PHYS 406, Spring 2016
Final Report

Refurbishing a 1960's Teisco "Melody" Tube Amplifier

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05/11/2016

Introduction:

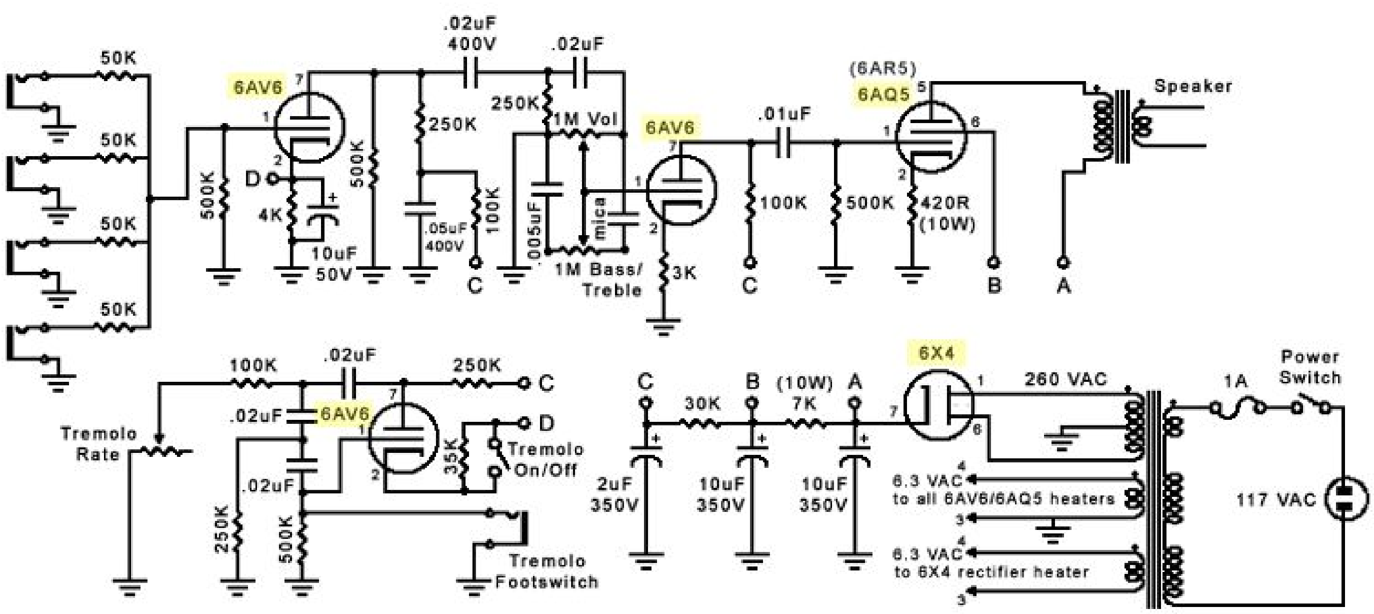
My enrollment in this course, and the genesis of the following project, came about from a string of unlikely coincidences. The first of which came about in a geology class I was taking in the spring of 2014. I was explaining to a physics major that I had always wanted to learn more about the physics behind common analog audio gear, namely tape recorders and tube amplifiers. The student then told me they were enrolled in a class, PHYS 406, which was taught by a tube amplifier phanatic. Prompted by genuine interest, I decided to dig into what this class was all about. This led me to me to Dr. Errede's PHYS 406 website, where I learned about his involvement with Analog Outfitters.

I then looked up this Champaign based company, only to find out they were having a sale later in the week. I attended the sale and found a tube amp that clearly wasn't working, as the circuit housing was dusty, oxidized and sitting at the base of the speaker cabinet, completely disconnected and missing tubes. After taking it home, I quickly realized that refurbishing the amp was way out of my league. So, it sat in my closet for a year until I was able to enroll in PHYS 406 and received permission from Dr. Errede to refurbish the the amp and take some basic acoustical measurements for my semester long project.

