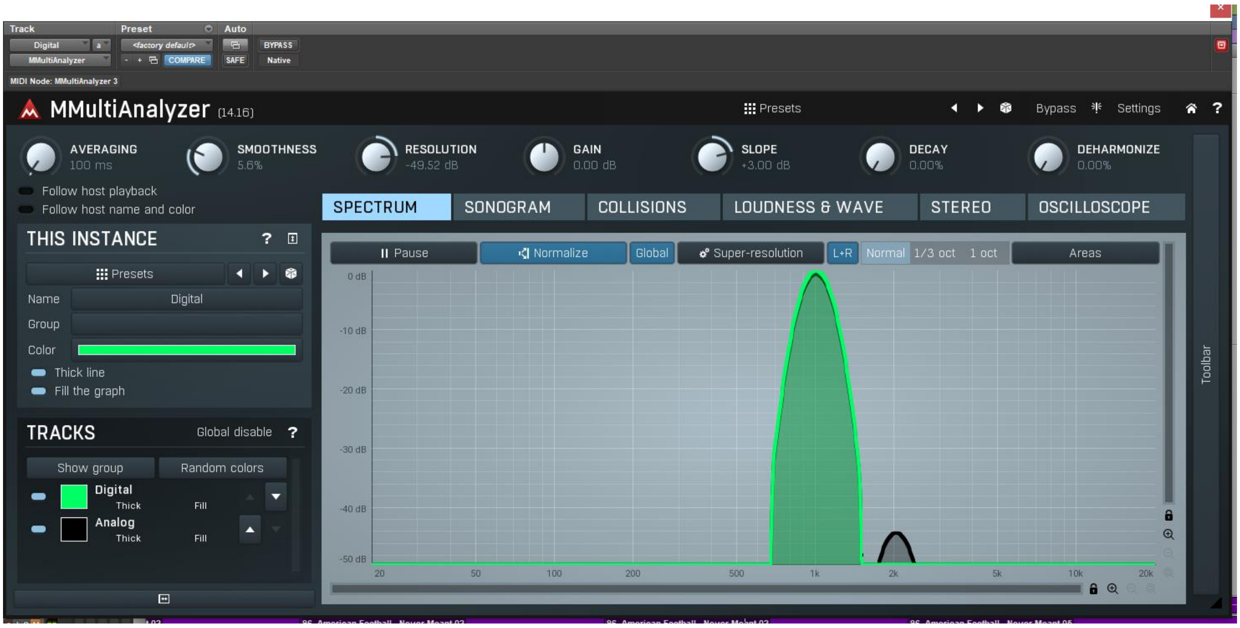
Appendix Figure 2.1 *GTR 2 Distressor Attack & Release*

