A Comparative Analysis on the Unique Characteristics of Microphone Preamplifiers

by
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Introduction

A microphone preamplifier is a device that takes a weak electrical signal from a microphone and brings it up to what is referred to as line level. Without a preamplifier, most microphones output a signal between -50 and -70 dBu depending on the type of microphone (Tremaine 211). In an article posted to his website, Mike Rivers says, “Building a good microphone preamplifier is a significant design challenge. It must provide gain ranging from 0 to as much as 75 dB while adding minimal noise to the low level microphone signal, rejecting electrical noise induced in the cables, and cleanly amplifying anything from pounding drums to subtle strings without distortion or unwanted coloration” (Rivers). In many ways, microphone preamplifiers can be thought of as a converter to make a microphone signal usable. This is not the only thing a microphone preamplifier does to the signal. Many preamplifiers are designed to impart their own special quality, or “tone,” on the signal. This “tone” is often described as a coloration of the original signal. Audio engineers use many different types of words to describe the types of coloration that a preamplifier can impart on a signal. A few different words that are commonly used are bright, dark, punchy, present, warm, articulate, and muddy. Because of these different characteristics that preamps have, audio engineers often pick different preamplifiers for different types of sources. For example, engineers often desire a different type of tone for the lead vocal than they would for the bass guitar. These different characteristics are often looked at as inherent aspects of the preamplifiers performance, and engineers rarely question why they sound the way that they do.

Definition of Terms

- **Amplitude** – In audio, loudness or volume.
- **Class A Amplifier** – “A mode of amplifier operation in which the amplifying device (tube or transistor) amplifies the entire musical waveform” (Harley 80).
- **Class AB Amplifier** – “A power amplifier that operates in Class A up to a small fraction of its output power, and then switches to Class B operation” (Harley 80).
- **Class B Amplifier** – “Mode of amplifier operation in which one tube or transistor amplifies the positive half of an audio signal, and a second tube or transistor amplifies the negative half” (Harley 497).
- **Decibel (dB)** – “The decibel…isn’t an absolute measure, but rather a ratio. It is used to describe how much larger or smaller a sound level or signal amplitude is than a standard reference level” (Kadis 5).
- **Distortion** - The name given to anything that alters a pure input signal in any way other than changing its magnitude (Bohn).
- **Impedance** – “Resistance to the flow of AC electrical current. An impedance is a combination of resistance, inductive reactance, and capacitive reactance” (Harley 504).
- **Line Level** – A signal of appropriate amplitude to be recorded. Defined as +4 dBu.
- **Mic Level** – A very low voltage signal produced by a microphone.
- **Preamplifier (Preamp)** – "Small signal amplifiers are commonly used devices as they have the ability to amplify a relatively small input signal…into a much

larger output signal to drive a relay, lamp or loudspeaker for example" (Introduction).

- **Signal-to-Noise Ratio (SNR)** – "Numerical value expressing in decibels the difference in level between an audio component's noise floor and some reference signal level" (Harley 513).
- **Slew Rate** – "The speed (measured usually in volts per microsecond, V/μs) at which an amplifier output shifts when a step source of extremely high speed is applied to the input" (Ballou 837).
- **Total Harmonic Distortion (THD)** - A form of nonlinearity that causes unwanted signals to be added to the input signal that are harmonically related to it (Bohn).
- **Transformer – "**Audio transformers can: 1) Step up (increase) or step down (decrease) a signal voltage; 2) Increase or decrease the impedance of a circuit; 3) Convert a circuit from unbalanced to balanced and vice versa; 4) Block DC current in a circuit while allowing AC current to flow; 5) Electrically isolate one audio device from another. A transformer is an electrical device that allows an AC input signal (like audio) to produce a related AC output signal without the input and output being physically connected together" (Transformers).

Thesis Statement

To many in the world of audio production, different preamplifiers hold a sort of magical essence that gives them their characteristics. I believe that there is a scientific explanation of why different preamplifiers are better suited for different jobs. The goal of my project is to qualitatively and subjectively answer the question, “What fundamentally makes preamplifiers different?” I believe I will discover that the slew rate of each preamplifier plays a major role in creating its unique sound. I expect this to have a major effect on why the API 512c preamp sounds punchier and why the Neve 1073 preamp has a smoother and warmer sound. I also believe I will see major differences in the frequency response as well as the amount of THD in each preamplifier tested. After conducting my research, I plan to use this knowledge to build a preamplifier of my own.

Overview

My approach to this project consisted of both a subjective and objective portion of analysis. For the subjective portion of my study, I interviewed different engineers about their understanding and usage of preamps. I asked the engineers what preamps they typically choose for different sources, why they make these choices, and what they believe makes one preamp different from another. The objective portion consisted of testing a Neil 1073 Lite, an API 512c, and a Millennia HV-3D for the extent of this project. I chose these three manufacturers because they represent a large share of preamplifiers that are commonly used today. The API 512c is usually considered to be a very punchy, aggressive preamplifier while the

Neve 1073 is typically described as very smooth and warm. The Millennia HV-3D acted as a "control" for my tests because it is considered to be a very transparent preamplifier.

The API 512c, Neve 1073, and Millennia HV-35 are all discrete preamplifiers. This simply means the amplification is done via individual components such as transistors, capacitors and resistors instead of integrated circuits. So, I did not expect that portion of the topography to have a large effect on my results. Both the Neve 1073 and Millennia HV-35 are Class A amplifiers while the API 512c is a Class AB preamplifier. Class A amplifiers use a single transistor or tube (transistor in the case of the Neve 1073 and Millennia HV-3D) in order to replicate the entire waveform. Class B operation is when a preamplifier has two transistors or tubes, one transistor or tube handles the positive side (180°) of the signal while the other transistor or tube handles the negative side of the signal (180°). In regards to Class AB operation, Harley says that it "operates in Class A up to a small fraction of its output power, and then switches to Class B operation" (Harley 80). However, when the Class AB amplifier switches to class B, they typically have a wider crossover than the 180° that a standard Class B amplifier operates at. A Class AB amplifier uses a crossover greater than 180° in order to minimize crossover distortion. Because of this, there is a portion of the signal that the two transistors, or tubes, share. I do not believe that this difference in design causes many differences between the preamps tonal characteristics, but I do believe this is why the API 512c preamplifier has a significantly higher output than the Neve 1073 and Millennia HV-35.

For this project, I chose to measure these preamplifiers' frequency response, dynamic range, noise floor, signal-to-noise ratio, total harmonic distortion + noise, equivalent input noise, input impedance, and slew rate. The frequency response test measures "the unit's bandwidth or the range of frequencies it passes" (Bohn). This test is designed to show us if a preamplifier passes more or less of a certain range of frequencies, which can have a significant effect on the unit's tonal characteristics. The dynamic range tests the maximum output voltage the unit is capable of and then tests the unit's output floor noise (Bohn). This test determines how loud and how quiet of a signal the preamplifier can process. Knowing the dynamic range of a preamplifier allows us to determine what types of signals it can process best. A preamplifier with a small dynamic range would not be able to accurately process a very dynamic piece of music. The noise floor is simply how much noise the unit produces when no signal is running through it. The signal-to-noise ratio measures the noise floor relative to the level of signal the preamp produces. This test shows us how "clean" a preamplifier's signal remains. Total harmonic distortion measures the amount of distortion that occurs harmonically to the signal. The Total Harmonic Distortion + Noise test measures every single component added to the signal by the preamplifier. Rane's website says it measures, "harmonics, hum, noise, RFI, buzz ... everything" (Bohn). This test shows us how "clean" or "transparent" a preamplifier's signal is compared to the signal before passing through the preamplifier. Testing the impedance shows us what the preamplifier's transformer is doing. Transformers are used to "match the relatively low output impedance of a microphone to the high input impedance of a vacuum tube, but with a solid state preamp, which typically has a fairly low impedance input, to use a transformer or not is the designer's choice" (Rivers). Testing the input impedance of a microphone preamplifier gives us a good look into what the transformer is doing if one is present. I expected this test to have more drastic results between the Millennia and the Neve and API preamps because the Millennia does not have a transformer. The final measurement I will take is for the slew rate of each preamplifier. The slew rate refers to how fast an amplifier can "ramp up" to the necessary frequencies in order to recreate the transient. Handbook for Sound Engineers says, "Slew-rate limiting occurs when the fastest signal rise time the amplifier is expected to pass exceeds the speed of the fastest stage in the amplifier; the input transient becomes slurred to as fast (or as slow) as the amplifier's capability" (Ballou 844). This is the test I expected to reveal the most about each preamp's characteristics, such as the punchiness of the API 512c and the smooth, warmth of the Neve 1073.