Amp Background:

The tube amplifier shown above is a 1960's Teisco Melody. This amplifier has a 10" speaker, four ¼" inputs, a footswitch input (which was missing when purchased), and three control knobs (volume, tone and tremolo speed). Teisco was a Japanese company that made audio gear including amplifiers, drums, keyboards and most famously, guitars between the 1960’s and 1980’s. Some of the musicians that popularized Teisco guitars were Hound Dog Taylor, Jim Reid of *The Jesus and Mary Chain* and James Iha of *The Smashing Pumpkins.*

After identifying the make and model, I tried to find a circuit diagram for the amp online. This search proved unsuccessful at first, until I realized that this particular amp was produced and sold under various names, one of which was the Beltone AP-A. Luckily this amp is identical to the Teisco Melody in terms of circuitry and basic design. Furthermore, a circuit diagram for the Beltone AP-A can easily be found on the internet and is shown below:



Beltone AP-A

Tube Amp Basics:

Almost all tube amplifiers function on the same fundamental principles. The amplifier is powered by 120V of alternating current from a wall outlet, which is supplied to the power transformer. This is in turn distributes electricity to each of the heating elements in the cathode of each vacuum tube and specifically to the rectifier tube (6X4 in the diagram above). This rectifying tube serves the crucial role of transforming the incoming AC current, to the DC current. The DC current that leaves the rectifier tube then flows through the electrolytic capacitor, which smoothes out the DC current and distributed electricity in fixed proportions between points A, B and C in the diagram above. The specifications of the electrolytic capacitor, and the remaining circuit in general, vary from amp to amp.

The signal supplied to the amplifier through the ¼" input (typically from a guitar) passes through the circuit and first encounters the preamp tubes (6AV6 in the diagram above). These vacuum tubes serve a primary purpose of amplifying the signal to levels which can be manipulated by the volume, tone and tremolo potentiometers. Next, the signal is supplied to the power tube (6AQ5 in the diagram above) which further amplifies the signal, but this time to audible levels which can be supplied to the output transformer.

It is worth noting that all vacuum tubes function on the same basic principles. A heating element in the cathode supplies the energy necessary to force electrons to flow off the cathode, which are then attracted to the anode. Between the cathode and anode is a wire grid, which has its own voltage and thus controls the rate at which the electrons can flow between the cathode-anode gap. Furthermore, this processes produces distortion in the audio signal as it passes through the vacuum tube. The distortion produced is what gives tube amplifier their characteristic, warm sound. Because not all vacuum tubes have the same specifications and design, different tubes distort, or “color”, the sound differently . This is why specific tube amplifiers become so collectible and appreciate in value over time. Additionally, the distortion produced by a tube amplifier is directly proportional to the amount of signal passing through the tube. At high volumes the tubes are able to “color” the signal to their maximum potential (a coincidental gift to early punk rock and rock ‘n’ roll). This is why turning the volume up as high as possible on a tube amp (without blowing the speaker) yields the highest sound quality.

As stated previously, the signal leaving the power tube goes to the output transformer, which uses high voltage to bring the final processed signal up to the bias of the speaker (8 ohms for the speaker in my Teisco Melody). Then, the signal provided to the speaker leads force the magnetic flux produced by the speaker's magnet to periodically reverse, causing the speaker’s voice coil to oscillate in the magnet’s gap and drive the speaker cone to compress air such that the electrical energy supplied by the output transformer is turned into acoustic energy.

Modifications:

As stated previously, the amplifier was nowhere near functional when I bought it. The power cord was completely cut off and the circuit chassis was detached and sitting at the base of the speaker cabinet. Furthermore, only the three 6AV6 vacuum tubes were provided.

The first step in restoring this amp was checking if the circuit diagram matched the circuit within the chassis (paying special attention to the wiring on each vacuum tube pin). I also tested each of the resistors with a voltmeter to see if they were functioning properly. Luckily most of the components were functional and in their correct locations, aside for the fuse/power switch arrangement. Additionally, the only non-original component was the power switch, which had clearly been replaced by the previous owner.

Thus, the first modification involved replacing the power cord and rearranging the placement of the power switch such that it sat between the fuse and power cord. This insures that a malfunction in the power supply won't fry the power transformer or any of the components farther along in the circuit.

