Reconstruction of Early Glenn Gould Broadcasts: From Acetate to Compact Disc

4616 (P-7)

Peter Cook
CBC Records
Canadian Broadcasting Corporation
Toronto, Ontario M5W 1E6, Canada

Presented at the 103rd Convention 1997 September 26–29 New York

AES

This preprint has been reproduced from the author's advance manuscript, without editing, corrections or consideration by the Review Board. The AES takes no responsibility for the contents.

Additional preprints may be obtained by sending request and remittance to the Audio Engineering Society, 60 East 42nd St., Suite 2520, New York, New York 10165-2520, USA.

AN AUDIO ENGINEERING SOCIETY PREPRINT

Reconstruction of Early Glenn Gould Broadcasts: From Acetate to Compact Disc

Peter Cook

CBC Records, Canadian Broadcasting Corporation, Toronto, ON, Canada

Airchecks of the earliest Glenn Gould broadcasts on CBC Radio were recorded on 16-inch transcription discs. The paper discusses the process of preparing these recordings for commercial release on compact disc. The digital tools available for restoration (declicking, decrackling, azimuth correction, broadband denoising, complex filtering, editing) are described. In particular the advantages and disadvantages of the current versions of Sonic Solution's NoNoise system and CEDAR's Series 2 Modules are discussed.

0 Introduction

Glenn Gould made his first radio broadcast for the Canadian Broadcasting Corporation on Christmas Eve in 1950 when he was 18 years old. He maintained a very close affiliation with the CBC until his death in 1982 performing in radio broadcasts, and producing radio documentaries and television programmes.

In April 1955 Gould signed an exclusive contract with Columbia Records. His first recording for the label was of Bach's Goldberg Variations and wi it he launched a spectacular international career. CBC Records <http://cbcrecords.cbc.ca/cbcrecords/> owns the rights to release materi broadcast prior to Gould's signing with Columbia. In the past five years CB Records has released six compact discs of Gould's original broadcast recordings from the early 1950's.

1 Source Material

1.1 Origin of Source Material

When remastering historical recordings it is important to locate the best possible sources. In the early 1950's at the CBC, airchecks -- if they were made -- were recorded on 16-inch transcription discs rotating at 33.3 rpm and cut from the centre to the outside. Each side held 12 to 15 minutes of music. When one disc was running out of record time a second turntable was started. A switch routed the audio signal from one turntable to the other resulting in no programme overlap between the two discs. The surviving transcription discs are now stored at the National Archives of Canada <http://www.archives.ca/>.

In most cases the original airchecks of Gould's early broadcasts are either lost or never existed. Fortunately Gould was fascinated with recording technology and had copies made of all his broadcasts for his personal use. These copies were apparently often made at Les Smith's private studio in Toronto on 12-inch acetates. From 1950 to about 1952 the discs used were 78 rpm and from about 1953 on the discs are 33.3 rpm microgroove LPs.

It is possible that some of these acetates were cut as the programme went to air, recorded either from a receiver tuned to CBC Radio or from lines directly from CBC to Les Smith's studio. In some cases it is obvious that the discs are copies made from another acetate (now lost), perhaps a transcription disc borrowed from the CBC. Turntables are heard getting up to speed and surface noise, not on the extant disc, is audible.

Following Gould's death the National Library of Canada (NLC) <http://www.nlc-bnc.ca/> purchased the contents of his apartment and in doing so gained possession of these 78s and LPs. The library hosts a special web site devoted to their Gould collection at <http://www.gould.nlc-bnc.ca/>.

1.2 Quality of Source Material

The quality of the 16-inch transcription discs is quite good. They have been played very little if at all and have been stored in a controlled environment. There is no line hum. However the turntables often ran at slightly different speeds creating a pitch difference at the side breaks.

The acetates were made of an aluminium base coated with a nitrocellulose lacquer. Over time the lacquer surface shrinks while the aluminium base remains stable causing the disc to crack and peel. These defects are heard on playback as pops, clicks, and hiss.

