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Bringing Acoustic Recording's Back to Life

Monograph on Correction of Acoustic Recordings for Edison Diamond Disc Records

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Correction of Acoustic Recordings

Overview

This monograph describes a method to correct the audio sound of acoustically recorded music so that the result is as close to "The way it was recorded", using music from the Edison Record Company.

Correction of the audio sound is defined as an attempt to bring back to the music lost parts of the song that were not recorded correctly with the technology present at the time. The technology that was used to record the music did not use any electronic equipment at all and has been called Acoustic Recording to highlight the fact that the music was recorded only by the acoustic power from the instruments and the blending of the sound depended solely on the physical placement of the instruments during the recording session.

The goal of the methods described in this monograph is to bring back the sound of the recording so that the music will sound the same to the listener as it was during the original recording. The music should have a natural sound.

It's important to understand that there are no musicians or production engineers available to guide the work on these recordings. The best that can be done is to listen to the results of the work and to use past music "experiences" to guide the modification to the original recording. The end result should always be to produce a song that sounds as close as possible to a natural sound.

The method that was used to bring back the original sound was to use the specialized audio software from the Diamond Cut Productions Company utilizing unique filters and effects that will be described in this monograph.

The method developed in this monograph is the first attempt by the author to improve the quality of Acoustically Recorded music and further refinements in the method are expected.

Motivation

The author of this monograph has enjoyed music from early Edison Phonographs for many years. As such, the author was drawn to the history of recorded music and enjoyed hearing the music played back on the original early phonographs since the 1960's.

As the technology advanced in computer systems and powerful software became available, the ability to perform complex digital signal processing at reasonable prices became possible. Thus, the author began playing the old records back on modern turntables and removing the surface noise using software from the Diamond Cut Productions company. While the quality of the early acoustic recorded music improved from removing the noise and using an electrical pickup, the sound still lack the vibrancy and excitement as compared to electrically recorded music.

The type of music that is recorded by the record companies is constantly changing as the music tastes of the public also changes. For Jazz music much of the early, "breakthrough" original music and musicians were limited to the acoustic recording process. Therefore, the author worked to find a method that would bring back to the acoustic recorded music the missing sound that was lost during recording so that the resulting song came as close as possible to that which could have been achieved if electrical recording had been available.

The solution that was found was to modifying the acoustic music so that missing and weak music frequencies that were lost during the recording process were returned to the song. The phrase "Correction of Acoustic

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Recordings" is used for this process since the goal is to replace the missing "sound" from the recording process. Note that the simple method of just boosting some low frequencies to improve the sound does not work since much of the low end on acoustic recorded music contains noise from the recording process and would add more distortion to the song.

After applying this method to acoustical recorded music, the result obtained was a pleasant and vibrant song that sounded more natural and lack the "tinny" quality heard in the past. Now, the rich sound from the early Jazz music can come through and provided an improved insight into the early days of recorded music. The method used to correct the music will now be explained.

Background

The recording of sound was invented by Thomas Edison in 1877 and patented in 1878. After Edison's initial design, the phonograph went through many changes to improve the quality of the recordings, but, the improvements were only mechanical in nature for many years. What this means, is that the acoustic power from the music was the only means to record and playback the music on the record. The acoustic power was gathered from the musicians and focused to the mechanical recorder by using a horn. The general term for this type of recording is called "Acoustic Recording".

Since a single recording horn was used to collect and focus the music, the physical location of the individual instruments had to be adjusted by the music engineers to produce a balanced, sound from the instruments and singers. Today, we can vary the sound of each instrument via production volume controls on the studio microphones.

A significant effect on the quality of the recorded sound during the acoustic era was caused by the use of mechanical devices for both the recording and playback of the music. For recording the music, the ideal device should faithfully pass all frequencies of musical interest to the recording media so that the sound that the musicians created can be accurately recorded. During the acoustic era, the horn and the mechanical components used to produce the record grooves greatly modified the music's sound. Many low and high frequencies did not get recorded and other frequencies were increased in volume due to resonances in the system. The various record companies were actively working to improve the performance of this mechanical method of recording, but the best that could be done was still very inadequate.

In addition to the degradation in music sound due to the recording of the music, the playback of the recorded music again suffered from the mechanical nature of the system. Thus, the acoustically recorded music was degraded from the original studio sound during both the recording and playback of the record due to the strictly mechanical nature of the technology.

Around 1925, the engineers at Bell Laboratory produced a new recording method that used electrical methods for the recording process. However, the playback for these early records still used a mechanical system (although improved). After a number of years, electrical pickups were introduced so that the entire process would be greatly improved.

This new recording system was adopted by Victor and most of the disc record companies with the exception of the Edison Company. The Edison Company continued to produce and develop acoustic music until 1927. During 1927, they started to phase in the use of electrical methods to record the music, but still provided mechanical playback phonographs for these records. Near the end of the Edison Music business, the company offered electrical recording and playback of records, but this closed down in 1929 (just prior to the market crash).

This time period using acoustical means for recording music is in sharp contrast to today's use of electronic devices that alter only the original studio sound as desired by the recording artists.

Source of Music

For this monograph, the music that was studied and later restored was obtained solely from Edison Diamond Discs that were recorded using the Acoustic Process. The use of music from the Edison Company provided two useful benefits. First, the Edison Music Division was dissolved in 1929 and the assets of the Edison Laboratory were later turned over to the nation as a national park which means that the music is in the public domain and thus avoids copyright restrictions. The second reason is that the Edison Laboratory was highly skilled in the art of acoustic recording and produced excellent, consistent recordings. While Edison himself was very hard of hearing, the product of his research at the time was to try and reproduce the music as best as possible to the degree that he would issue records based on the quality of the recording as well as the value of the potential sales. While the business practices of the Edison Phonograph Company have been criticized as poor, the recording qualities of the music are the best that was possible at the time using the acoustic recording method.