Next, we replaced the original electrolytic capacitor. This is usually the first component within a tube amp to give out, as they only function for a given number of playing hours. Furthermore, given that this component was 50+ years old, it's fair to assume it needed to be replaced. We also added a screen resistor between the electrolytic capacitor and the power tube (6AQ5 in the diagram above). This additional resistor puts a cap on the voltage being supplied to the power tube, such that this tube and the subsequent components are protected from overheating and potentially becoming damaged.

After taking care of the power supply and a few cosmetic issues (a missing volume control knob and a burnt out bulb within the “ON” light), we tested the voltage on the speaker’s output transformer. In doing this, we ran into an immediate red flag. The high voltage leads were completely exposed, providing an unreasonably high risk for being shocked or potentially electrocuted. Fortunately, the output transformer wasn’t functioning properly and needed to be replaced regardless. So, we replaced the original part with a new output transformer with extra output leads, such that an additional speaker cabinet can be added to the circuit in the future.

After obtaining the missing tubes, we were able to fire up the amp for the first time. In doing so, the amp proved functional. However, we were able to identify some additional issues. First, the tremolo unit was not functioning at all. Second, the floor noise (or hum) was unpleasantly loud, indicating a grounding issue.

After taking a closer look at the tremolo circuit, we realized there were some fundamental flaws in its design, preventing enough voltage from reaching the first gain stage and allowing the 4K resistor at point D to oscillate and produce the tremolo effect. In order to increase the gain and achieve oscillation, we removed a few 250K and 500K resistors and replaced them with 1000K resistors, preventing some of the current from being grounded. We also removed the 0.02uF capacitors and replaced them with 0.03uF capacitors. This made enough of a difference in the circuit to yield oscillation in the first gain state and produce a tremolo effect.

Finally, we noticed that each of the four ¼" input jacks had a wire running between the jack and a four pronged terminal. This terminal was then connected to pin 1 in the first gain stage by another group of four wires that were twisted together and secured by a heat shrink cover. The large amount of wiring used in making this connection produced an antenna effect that was creating the large amount of hum (even picking up radio broadcast when the inputs were floating). So, to reduce that amount of wiring, we bypassed the four pronged terminal and connected the input jacks to the first gain stage by the single grouping of wires in the heat shrink cover. Dr. Errede also repositioned the grounding such that the ¼" jacks float (ungrounded) until a ¼" jack is inserted. Thus, there is still a noticeable amount of hum when the jacks are floating, but the hum is minimal once an input jack has been inserted.

Most of the data presented in the remainder of this report was measured and provided by Dr. Errede. Critical voltages measurements were obtained using a voltmeter. The data presented in graphs were measured using a function generator that supplied a 5mV sine wave over a range of frequencies between the speaker leads which were in parallel with a resistor, across which the speaker voltage could be measured. Other measurements were made using a function generator, spectrum analyzer and particle velocity microphones (these are the graphs with missing bass curves).

Critical Voltage Measurements (original circuit):

