The Audio Limitations of the Vinyl Record: A Recording and Mixing Project Comparing Traditional Mixing Techniques to Vinyl-Specific Mixing Techniques

Connor Chase

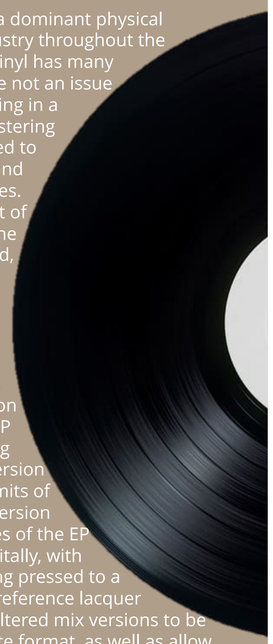
Middle Tennessee State University, Department of Recording Industry

Master of Fine Arts, Recording Arts and Technologies

Advised by: Cosette Collier, Misty Jones-Simpson, and Bill Crabtree

Abstract

Vinyl has reemerged as a dominant physical format in the music industry throughout the past decade. However, vinyl has many audio limitations that are not an issue for other formats, resulting in a different mixing and mastering process for music pressed to vinyl as opposed to CD and streaming service releases. The research component of this project focuses on the history of the vinyl record, the processes of cutting master lacquers and pressing vinyl, and the audio limitations caused by these processes. The creative portion involves using the research portion to produce and mix an EP of five songs, each having two mix versions; one version does not consider the limits of vinyl, while the second version does. The standard mixes of the EP will then be released digitally, with the altered versions being pressed to a type of disc known as a reference lacquer disc. This will allow the altered mix versions to be heard in their appropriate format, as well as allow for analysis and comparison of both mix versions.



Vinyl Timeline

- **1857** – Edouard-Léon Scott de Martinville patents the phonautograph.
- **1878** – Edison patents the first iteration of the phonograph.
- **1886** – Charles Sumner Tainter and the Bell Brothers patent the graphophone.
- **1887** – Emile Berliner receives a patent for the gramophone in Germany.
- **1888** – Edison releases the perfected phonograph, utilizing changes introduced by the graphophone
- **1893** – Berliner launches the gramophone in the US, which would eventually pass Edison's cylinder in popularity.
- **1897** – Shellac becomes standard material for the disc. This material would dominate until the advent of vinyl.
- **1920s** – Electric recording takes off due to microphones and amplification. First rotational speed standard set at 78 rpm.
- **1930** – RCA Victor launched the first vinyl long-playing record; a commercial failure.
- **1948** – Vinyl is proved to be a commercially viable material for discs by Columbia's long-playing record; the 33 1/3 rpm is established as standard.
- **1949** – RCA Victor introduces the 45 rpm 7 inch single; a rotational speed battle ensues. Both were used and still are today, but Columbia's 33 1/3 rpm 12 inch became the standard.
- **1950s** – The Westrex Company establishes the 45/45 System for combining two channels of information into a single groove.

Cutting a Master Lacquer Disc

A master lacquer disc is the physical bridge between recorded sound and a physical disc. The lacquer disc is typically made of a flat aluminum base, coated in a thin layer of synthetic lacquer. The aluminum center must be treated to remove any abnormalities to help the lacquer adhere. The lacquer is primarily cellulose nitrate, consisting of several ingredients such as resins, pigments, plasticizers, and solvents, which all have different benefits. The process of cutting a master lacquer is simplified and shown in the graphic below; this cutting process is always the first step before mass-production of a vinyl can begin.

Figure 1. A Neumann VMS70 cutting lathe (Boden 1981, 8).

This is an image of a Neumann VMS70 cutting lathe, which are still extremely common today. While it may appear to be a simple machine, there are several moving parts and devices that all must work together in a very specific way. Today, repairing lathes can be extremely difficult, and many manufacturers of the past era are not still producing record cutting lathes, making them very valuable.

The Westrex Company and the 45/45 System

One of the final major developments for vinyl was the 45/45 System, introduced by the Westrex Company in the 1950s. This system allowed for the groove to become stereophonic instead of monophonic, meaning two channels of information, left and right, could be within the same groove.

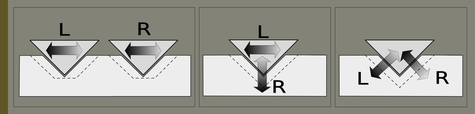


Figure 2. The left shows the original lateral movement of the groove. The middle shows the initial proposed way of embedding stereo information into a single groove, through lateral and vertical movement. The right shows the 45/45 System, which involved rotating the original design 45 degrees to maintain compatibility with mono cartridges.

