

Fever 6J1 Pre-Amplifier Measurements



Cheap and fun little tube pre-amplifier, sells for around \$10-15 at the usual places, just search for "6j1 preamp".

It is a real tube pre-amplifier, there are no hidden opamps under the board. However it needs 12VAC/1A to work, 12VDC cannot be used because of how the power supply is designed to boost the tube voltage.

I recommend adding a fuse between the transformer and the board in case you short something. I also recommend adding some standoffs to the board to make it less likely you'll short something.

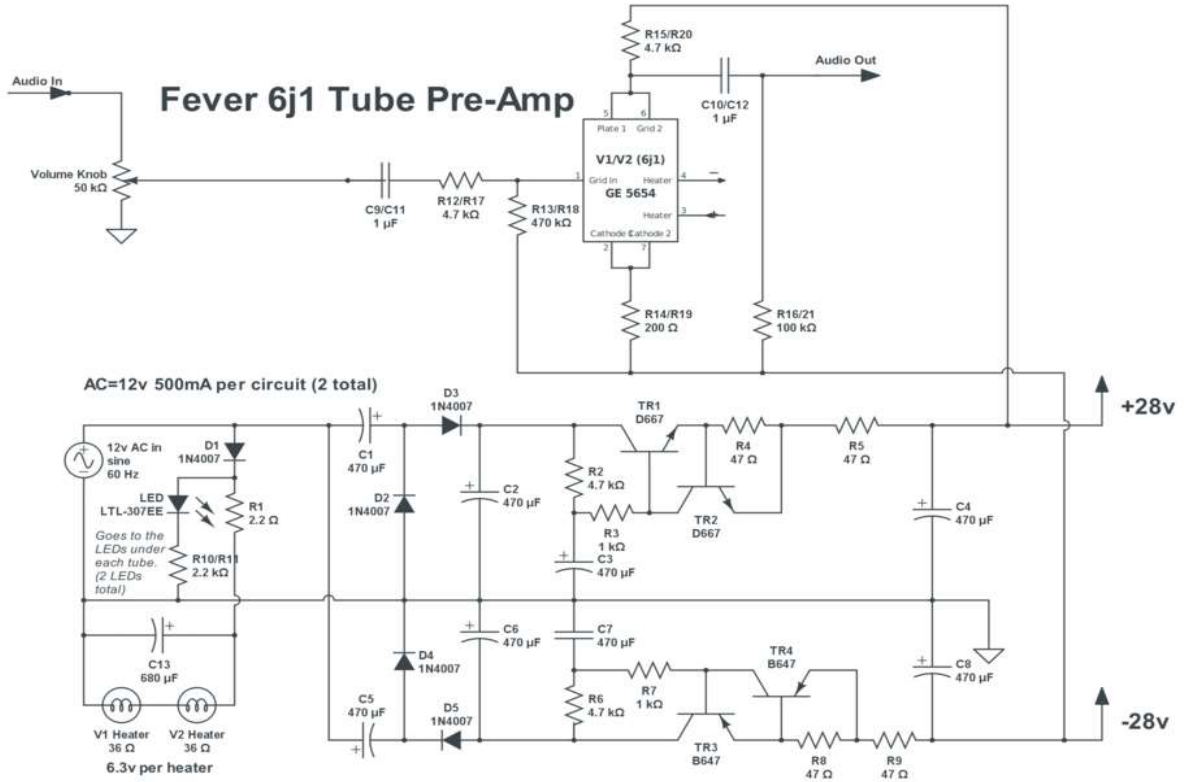
Note: The 60Vdc on this board is considered safe under normal circumstances, but you will get sparks if you short something. There are no bleeding resistors on the larger capacitors, so they will hold a charge for a long time.

Please leave any comments and questions on the youtube video, I rarely check the contact email. Thanks.

Table of Contents

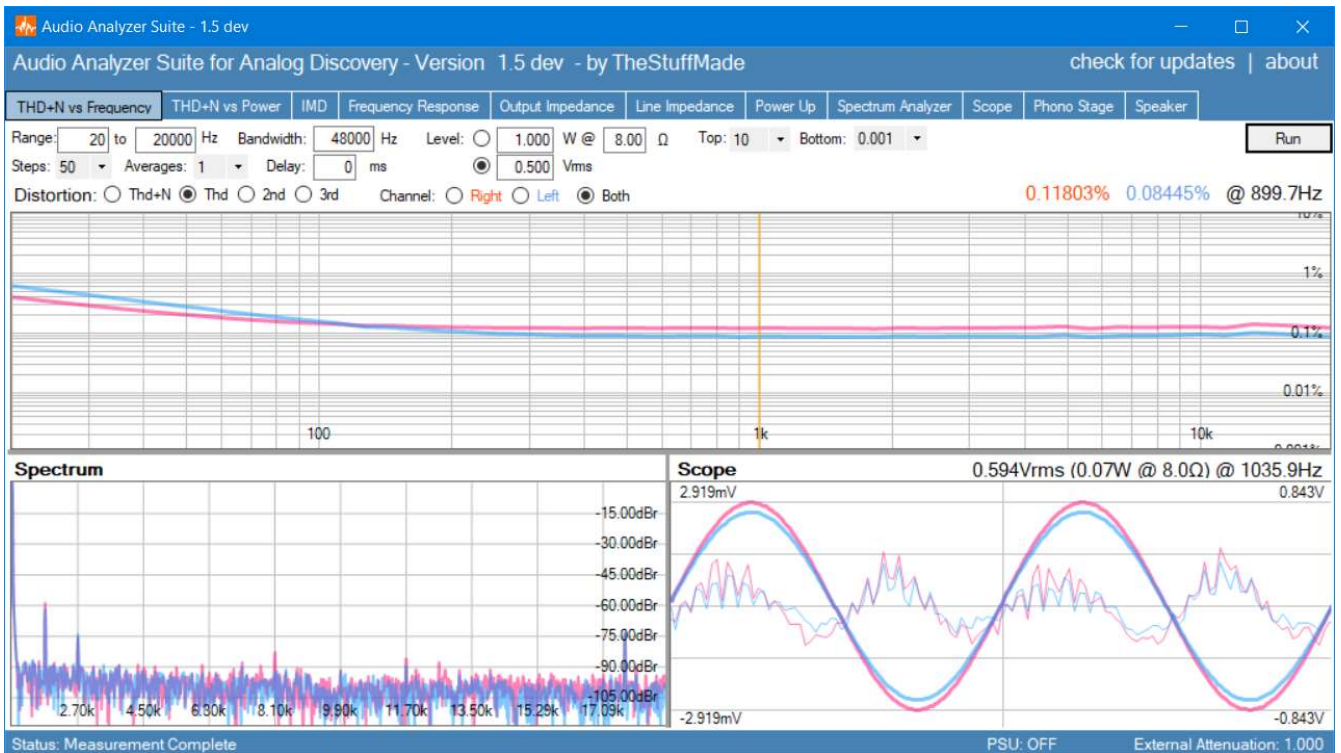
Schematic:.....	3
Distortion vs Frequency – Volume 25% - 500mV input.....	4
Distortion vs Output Voltage – Volume 100% - Load 1MΩ.....	5
Frequency Response – Volume 100%, Load 1MΩ.....	6
Frequency Response – Volume 10% - Load 1MΩ.....	7
Frequency Response – Volume 50% - Load 1MΩ.....	8
Frequency Response – Vol 100% Load 3kΩ left, 1MΩ right (for comparison).....	9
Scope – Input vs Output.....	10
Input and Output out of phase, meaning the output is inverted.....	10
Spectrum Analyzer – 50% Volume and 1MΩ Load.....	11
Intermodulation Distortion.....	12
Channel Separation.....	13
Input and Output Impedance.....	14
Power On/Off Output Spikes – Load:1MΩ.....	15
Initial Listening:.....	16
Summary of Problems:.....	17
Modifications: (everything after this are just experiments to improve performance).....	18
Frequency Response – Vol 10% Load 1MΩ After Mods.....	20
Frequency Response – Vol 50% Load 1MΩ After Mods.....	21
Output Impedance after mod (1uF Coupling).....	22
Output Impedance with 2uF Coupling Capacitors.....	23
Switch On/Off Spikes on Output With 1uF Film Caps.....	24
Switch On/Off Spikes on Output with 2uF Film Caps.....	25
Frequency Response into 3kΩ load with 2uF.....	26
Conclusion:.....	27
Quick test with 100kΩ feedback and 220uF cathode bypass.....	28
Updated Schematic:.....	29
Board with all Modifications for Reference.....	30
Tube Datasheet: (with translation).....	31
Tube Chart with Loadlines and Operating Point.....	32
Distortion vs Frequency.....	33
Distortion vs Output Voltage.....	34
With and Without 220pF Cap to Limit Bandwidth.....	35
Frequency Response, 1MΩ vs 2.7kΩ Load.....	36
Input and Output Impedance.....	37
Switch On/Off Spikes.....	38
Final Words.....	39

Schematic:



CIRCUIT LAB jcolber2 / Fever 6j1 Tube Pre-amp Circuit <http://circuitlab.com/c9vnehk>

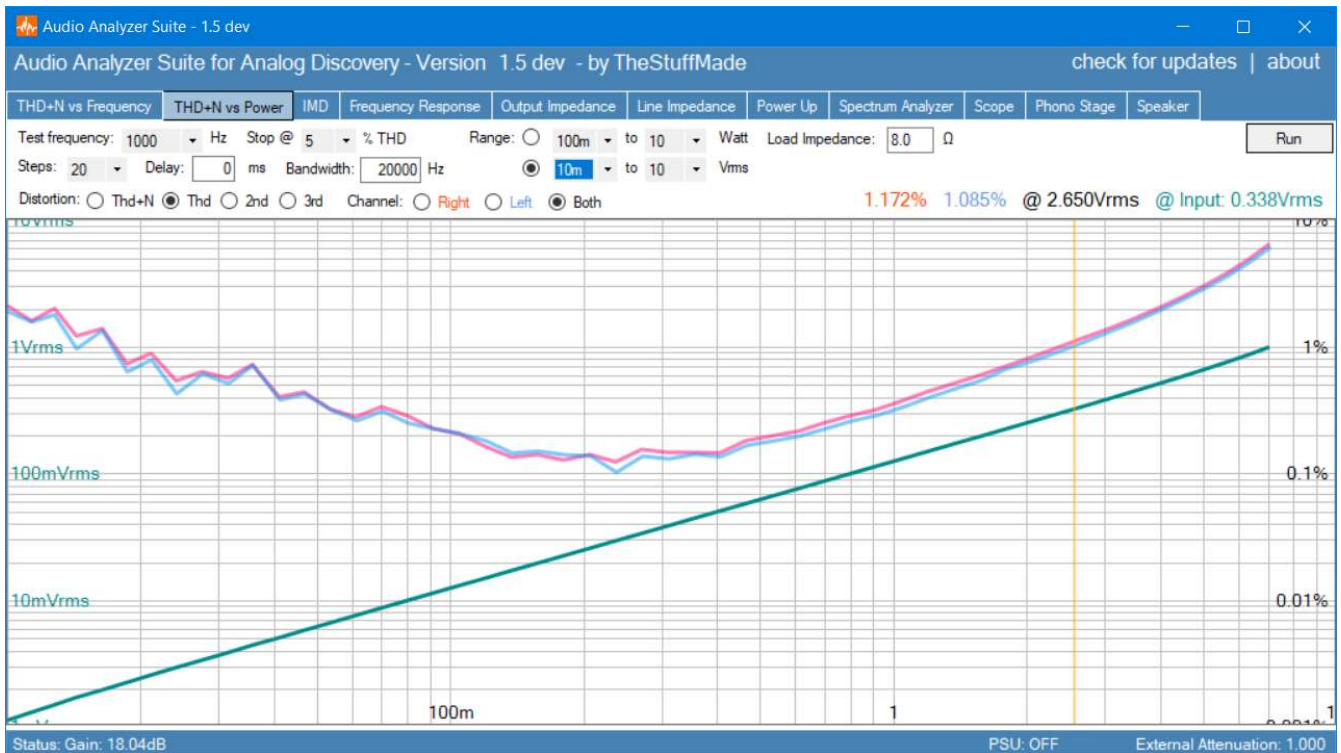
Distortion vs Frequency – Volume 25% - 500mV input.



Measurement done at low output level where most listening is likely to be done.

No problems here, distortion is dominated by the 2nd harmonic.