Appendix Figure 2.2 *GTR 2 Distressor Sine Tone Test*

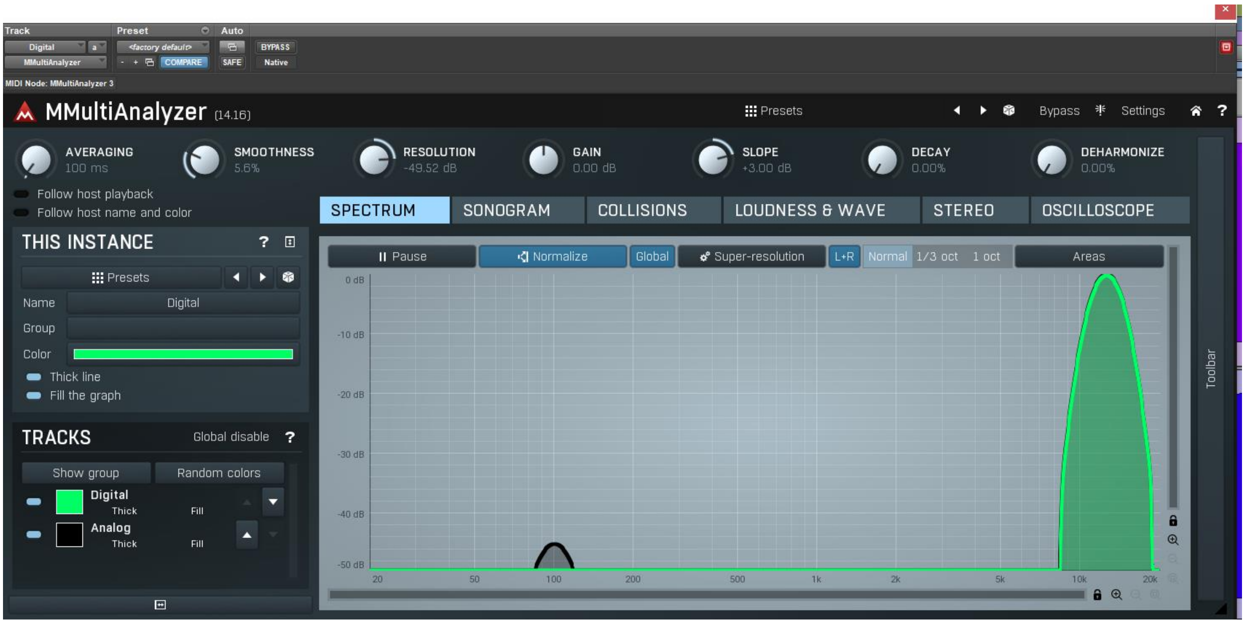
Appendix Figure 2.3 *Spectral Analysis Guitar 2*



Appendix Figure 2.4 *Vocals 1176 Attack and Release*



Appendix Figure 2.5 *1176 LN Voals THD*



Appendix Figure 2.6 *Lower Harmonic in Vocals 1176 LN*

Appendix Figure 2.7 *SSL Channel EQ Vocals Analysis*

Mic List	Instr	Mic
1	Kick In	57
2	Kick Front	D112
3	SNR TP	FET (C414, U87 Ai, U47 FET) SD Cond
4	SNR BTM	57
5	HI RAC	604
6	FLR	604
7	HTS	184
8	BCK L	Coles
9	BCK R	Coles
10	Stereo Front L	C414
11	Stereo Front R	C414
12	ROOM L	Omni
13		Omni
14	BASS D.I	D.I
15	BASS AMP	Beyer M88
16	GTR ETC	Royer 121
17	GTR ETC	TLM 103
18	ACST Mono	C414
19	Violin	SD Condenser
20	Violin Amp	Royer 121
21	Kai VX	U87
	Trad Sesh	Stereo Pair/ Mid Side Coles

Appendix Figure 2.8 *Mic List*

Software / Plug-Ins:

AVID Pro-Tools Ultimate

Fab Filter Bundle

Izotope

Plug-In Alliance

Everything Bundle

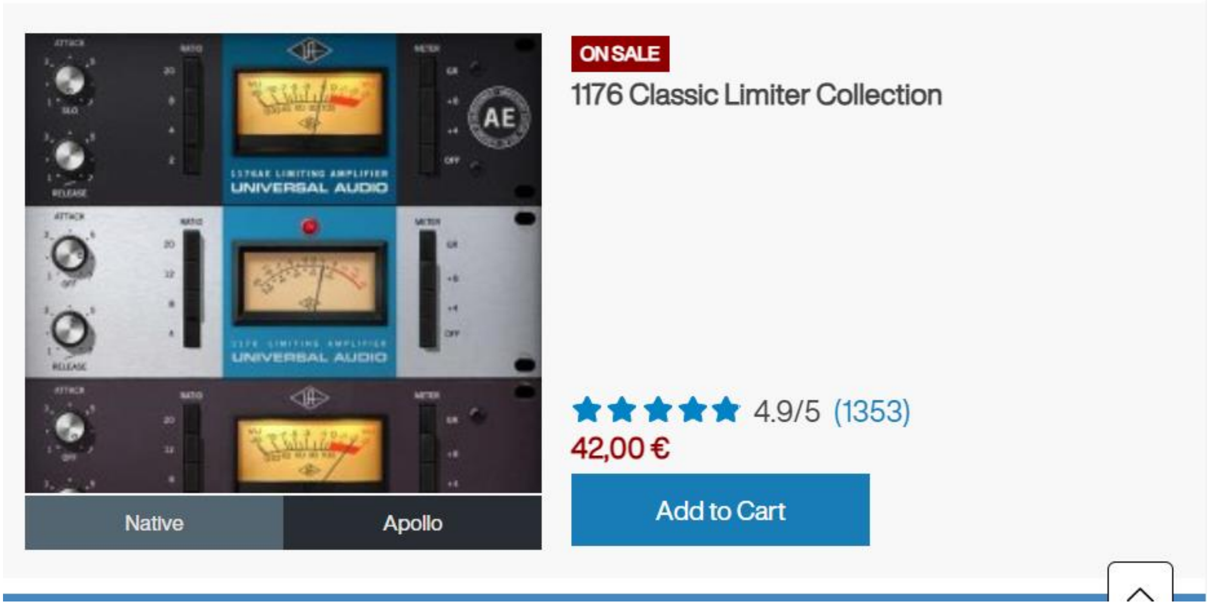
Waves

UAD

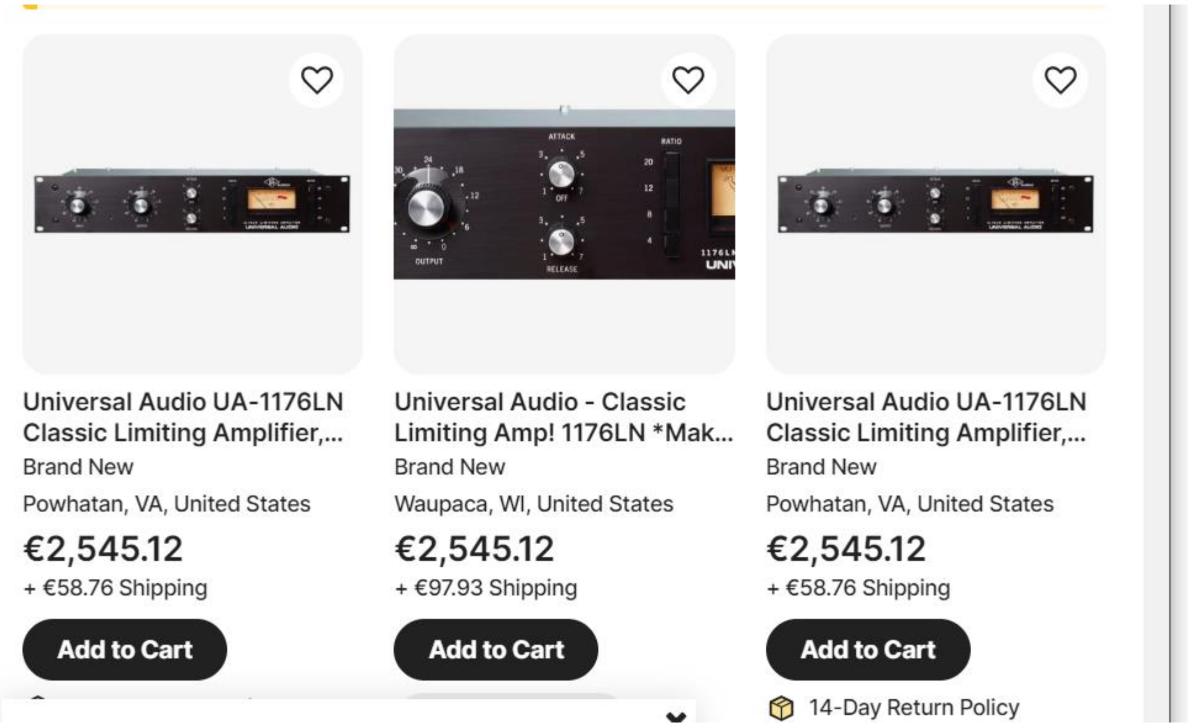
Appendix Figure 2.9 *Cúan Studio Plug-in List*