Questionnaire

My goal with the questionnaire was to evaluate professional engineers' thoughts on the different preamplifiers I would be testing. I had ideas of the "unique characteristics" that I would assign each of these preamps, but wanted to use the questionnaire as evidence of these ideas. I designed the questionnaire and sent it out to some great engineers and people whose opinions I trust. My questionnaire consisted of 10 questions. They were:

1. If you only had one preamp choice when recording would you choose a(n):
    a. API
    b. Neve
    c. Millennia
    d. Other
2. How would you describe a Neve preamp? (Choose as many as apply.)
    a. Warm, Punchy, Transparent, Colorful, Bright, Dark, Smooth, Aggressive?
3. How would you describe an API preamp? (Choose as many as apply.)
    a. Warm, Punchy, Transparent, Colorful, Bright, Dark, Smooth, Aggressive?
4. What preamp would you use to record a vocal?
    a. API
    b. Neve
    c. Millennia

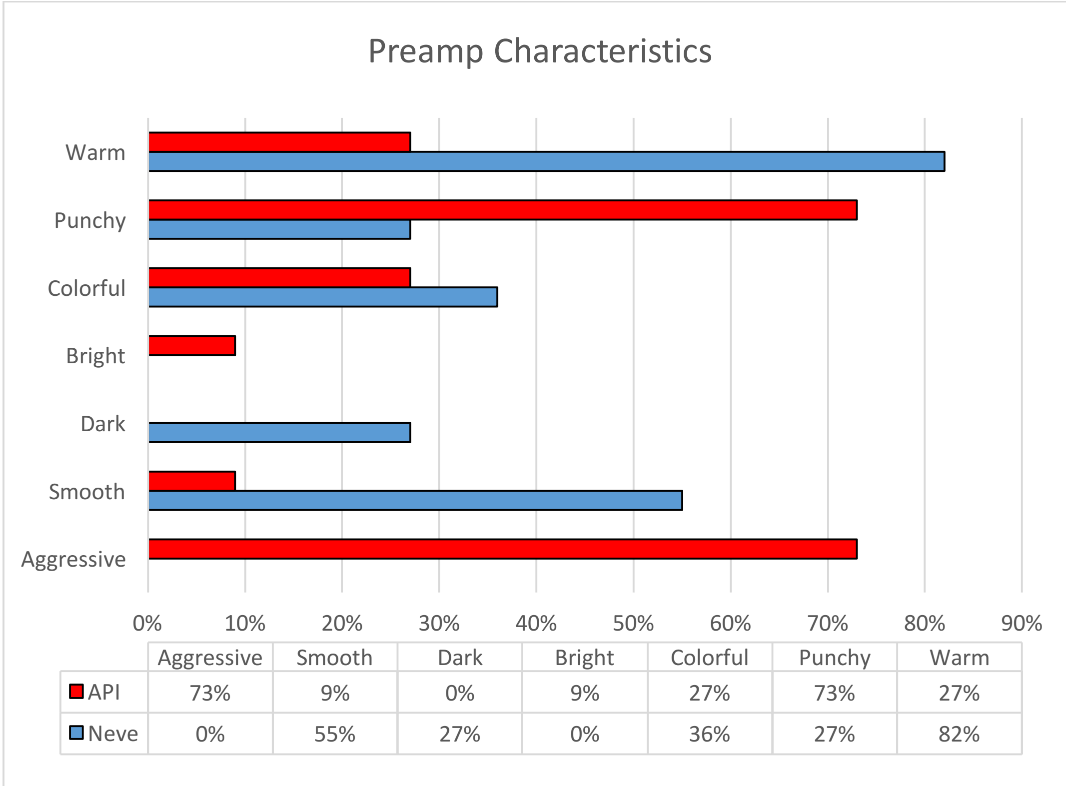
   d. Other

5. What preamp would you choose to record drums?
   a. API
   b. Neve
   c. Millennia
   d. Other
6. How would you describe the differences between a Neve and API preamp?
7. What do you think causes these differences?
8. Explain your answer to question 4. (What preamp would you choose to record a vocal?)
9. Would your answer to question (4) be different for a male or female vocalist?
10. Explain your answer to question 5. (What preamp would you choose to record drums?)

I received responses from eleven of the professional engineers that I asked to take my questionnaire. For the most part, the responses to the survey aligned very well with what I expected to see. About 82% of my responses said that a Neve preamp was "Warm," and 55% said it was "Smooth." On the other hand, 73% of my responses said an API preamp was "punchy" and "aggressive." I thought this was a very interesting result and was very intrigued as to what gives API preamps this "aggressive" characteristic. I also found it very interesting that no one said that a Neve or API preamp was "transparent." "Transparent" is a word that is frequently used in the pro-audio community and is often touted as being synonymous with being sonically perfect.

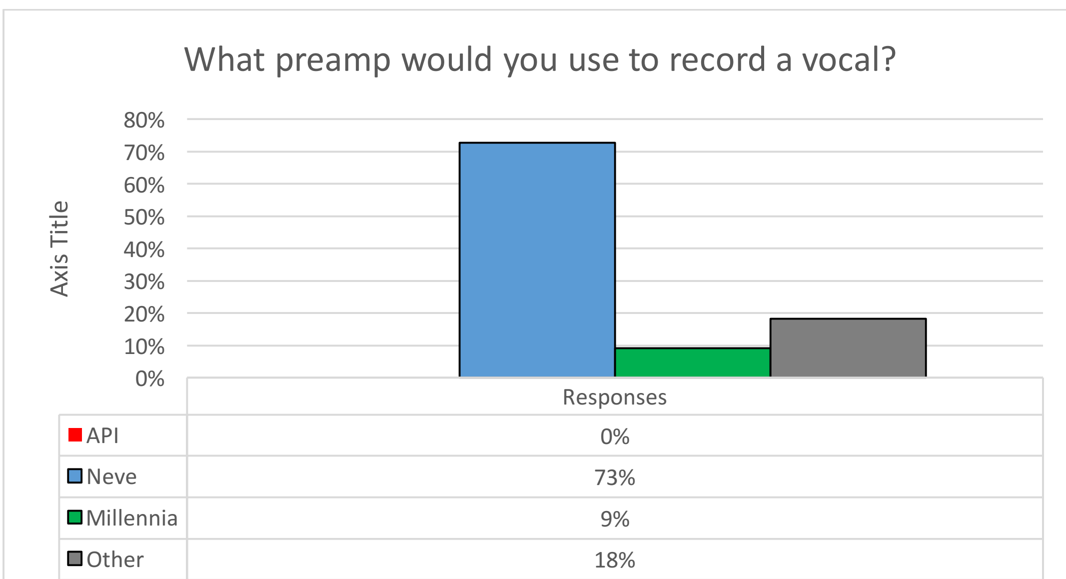
However, no one seemed to think that two of the most renowned and sought after preamps were transparent! Rather, about 30% of my responses said that both preamps were “colorful.” Almost all of my responses indicated that they would prefer a Neve to record vocals, and there was about a 50/50 split between the Neve and API for recording drums.