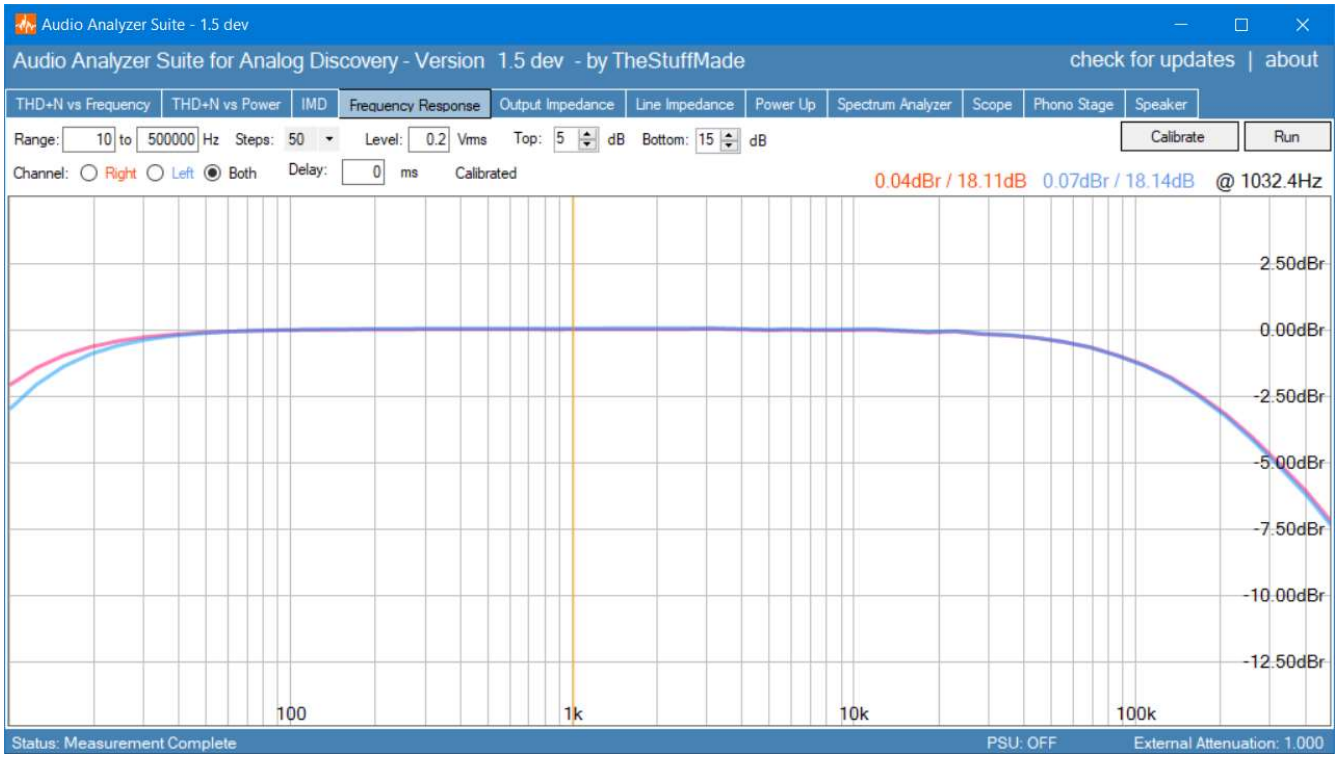
Distortion vs Output Voltage – Volume 100% - Load 1M Ω



Maximum output voltage is $\sim 2.6\text{Vrms}$ when reaching 1% distortion (1kHz) with max volume at just 0.338V input.

At 2% distortion the output voltage is 4Vrms.

Frequency Response – Volume 100%, Load 1MΩ



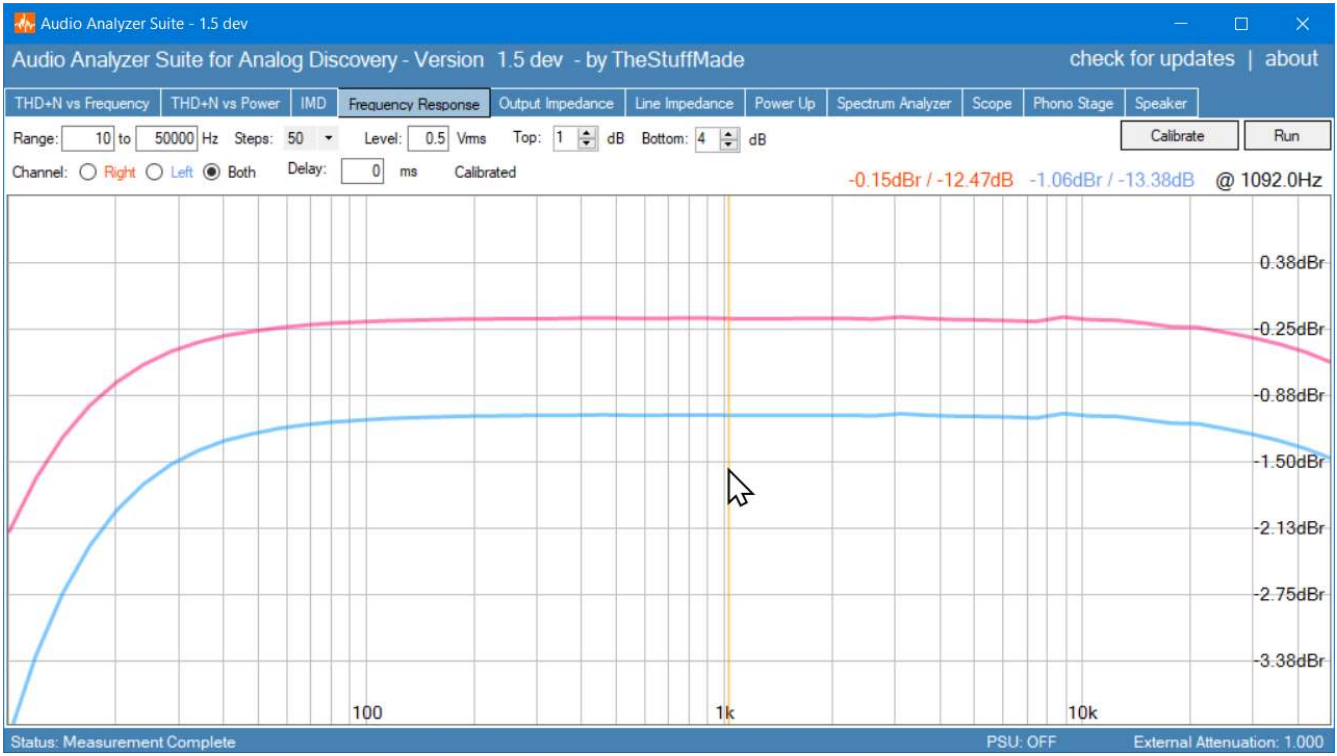
Flat response in audio range @ 1MΩ load and full volume.

Wide bandwidth, -3dB at 200kHz.

Both channels reasonably well matched at full volume.

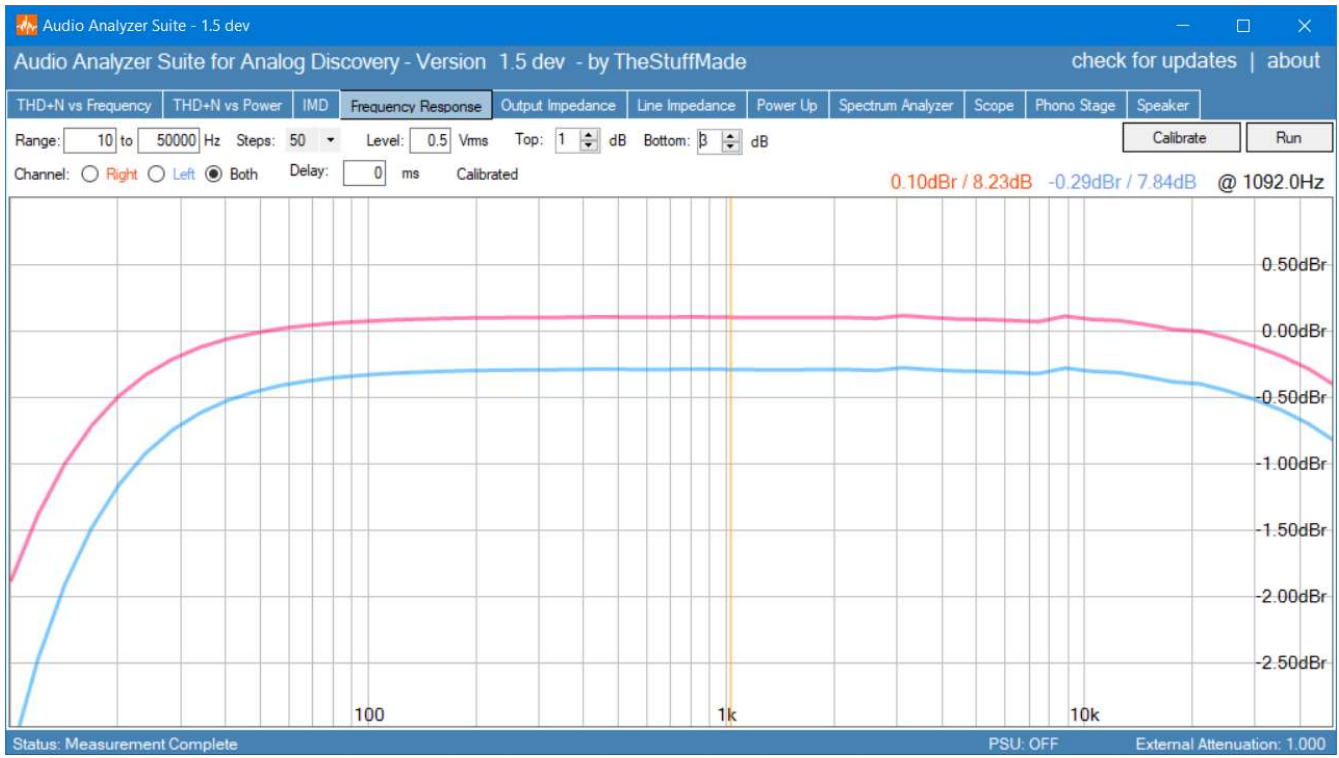
Gain a bit high at 18dB.

Frequency Response – Volume 10% - Load 1MΩ



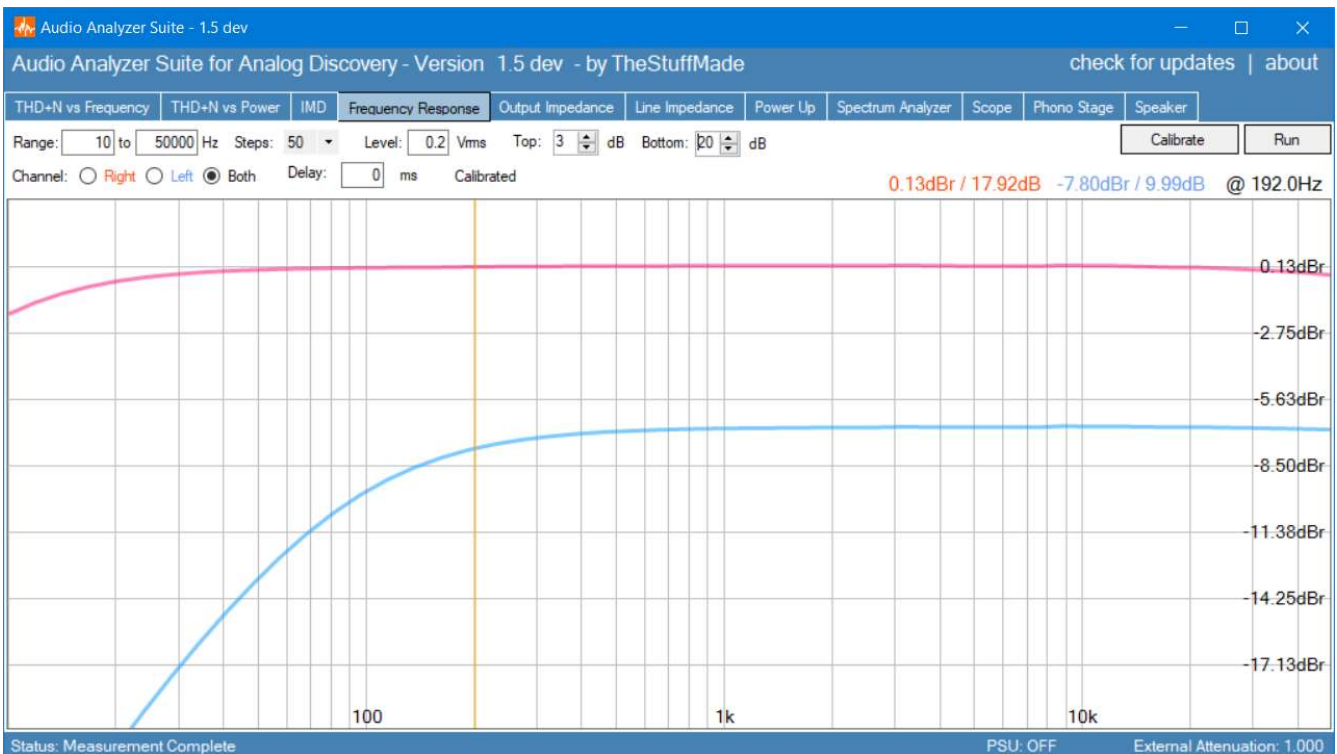
1dB difference between left and right channel at 10% volume.