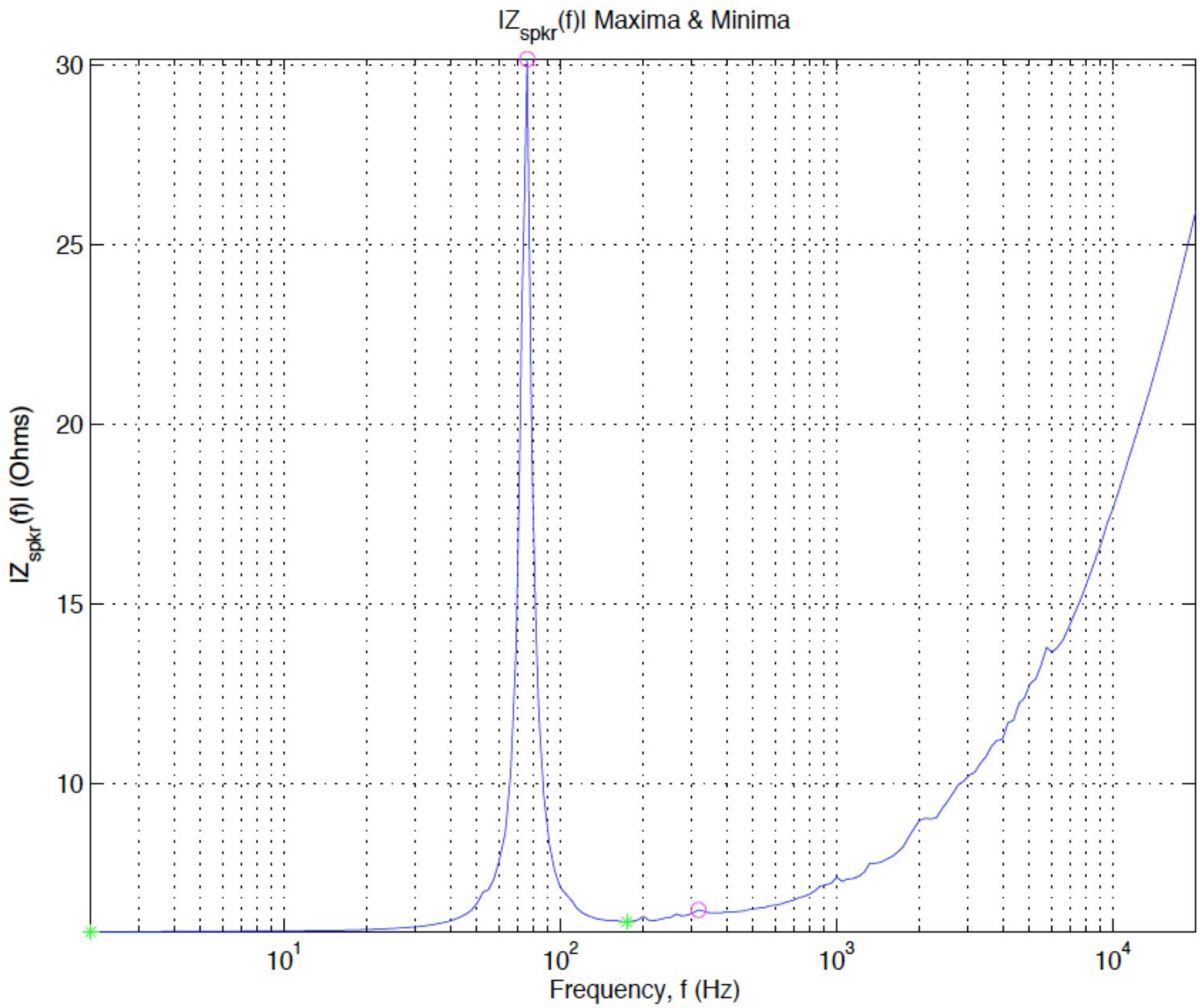
<table>
<tr><th></th><th>GRID, Pin 1</th><th colspan="2">CATHODE, Pin 2</th><th colspan="2">PLATE, Pin 7</th></tr>
<tr><td>6AV6, 1st Gain Stage</td><td>0.031</td><td colspan="2">0.923</td><td colspan="2">130.0</td></tr>
<tr><td>6AV6, 2nd Gain Stage</td><td>0</td><td colspan="2">1.303</td><td colspan="2">146.8</td></tr>
<tr><td>6AV6, Tremolo</td><td>0</td><td>OFF: 2.6</td><td>ON: 1.478</td><td>OFF: 176</td><td>ON: 139</td></tr>
<tr><td>6AQ5, Power Tube</td><td>0.038</td><td colspan="2">17.92</td><td colspan="2">302.3</td></tr>
</table>

$P^{420\Omega}_{DISS}$	0.76 Watts
P^{6AQ5}_{DISS}	12.23 Watts (ABS max)
$I_{420\Omega}$	0.043 A
P^{6AQ5}_{K}	43 mA (DC)
$V_{B+} = V_A$	309.8
$V^{6AQ5}_{SCR} = V_B$	268.4
V_C	193.6