When asked specifically to describe the differences in these two preamps, I got statements like, “One Is midrangey and punchy (API) and the other is smooth and big (Neve)”, “Warm (Neve) vs bright (API)”, “Neve appears to have more bottom end punch and beef, whereas API's tend to be more mid forward/aggressive”, and “Neves are a bit warmer and thicker, where as API's sound more present and aggressive.” A lot of these responses hint at both the frequency response (bright, warm, mid-forward, present) and the smooth vs. aggressive nature of these preamps. This information aligned very well with what I expected to find and helps support my statements on the “unique characteristics” of these individual preamplifiers.



	Aggressive	Smooth	Dark	Bright	Colorful	Punchy	Warm
API	73%	9%	0%	9%	27%	73%	27%
Neve	0%	55%	27%	0%	36%	27%	82%

Figure 1: Chart showing the responses to the questionnaire about the unique characteristics of different preamplifiers.



	Responses
API	0%
Neve	73%
Millennia	9%
Other	18%

Figure 2: Chart showing the responses to the question "What preamp would you use to record a vocal?" from the questionnaire.

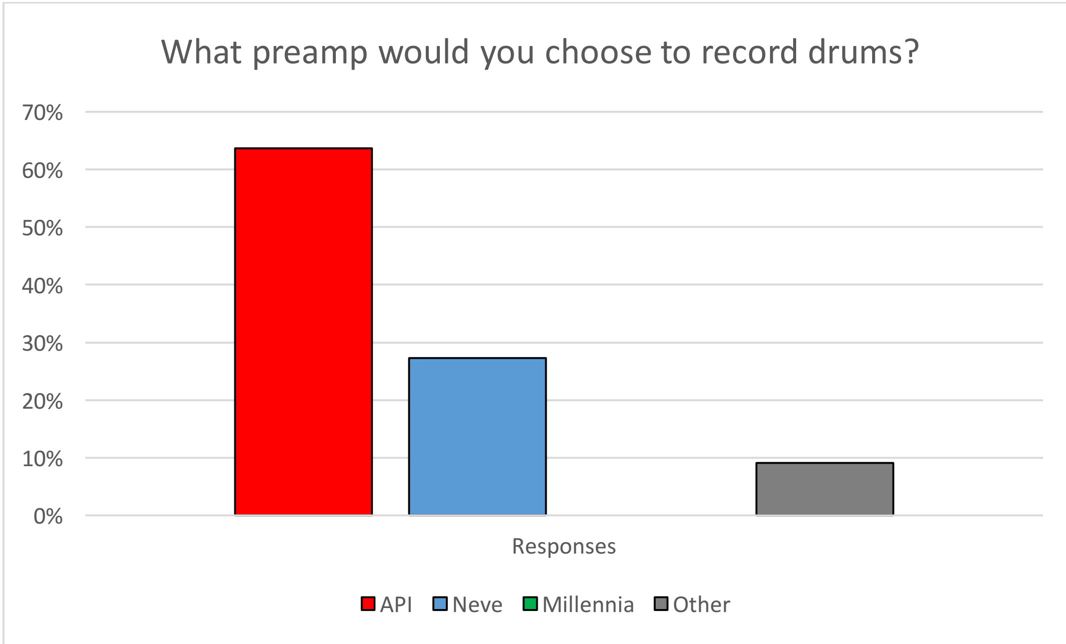


Figure 3: Chart showing the responses to the question "What preamp would you choose to record drums?" from the questionnaire.

Testing - Methodology

I performed all of my tests in the Audio Maintenance Lab of Middle Tennessee State University under the supervision of Alton Dellinger. I used the *Audio Precision ATS-2 Audio Test System* for all of the tests. This system is an industry standard for testing audio equipment. Professor Dellinger informed me that many manufacturers use Audio Precision (AP) equipment, like the ATS-2, to perform the tests to gather the information they use as specifications for their equipment. As I was unable to procure an actual Neve 1073 for testing, I used Michael Hanson's EIL 1073 LITE preamp for all of my Neve measurements. When building this preamp, Hanson performed extensive tests comparing it to an actual Neve preamp, so he assured me that it was a very accurate representation. The Neve's input impedance is switchable between 300 and 1200 Ohms. For my measurements, I set the preamp to 1200 Ohms. I chose to use 1200 Ohms because it was closer to the input impedance of the API and Millennia preamps, which were 1500 and 2210 Ohms, respectively. I bypassed the EQ circuit of this preamp completely for the tests. For my API preamp, I used one of Middle Tennessee State University's API 512c preamps that they keep in some of their studios. For consistency, I ensured that I used the same preamp for all of the tests. For my Millennia preamp I contacted Millennia and they lent me an HV-35 to use for this project, but upon delivery I discovered that the preamp would not power on. So, I decided to use Middle Tennessee State University's Millennia HV-3D. For consistency, I ensured that I used the same HV-3D for all of the tests and only used the first channel. I tested frequency response, dynamic range, noise floor, signal-to-noise ratio, total harmonic distortion +

noise, equivalent input noise, and slew rate. Although I had planned on testing input impedance, I decided to use the published values for this specification at Professor Dellinger's recommendation.

Testing – Results

Frequency Response

The first test I performed was frequency response. To perform this test, I used the AP ATS-2 system, which sweeps a tone across the frequency spectrum through the preamplifier and measures the response of the output of the preamplifier. Although I found the results very interesting, I do not believe they are something that would have a large affect on the overall characteristics of the preamp. I tested the preamps with a range from 15Hz to 25kHz. Many engineers believe that even though the range of human hearing is 20Hz to 20kHz, frequencies above and below this range have a large effect on how we "feel" sounds. For this reason, I decided to extend my test frequencies past the range of human hearing. When set to a ±10 dB range, all three preamps appeared to have a very even response. So, I changed the graph to a ±1 dB range and ran the tests again. Over such a small range, the results were much more evident, but it was also evident how inconsequential these changes probably are to the preamps' sound. The Neve preamp had a very slight dip around 100Hz and another deeper (-0.2 dB) dip around 10kHz. On the other hand, the API had a +0.2 dB boost on the low-end and a +0.8dB slope from around 2kHz up to 25kHz. The Millennia preamp was nearly completely flat except for a slight bass roll-off starting around 75Hz. I was surprised by how flat all of these preamplifiers' frequency responses were. Many of the terms we use to describe preamplifiers' unique characteristics are based on frequency (bright, dark, present, warm). Because of this, I expected the frequency responses of these preamps to have more variance between them.