Frequency Response – Volume 50% - Load 1MΩ



Difference between left and right still almost 0.5dB at 50% volume.

Frequency Response – Vol 100% Load 3kΩ left, 1MΩ right (for comparison)



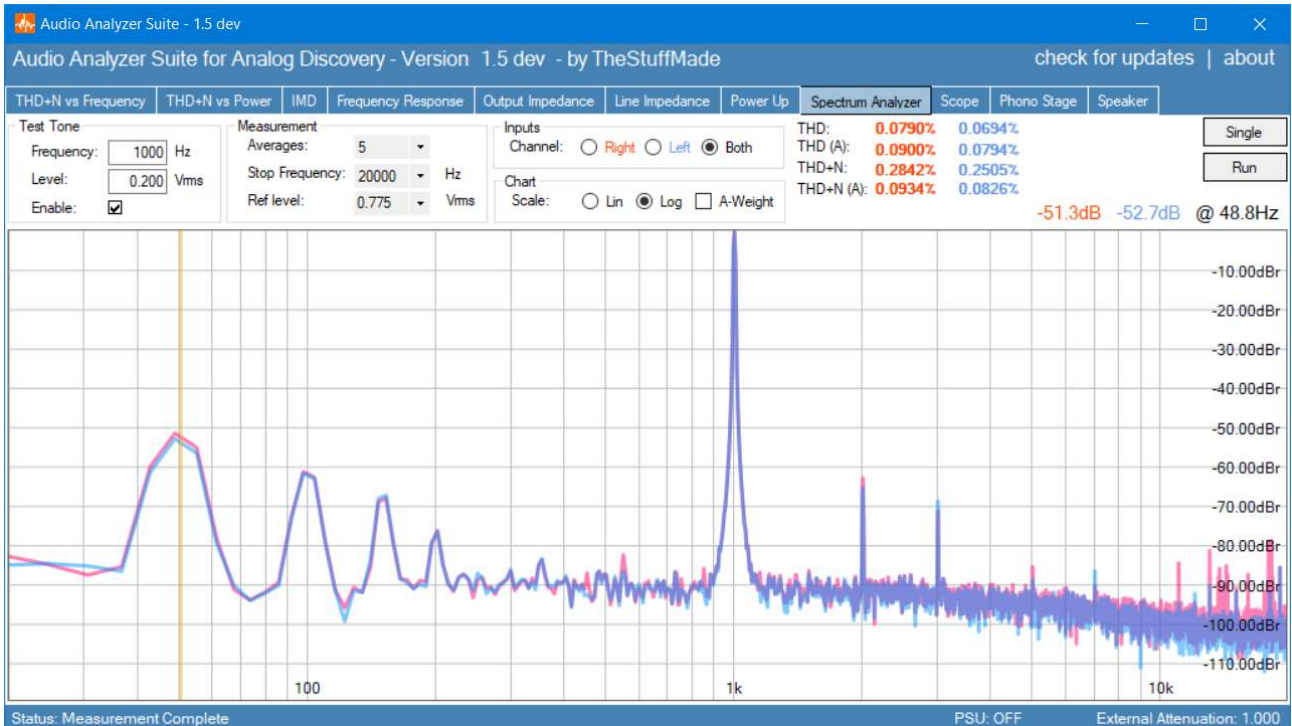
Into 3kΩ load the low frequencies start rolling off already at 200Hz. This is not good, this preamp can only be used with amps having an input impedance of at least 40-50kΩ, otherwise there will be no bass.

Scope – Input vs Output



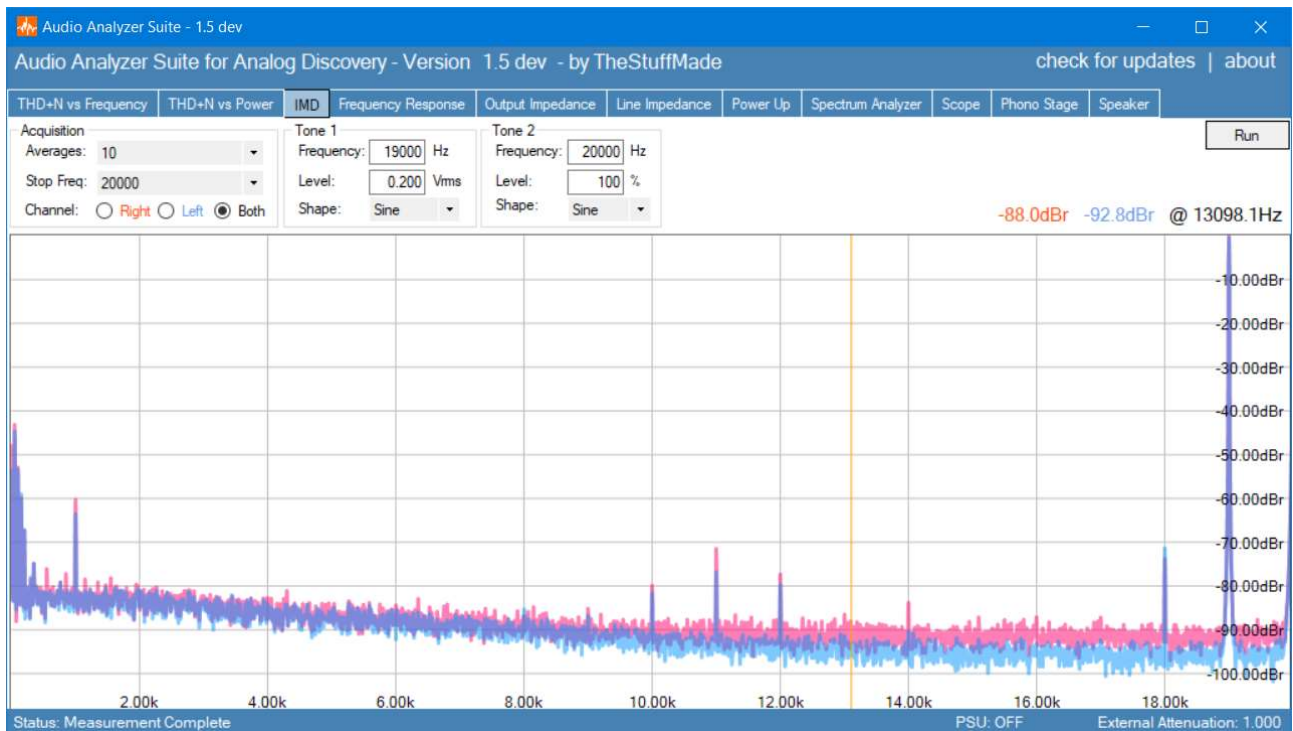
Input and Output out of phase, meaning the output is inverted.

Spectrum Analyzer – 50% Volume and 1MΩ Load.



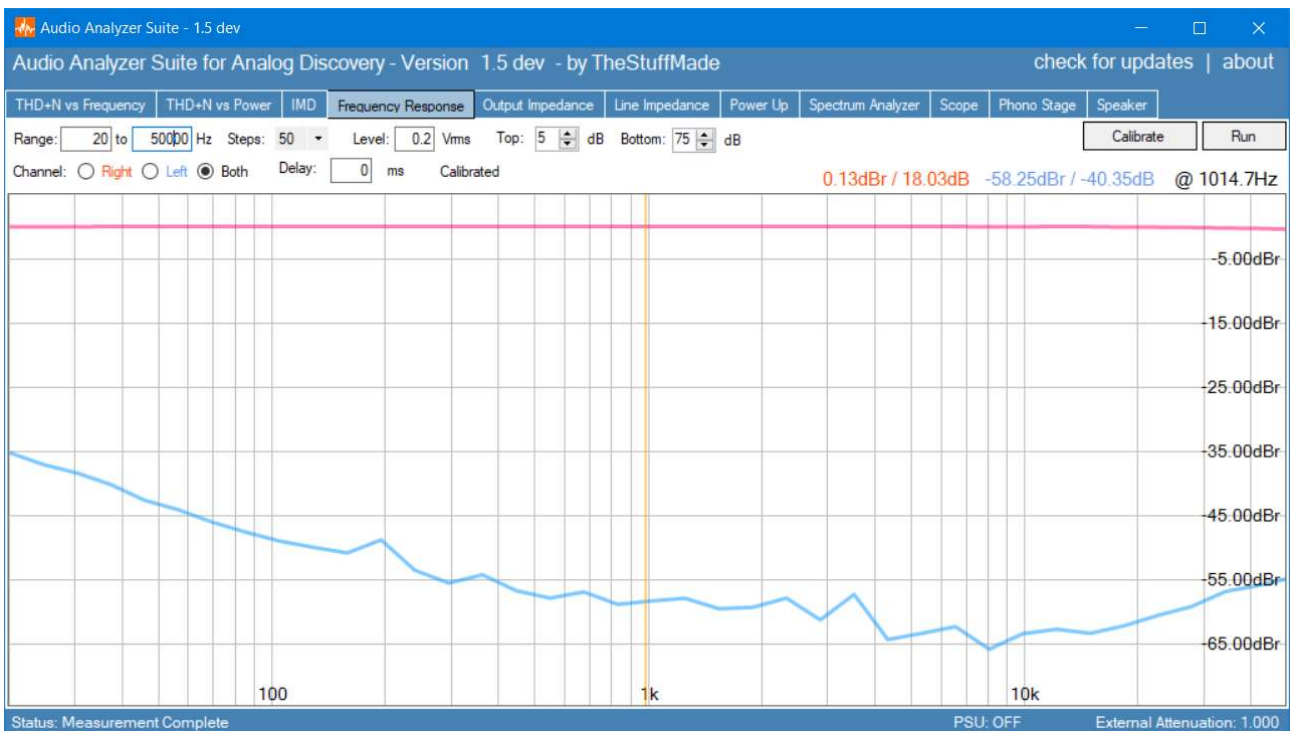
High level (-50dB) of mains hum at 50Hz plus harmonics at 100Hz, 150Hz and 200Hz.

Intermodulation Distortion



Intermodulation distortion with 19kHz and 20kHz tones is acceptable with highest peak at -60dB (0.1%).

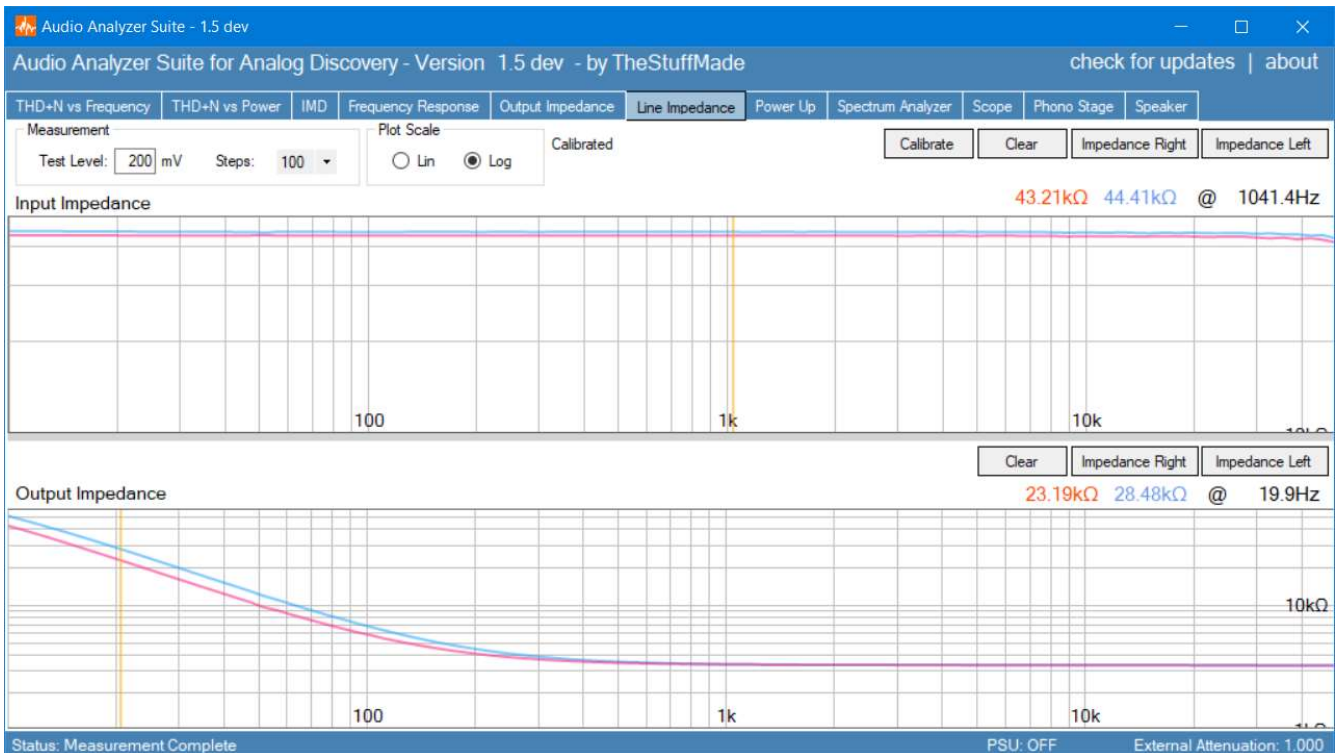
Channel Separation



Left input shorted vs right channel. 35dB at 20Hz, 60dB at 1kHz, 65dB @ 10kHz.