Where the transcription discs do not exist, Gould's own copies of the broadcasts are the best sources available. The quality of these 78s and LPs is not as high. The discs were played many times and were stored haphazardly. The surfaces are in rather poor shape. There is a great deal of line hum and sometimes crosstalk from other radio stations can be heard. In at least some cases they are second generation copies, the originals now lost.

2 Transfers

All transfers from acetate disc to the digital domain took place at the National Library of Canada in Ottawa in collaboration with Gilles St-Laurent, Audio Conservator for the Music Division of the library.

2.1 Cleaning

Having selected the best possible source material it is important to ensure the discs are clean before the transfer takes place. A Keith Monks machine was used to apply Tergitol highly diluted in distilled water, wash the disc with a brush, and vacuum the liquid off the disc. [1]

2.2 Signal Path

The signal path was as follows:

Stereo cartridge -> preamp (flat) -> 20-bit ADC -> Sonic Solutions

Even though the source material was mono a stereo cartridge and preamplifier was used during the transfer to gather the maximum available information. Clicks often appear in one groove wall only or in both walls but at slightly different times. Summing the groove walls to mono before reconstruction complicates matters. At best, the reconstructed signal will have a higher percentage of interpolations than necessary.

Other advantages of using a stereo cartridge and preamplifier include an improved signal to noise ratio, the ability to edit between groove walls, and the ability to accurately correct azimuth errors. [2] These benefits will be discussed later in the paper.

The transfers were made with the preamplifier set flat, that is, with no compensation equalization. All these discs were recorded prior to the RIAA standard and the pre-emphasis used in the cutting lathe is unknown. Rather than playing the irreplaceable discs repeatedly to select a compensation EQ it was decided to perform the compensation EQ at a later date and in the digital domain. In addition the reconstruction tools have a better chance of finding clicks and crackle if the high frequency content is boosted.

A 20-bit analogue-to-digital converter may seem excessive for material of this nature. The rational was that the material would be subjected to many levels of digital processing. It is best to start with and keep the longest wordlength possible throughout the processing to reduce accumulating quantization errors and to avoid adding layer after layer of dither.

Recording directly to the Sonic Solutions afforded many advantages. Sounds could be accessed quickly and repeatedly, and basic editing performed to ensure that all the material had been gathered, especially following skips and side swaps. Approximate compensation EQ was applied in the monitoring chain to reduce listening fatigue and to better judge the quality of the signal. The full 20-bit word was stored (24-bit following digital processing). The files were archived to exabyte and later quickly restored to the drives for further processing.

2.3 Stylus Selection

Not having access to the original recording devices it was necessary to experiment to determine the correct size and shape of stylus. The goal was to get the stylus into a portion of the groove so that it was picking up the maximum amount of music and the minimum amount of noise and distortion. Occasionally a particular stylus resulted in louder clicks than another but the piano sound was better. The sytlus with the better piano sound was used since the clicks could be easily removed later on.

There are over 25 styli to choose from at the NLC. An educated guess was made about the size of the stylus required and this was tried on the inner (or outer) spiral where there was no music programme to damage. Once a good candidate was found we recorded a brief passage to the Sonic with the selected stylus. The same passage was recorded with a stylus a size smaller and a size larger. The results were compared by playing back the recorded files from the Sonic.

2.4 Other tips

During the transfer it is important to check the condition of the stylus regularly. Debris can build up seriously affecting the high frequency response of the transfer.

These discs were under restricted circulation and available only for a brief period of time. It was helpful to have a music score on hand to ensure that all the programme material had been transferred. It is particularly important to verify that nothing is missing following skips or side changes.

Announcers voices are heard before and after performances on the airchecks. These were not used on the final CD but it was helpful to have the sound of the voice transferred as well when verifying the compensation EQ.

It is good practice from an archival point of view to record a completely unprocessed signal from the original sources. In the future more powerful reconstruction tools will be available. Should the original source deteriorate the flat transfer can be used as a source for reconstruction.

3 Tools for Restoration

For the most recent discs in the Gould restoration project both Sonic Solutions' NoNoise and CEDAR's Series 2 Modules were employed in the reconstruction. Working with the products from these two companies provided an opportunity to examine each system's advantages and disadvantages.