Frequency Response Graphs:

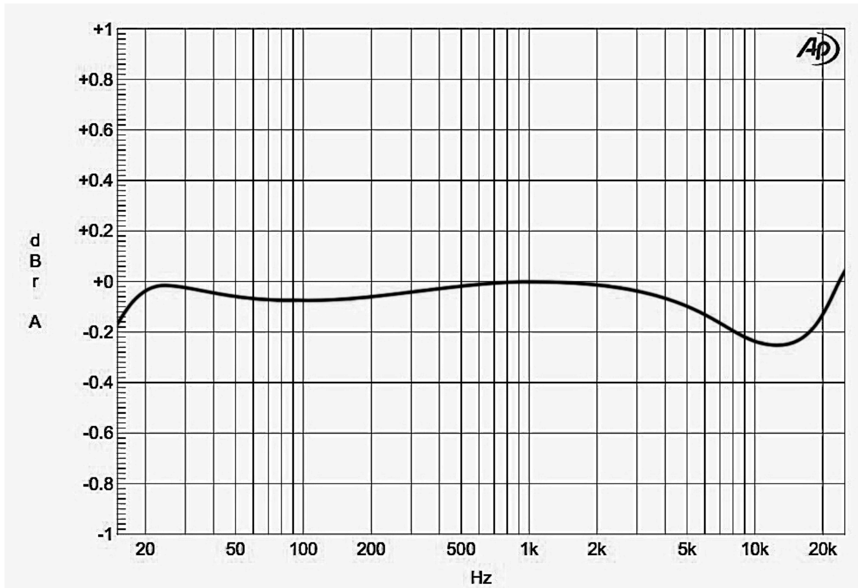


Figure 4: Graph showing the frequency response of the Neil 1073 Lite (Neve 1073) preamplifier. Notice the slight dip around 10kHz.

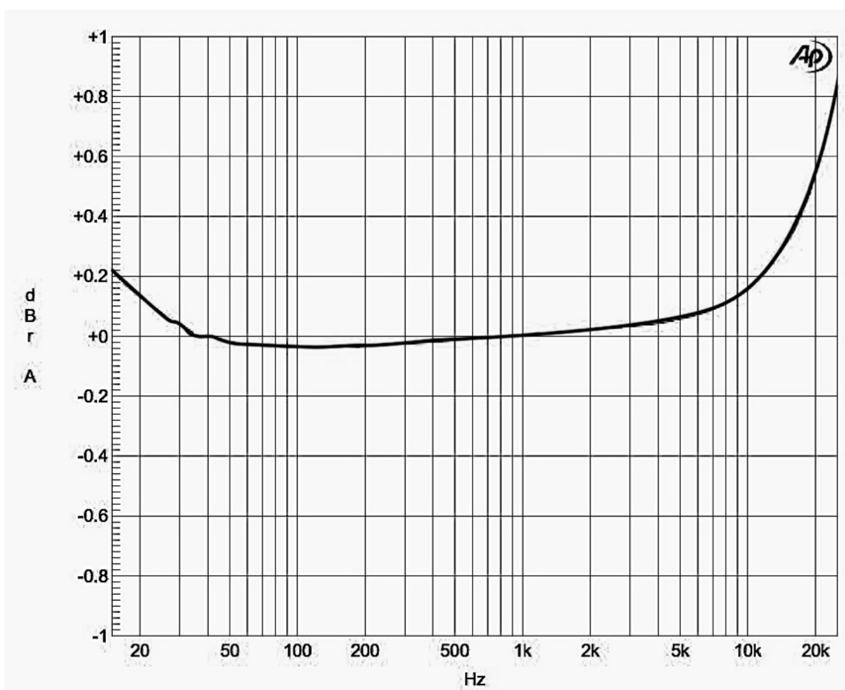


Figure 5: Graph showing the frequency response of the API 512c. Notice the boost on the low-end and the upward slope from around 2kHz up to 25kHz.

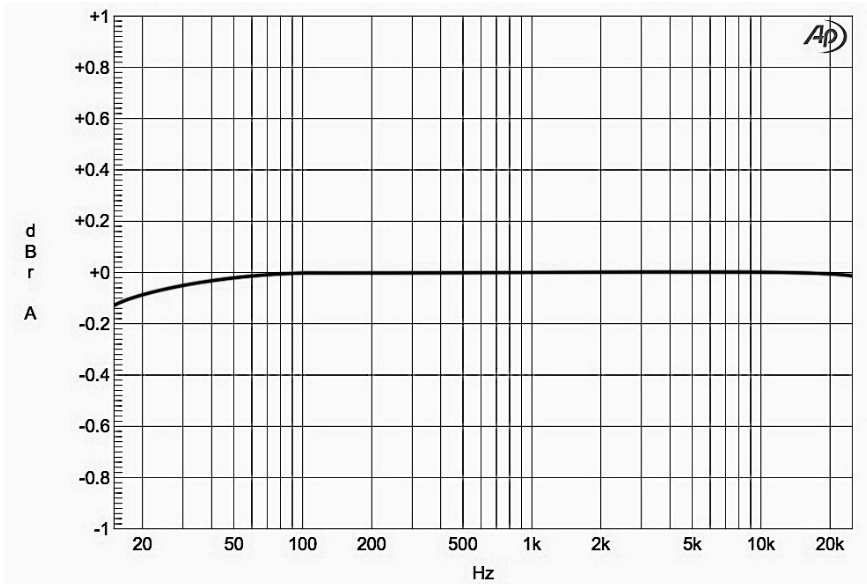


Figure 6: Graph showing the frequency response of the Millennia HV-3D. Notice the slight bass roll-off starting around 75Hz.

Noise Floor & Signal-to-Noise Ratio

Next, I tested the preamplifiers' noise floors. To perform this test, I hooked the microphone preamplifiers up to the ATS-2, but did not send a signal through the preamps. By doing this, the measured output showed what noise was present with no signal running through the preamp. This is the noise floor. For this test, I used a bandwidth of 10Hz to 20kHz. This test did not reveal any major differences among the three preamplifiers. The Neve, API, and Millennia preamplifiers' noise floors were -74.0 dBu, -70.9 dBu, and -63.7 dBu, respectively. From these numbers, the signal-to-noise ratio is easily calculable. The Neve, API, and Millennia preamplifiers' signal-to-noise ratios were -78.0 dBu, -74.9 dBu, and -67.7 dBu, respectively.

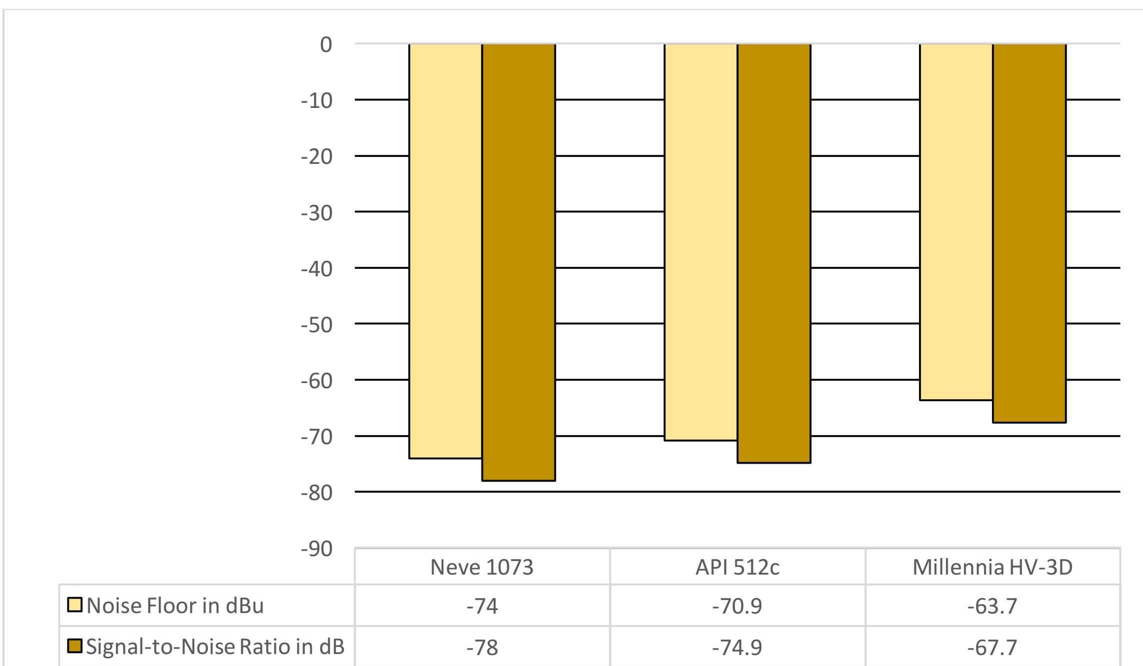


Figure 7: Chart showing the noise floor and signal-to-noise ratio of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Dynamic Range