Thus, the use of Edison Diamond Disc Acoustic Records for restoration avoids copyright problems and provides the best source for music that came from the acoustic recording method era.

Source of Tools Used

In order to remove the distortion in the music and restore the lost frequencies, a powerful digital computing software product was used. The author used software from Diamond Cut Productions labeled "Diamond Cut Forensics10 Audio Laboratory Version 10.02". This software was the latest version as of the date of this monograph.

Screen shots of the software all came from the Diamond Cut Productions product. Those that are interested in trying this technique should visit the internet site for this company to learn more about this software.

Description of Correction Method

Example

In order to help to explain this method, an Edison song "Valencia" and frequency spectrums of the different versions will be used. This song was recorded in April 20, 1926 at the Edison music studio. At this time, Edison was not using electrical equipment to record the music although other record companies had started to use the Western Electric system. The original recording was made and used to create an Edison Diamond Disc Record with a Coupling number 51738-R and Matrix number 10934. This record was also used to create an Edison Cylinder Record number 5164. The Edison Cylinder record was copied from the original Diamond Disc record by what was thought to be a pneumatic method whereby the output from the Diamond Disc record was coupled to the cylinder recorder by a closed air tube. The Edison Company did not publish detailed information on this system. The first frequency spectrum shown is from the song as played back on an Edison Amberola

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Phonograph with a microphone placed near the phonographs horn. This represents the quality of the song that you would hear from playing the cylinder record in 1926 in your home on an Edison Phonograph. Refer to the frequency spectrum below. This is a plot of signal amplitude (in dB) verses frequency (in Hz). The frequency goes from 10 Hz to 11KHz. The amplitude is relative.

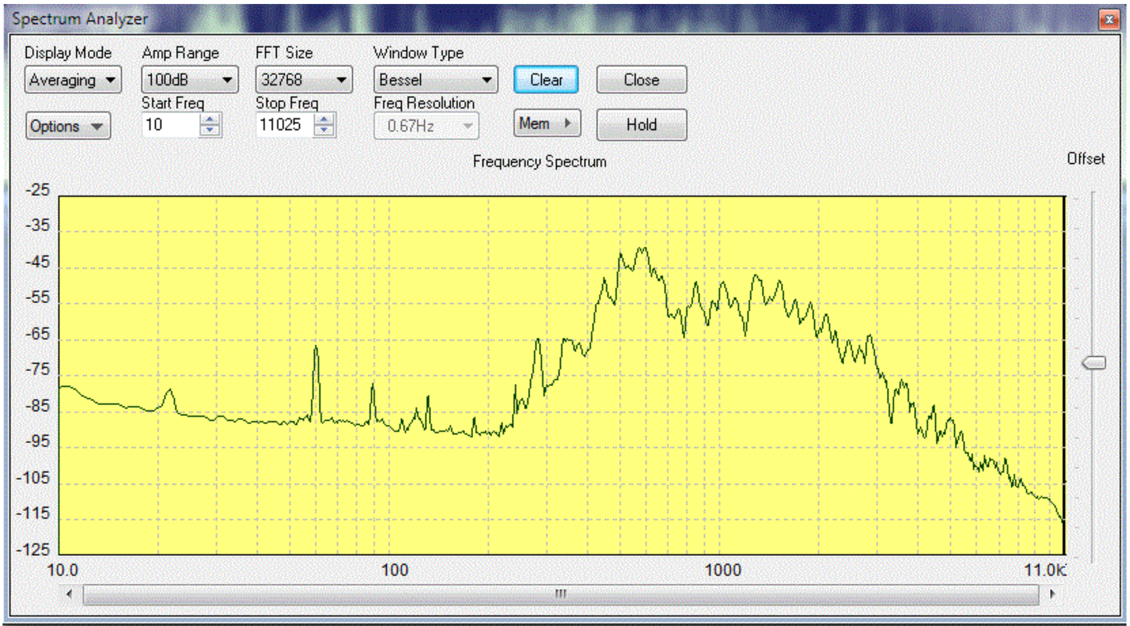

Figure 1, Song Valencia from the Output of a Cylinder Phonograph.

Note a number of important features:

1. There is energy at 60 Hz from the process (microphone) used to hear and record the song and not from the actual original song recording.
2. There is some mechanical noise around 22 Hz and 90 Hz.
3. The music energy seems to start around 250 Hz and continues out to about 4000 Hz.

When this song is played, most people will hear a “tinny” song with little bass. This represents a typical acoustic recording and playback on original phonographs

Next, let’s see the frequency spectrum of the original Edison Diamond Disc record as played back using a modern turntable and pickup. The song has had the noise removed but there has been no significant modification to the songs frequency output. Refer to the frequency spectrum below.

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Figure 2, Song Valencia from the Output of the Disc Record.

Note a number of important features:

1. The frequency spectrum was obtained from an electrical pickup and shows what was recorded from mechanical methods without the additional degradation from the mechanical playback.
2. There are two spikes at 83 Hz and 123 Hz that are related to rumble and noise from the original recording process. Also, the music frequencies below 250 Hz are masked by a general level of mechanical noise. Other Edison Diamond Disc songs that been examined have similar spikes and general levels of mechanical noise. The original recording engineers knew that the mechanical playback Edison phonograph would not reproduce the frequencies below 250 Hz so they didn't try and remove these rumble and noise frequencies.
3. The music energy still continues out to about 4000 Hz.
4. The music energy is flatter from about 250 Hz to 2000 Hz versus the previous same song as played back on a cylinder phonograph since the Diamond Disc is the original version, not the copy version and preserves more of the original recording.
5. If the songs energy below about 250 Hz could be restored, then the song has the potential to have a nice balanced sound since much of the frequencies above 250 seem to be well represented. This song has potential to greatly improve it music if the missing frequencies could be restored.