Three tools are common to NoNoise and CEDAR. There is a declicker for removing clicks, a decrackler for removing crackle and some forms of distortion, and a process for reducing broadband noise. Other tools are unique to one platform. CEDAR has an azimuth corrector while Sonic has manual declicking, complex filtering, and a powerful audio editor.

Sonic Solutions' NoNoise runs as an option on Sonic's hard disc editing platform. Only the broadband denoising operates in real-time. Declicking and decrackling run in the background. Sound is loaded to the system, the file is called up, a number of parameters are entered, and the computer begins processing a new file. Figure 1 shows a typical dialogue box. When the processing is complete the results can be compared with the original. Tuning the parameters can involve a number of trial runs so typically only a portion of the soundfile is processed during these trials. Multiple processes run sequentially.

All of the CEDAR processing operates in real-time and has a very simple user interface. Parameters can be adjusted and the results evaluated in real-time and processing can be switched in and out for quick comparisons of before and after. It is possible to chain a number of processors together via the AES/EBU digital interface.

Experience showed that while there is overlap between the two systems, they complement each other very well.

4 The Reconstruction Process

The following describes the general order of processing involved in the reconstruction stages. Some processes were repeated at different intervals. All routing of signals was via the AES/EBU digital interface and the resulting signals were stored at 24 bit resolution.

4.1 Declick

The flat transfers were played back from the Sonic to the CEDAR DC-1 and recorded back onto the Sonic. Typically a pass with the algorithm set for Large or Medium clicks was used, followed by an additional pass with the Small algorithm selected. In some cases an additional pass with the small algorithm selected but set for a lower threshold was used. Successive light passes will often give better sonic results than one aggressive pass.

It is important to remove the larger clicks first and then the smaller ones. Being very aggressive with the threshold setting can dull the overall sound but otherwise this process does not generally produce artifacts.

4.2 Decrackle

Often the final declick pass was combined with a decrackle pass by routing the output of the DC-1 to the input of the CR-1. The decrackle process must be used judiciously. Over processing can soften transients and result in a compressed, hardened or sometimes an "under water" sound. The piano seems particularly prone to this and even more so with Gould because of his trademark marcatto attack. Particularly rough passages required a second more aggressive pass. These passages were later edited back in to the less aggressive overall pass.

4.3 Broadband Denoising

Given sufficient processor cards it is possible to perform broadband denoising in real-time on the Sonic. Therefore the choice between the

CEDAR and NoNoise processing is less clear cut. NoNoise requires a sample of the noise, free of programme material. The noise fingerprint can be adjusted to attack specific frequency ranges more or less aggressively. The noise floor on an acetate sometimes shifts. When it does the fingerprint no longer represents the noise.

The DH-1 does not require a fingerprint and can therefore adjust to the noise floor in real-time. This is fine if the noise floor shifts very gradually but in a quickly shifting noise floor can introduced artifacts. If the noise is concentrated in one frequency range there is no user control to attack this range more aggressively.

With either process great care must be taken to avoid compromising the music programme. Listen for an altered frequency response, pumping of the noise floor, and a swirling "under water" sound.

The approach taken with this project was to perform a very light pass on the DH-1 at this stage. Following compensation EQ when the final noise level could more properly be evaluated, another light pass was sometimes made using Sonic's NoNoise. This decision was partly based on the availability of equipment at the time. When using Sonic the denoising was adjusted for less aggressive processing in the midrange where the bulk of the desired signal exists. No broadband denoising took place below about 300 Hz since it was felt that the complex filtering was more effective here.

4.4 Azimuth Correction

The AZ-1 is perhaps the most underrated of the CEDAR boxes. As explained below the two groove walls will be summed to mono before release on compact disc. Slight azimuth errors between the two groove walls will cause some of the desired signal to cancel when summed to mono. The AZ-1 corrects azimuth errors to the accuracy of one twentieth of a sample.

There is an auto-detect mode but with this particular source material it could be unreliable at times. During long pauses in the music, such as between movements, the processor would sometimes drift off in one direction creating very large delays. When the music began the processor would take a few seconds to return to an accurate setting, usually overshooting that setting before finally settling down.