Next, I tested the dynamic range of each preamplifier. This test measures the maximum input of each preamp. To do this, I continuously applied signal to each preamp until I measured 3% THD on the output. This is regarded as the amount of distortion necessary to qualify as "clipping." I then subtracted that number from the noise floor that I had previously measured (*Noise Floor - Clipping = -Dynamic Range*). The results of this test also surprised me. Millennia preamplifiers are considered very "dynamic" preamps and are often used to record classical music because of this. Since classical music is much more dynamic than pop, most engineers will use Millennia to capture this dynamic performance. However, the Millennia preamp actually had the smallest dynamic range of the three preamplifiers! With that being said, it did not have a small dynamic range by any means; the Millennia preamp's dynamic range was 96.23 dB. However, the API had a dynamic range of 103.38 dB while the Neve's was 103.28 dB. This lead me to believe there was another factor that made the Millennia preamplifier optimal for classical music recordings.

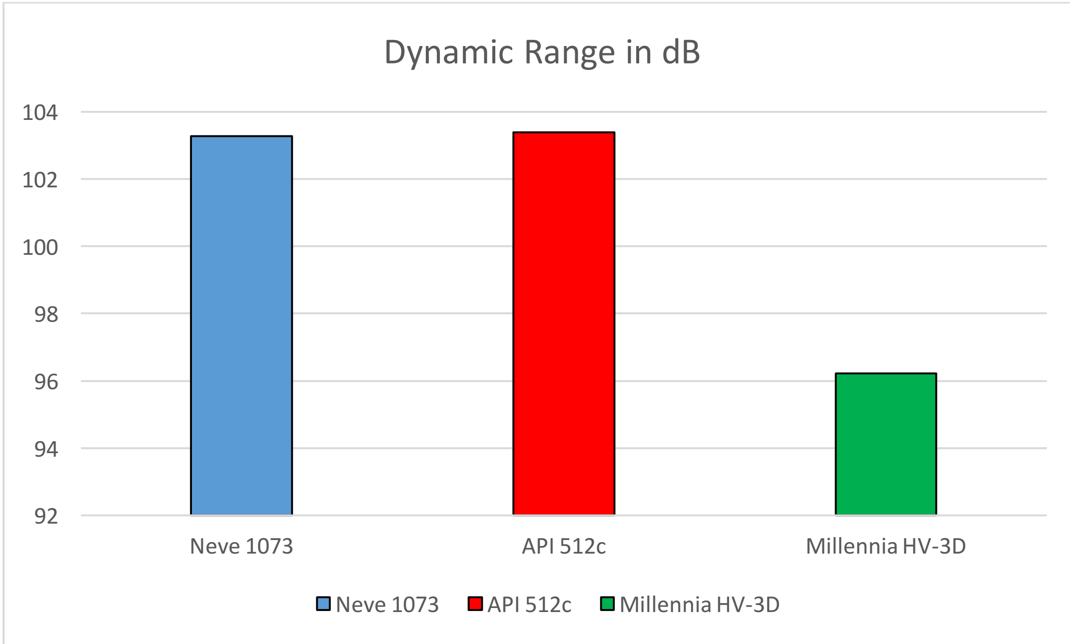


Figure 8: Chart showing the dynamic range of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Equivalent Input Noise (EIN)

The equivalent input noise (EIN), is another measurement that is calculated based upon the noise floor. To get this measurement, I subtracted the measured gain that I was applying on the preamp from the noise floor (*Noise Floor - Measured Gain = EIN*). For all of the tests, I set each preamplifier to as close to +50dB of gain is possible. For this test, I measured what the precise amount of gain each preamplifier was actually adding and used this number for my calculations. For the Neve, API, and Millennia preamps, my measured gain was 49 dB, 49.8 dB, and 49.9 dB, respectively. This yielded EIN measurements of -123 dB, -120.7 dB, and -113.6 dB, respectively.

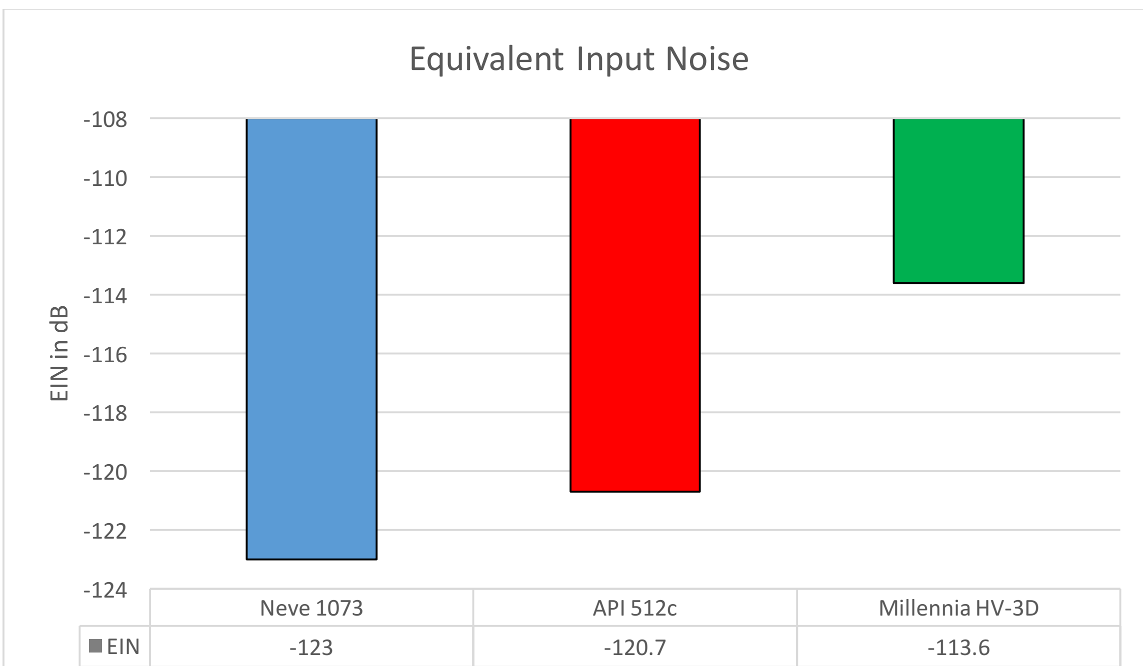
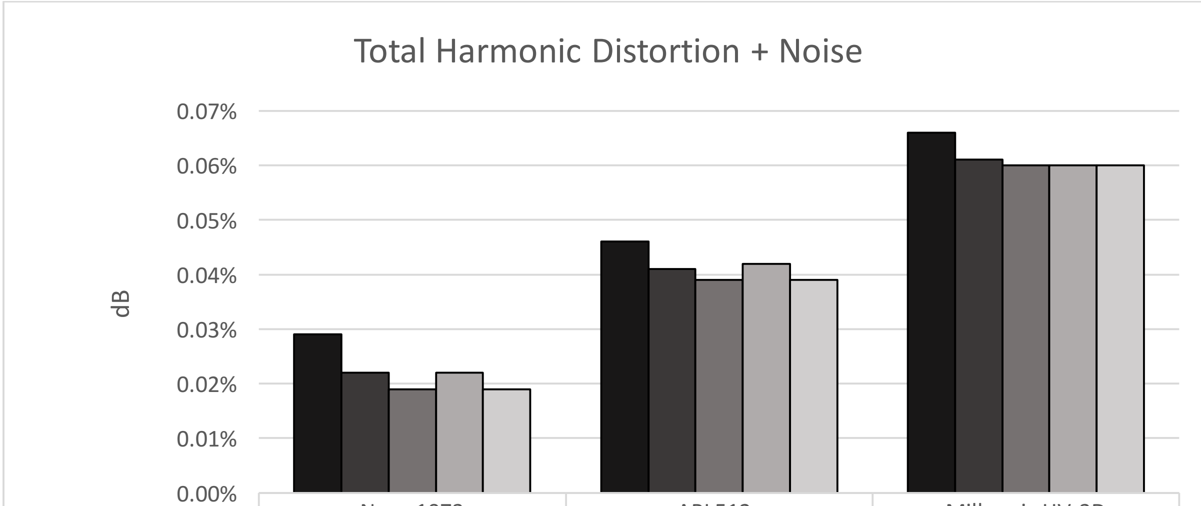