Key Observations

These results highlight that the correction of these acoustical recordings have a number of key items to address. First, the strong presence of mechanical noise at the lower frequencies (below roughly 250 Hz) means that if the "bass" frequencies were boosted at this point, the music would suffer from distortion with the amplified noise as heard on today's wide range audio systems.

The higher order frequencies are well represented and if amplified some should make the song sound much more "bright" and clear than initially thought possible from an acoustic recording.

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Correction Result

After applying the correction processing to the disc recording, the following frequency spectrum was produced:

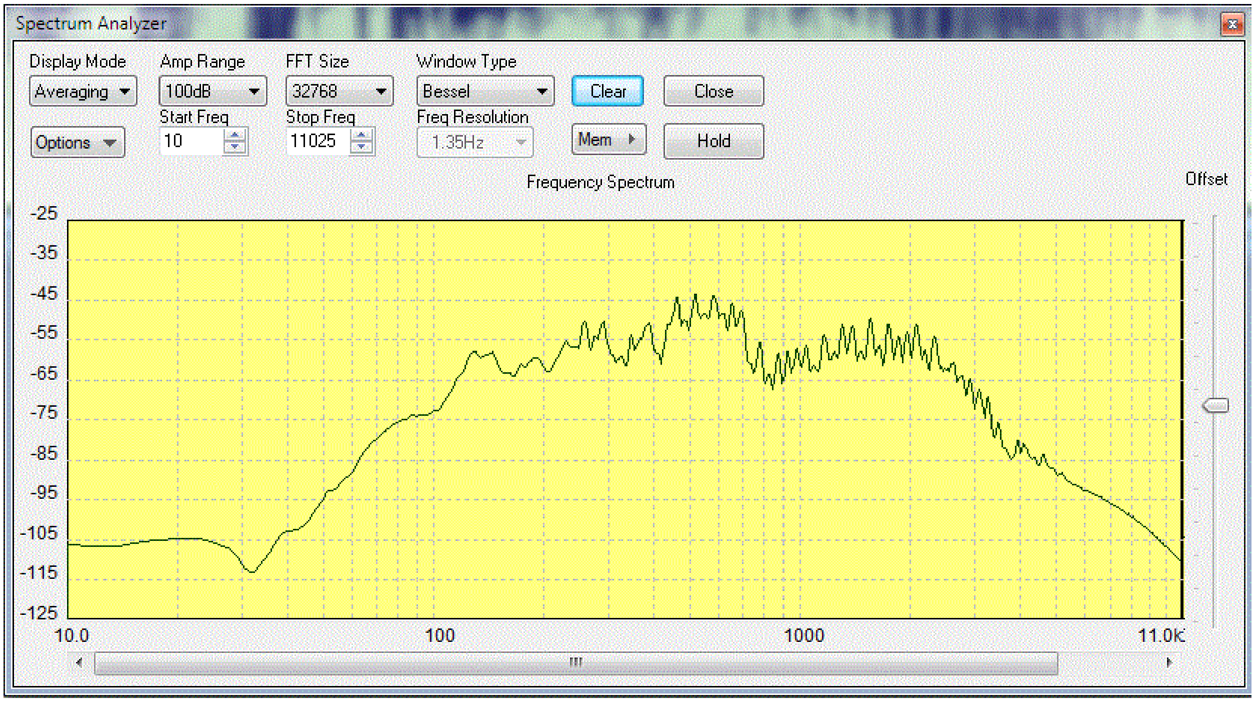

Figure 3, Song Valencia from the Output of the Disc Record after Correction.

In order to compare the effect of the correction, the previous curves are combined below:

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Figure 4, Black is before and Red is after Correction.

In this graph, the Red line is the enhanced response and the Black line is the basic or original music recorded from the Edison Diamond Disc (using an electrical pickup). Note a number of important items:

1. The two strong frequencies at 83 Hz and 123 Hz have been removed during the correction process.
2. Frequencies below 100 Hz have been greatly reduced so that the song has much less rumble and low frequency noise.
3. Frequencies above 350 Hz are roughly similar.
4. Frequencies below 350 Hz have a significant difference between the original (Black) and enhanced (Red) frequency spectrums with the addition of some new frequencies.

When the enhanced song is played back and compared to the original, the song now has a much “fuller” sound and has much more low end sound which allows the listener to hear instruments like tubas much better. Thus, the music is now closer to the way that it was originally played in the music studio during the recording.

Details

The details in the restoration method will be described next. Prior to this stage, the record music has been transcribed from the original source and stored as “wav” files using a digital depth of 16 Bits and a sample rate of 44.1 thousand samples per sec. Record noise from surface imperfections have been removed but no change has been made to the original file. The frequency range for the music is limited to 100 Hz to 8000 Hz. While this range is wider than the actual recorded music, the wide range is helpful to remove noise events using the Diamond Cut software.

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Correction

The goal of the correction process is to improve and modify the sound of the music so that the result will be as close to the sound as played in the studio or as close to the way that the recording engineer wanted the song to sound.

There is a benefit from using todays' turntable and cartridge to transpose the music from the original record to a wav type file, namely the fact that although the mechanical recording structure attenuated high and low frequencies, some important music harmonics were reproduced to some reduced level and that further reduction through a mechanical playback system will not happen.

The recording engineers knew that the playback mechanisms that would be used for their records had a very limited range of frequencies. Therefore, the presence of low frequency rumble in the recording would not a problem for the listener. However, the playback methods used today will pick up low frequency noise so that a recording that would have sounded fine on an Edison phonograph would sound distorted from the transcribed recording using the latest turntable and cartridge. Thus the low frequency rumble has to be removed from the recording. This removal of low frequency rumble has a secondary effect on the music. The filter that is used to remove the rumble has no intelligence and will also remove some music energy. Thus, a balance is needed between noise removal and music removal.

The processing of the music harmonics to add back into the music the missing/reduced ones is the key effect that is used to enable the ability to correct the acoustic recording. If the frequencies are not present, then traditional equalizers and filters would have no effect on the music sound. Thus the added back new frequencies are critical to this correction methods success.