The Process of Cutting a Master Lacquer

1. The source audio material arrives to a cutting studio or facility.
2. The engineer does a listening analysis of the material; they make note of any processing that may need to be done before cutting.
3. A treated 14-inch lacquer disc is placed on the turntable of the cutting lathe.
4. The cutterhead is lowered onto the rotating master disc for a test cut on the outer portion of the disc.
5. The cutterhead is lowered onto the rotating disc to begin cutting the master lacquer disc.
6. After the entire side is cut, the engineer will examine the groove with a microscope. If there is another side, the process is repeated.
7. The master lacquer is then shipped to a vinyl pressing plant where the pressing process begins.

Pressing a Vinyl Disc

Following the creation of the master lacquer disc, the lengthier process of creating stampers to mass-produce vinyl records begins. This process, listed below step by step, is much more involved and intricate; there are also many more steps where things can go wrong. The timing of certain steps is especially important throughout the electroplating, as too little or too much time can cause the material to be too thin or thick. The use of the word "pressing" comes from the groove being created by the vinyl being pressed rather than cut, like in the process of the master lacquer.

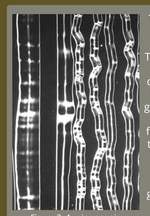


Figure 3. A microscopic photo of grooves displaying the benefit of the variable depth control (Boden 1981, 19).

These images show two microscopic photos of grooves. The left image shows how the variable depth control works by allowing the left grooves to be deeper and then adjusting for the right grooves to be less deep. The right image showcases an overcut, where the groove left of center has run into the center groove, damaging both grooves in the process.

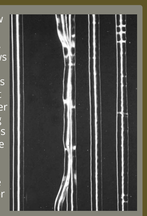


Figure 4. A microscopic photo of grooves displaying overcutting (Boden 1981, 19).

There are several issues and defects that can occur in the pressing process, including:

1. **Deticking** – The process of removing small pieces of the metal master that may be embedded in the metal mother during separation.
2. **Dehorning** – The process of removing horns, which are small ridges that form at the top edge of the groove wall during cutting due to an excess amount of heat around the stylus.
3. **Pull-Out** – A defect when the vinyl doesn't separate from the stamper cleanly, resulting in a harsh, unpleasant distortion. It can usually be seen on the vinyl with a naked eye.

The Process of Pressing a Vinyl

1. The master lacquer arrives at the pressing plant and is examined for any imperfections; if any are found, the cutting facility must recut the lacquer.
2. A deep cleaning of the master lacquer takes place and the mold making process begins. The master lacquer is submerged in a solution of tin known as stannous chloride.
3. The master lacquer is locked in place in a spinning drum and sprayed with a layer of silver nitrate.
4. The master lacquer is submerged in a solution of nickel sulfamate receiving a low current. The nickel comes out of the solution and forms on the disc; this is known as electroplating.
5. The master lacquer is separated from the newly formed metal coating, known as the metal master.
6. The process is repeated with the metal master now being submerged in the nickel sulfamate solution for electroplating.
7. The metal master is separated from another newly formed metal coating; this one is known as the metal mother, as it is an exact replica of the master lacquer.
8. The metal mother is played and examined for any imperfections, which can usually be fixed without repeating the process.
9. From the metal mother, the electroplating process is repeated again to create the stampers.
10. The stampers are sanded and smoothed, and then bolted into the record press to begin pressing vinyl.
11. The vinyl is heated in an extruder to achieve a similar texture to modeling clay. It is then placed into the record press along with the labels for the disc.
12. The press closes with each stamper pressing the vinyl together; the vinyl is heated to 300 degrees Fahrenheit.
13. After a set amount of time, cool water is pumped into an area behind the stampers, which helps the vinyl firm up.
14. After another set amount of time, the press opens; the vinyl is then analyzed for any problems as several issues can occur.
15. If acceptable quality, the excess vinyl is trimmed from the record.
16. The vinyl then cools to room temperature, is checked a final time, and then sleeved and placed into the album jacket.

The Limitations of Vinyl

Due to the nature of the format, vinyl has several restrictions that must be considered when pressing vinyl, including but not limited to:

1. **Length of the Material** – The space available on each side of a vinyl record is limited; there is only so much physical space that can be utilized. Maximizing this space by having grooves spaced closer together and more shallow means that the audio quality will suffer, making the balance of length of material as well as the spacing and depth of grooves a tricky situation.
2. **Speed or RPM** – The speed or rpm of vinyl is limiting because faster speeds tend to result in better sound reproduction and louder playback. However, a faster speed severely limits the available material length.
3. **Frequency Content** – Extreme low frequency content can introduce many issues throughout the process, including overcutting, groove lifts or skips, and groove collapsing. Extreme high frequency content can cause issues with the overheating of the cutting head, sibilance, and cutting loss. All of these potential issues introduce audible artifacts into the vinyl, making them important limitations to consider.