Figure 9: Chart showing the equivalent input noise of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Total Harmonic Distortion + Noise (THD+N)

Like the frequency response test, the ATS-2 system has a specific setting for testing the total harmonic distortion + noise. I ran this test at many different bandwidths in order to get an idea of what part of the frequency spectrum of each preamplifier's THD was most prevalent. Interestingly, the THD+N measurements across each preamplifier's frequency spectrum remained pretty consistent. Overall the Neve was much cleaner than the API or Millennia preamplifier. The API added about twice as much THD+N as the Neve, and the Millennia added about three times as much. This lead me to hypothesize that this was one of the specifications related to the Neve's clean and smooth characteristics. I also believe that the additional THD+N added to the signal in the API could contribute to the aggressive nature of that preamplifier. However, this seems completely contrary to the characteristics of the Millennia preamp. It is known for being very smooth and "transparent", but it actually adds much more to the signal than either the Neve or API preamp. This means that statistically it is the least transparent of the three preamplifiers measured. Like the dynamic range test, this seems to contradict the reputation of the Millennia preamplifier. Once again, this leads me to believe that there is another factor contributing to the Millennia's reputation of being the optimal preamp for classical recordings.



	Neve 1073	API 512c	Millennia HV-3D
< 10 Hz to Fs/2	0.03%	0.05%	0.07%
< 10 Hz to 20kHz	0.02%	0.04%	0.06%
< 10 Hz to 15kHz	0.02%	0.04%	0.06%
22 Hz to 20kHz	0.02%	0.04%	0.06%
22 Hz to 15kHz	0.02%	0.04%	0.06%

Figure 10: Chart showing the total harmonic distortion + noise of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Input Impedance

As I stated before, I chose to use the manufacturer's specified input impedance readings instead of measuring them myself. After discussing it with Alton Dellinger, he informed me that in order to truly test the input impedance of the different preamplifiers, I would have to partially disassemble them. Since many of the preamplifiers I was testing were on loan from other people or companies, I chose not to do so. Furthermore, the specification of input impedance is one that is very consistent, and should not be skewed by the manufacturer to make their preamps look better. According to the manufacturer, a Neve 1073's input impedance is switchable between 300 Ohms and 1200 Ohms. I chose to use the unit at 1200 Ohms for all of my tests, as it was closer to the input impedance of the other preamplifiers. The API 512c's input impedance is 1500 Ohms. The Millennia HV-3D has an input impedance of 2210 Ohms.

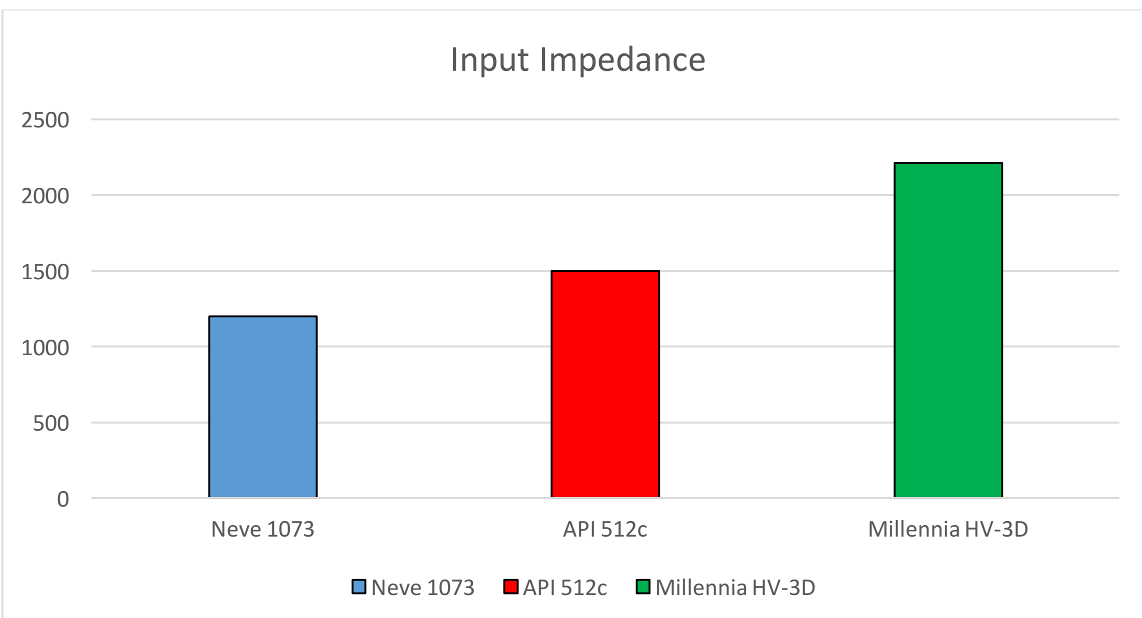


Figure 11: Chart showing the input impedance of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Slew Rate

The last test I performed was to measure the slew rate of each preamplifier. This was the most difficult measurement to take, as it required the use of the Audio Precision ATS-2 Audio Test System and an oscilloscope. To perform this test, I attached the input of the preamp to the ATS-2 and sent a square wave through it. Then, I hooked an oscilloscope up to the output of the preamp and triggered off of the waveform so that it captured a section of the wave where it was ramping up. Next, I measured the amount of volts (y-axis) that the signal increased every 1 microsecond (x-axis). This gave me a number in V/μs that is the slew rate.