A DSP method that is used to add back frequencies is a "subharmonic" generator. This software is produced by the Diamond Cut Productions Company and examines frequencies below a variable level for processing. If the software finds a frequency in its range, it will add to the output a frequency half that of the original along with the original. Thus, new low frequencies will be produced that are related to those present in the original. Because the frequencies are related as subharmonics, the likelihood that the new frequencies were present in the original recording is high. Thus, the quality of the music can be improved as the needed missing frequencies lost during the acoustic recording process have been returned. Note that this technique is not a perfect method, since the DSP effect does not have any intelligence about the source of the frequencies. All frequencies within the range of the software will be treated and a lower/half value will be created. Since the software has an amplitude adjustment to the new created frequencies, a balance can be made in using this effect between correction of the recording and creating an un-natural sound.

After the creation of the "missing" frequencies, more DSP software can be used to increase the lows and highs of the recording and remove any remaining noise.

The method used will now be discussed.

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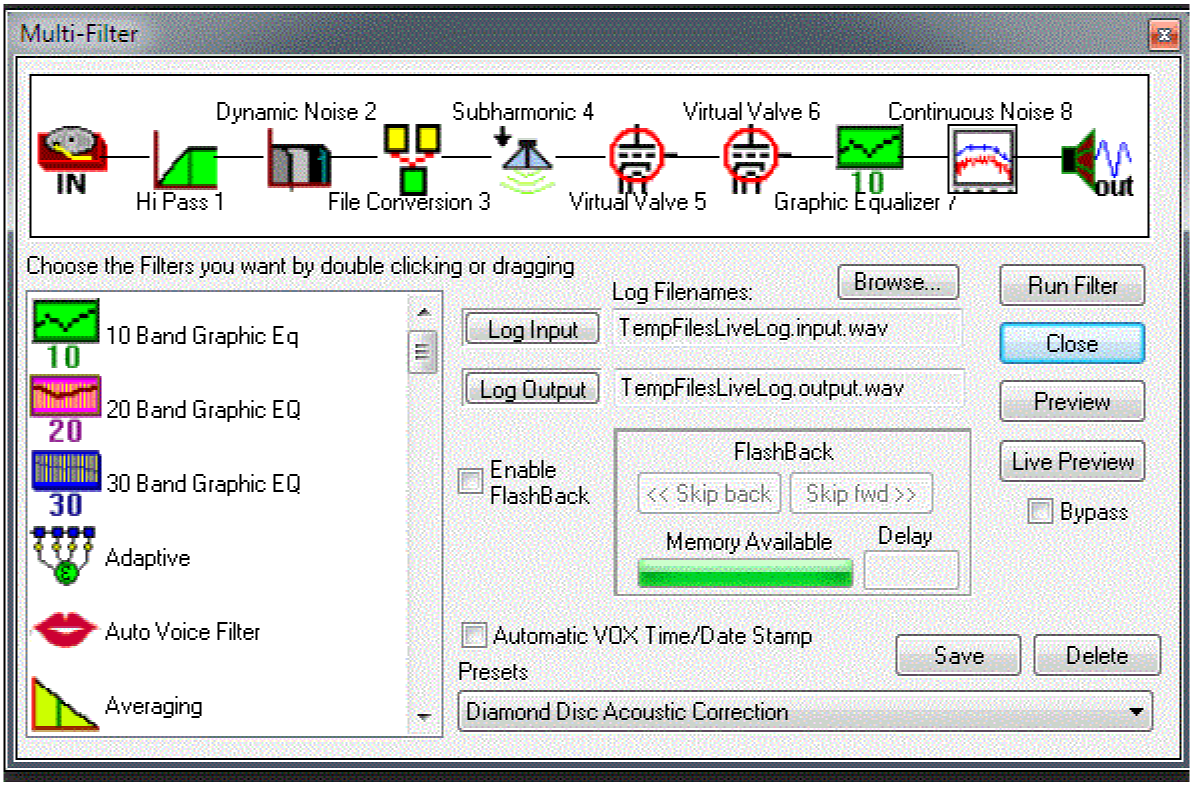
Implementation

Diamond Cut Productions software provides a number of digital signal processing filters and effects to modify the music file. The software also provides a means of chaining the filters so that a series of filters and effects can be linked together and used to make a large "multifilter". This multifilter can then be used as a one-step operation that applies the processing steps in a set sequence of operation from left to right.

The multifilter that is used to enhance the music is shown below:



The signal from the song is processed from left to right as it proceeds through the various filters and effects. Each one will now be discussed. Note: The specific settings that were used on each "Block" in the multifilter will be shown. However, for those that want to try this method for themselves, the Diamond Cut Productions web site and user forum contains much of the needed detail information. Also, the settings as used by the author are under constant revision.