No problems, Right to Left looks the same.

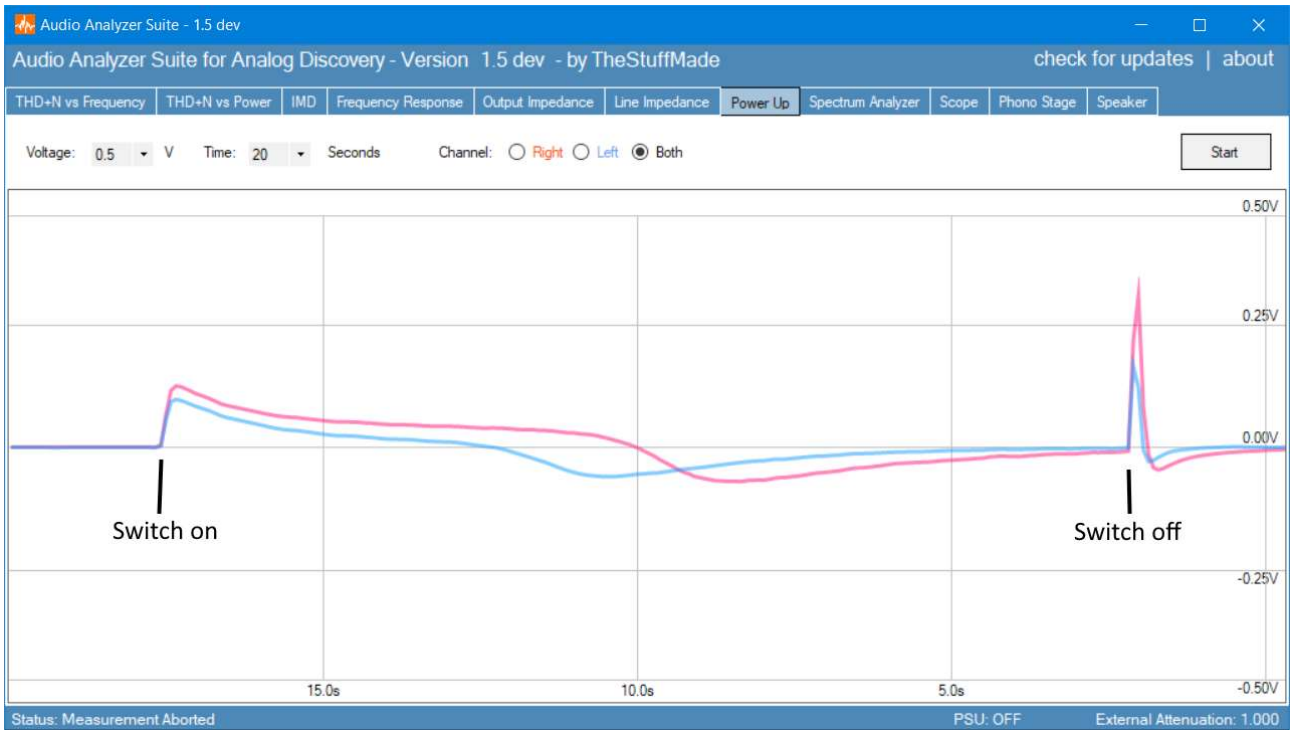
Input and Output Impedance



Input impedance is very good at 43-44kΩ flat across the range.

Output Impedance is terrible at 23-28kΩ at 20Hz down to 3.3kΩ at 1kHz and up.

Power On/Off Output Spikes – Load:1MΩ



Minimal switch on/off spikes on the output, not likely to destroy any speakers.

Initial Listening:

Using headphone amp with 100k Ω input impedance + AKG-K701

- Stereo imaging is pushed to the right at low volume.
- Distortion is vaguely audible at high volume, but not bad sounding.
- Mains hum is audible without music, but not noticeable with most music.
- When changing input impedance to 3k Ω the bass is gone and it sounds very thin.

Summary of Problems:

- Volume pot is low quality and there is a large different between left and right channels at low volume.
- Output impedance is way too high at low frequencies making the preamp unsuited with any amplifier having an input impedance below $50k\Omega$
- There is mains hum on the output.

Modifications: (everything after this are just experiments to improve performance)

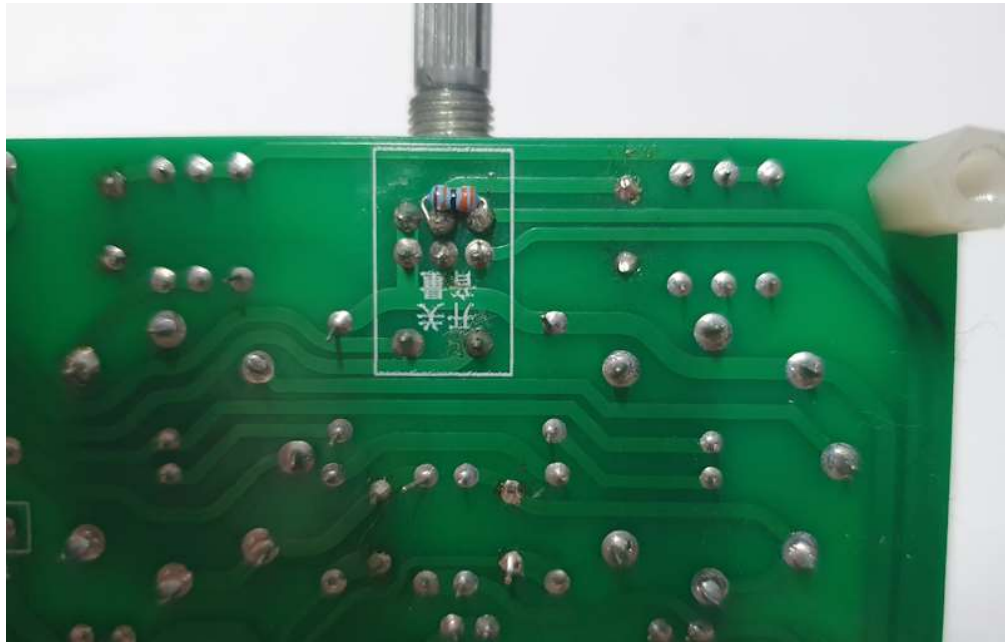


It's a terrible choice to use multilayer ceramic capacitors as coupling caps. The problem with them is that beside being microphonic their capacitance is voltage dependent, higher voltage means less capacitance. These are operating with 30V+ across them and at that level the capacitance is probably down to a few 100nF, resulting in the high output impedance at low frequencies.

I have some 1uF/100V film capacitors I will use instead, you can also use electrolytic bipolar capacitors, just make sure they are rated for at least 50V.

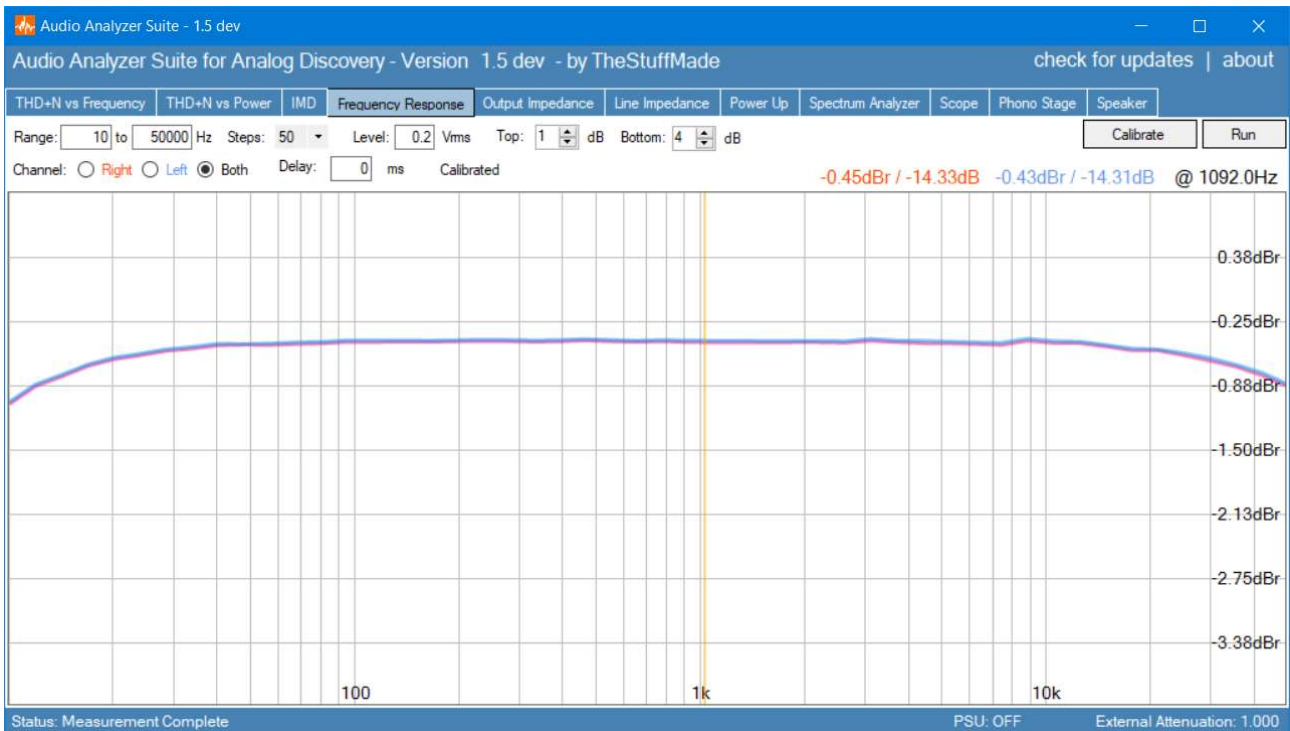


For the large difference between right and left on the volume potentiometer I ended up adding a resistor that pretty much solved the problem:



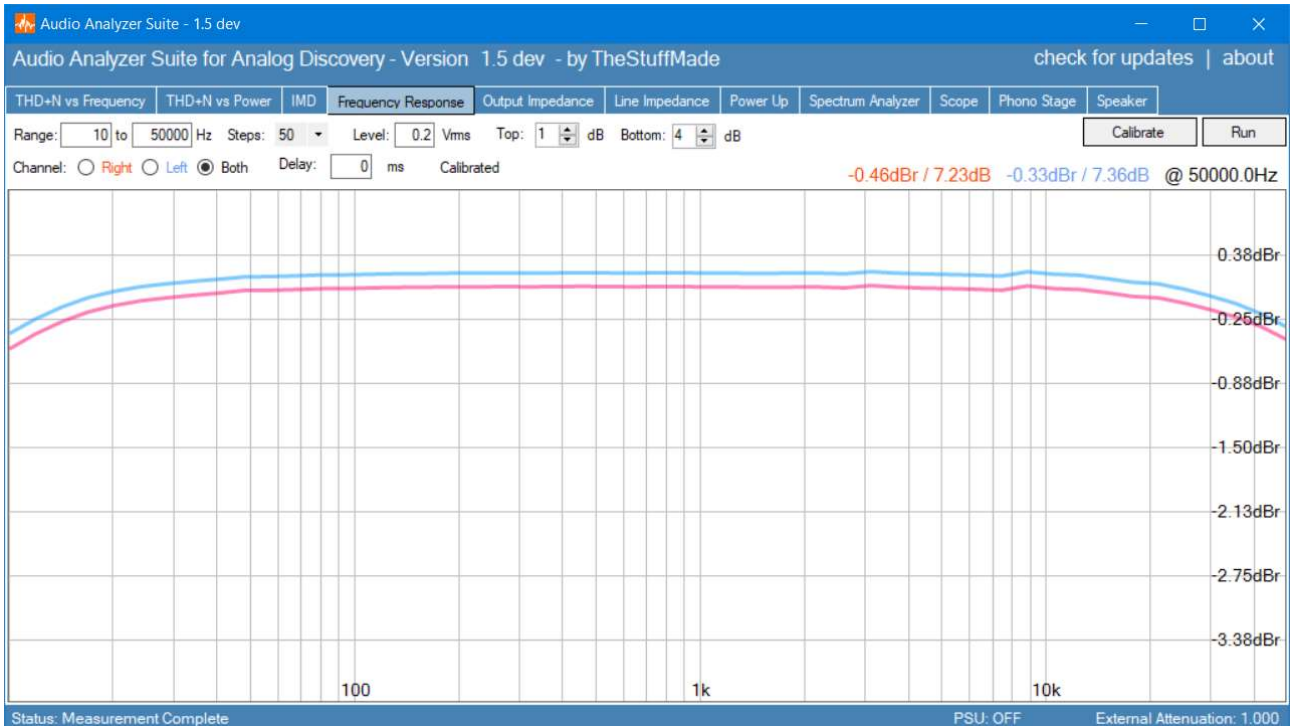
This is of course unlikely to be a general fix as I suspect the tolerances on these pots are quite bad, however what I did was measure the resistance across the pot for both left and right, I got the values of $44\text{k}\Omega$ and $43\text{k}\Omega$, then I added a $330\text{k}\Omega$ resistor across the one that measured the highest. (I did have to experiment a bit with the value)

Frequency Response – Vol 10% Load 1MΩ After Mods.