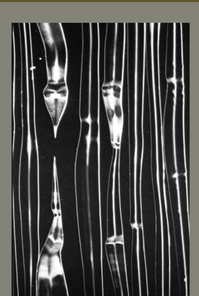


Figure 5. A microscopic photo of a groove that has lifted out, therefore breaking the groove. (Boden 1981, 19).

These images again show two microscopic photos of grooves. The left image shows a groove on the left side of the image that has "**lifted out**" of the groove, meaning the groove is disconnected completely. This was a result of out of phase low frequency content causing a nearly entirely vertical jump. The image on the right shows the same groove, but this time aided with a **low frequency crossover** to help eliminate the excessive vertical groove jump. A low frequency crossover is an extremely important tool utilized in almost every cutting facility.

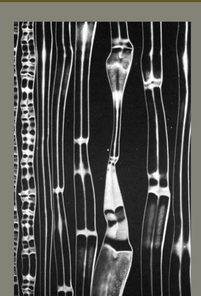
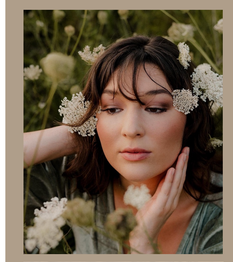


Figure 6. The same section as Fig. 5, except this time, a low frequency crossover was utilized to correct the lift out; it was successful (Boden 1981, 19).

Recording and Mixing Process

The creative component of this project is currently underway. My artist is **Emily Jaloma**, an alumni from MTSU that is an extremely gifted songwriter and vocalist. We are currently in the process of recording the EP, with all five songs in various stages of production. Throughout the mixing stages, I will be referring to my research on the limitations of vinyl, like the extreme low-end and high-end of the frequency spectrum as well as the length of the material. The altered mixes will look at addressing each of these problem areas in the mixing stage rather than after the EP has been delivered to a cutting facility, which is the typical workflow. The altered mix versions will then be sent to a facility to cut a reference lacquer; this reference disc is a different, less durable material often used for final quality checking before the pressing process. The reference lacquer disc will be used to compare the altered mixes to the original mixes for analysis to see if the changes made for vinyl production were noticeable.



The standard mixes of the EP will hopefully be released later this year.

Conclusion

The research and creative components of this project have been extremely fulfilling. As a collector of vinyl for over 10 years, learning about the intricate details of the cutting and pressing processes has been eye-opening to the amount of work that goes into producing a vinyl record. Not only have I learned so much technically, but my creative skills regarding producing and mixing music have also increased throughout this process. Although a format with many specific limitations, vinyl has proved that it is here to stay, and will continue to be the driving force behind physical music sales for the foreseeable future.

Acknowledgements

First, I'd like to thank my advisors, Cosette Collier, Misty Jones-Simpson, and Bill Crabtree for offering incredible guidance throughout this process, as well as the entire Department of Recording Industry. Second, my family, who always have shown me support in whatever I pursue. Third, my friends, who have been the biggest help through it all. And finally, my artist for this project, Emily, for writing incredible music and allowing me to work on these songs.

References

Berson, Steven. 2023. "Direct Metal Mastering Studios." Total Sonic Media. 2023.

Boden, Larry. 1981. *Basic Disc Mastering*. Full Sail Recording Workshop.

Christopher, Brianne. 2021. "The History and Science Behind Vinyl Records." COMSOL, August 17, 2021.

Eargle, John. 2003. Handbook of Recording Engineering. 4th ed. New York City: Springer.

Feaster, Patrick. 2010. "Édouard-Léon Scott de Martinville: An Annotated Discography." ARSC Journal 41 (1): 42–82.

Furnace Record Pressing. 2022. "Vinyl 101: How to Prepare Your Audio for Vinyl." Furnace Record Pressing. 2022.

GZ Media. 2017. "DMM Technology." GZ Vinyl. GZ Media. 2017.

Mall, Andrew. 2021. "Vinyl Revival." Journal of Popular Music Studies 33, no. 3 (September 1, 2021): 73–77.

The New York Public Library. n.d. "Berliner Gram-O-Phone." New York Public Library.

Osborne, Richard. 2012. *Vinyl: A History of the Analogue Record* (1st ed.). Routledge.

Robair, Gino. 2011. "Tips for Mixing for Vinyl." Electronic Musician 27 (5): 78–81.

The Smithsonian Institution. 2015. "Picturing Sound: Édouard-Léon Scott de Martinville." National Museum of American History. The Smithsonian Institution. 2015.

UCSB Cylinder Audio Archive. 2005. "Tinfoil Recordings." UCSB Cylinder Audio Archive. University of California. November 16, 2005.

Welch, Walter L., and Oliver Read. 1976. *From Tin Foil to Stereo: Evolution of the Phonograph*. 2nd ed. Indianapolis, Indiana: Howard W. Sams.