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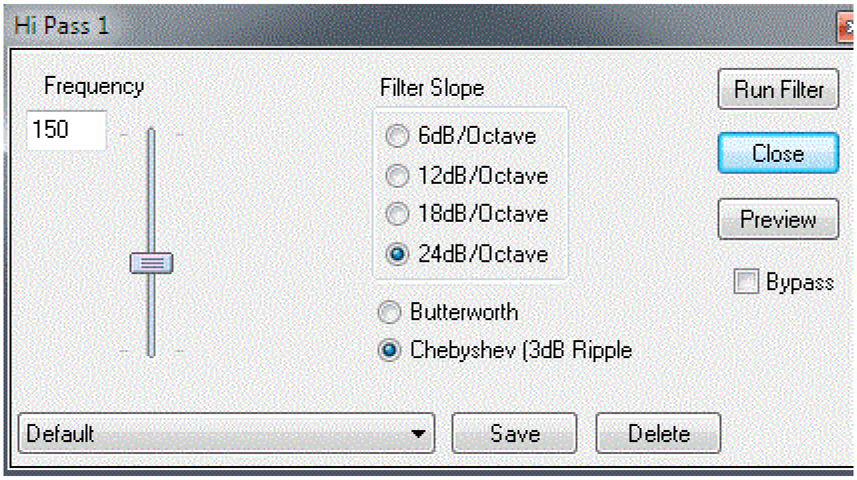
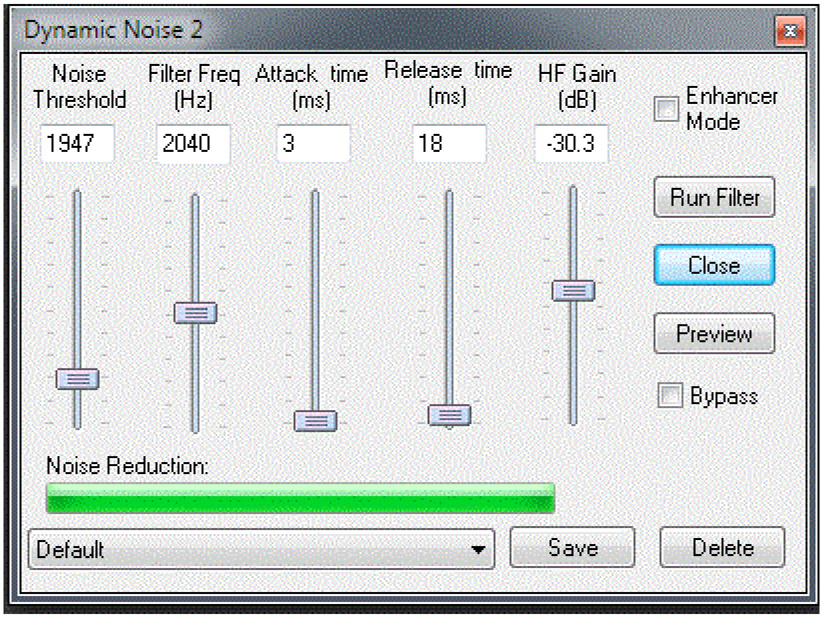
Description of Blocks



1. Hi Pass 1. This filter is used to remove all frequencies below 150 Hz. In this manner, the mechanical rumble and other mechanical noise frequencies are removed from the song.



2. Dynamic Noise 2. This filter is used to remove some of the "hiss" or constant high frequency noise present. This filter takes advantage of the fact that the human ear does not hear all frequencies equally well at a low level and therefore a low pass filter (2040 Hz) is applied to the song until the amplitude level of the music rises to a point that the human ear can hear the higher frequencies. At this point, the value of the low pass filter is raised up so that the quality of the song is not changed, but some hiss or high frequency noise has been removed.

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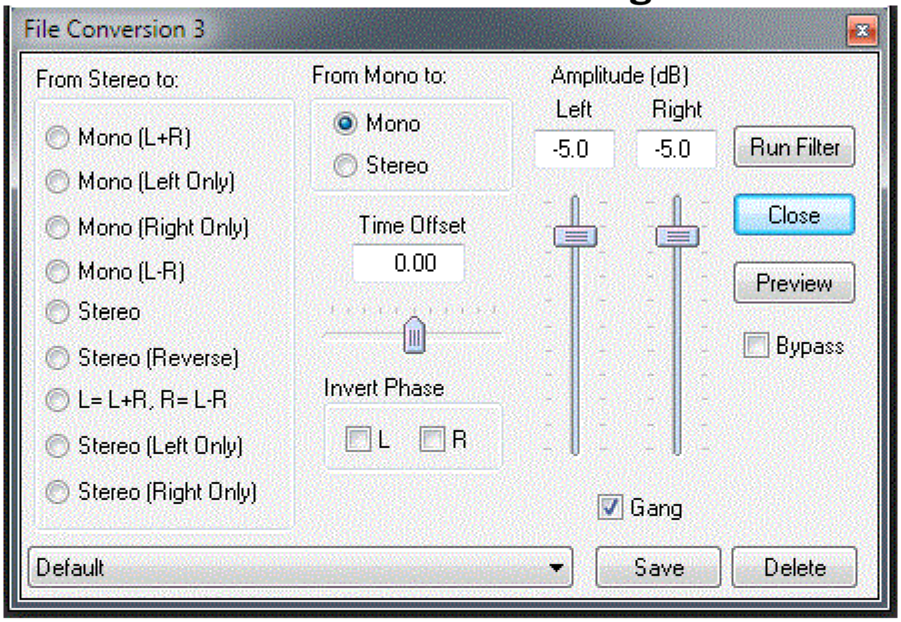
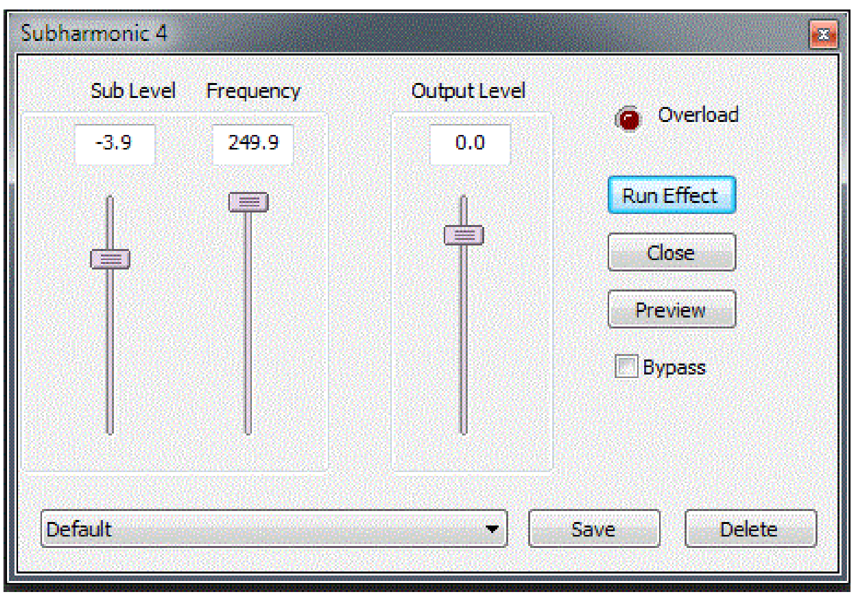


3. File Conversion block. This effect is used to decrease the amplitude of the music so that the next effects in the multifilter will not overload the music. The correction multifilter is used on a music file that has been previously normalized so that the loudest portion of the song corresponds to the maximum digital value in a 16 bit word. Thus the file conversion block is used to slightly decrease the music level so that if frequencies are to be boosted, the music will not be overloaded and exceed the maximum possible value.