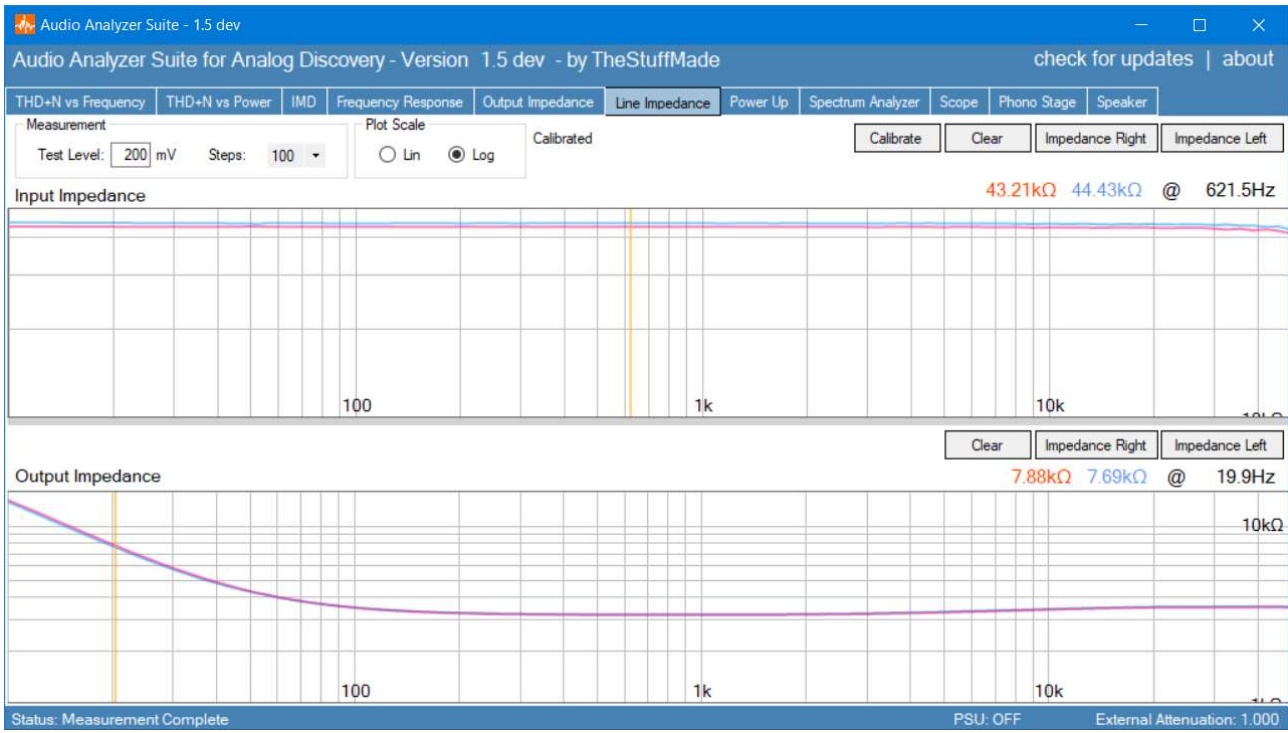
Now almost no difference between left and right at 10% volume.

Frequency Response – Vol 50% Load 1MΩ After Mods.



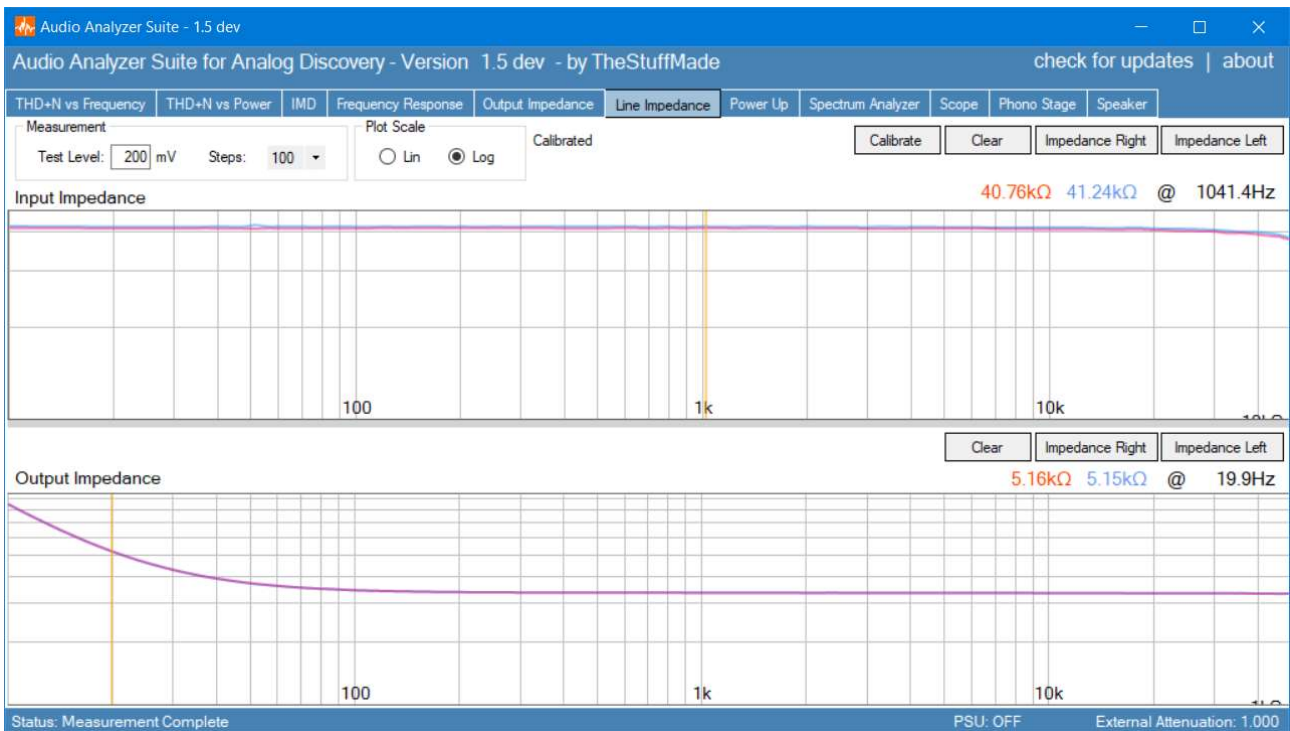
Only ~0.1dB difference at 50% volume.

Output Impedance after mod (1uF Coupling)



Much improved, 7.8kΩ at 20Hz vs 28kΩ previously. Now it will work with power amps with input impedance down to 10kΩ, compared to 50kΩ previously. (assuming the power amp input impedance doesn't change significantly across the audio range)

Output Impedance with 2uF Coupling Capacitors



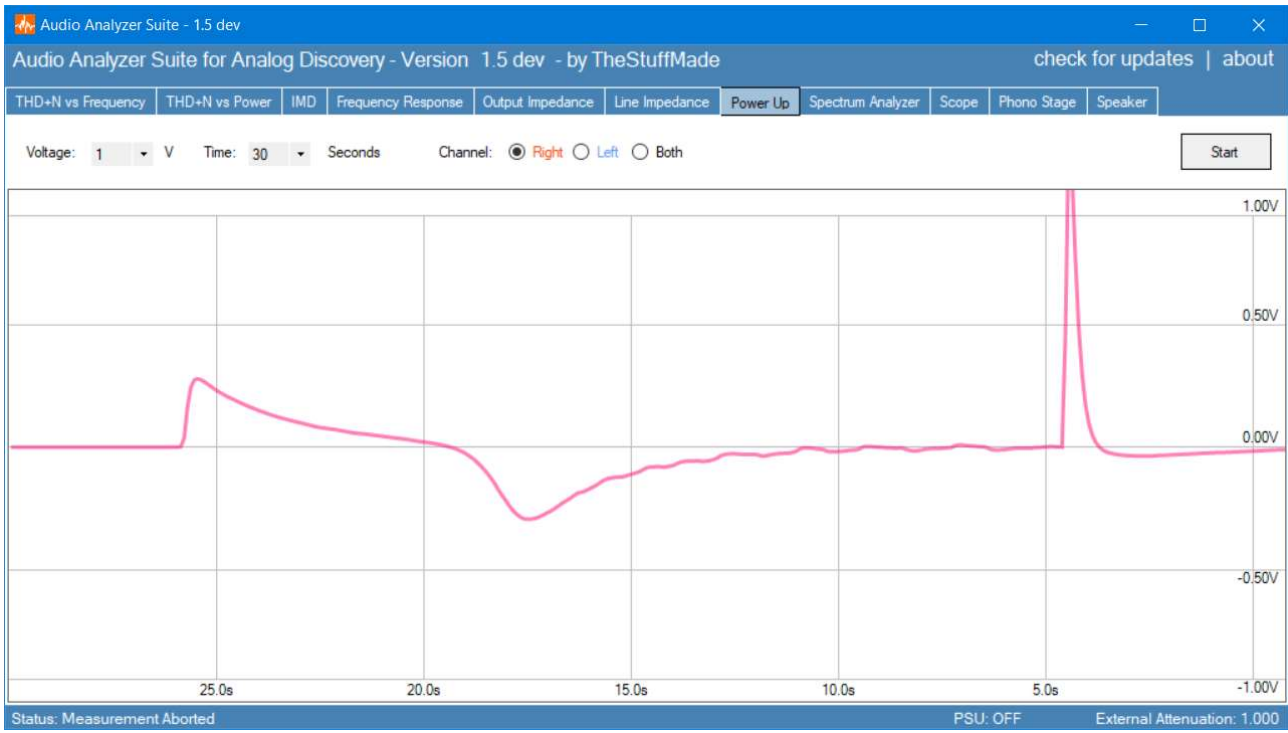
This is even better with 5kΩ output impedance at 20Hz and 3.3kΩ flat from 100Hz and up.

Switch On/Off Spikes on Output With 1uF Film Caps



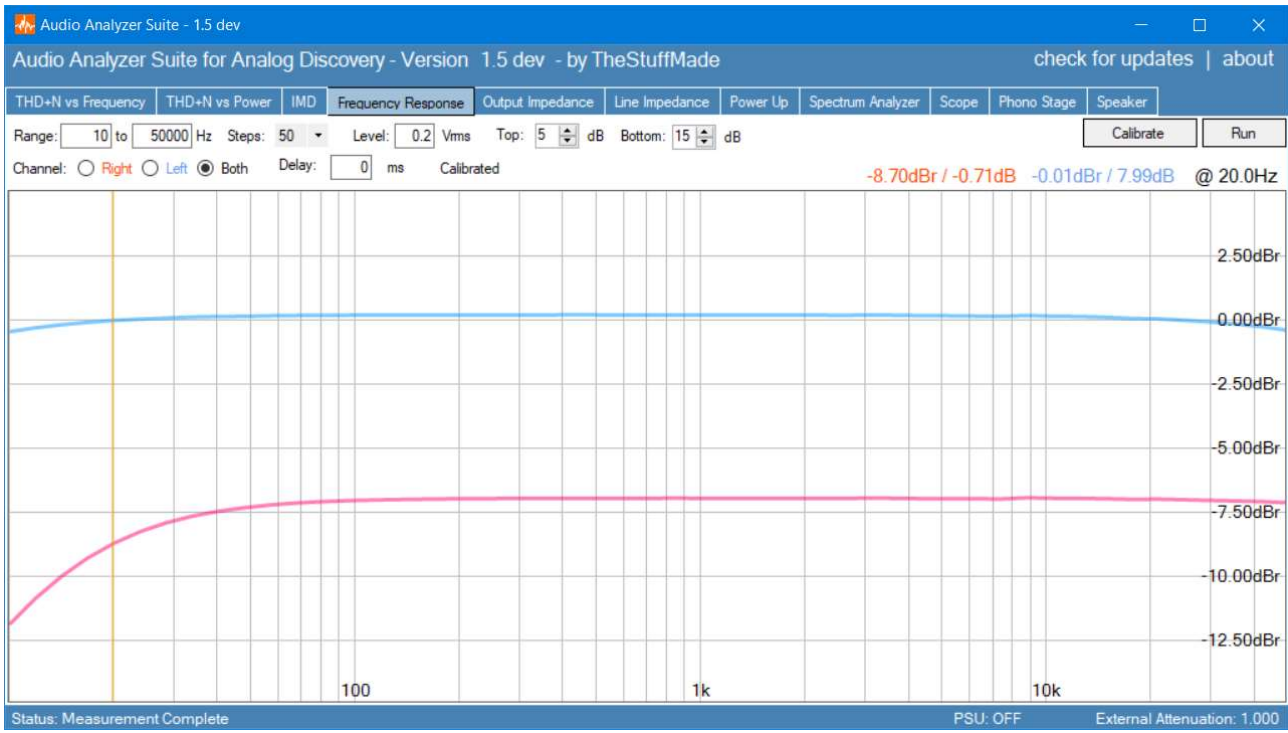
Increasing the capacitance on the output coupling capacitor does also increase the spikes on output during power on/off. This was into a 47k Ω load, lower load will have less spikes.