It was noted that over the course of a side of an acetate there was a general trend from a short error to a long error. The method adopted for this project was to play a side through the AZ-1 in auto-detect mode without recording the output. As the error increased a set interval, the average error was noted with marks throughout the file as shown in Figure 2. The AZ-1 was set to manual mode and the delay was gradually increased manually as the output was recorded to the Sonic.

A typical 12-inch disc started with an error of about 0.2 samples and ended with an error equivalent to 1.0 samples. The 16-inch transcription discs which were cut from the inside out started with an error on about 1 sample and ended with an error of 0.5 samples.

4.5 Stereo Manual Declicking

Much of the source material for this project still contained clicks at this point in the process. Sonic's Manual Declick algorithms were used to remove clicks heard only on one groove wall. Clicks which were heard in the centre -- that is, equal in both groove walls -- were left until after the signal was summed to mono. Manual declicking is a very time intensive operation and there is no point removing a click in two operations when it can be done in one later on. Some clicks sound as though they are coming from one groove wall but are in fact present on both but in opposite polarity. Time is wasted and more harm done trying to remove clicks which will cancel out when summed to mono.

Different techniques were used depending on the source material. It is possible to monitor the signal summed to mono and switch to stereo when a click is heard to determine if it is only on one channel. Alternatively, one can monitor in stereo and switch to mono when a suspect click is heard to determine if it will cancel upon summing.

A number of interpolations are available. The B-type interpolator works quickly but was only useful in very static passages such as in the middle of a long decay or during pauses where no music is heard. If the source is at all complex, artifacts were audible. The D-type interpolator operates more slowly but is highly effective in correcting clicks in complex passages. It was by far the most commonly used interpolator. The E-type interpolator is useful where very brief clicks and sometimes distortion occur. At times when it was difficult to locate a tick precisely, an E-type interpolator was applied to the general area of the click. Occasionally the tick was removed. When it wasn't the resulting interpolation marks sometimes made the exact location of the noise more obvious.

Figures 3 to 6 show various examples of manual declicking.

4.6 Editing

Sonic Solutions' powerful editor was used to solve many problems. At times one groove wall was in very bad shape while the other was fine. It was possible to edit back and forth between the two groove walls to get the best result. Typically the swap lasted much less than one second but in extreme cases could go on for thirty seconds. This process was carried out at the same time as the stereo manual declick pass since the condition of the two groove walls was being judged at this time. An edit like this could save hours of reconstruction of a heavily damaged groove wall and often give a better final result.

Other editing techniques were used at various stages during the reconstruction. Early on, skips were easily removed. Near the end of the process, side joins were made seamless. On one occasion a note at the end of a side was clipped. This partial note was sent to a reverb unit to create a decay for the note. The newly manufactured note was then mixed with some record surface noise -- suddenly missing in the reverb-only portion -- and edited back in to the programme.

It was tempting to use repeats to correct severe problems with the surface at certain times. However, the unique historical nature of the recording -- a live-to-air performance by a musician well-known for his penchant for editing [3] -- seemed to dictate that the performance be left intact.

4.7 Sum to Mono

At this point the two groove walls are finally summed to mono. Having used the azimuth corrector there was no change in the spectrum of the programme material. However, a surprising amount of noise canceled out. It is important to use the groove wall swapping technique described abov judiciously because of this very point. When ever a groove wall swap was considered the passage was auditioned summed to mono before and after the swap to ensure that the edit was in fact improving the final result.

Generally the original signal is present with equal amplitude and polarity in both groove walls. When summed to mono the desired signal increases dB. Generally the noise is incoherent and upon summing increases only 3 dB. Here we see an additional benefit of removing the noise from each individual groove wall before summing to mono.

Summing to mono has the added benefit of reducing the amount of disc space required to store the files on the Sonic System.

4.8 Mono Manual Declicking

At this point the clicks left in during the stereo manual declick pass were removed where ever possible.

4.9 Pitch Correction

It would have been preferable to correct the speed of the playback turntable during the transfer. Limited time with the source material and other practical limitations prevented this so the pitch was corrected using Sonic Solutions Background Sample Rate Conversion.