4. Subharmonic 4 effect. This effect is a critical part of the correction process and as such, its value has to be adjusted for each song. This effect examines any frequencies below a setting and if a frequency is found, the effect adds back to the file a new frequency that is one half that of the value found and at an amplitude as set by the user. The effect operates on all frequencies present in its operating range. The range selected for this effect is 250 Hz and below. Since this effect does not know if the frequencies found are music or noise, the amount of added frequency is dependent on the quality and type of recorded song. The added low frequencies can significantly help to restore the sound of musical

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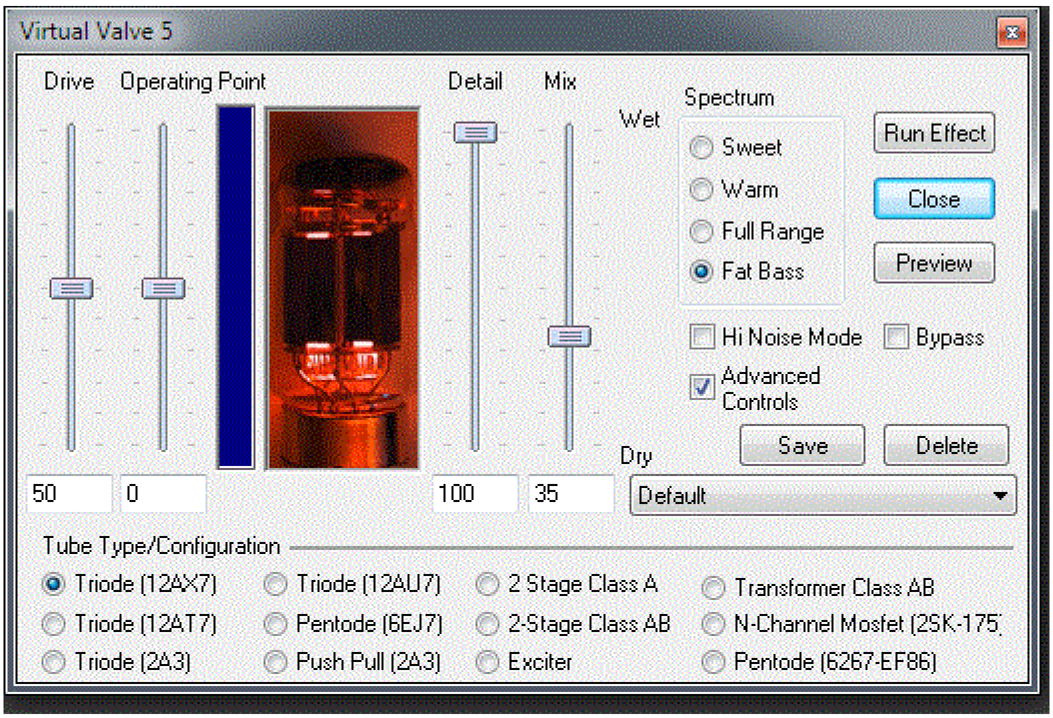
Instruments that have lost their fundamental frequency and only have higher order harmonics remaining on the record. Thus, this effect can provide some of the missing frequencies to a song that have been lost in the recording process and restore the sound of low frequency instruments.

Thus, the subharmonic block is used to create new low frequencies and to act as a secondary control for the rest of the blocks on just how much low frequencies are made and boosted.

It is important to note that after the subharmonic block the remaining sets of blocks are only effective if frequencies are present. Thus the subharmonic block is critical to the performance of this correction process.



5. Virtual Valve 5 effect. This effect is used to add to low frequencies various harmonics that improve the sound of the fundamental. The amount of this effect is adjusted once for all acoustic recordings as the effect does not create frequencies unless they are present.