1 x Metron 1961 Valve Comp
2 x Urei LA4
1 x Urei 1178
1 x Urei 1176 LN (Blackface)
1 x Universal Audio LA-610
3 x Universal Audio 1176 LN
2 x DBX 160
1 x Tube Tech LCA2B
2 x Empirical Labs Distressor
1 x Empirical Labs Fatso
1 x Aphex Expressor
1 x BBS 901-2 Multiband Compressor
1 x SPL Stereo Transient Designer
1 x Thermionic Culture Vulture Culture 11th Anniversary Edition Mastering Version
1 x Altec 1591A Mic/Line Pre Amp, Compressor

Appendix Figure 3.0 *Black Mountain Hardware List*



Appendix Figure 3.1 *UAD 1176 Bundle Sale*



Appendix Figure 3.2 *Analog 1176 LN Rev Retail Price*

Bibliography

Audio, Sage. 'Analogue Mastering for the Digital Age'. Audient (blog), n.d. - - https://audient.com/tutorial/mastering-for-digital/.

Cleland, Jennifer Anne. 'The Qualitative Orientation in Medical Education Research'. Korean Journal of Medical Education 29, no. 2 (June 2017): 61–71. https://doi.org/10.3946/kjme.2017.53.

'G.711'. In Wikipedia, 21 October 2023. https://en.wikipedia.org/w/index.php?title=G.711&oldid=1181221123.

Inglis, Sam. 'The Price Of Plug-Ins', May 2023. https://www.soundonsound.com/people/price-plug-ins.

Jyri Pakarinen. 'Distortion Analysis Toolkit - A Software Tool for Easy Analysis of Nonlinear Audio Systems'. Edited by Udo Zölzer. Department of Signal Processing and Acoustics, School of Science and Technology, Aalto University, 17 May 2010.

Lambert, Mel. 'Plug-in Modelling: How Industry Experts Do It,' August 2012. https://www.soundonsound.com/techniques/plug-in-modelling-how-industry-experts-do-it.

Mixing Masterclass with Richard Furch [Prince, Jay-Z, Frank Ocean, The Weekend], 2022. https://www.youtube.com/watch?v=049u0zWW9cw.

Niada, Laura. 'Lib Guides: Dissertations 4: Methodology: Methods'. Accessed 11 December 2023. https://libguides.westminster.ac.uk/methodology-for-dissertations/methods.

Palinkas, Lawrence A., et al. 'Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research'. Administration and Policy in Mental Health, vol. 42, no. 5, Sept. 2015, pp. 533–44. PubMed Central, https://doi.org/10.1007/s10488-013-0528-y.

Robjohns, Hugh. 'Q. Is There a Difference between Clipping and Limiting?', August 2013. https://www.soundonsound.com/sound-advice/q-there-difference-between-clipping-and-limiting

Skinner, Tom. 'Nearly Half of Commercial Recording Studios Could Close down without Government Support'. NME, 5 May 2020, https://www.nme.com/news/music/nearly-half-of-commercial-recording-studios-could-permanently-close-without-government-support-2660033.

Tarr, Eric. 'Analyzing Effects: Compression (Part 2)'. Pro Audio Files, https://theproaudiofiles.com/video/analyzing-effects-compression-part-2/. Accessed 21 Apr. 2024.

Watkinson, John. An Introduction to Digital Audio. Second. Oxford, England: Focal Press, 2002.

W.Edgar, Thomas, and David O.Manz. Convenience Sampling - an Overview | ScienceDirect Topics. https://www.sciencedirect.com/topics/computer-science/convenience-sampling. Accessed 21 Apr. 2024.

Wilmering, Thomas, Et al. 'A History of Audio Effects.' Applied Sciences, MDPI, 22 January 2020.

Zölzer, Udo, ed. DAFX: Digital Audio Effects. First. Helmut Schmidt University: Wiley, 2011.