This test was definitely the most telling of the different tests I performed. As shown in *Fig. 9,* the slew rates of the Neve, API, and Millennia preamps were 8 V/μs, 10.2 V/μs, and 24 V/μs, respectively. The measurements for the Neve and API preamps were precisely what I expected to find, but the slew rate of the Millennia preamp really surprised me. I had hypothesized that the API would have a faster slew rate than the Neve preamp, and that this is what gives the API the "punchy, aggressive" characteristic that it is known for and the Neve it's "smooth, warm" characteristic. The reason for this is that a slower slew rate is basically "smearing" the attack of the signal. If a preamp has a slower slew rate, it essentially has a softer, and therefore less aggressive, attack. However, I was very surprised by how drastically higher the Millennia's slew rate is than the Neve or API. After considering its common uses, it made sense why the Millennia has such a fast slew rate. As I stated before when talking about dynamic range, Millennia preamps are often used for recording classical music because they are able to capture the huge dynamic range that is present in classical music in a very transparent fashion. However, both the dynamic range and THD+N tests seemed to contradict these facts about the Millennia preamp. As I stated, this made me believe that there was another factor that gave the Millennia preamp its characteristics. I believe that factor is its extremely fast slew rate. This fast slew rate allows the Millennia to capture the full attack of different orchestral instruments as their dynamics vary throughout a performance. So, this fast slew rate is what makes the Millennia so optimal for classical recordings.

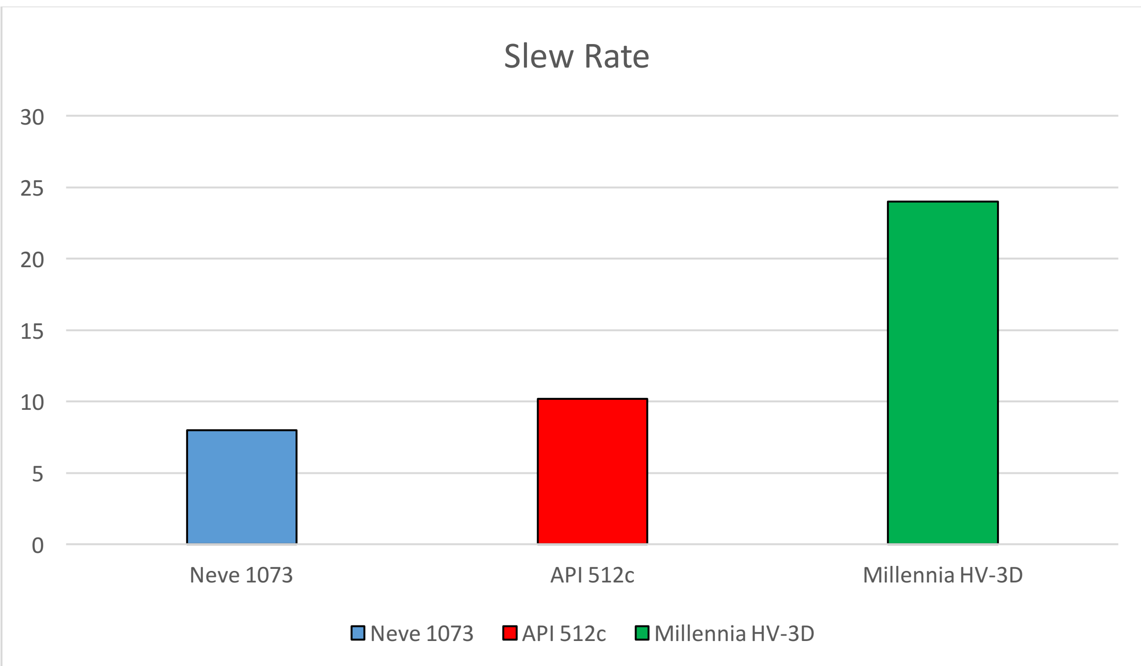


Figure 12: Chart showing the slew rate of the Neve 1073, API 512c, and Millennia HV-3D preamplifiers.

Conclusion

I was surprised by the results of many of the tests I performed. I did not expect the frequency response of all three preamps to be so incredibly flat. In all, they varied by less than a dB each over the entire 15 Hz – 25 kHz range I tested. I truly expected to see more variance in the frequency response and for this to lead to the characteristics we so often call bright, dark, warm, and present. I also expected the Neve and API preamps to have EQ curves that were more flattering to the different sources they are usually used to record. However, they were all incredibly flat. I was also surprised by the uniformity in all of the noise related measurements. The noise floor, signal-to-noise ratio, dynamic range, and equivalent input noise were all very similar. Overall, they varied by very small amounts between the different preamplifiers.

While I think it is important that these specifications be as good as possible to have a quiet, professional sounding preamplifier, it does not appear that they contribute to the unique characteristics we prescribe them. Although not a huge difference, the total harmonic distortion + noise test showed that the API preamplifier adds about twice as much THD+N to the signal as the Neve does. While the Neve, on average across the different bandwidths I tested, had a THD+N reading of about 0.02%, the API's was 0.04%, on average. So, despite the fact that the API had twice as large of a reading, they both were very, very small numbers.

The final measurement was the slew rate test. Of all the specifications I tested, this one appears to have the largest effect on the characteristics of these preamps. As stated earlier, the slew rate refers to how fast an amplifier can "ramp up" to necessary frequencies in order to recreate the transient. Handbook for Sound Engineers says, “Slew-rate limiting occurs when the fastest signal rise time the amplifier is expected to pass exceeds the speed of the fastest stage in the amplifier; the input transient becomes slurred to as fast (or as slow) as the amplifier’s capability” (Ballou 844). This specification has a large effect on what is often referred to as the “attack” of a sound. It is the very initial response of the preamplifier to a signal. As I expected, the API had a much faster slew rate than the Neve preamp. One of the main characteristics the API preamplifier is known for is its fast, punchy attack. So, this test definitely showed that the slew rate is responsible for this characteristic.

As thorough as my tests were, there are still many unanswered questions at the end of all of my measurements. There are many more tests that could explain this topic further. More advanced measurements like a multi-tone test, a frequency response test that shows the phase change of different frequencies after passing through the preamplifier, and tests showing the harmonic structure of the distortion present could reveal more information about what really makes these preamplifiers so unique. These tests would be capable of digging in “deeper” to what exactly is happening in the preamplifiers. Although I do believe there are more answers to be discovered, I think of the measurements taken, the slew rate has the largest effect on the unique characteristics of these three different preamplifiers.

Preamp Build

After performing all of these tests, I had to choose what type of preamplifier I wanted to build. Obviously, there are a lot of different applications for these different preamps. As none of the tests revealed that any of the preamps are inherently better than the others, I do think they are better for different purposes. The clean, smooth, and warm character of the Neve preamp is very well suited for vocals. On the other hand, the fast, punchy, and aggressive character of the API is very well suited for rock drums and guitars. As a guitar player, most of the time I am recording guitars and sending the recordings to others. So, I decided it would make the most sense for me to build an API style preamplifier.

Professor Hanson suggested that I look into using one of Jeff Steiger's designs. Steiger is the owner of Classic Audio Products, Inc. (CAPI), a company that designs do-it-yourself gear based on vintage API products. After some research, I decided to build one of CAPI's VP312 preamplifiers. This model is based on a vintage API 312 preamplifier, which was actually the predecessor of the API 512c I used for my study. CAPI's website says, "The preamp is essentially an exact recreation of the legendary API 312 preamp circuit that has become the benchmark for the API sound" (Steiger, Classic Audio Products, Inc.). This seemed like an excellent fit for my build. I bought the kit with many of the parts from CAPI, and then sourced the other needed parts for my build. This kit uses an EA2622 input transformer, which mimics the AP2622 transformer initially used in the API 312 preamps. To make my preamplifier an even more accurate representation, I chose to use an original API 2520 op-amp. API is very protective of their op-amps, so CAPI offers many other options to use in their preamps. However, I was able to find a source for an original 2520 op-amp. After sourcing all of the parts, I built the preamplifier.