The LPs tended to be recorded at the correct speed. The 78's were sometimes recorded off speed and the entire file had to be pitch shifted. The transcription discs were often running at slightly different speeds anc the off speed disc had to be corrected to avoid a pitch shift at the join of the sides (which often occurred mid note).

The correct pitch was determined by ear. The Sonic's digital clock was locked to a Sony PCM-7030. The vari-speed on the 7030 shifts the frequency of the clock in 0.1% increments. When the correct amount of shift was found the reading on the 7030 was noted. This number was entered in the parameters for the Background Sample Rate converter and the pitch corrected file was created in a background process.

4.10 Compensation Equalization and Filtering

Determining the correct compensation equalization using modern parametric EQs can be a daunting task. The strategy used on this project was to use a purpose-built analogue device to determine the basic parameters of the compensation EQ and then implement the EQ in the digital domain. In some cases an Owl 1 Restoration Module was used and in others a McIntosh C20. These units contain selectable preset equalization curves intended for playback of pre-1955 recordings.

Each disc was auditioned on one of these devices and an appropriate playback curve selected. White noise was applied to the unit and each of the desired settings was measured. The curve was then matched using the digital equalization in the Sonic System. A good starting point for the low frequency boost is to use a parametric EQ with a broad Q and the centre frequency set for 20 Hz. Similarly, for the high frequency cut set the centre frequency at 20 kHz. Adjust the Q factor and amount of boost to best match the analogue device's curve. [4]

It was found that even with matching the curves very carefully the digital EQ sounded quite different from the analogue. Additional experimentation lead to more appropriate settings for the digital EQ.

An FFT was performed using the Sonic System (see Figure 7) and problem frequencies were noted. A great deal of unmusical information below 30 Hz was removed. Except for the CBC transcription discs there was a great deal of hum, typically at 60 Hz and it's harmonics. Appropriate parametric EQs were carefully applied to reduce the amount of hum without causing too much damage to the music.

The Complex Filtering component of Sonic Solutions' NoNoise suite allows the user to apply up to 512 filters and equalizers to a file in a single background pass. This allowed the compensation and corrective EQ to be applied in a single processing stage.

4.11 Fine Tuning

Much touch up work was performed at this stage. Sides were joined. Some discs are fairly bright at the beginning of a side and become increasingly dull as the side progresses. It is sometimes necessary to gradually adjust the brightness over time so as to avoid a sudden tumbrel shift at the side join.

A final light broadband denoising was appropriate in some instances when the programme was heard with its final equalization. Fine tuning of the over all equalization often took place.

5 Conclusion

The CEDAR Series 2 Modules from CEDAR Audio and the NoNoise suite of tools from Sonic Solutions are both very powerful tools. While there is overlap between the two systems they complement each other very well. A number of facilities doing extensive restoration work take advantage of the best that each system has to offer.

Each system provides a broadband denoising system with its own strengths and weaknesses. The CEDAR declick and decrackle boxes in particular are very efficient at removing surface noise from acetates. CEDAR's azimuth corrector is a unique and powerful tool. The Sonic provides a powerful editor as well as the indispensable manual declicking and complex filtering.

7 References

[1] Gilles St-Laurent, "The Care and Handling of Recorded Sound Materials", published by the Commission on Preservation and Access, 1991. An updated version appears at <http://palimpsest.stanford.edu/byauth/st-laurent/care.html>. [accessed 14 June 1997]

[2] Robert Rapley, "The Transfer and Restoration of Old Recordings", Masters thesis, Faculty of Music, McGill University, Montreal, May 1993.

[3] Glenn Gould, "The Prospects of Recording" *High Fidelity Magazine*, vol. 16, no. 4, April 1966, pp. 46-63. The article appears at <http://www.gould.nlc-bnc.ca/exhi/iv30.htm>. [accessed 14 June 1997]

[4] Gilles St-Laurent, personal communication, January 1997.