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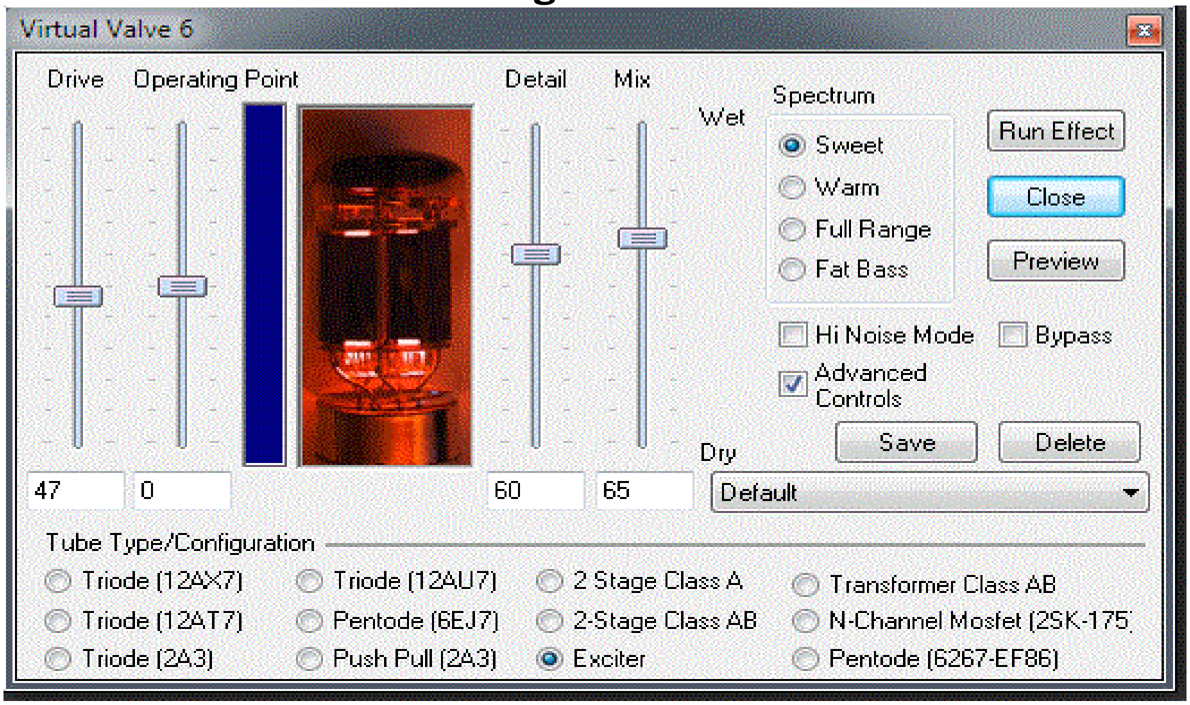
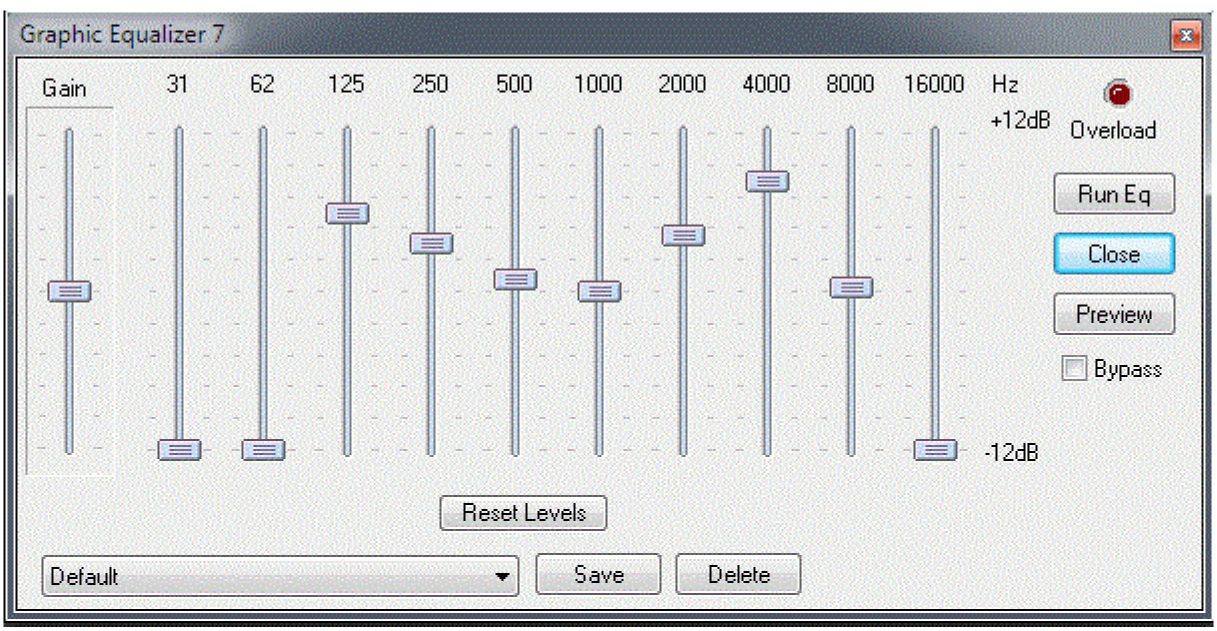
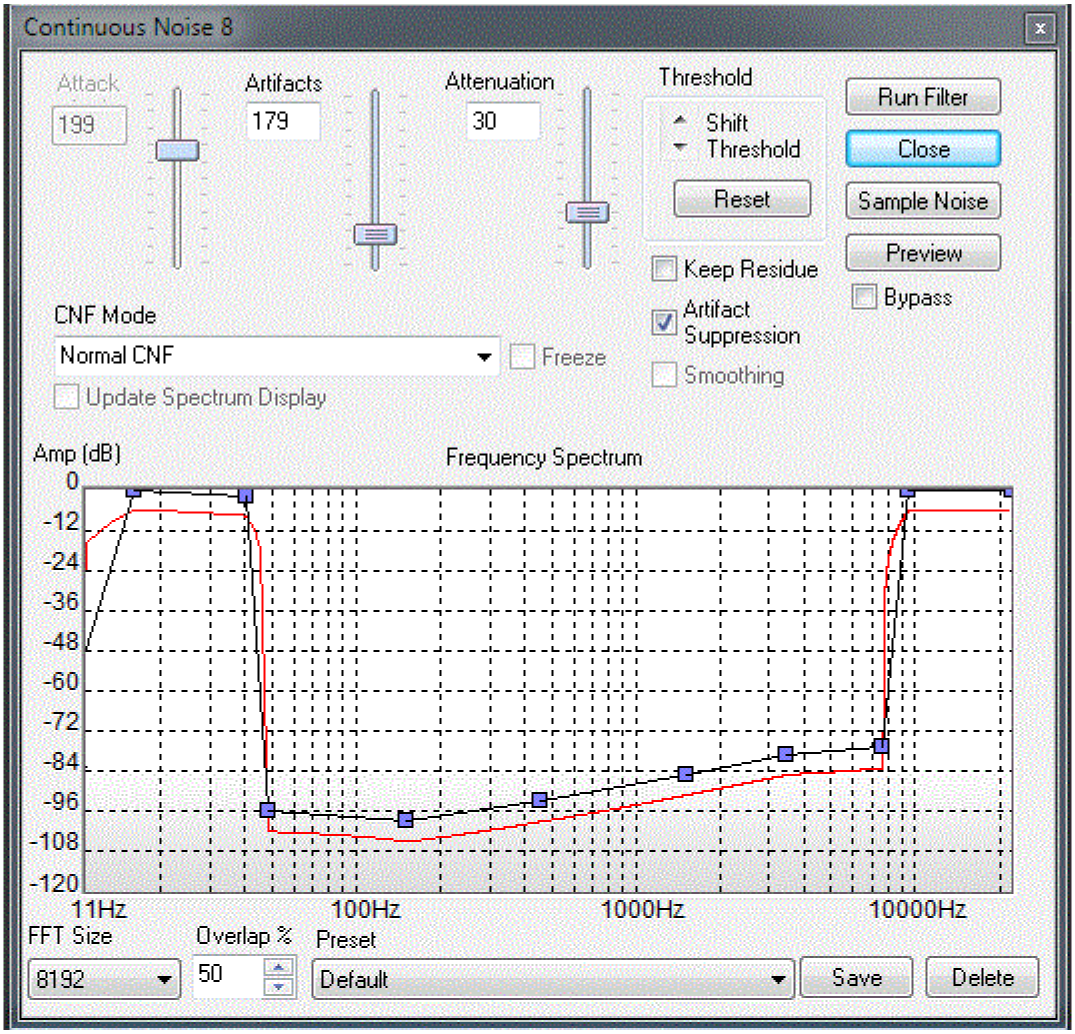