Based on my research and testing of the API 512c preamp, I chose to modify the design in two different ways. The first was my choice to obtain an original API 2520 op-amp. Because this individual component of the preamplifier is so famous, I thought it was important to use one in my design. Next, I chose to use a Litz 2503 output transformer for my preamplifier. This specific transformer is considered to be more accurate to the vintage API preamplifiers' output transformer. According to Steiger, "Litz wire is a type of cable made up of multiple strands of wires electrically insulated from one another and twisted together in a prescribed pattern. It has been said that winding with Litz wire produces a more uniform high frequency response but we have also noticed the bottom end seems to be a little "bigger" and "deeper" (2503-L Output Transformer). I believed that both of these design modifications would greatly benefit the quality of my preamplifier.

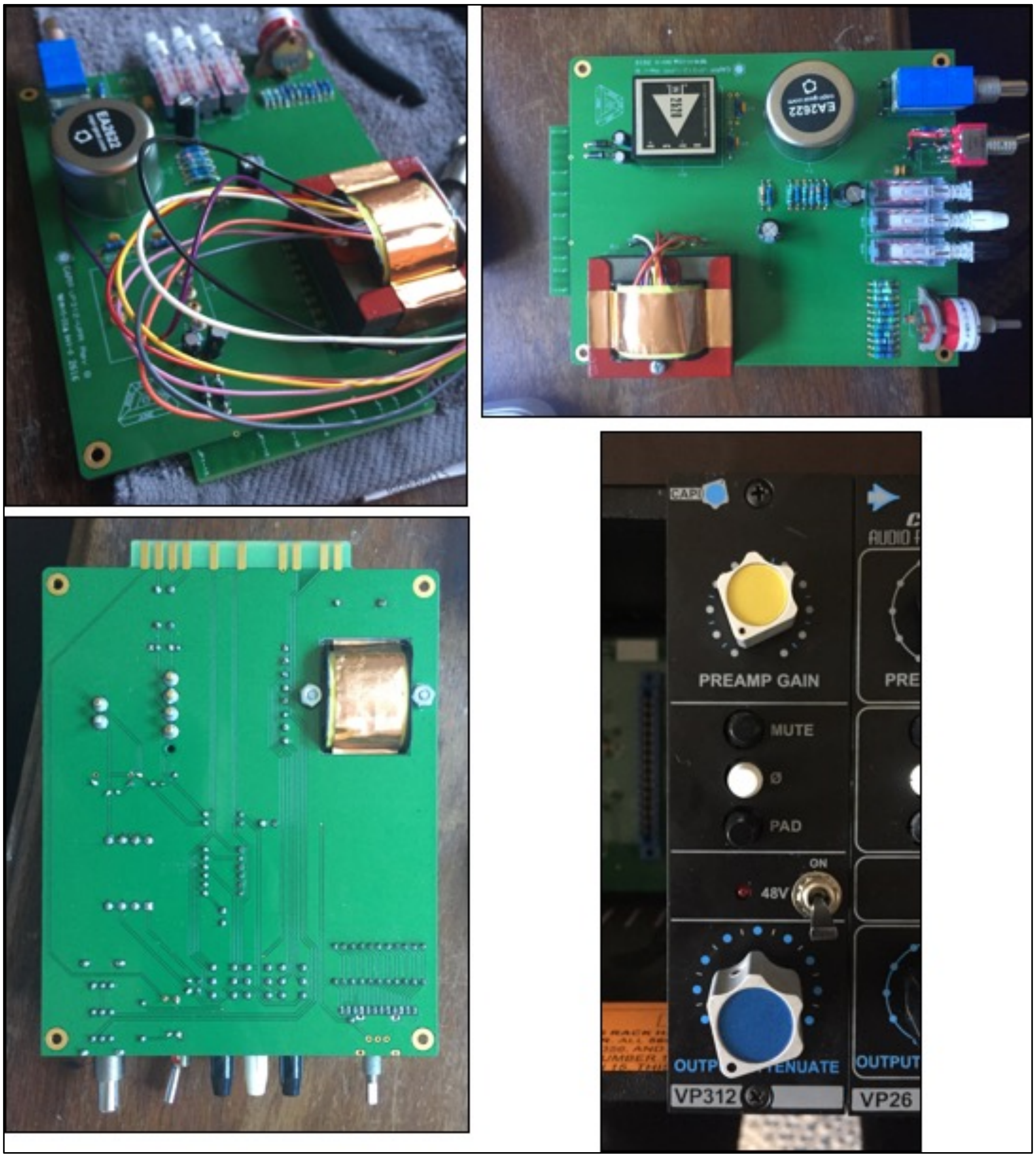


Figure 13: Pictures showing the preamplifier I built during and after the build process (Ferrell).

After I finished building the preamplifier, I tested it in order to compare my new preamplifier to the ones I had previously tested. The frequency response test showed that my preamplifier's response was very close to that of the API 512c that I tested. The high-end was nearly identical, but my preamplifier had a fraction of a dB less low end than the original API.

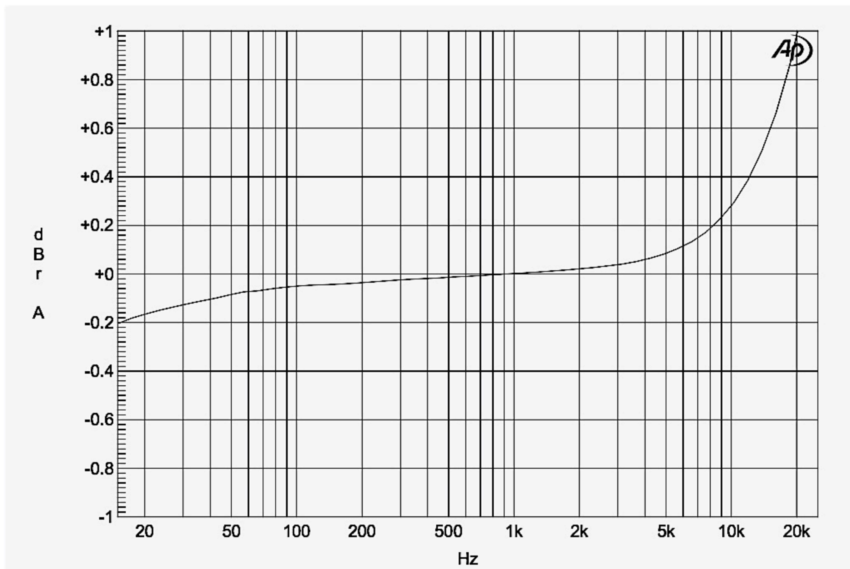


Figure 14: Graph showing the frequency response of the preamplifier that I built.

The noise floor and signal-to-noise ratio were -74 dBu and -79 dB, respectively. These measurements were actually slightly quieter than those of the API 512c. I measured the noise floor and signal-to-noise ratio of the API 512c to be -70.9 dBu and -74.9 dB, respectively. My preamplifier's equivalent input noise was approximately -124 dB, which was also less than the API. I measured the dynamic range to be 102 dB, which was just one dB less than that of the API 512c. The THD+N was 0.018% which is about half of the THD+N of the original API preamplifier. The slew rate test showed a reading of about 8.4 V/μs. This measurement is slower than the API 512c's slew rate of 10.2

V/μs, so I expect my preamp to be slightly smoother and not as punchy as the API 512c preamplifier. Based on the tests performed my preamplifier is very comparable to the original API 512c preamp I used for my study.

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