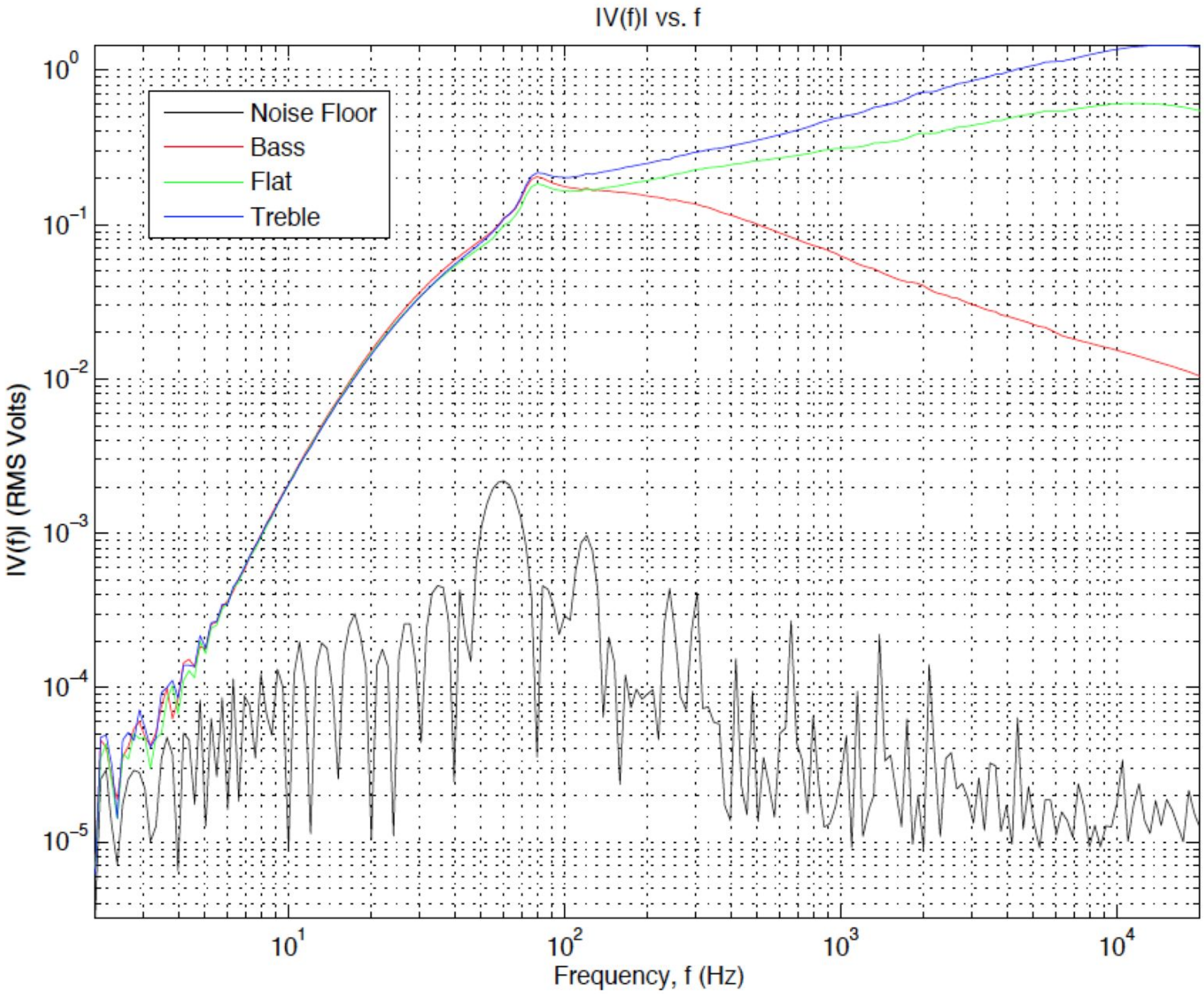
V^{LINE}_{AC}	119.4
$V^{MAIN\ SECONDARY}_{AC}$	542
$V^{PREAMP\ HTRS}_{AC}$	6.52
$V^{6X4\ HTR}_{AC}$	6.55