Switch On/Off Spikes on Output with 2uF Film Caps



With 2uF coupling capacitors on the output the Switch off spike is getting a bit high into 47k Ω . I wouldn't recommend using anything larger than 2uF.

Frequency Response into 3kΩ load with 2uF



Left channel 1MΩ load and right channel 3kΩ load. With 2uF coupling capacitor the right channel is down less than 2dB at 20Hz compared to the level at 1kHz. However the output level is down 7dB into 3kΩ compared to the level into 1MΩ. But as long as the power amp's input impedance is reasonably flat the preamp will now work with a low input impedance without losing all the low end.

Conclusion:

Replacing/adding a few cheap components will significantly improve the performance.

It's a cheap and fun little tube pre-amp, anyone curious about tubes should get one and see if it's something they might be interested in.

It also comes as a kit where you have to solder all the components, could be a fun little project.

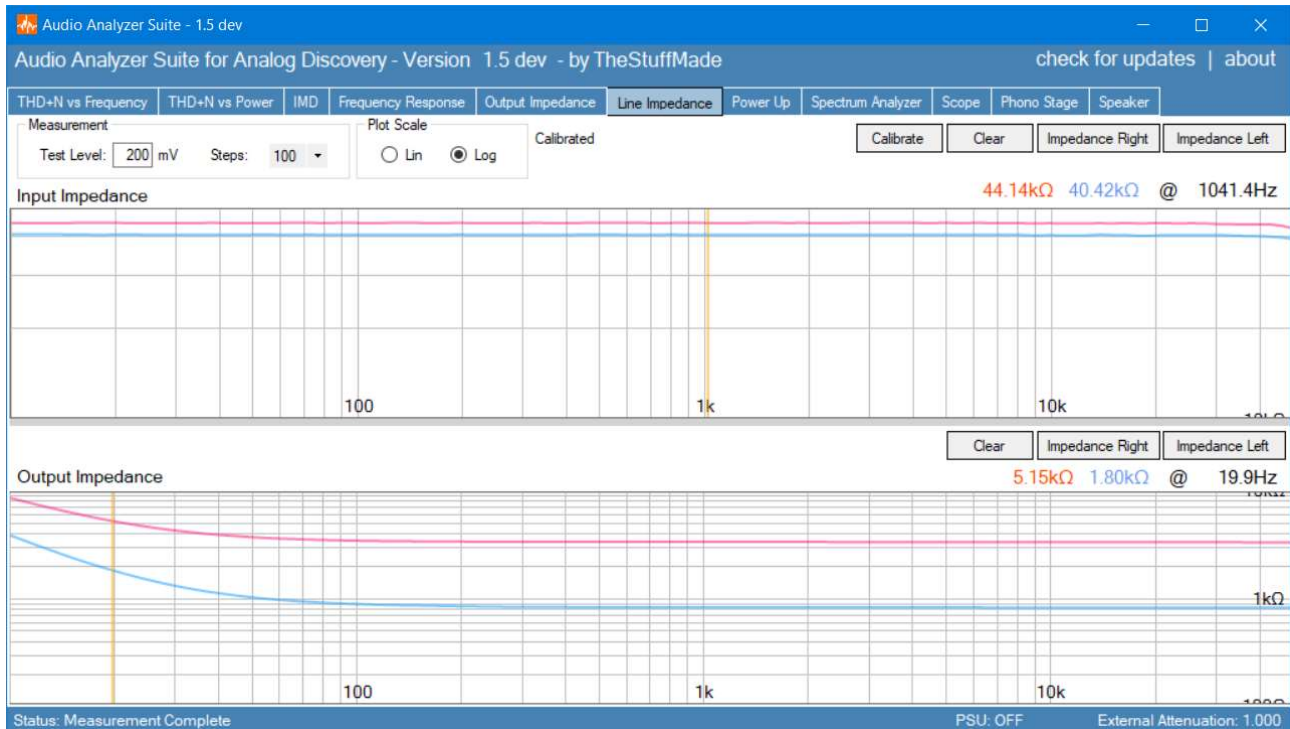
It's a nice platform for anyone interesting in experimenting.

Other possible mods:

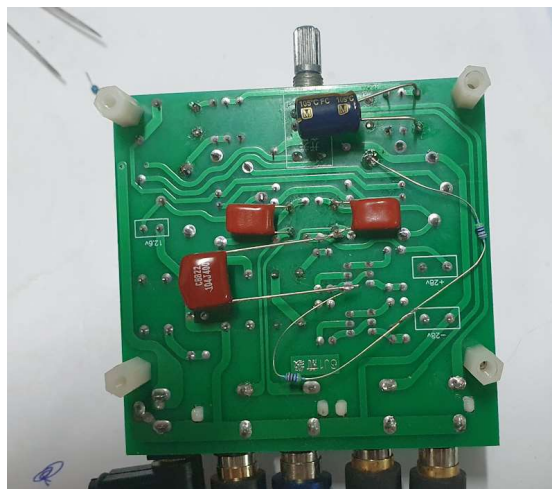
- Try feedback to lower the output impedance.
- Try a cathode bypass capacitor together with feedback.
- Try LED/Diode biasing.
- Add grid stopper resistors.
- Add some 100k Ω resistors to bleed the large capacitors.
- Re-balance the tube with different bias.
- Redesign the power section/replace it with a high voltage boost converter.
- Add regulated DC for the tube heaters.
- etc

Can the mains hum easily be fixed? No, it's a compact board with AC and high impedance signals, you'd probably need to split the tube section and the power supply section into 2 boards. Maybe just buy 2 of them, then use 1 for the tube amp section and 1 for the power supply.

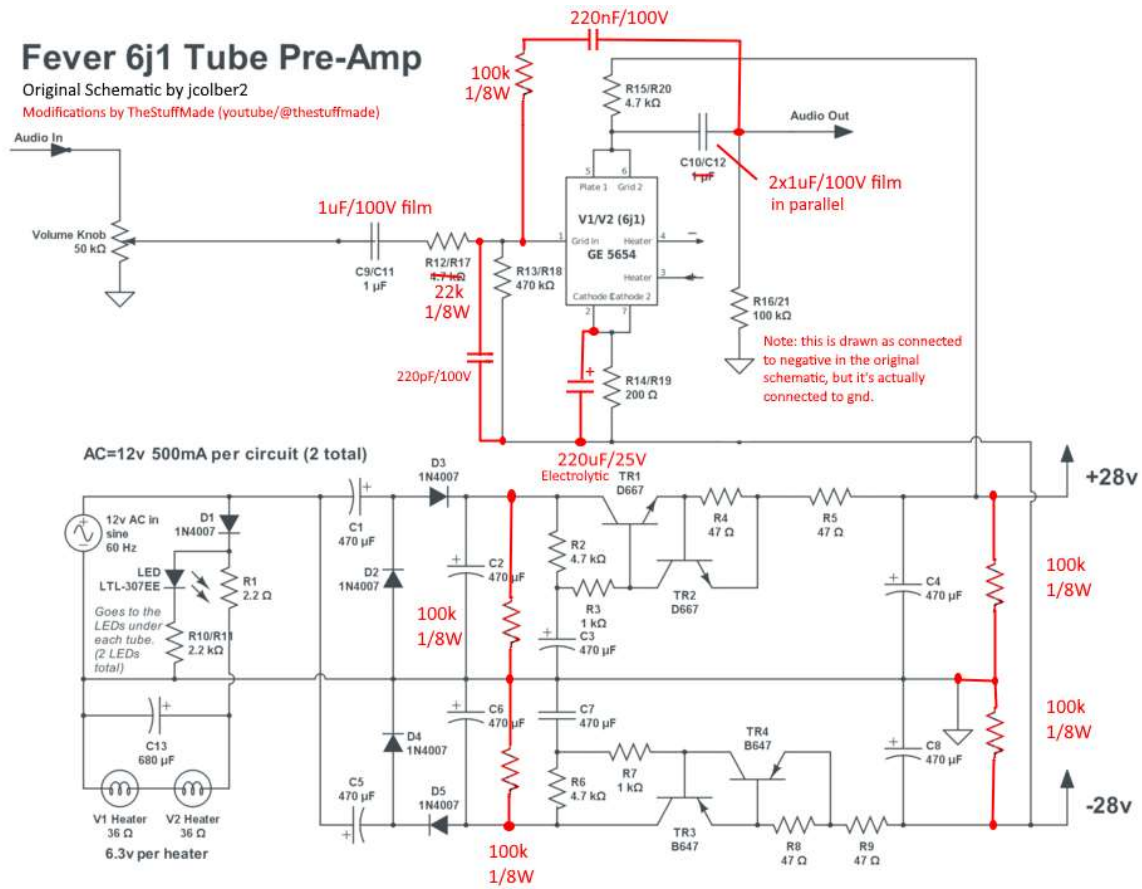
Quick test with 100k Ω feedback and 220 μ F cathode bypass.



With these changes the output impedance is down below 2k Ω at 20Hz and 850 Ω from 100Hz to 50kHz. Only left side modified with feedback and bypass cap.



Updated Schematic:

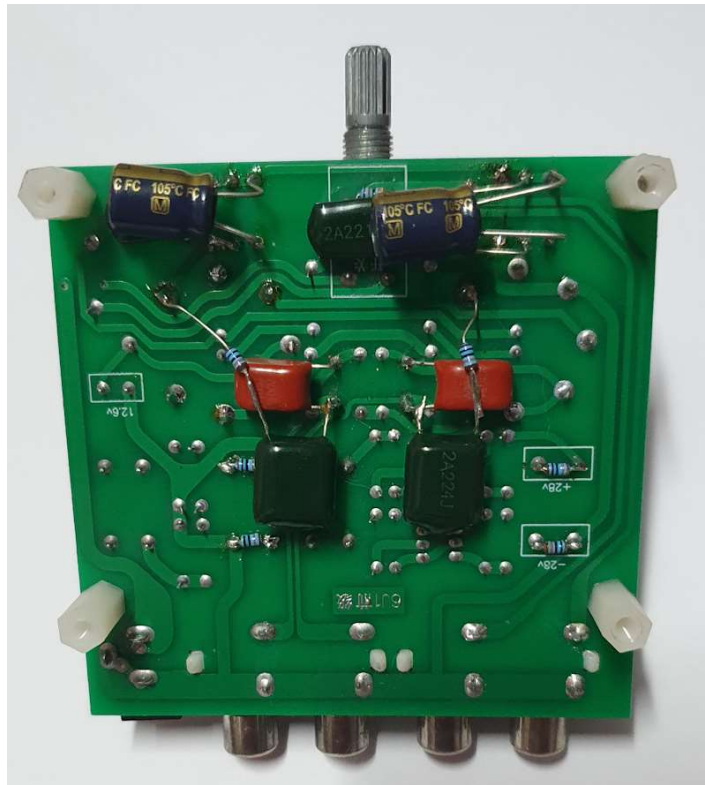


I haven't drawn the volume pot modification as it's unlikely to be the same for everyone.

These are not necessarily ideal component values, but close enough that implementing these changes will objectively give a better performing preamp, however I do understand some people might prefer the higher distortion without feedback.

These modifications are all reversible as they do not require any permanent changes to the circuit board.