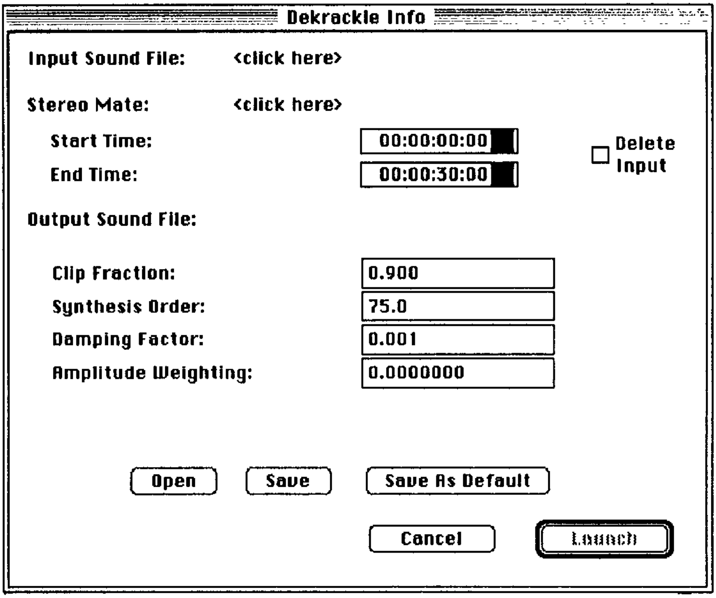

Figure 1. The dialogue for entering parameters for the Decrackle processing in Sonic Solutions' NoNoise.

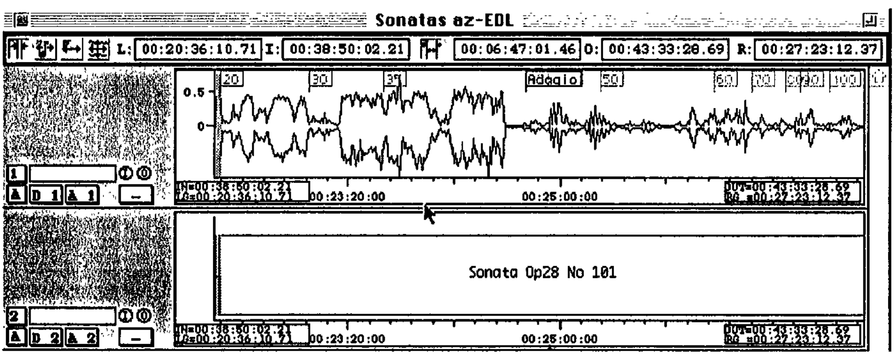

Figure 2. Comment marks are used to indicate points in time when the average azimuth error has changed. This 78 rpm acetate starts with a 0.20 sample error and finishes with a 1.00 sample error.

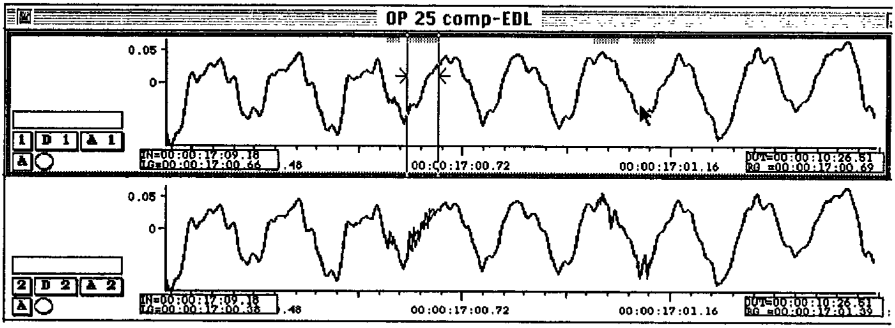

Figure 3. The bottom panel shows a file with a nasty glitch in four spots. The top panel is the same file following manual D-type interpolation with Sonic Solutions's NoNoise.