6. Virtual Valve 6 effect. This effect adds harmonics of the frequencies that are input into the block. The settings provide a slight effect that helps to brighten up the higher frequencies in the song that have been lost in the recording process.



7. Graphic Equalizer 7 effect. At this point in the signal chain, a traditional boost or cut to various frequency ranges is used. This effect is used at this point since the desired original and a new frequency has been produced and now is the correct moment to add in more low end and high end. If this effect

had been used first, then the boosting of signals would have had no result since the needed frequencies were not present.



8. Continuous Noise 8 effect. This filter is a general cleanup of the music to remove any hiss or rumble that has been left over from the previous blocks.

For those who want additional information on these various blocks, the Diamond Cut Productions user manual should be consulted.

Implementation

The first step is to select the music that is to be corrected. The music should be from the Acoustic Recorded Era and if possible Edison Diamond Disc records. The surface noise and imperfections should be removed but no modification should be made to the frequency of the recording except to limit the low end to around 100 Hz and the high end to about 8000 Hz.

Next, the final cleaned up version should be normalized so that the loudest part is at the limit of the 16 bit digital conversion that is used. These songs are then processed with the previously described Multifilter with unique settings in the subharmonic block so that the result has a “natural” sound. This part of the correction has no specific setting as the user must use previous musical knowledge to decide just how the music should sound.

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Once the song has been processed with its unique multifilter settings, it is again normalized and available for listening by the user.

Results of Correction Method

The multifilter described in this monograph was found to significantly improve the sound of the acoustic recordings. The "tinny" sound that was very noticeable was removed. In addition, low frequency instruments were brought back to the music and provided a much more natural sound.

The subharmonic generator was found to be very sensitive and needed careful adjustment. Because the generator has no "intelligence", it can create both correct and wrong frequencies at the same time. Thus, a singer's voice could have an "echo" from extra frequencies while at the same time, the tuba now sounds "great" for the same setting of the generator. Thus, the user must make a compromise at times to find a setting that is "the best" that can be done.

Extension Beyond Edison Diamond Disc Recordings

This same multifilter has been tried on other Acoustic Recordings from the Victor Record Company with poor results. An examination into the details between the two companies studio recording revealed a possible reason.

Edison believed in having a "dead" type of studio, i.e. one that had no sound reflections during the recording. He felt that by removing the sound reflections during the recording the resulting sound reflections during playback *at the user's location* would provide the best playback sound. Another belief by Edison was that the recording should allow the listener to pick out each instrument during the playback of the record. As such, the number of instruments in his songs was limited.

The Victor Record Company didn't share Edison's ideas. The Victor records of the Acoustic era tended to have a "bright" sound from a "lively" type of studio, i.e. strong reflections from hard surfaces. In addition, Victor would use a much larger number of instruments in many of the recordings.

The author's opinion regarding the success/failure between Edison/Victor with the method in this monograph is that the use of the "subharmonic" DSP block to create new low frequencies (which is the key to this method) works well with distinct frequencies but fails with blends of frequencies. The dead studio and limited number of instruments creates distinct frequencies for Edison Diamond Discs which is in contrast to the blends of reflections and multiple instruments in the Victor Records.

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Summary

This monograph described a method to modify the playback of Acoustically Recorded Music so that the song now sounds close to the "Way it was Recorded" in the music studio.

The described process uses a special multifilter with a unique subharmonic generator to add back to the music those frequencies that were lost in the recording process. The generator produces lower frequencies that are related to the remaining higher order frequencies present and as such, the "lost" frequencies from the recording process are restored.

This return of the lost frequencies is not a "perfect" process but with the additional blocks in the multifilter the resulting sound is greatly improved from the original.

Within this monograph, the phrase "correction" is used to emphasize that the music is brought back to the condition it was during the original recording, rather than adding an artificial sound to the music. The author of this monograph has applied this method to a large number of early Jazz music from the Edison Phonograph company with excellent results. Although each song requires unique settings, the final result provides a unique musical connection into the past that provides insight into the history of Jazz music.

The author of this Monograph has produced 100's of songs from Edison Diamond Disc records using this technique. The music has a nice "balanced" sound and is very pleasant to listen to.