Board with all Modifications for Reference



Tube Datasheet: (with translation)

= 67 =
= 67 =

6J1型 锐截止高频五极管

类型：旁热式氧化物阴极
用途：高频电压放大

主要电参数

灯丝电压(~或-)	6.3V
灯丝电流	170±20mA
阴极电压(-)	120V
第二栅极电压(-)	120V
阴极电路自给栅偏压电阻	200Ω
阳极电流	7.35 ^{+3.85} _{-2.75} mA
第二栅极电流	不大于3.2mA
跨导	5.1±1.4mA/V
内阻	0.1-1.1MΩ
输入电阻	12-25KΩ
板间电容	4.3 ^{+0.5} _{-0.1} PF

电极和管脚连接图

1-第一栅极 2-阴极、第三栅极和屏蔽 3-灯丝 4-灯丝 5-阳极 6-第二栅极 7-阴极、第三栅极和屏蔽

Type 6J1 Sharp cut high frequency pentode

Type: Side-heated oxide cathode
Purpose: high frequency voltage amplification

Main electrical parameters

Filament voltage (~ or -)	6.3V
Filament current	170±20mA
Anode voltage (-)	120V
Second gate voltage (-)	120V
Cathode circuit self-contained grid bias resistor	200Ω
anode current	7.35 ^{+3.85} _{-2.75} mA
second gate current	Not more than 3.2mA
transconductance	5.1±1.4mA/V
input resistance	0.1-1.1MΩ
interelectrode capacitance	12-25KΩ
input capacitance	4.3 ^{+0.5} _{-0.1} PF

Electrode and pin connection diagram

1 - first gate 2 - Yin level, third level and screen level 3 - filament 4 - filament 5 - Anode 6 - Second gate 7 - cathode, 3rd grid and shield

输出电容 2.35±0.25PF
过渡电容 不大于0.02PF
阴极灯丝间电容 不大于4.6PF
(电容数值系在屏蔽内测量)

极限运用数据

最大灯丝电压(~或-)	6.9V
最小灯丝电压(~或-)	5.7V
最大阴极电压(-)	200V
最大第二栅极电压(-)	150V
最大阳极电流	20mA
最大阳极损耗功率	1.8W
最大第二栅极损耗功率	0.55W
最大阴极与灯丝间电压	±120V
最大第一栅极电路电阻	1MΩ

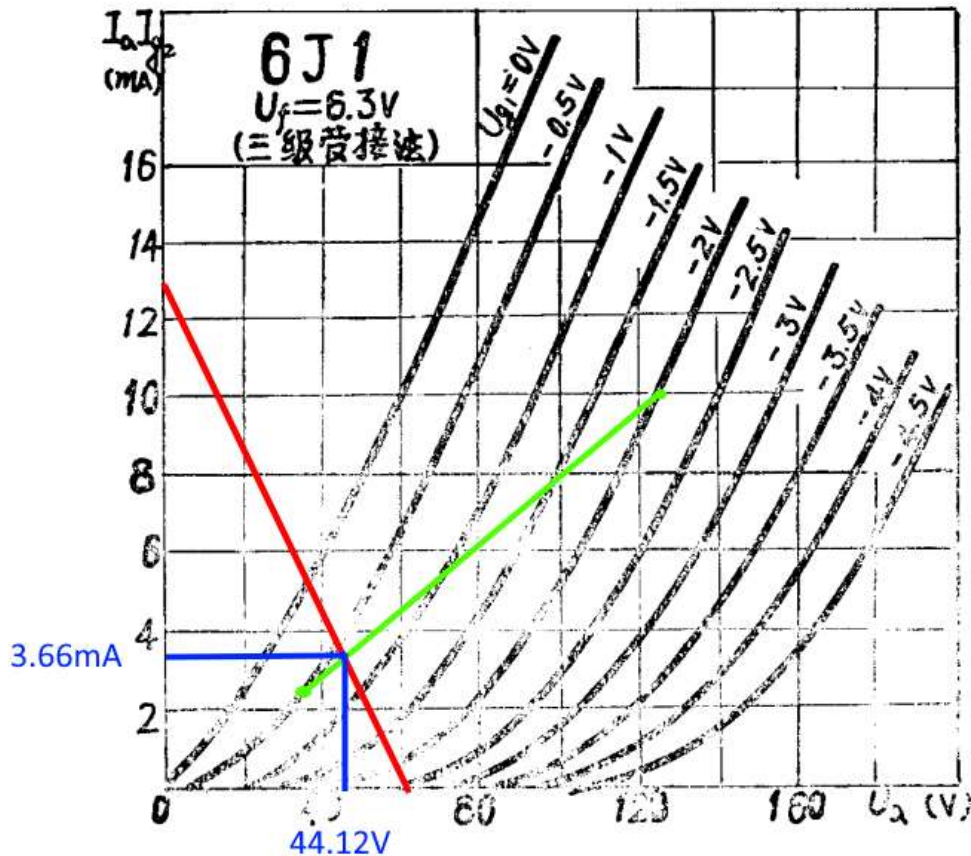
Output capacitor 2.35±0.25PF
transition capacitance Not greater than 0.02PF
Capacitance between cathode filaments Not more than 4.6PF
(Capacitance values are measured within the shield)

Extreme usage data

Maximum filament voltage (~ or -)	6.9V
Minimum filament voltage (~ or -)	5.7V
Maximum anode voltage (-)	200V
Maximum second gate voltage (-)	150V
Maximum cathode current	20mA
Maximum anode power loss	1.8W
Maximum second gate loss power	0.55W
Maximum voltage between cathode and filament	±120V
Maximum first grid circuit resistance	1MΩ

The datasheet looks like a 20th generation photocopy that was scanned in. It's the only one I've been able to find. It's all in Chinese and then machine translated.

Tube Chart with Loadlines and Operating Point



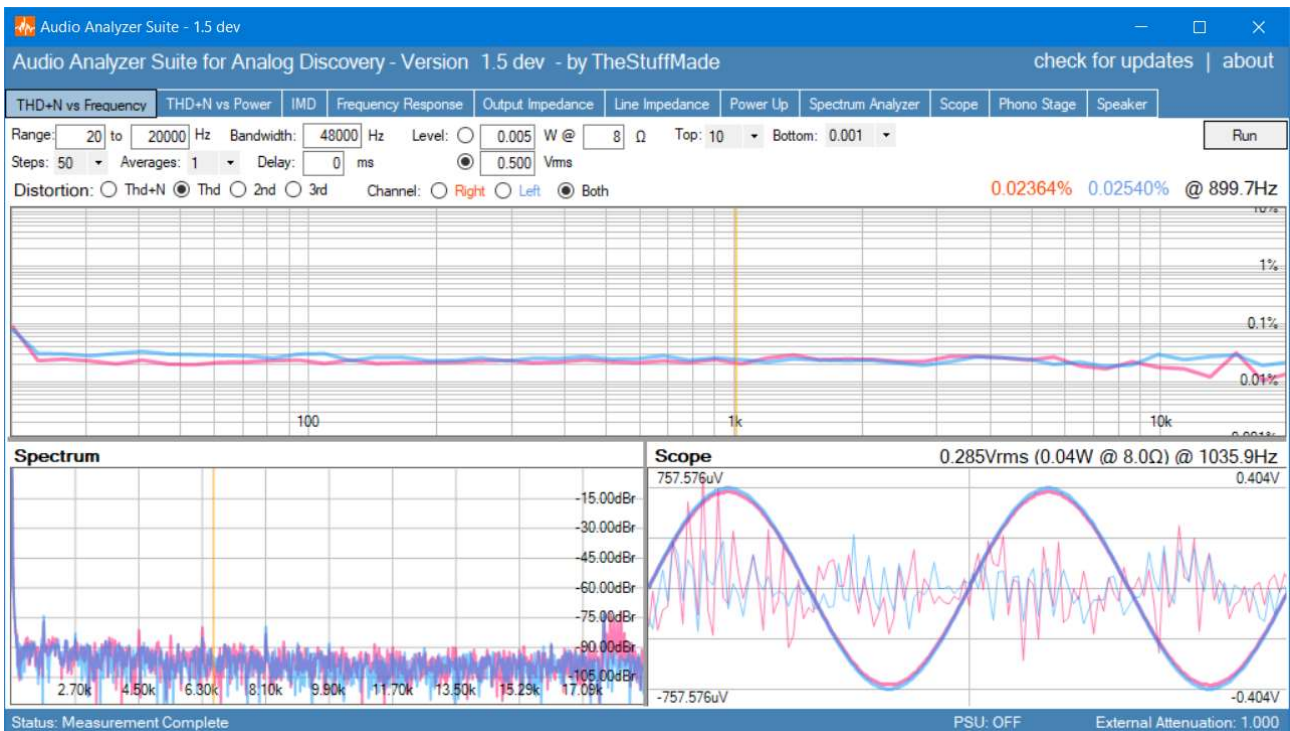
Red is the load line for the 4.7k Ω anode resistor.

Green is the line for the 200 Ω cathode resistors

Blue is the operating point, the values are from measurements on the board.

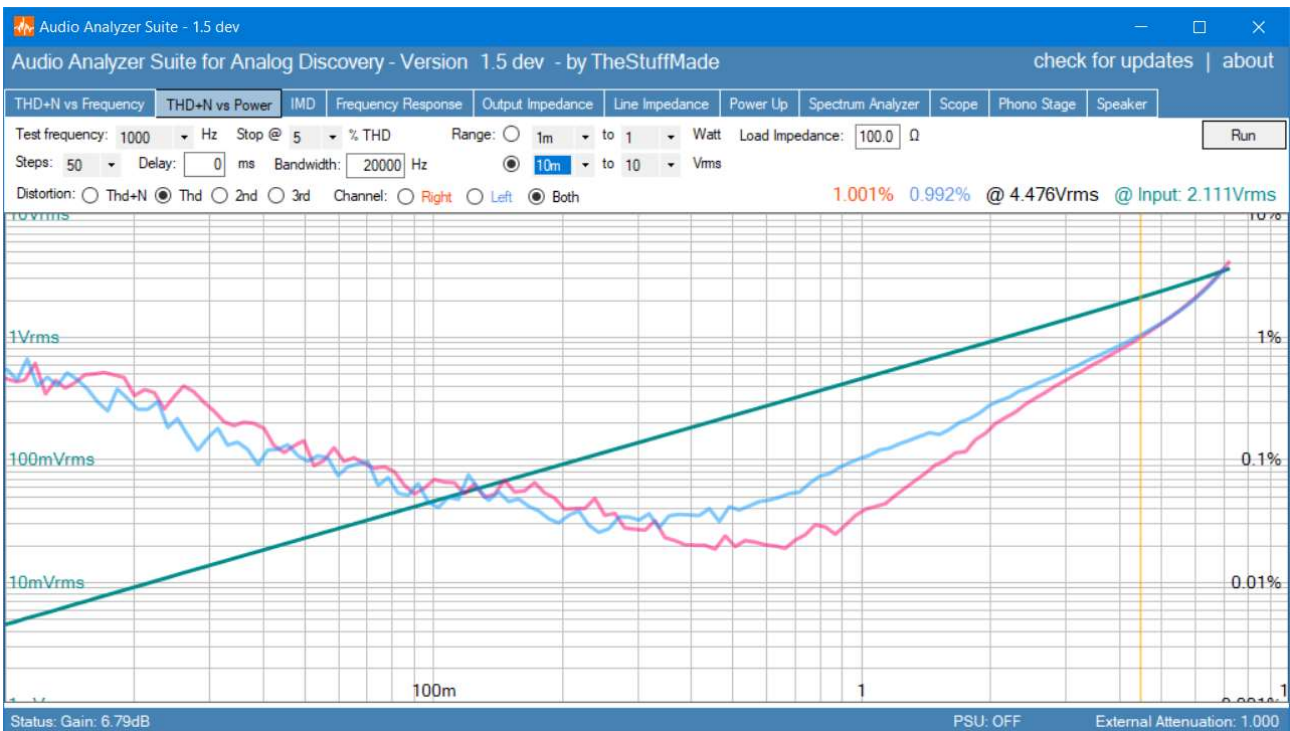
The measurements match well with the chart so I believe both the tubes and chart are correct. 120V supply would've been better, but it works with just 60V.