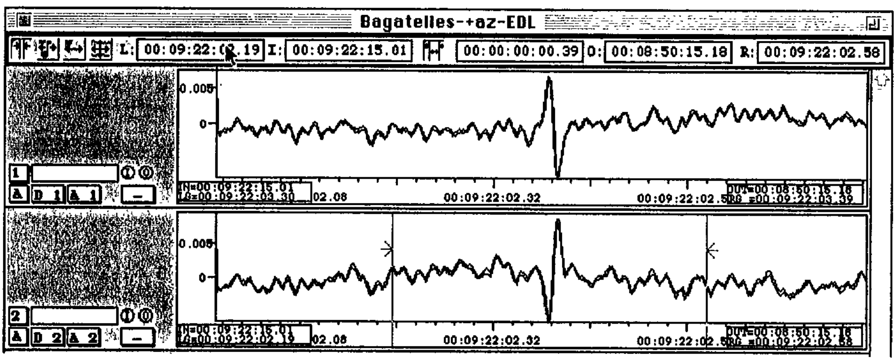

Figure 4. This signal creates a loud click when reproduced in stereo but cancels completely when summed to mono.

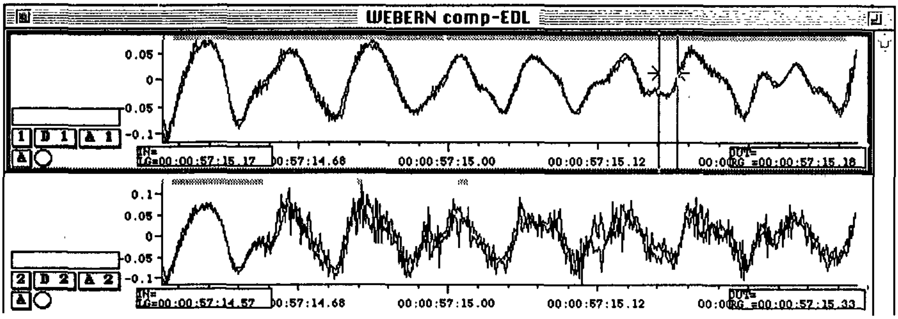

Figure 5. The top panel shows a file after extensive E-type and D-type manual declicking in Sonic. The bottom panel shows the same file before declicking. Before declicking a blast of high frequency noise was heard.

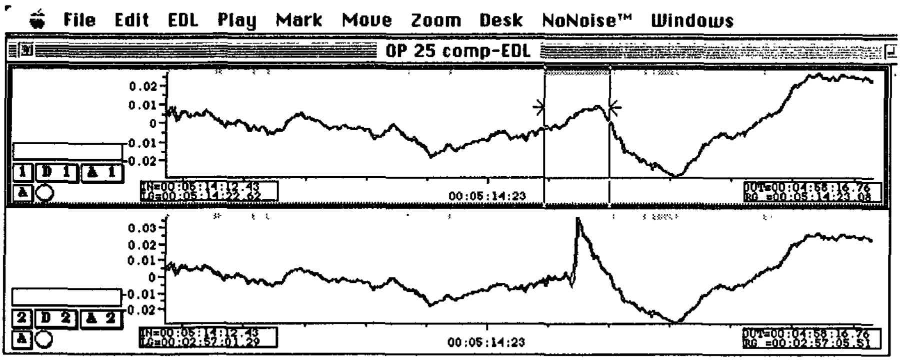

Figure 6. The bottom panel shows a large thump. The top panel is the same file following manual D-type interpolation with Sonic Solutions's NoNoise. The other small marks near the top of each panel indicate where E-type interpolations have occurred.

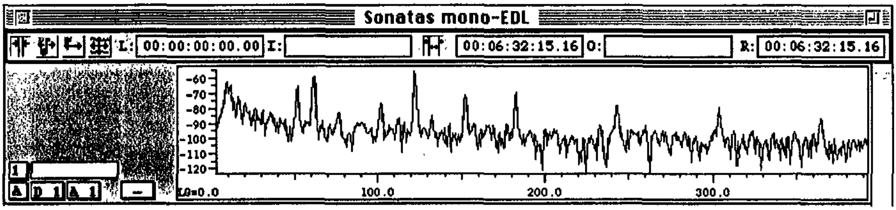

Figure 7. An FFT of a 78 rpm disc from Gould's collection before the low end boost of the compensation EQ was applied. There are large peaks at 60, 120, 180, 240 and 300 Hz as well as at 50, 100 and 150 Hz.