Graphs:

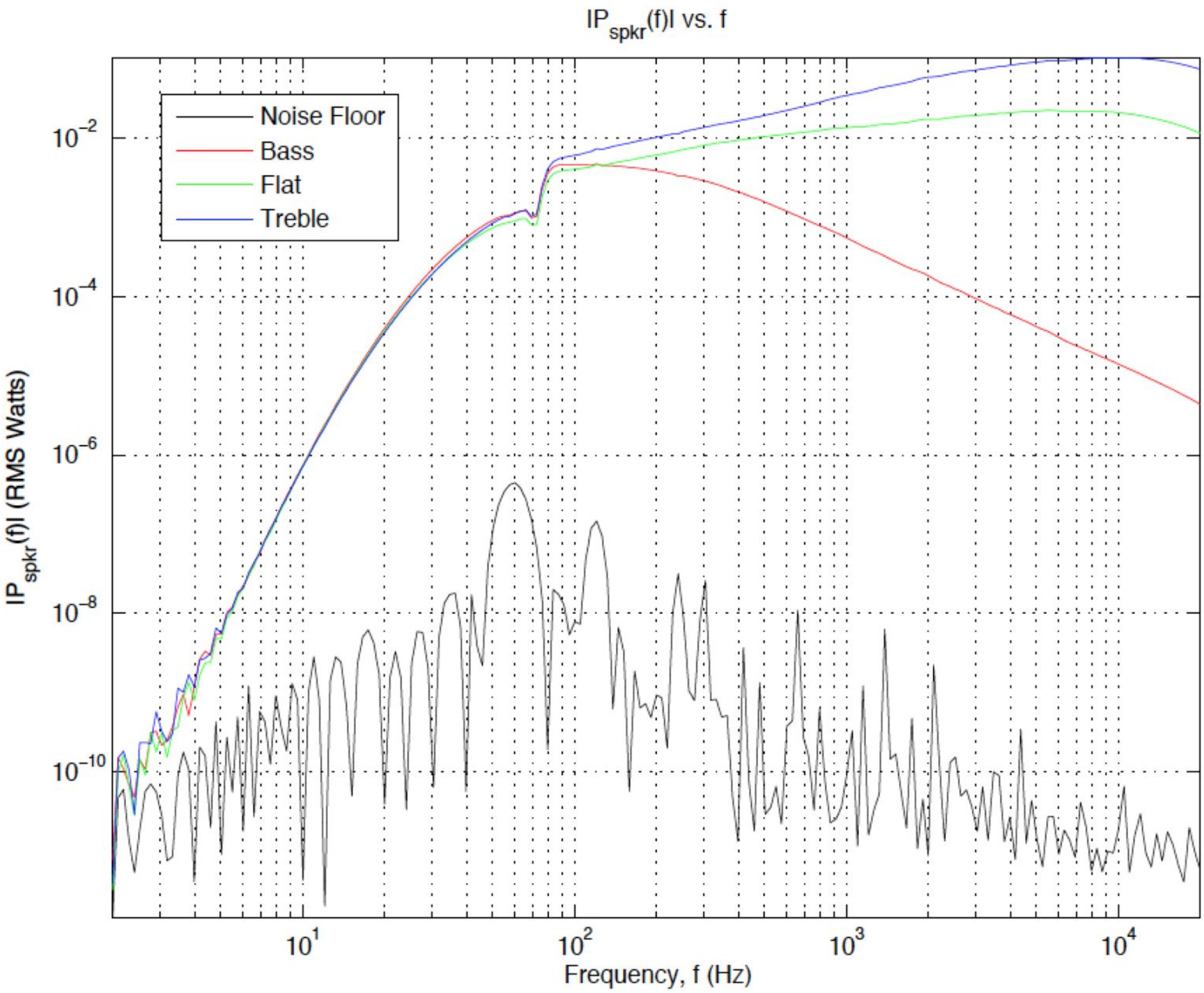
Speaker impedance

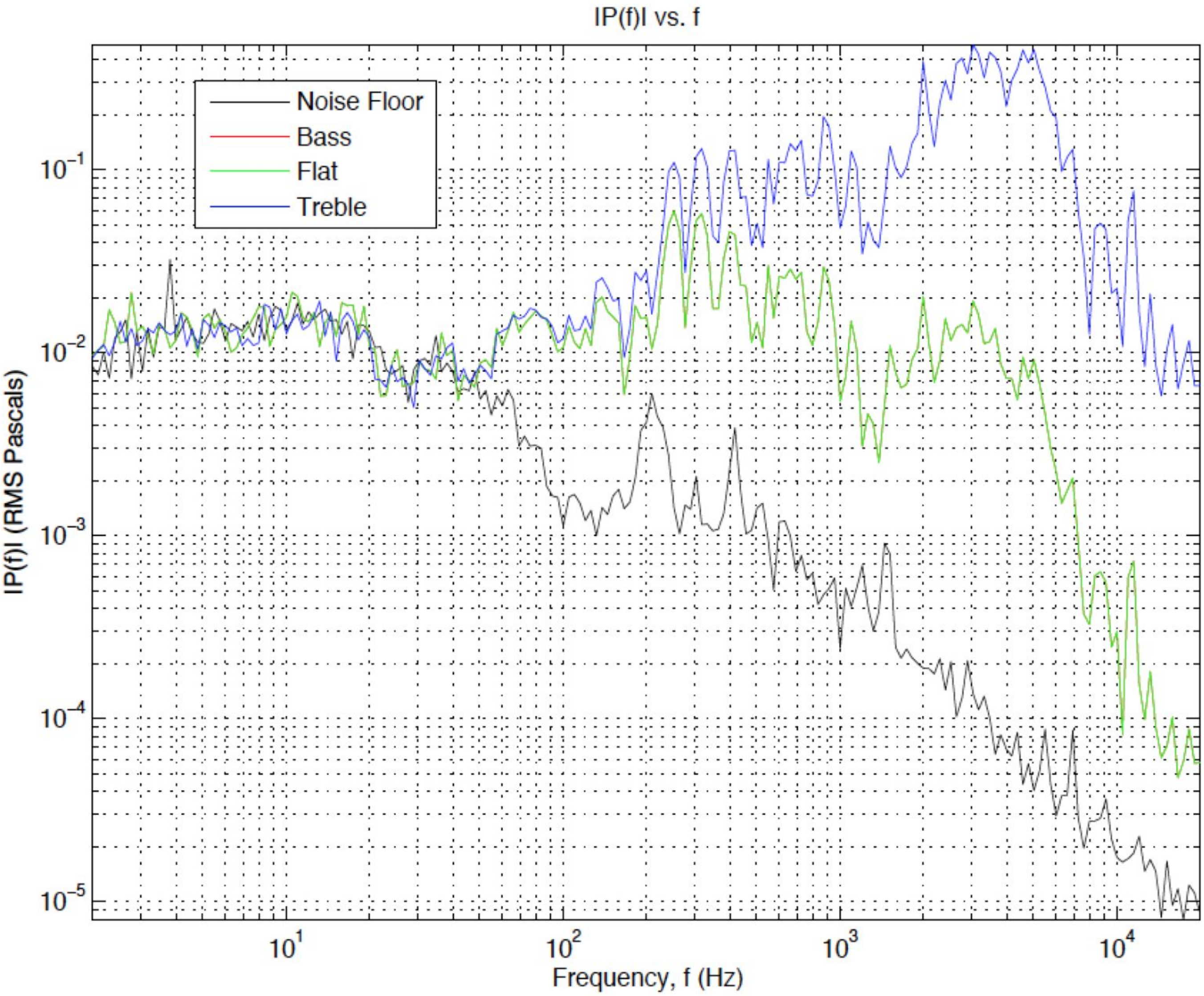


Complex Voltage Measurements

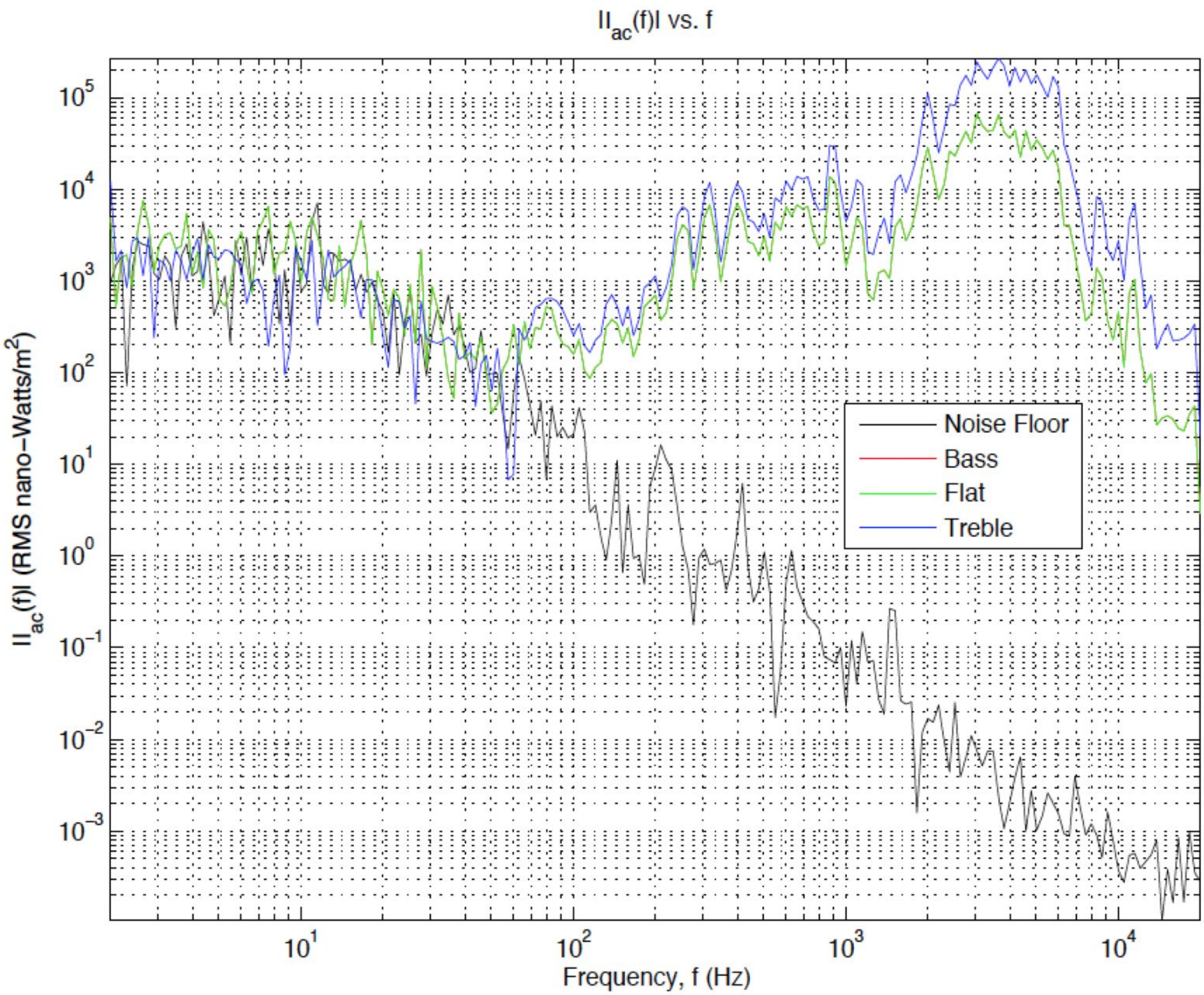


Complex Power Measurements




IP(f)I vs. f
Noise Floor
Bass
Flat
Treble
IP(f)I (RMS Pascals)
Frequency, f (Hz)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{1}
10^{2}
10^{3}
10^{4}

Current Measurements Using Particle Velocity Microphones



Online References Describing Teisco History:

https://en.wikipedia.org/wiki/Teisco

http://www.larryjohnmcnally.com/Teisco/