Distortion vs Frequency



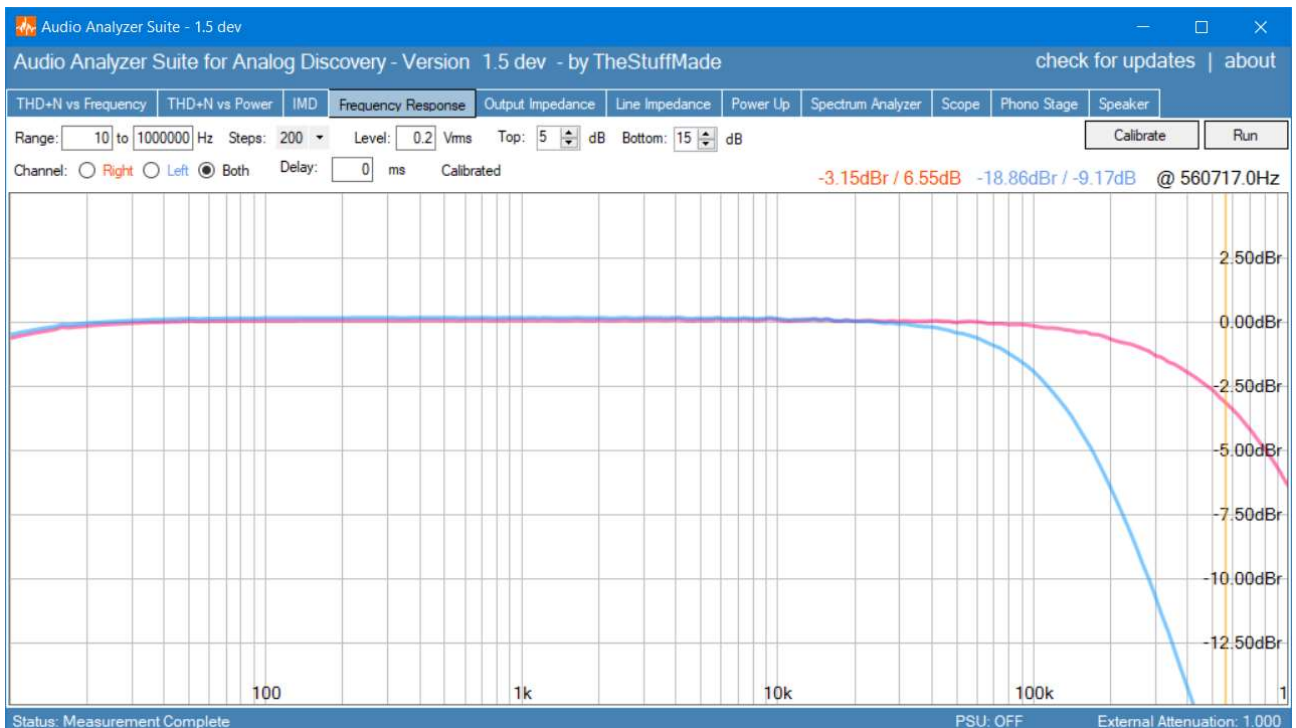
Distortion vs frequency much lower in level, ~0.02% vs ~0.1% without modifications.
 Still dominated by 2nd harmonic distortion.

Distortion vs Output Voltage



Now we get 4.5V output at 1% distortion compared to 1% @ 2.5V unmodified.

With and Without 220pF Cap to Limit Bandwidth.

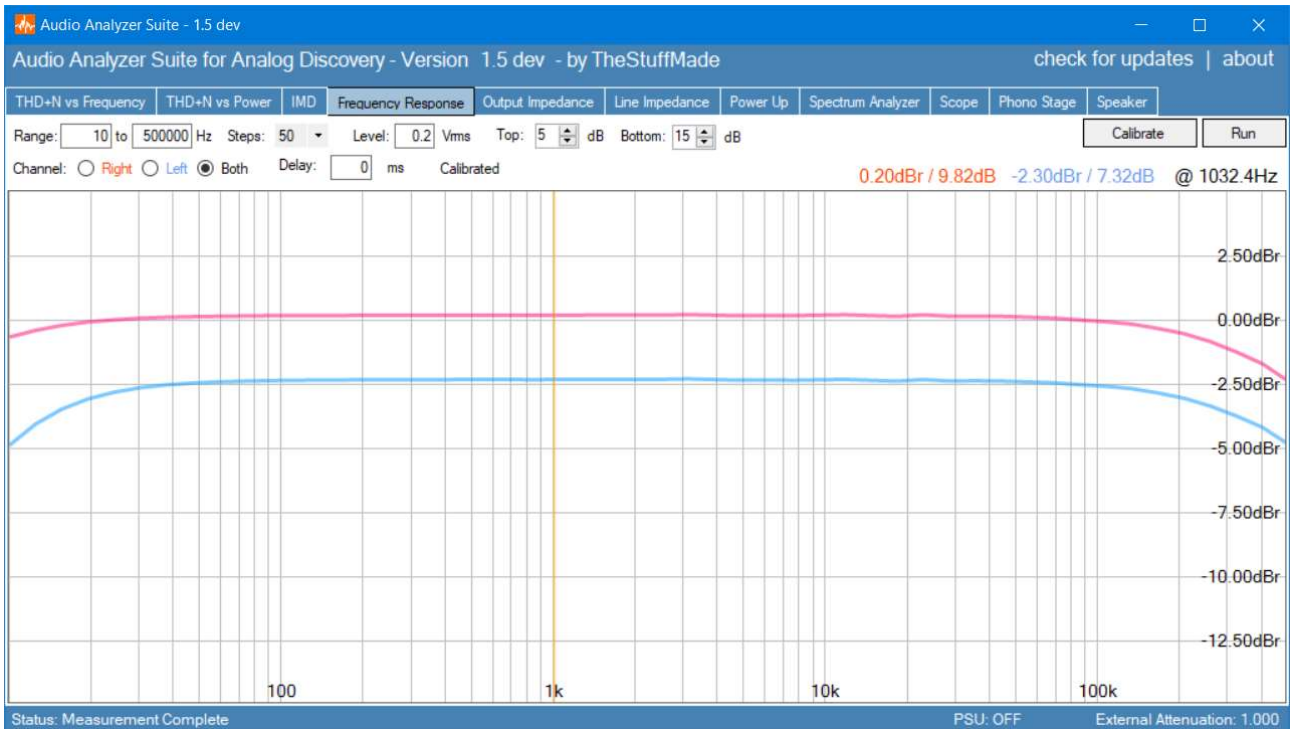


Right channel without 220nF across R13/R18: -3dB is at 560kHz, much too high.

Left channel with 220nF across R13/R18: -3dB is 125kHz, much better.

Alternatively a grid stopper resistor could be used to reduce the bandwidth, but it does require cutting a couple of traces on the board.

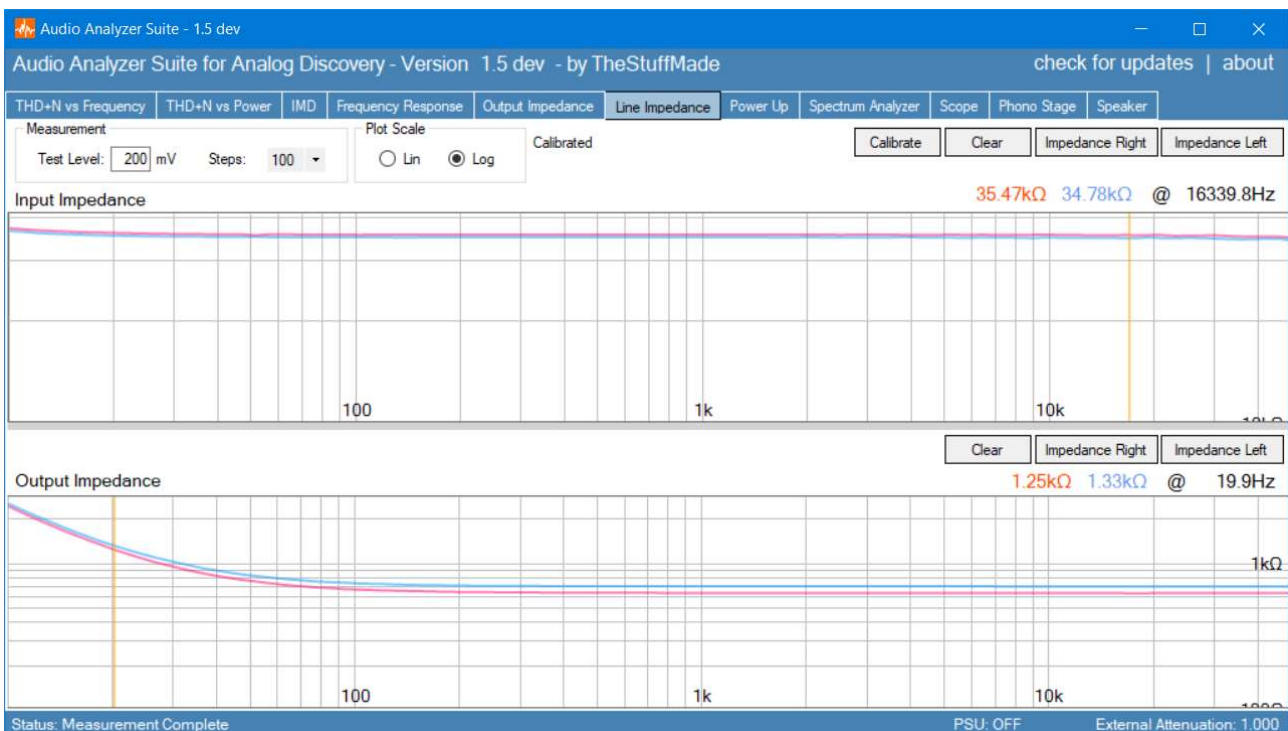
Frequency Response, 1MΩ vs 2.7kΩ Load.



Right channel: 1M load, Left Channel: 2.7k Load

Gain into 1M is now 9.8dB compared to 18dB unmodified.

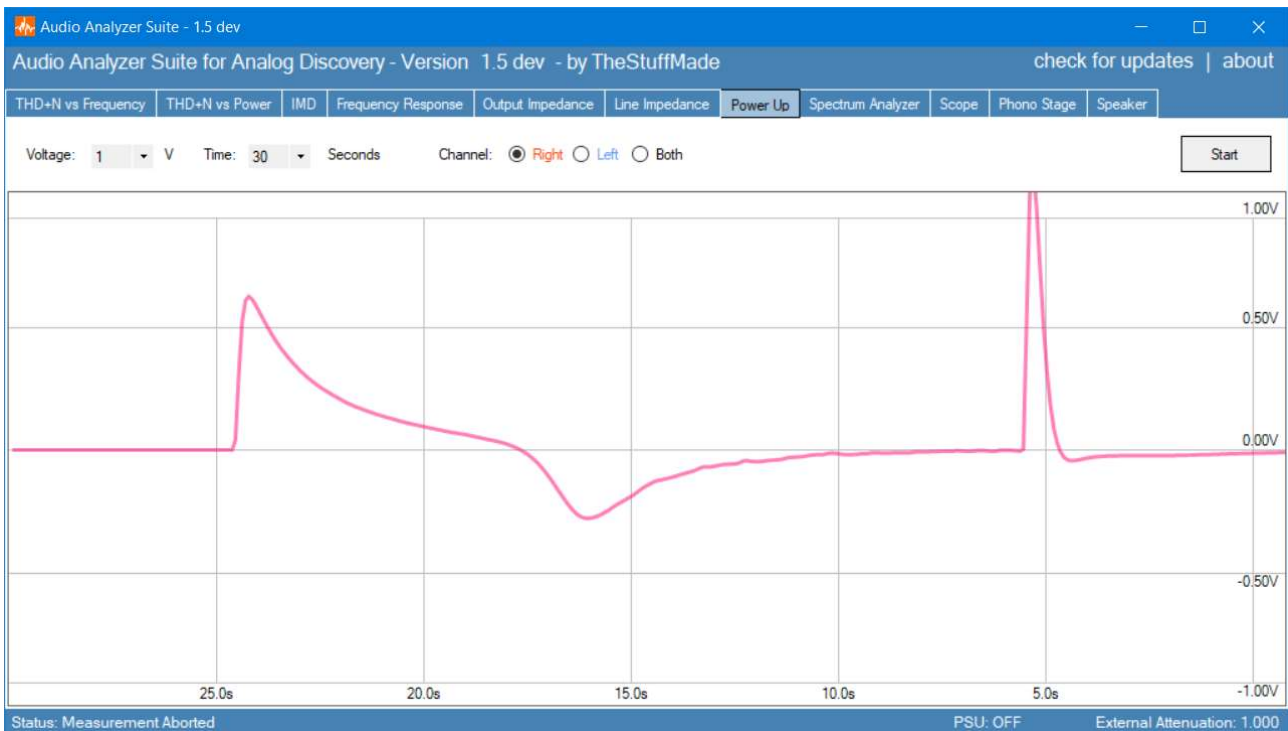
Input and Output Impedance



After modification the input impedance will now change slightly based on volume setting. 40kΩ at minimum volume and down to near 20kΩ at maximum volume, but still flat across the audio range.

Output impedance is just 1.3kΩ at 20Hz compared to 28kΩ unmodified, and 650Ω at 1kHz compared to 3.3kΩ unmodified, that is a huge improvement.

Switch On/Off Spikes



The spikes at switch on and off are worse after the modification. It's good practice to switch on the pre-amp before the power amp and switch off the power amp before the pre-amp when powering down. However this does of course not help if the power cuts out.

Final Words

I think this shows how much fun you can have with a cheap amp and how useful it is to have affordable measurement equipment like the Analog Discovery and the Audio Analyzer Suite even if you're just doing trial and error modifications.

Note: I have no affiliation with Digilent and my Audio Analyzer software is free.