X-Altra HPA-1 Headphone Amplifier

This project uses SMD components down to SOT23 and 0805

A DSTHP Silk Screened PCB is available for this project here:-

X-Altra HPA-1 Class A Headphone Amplifier (hifisonix.com)

Updated 15 May 2023 to reflect latest schematics and PCB

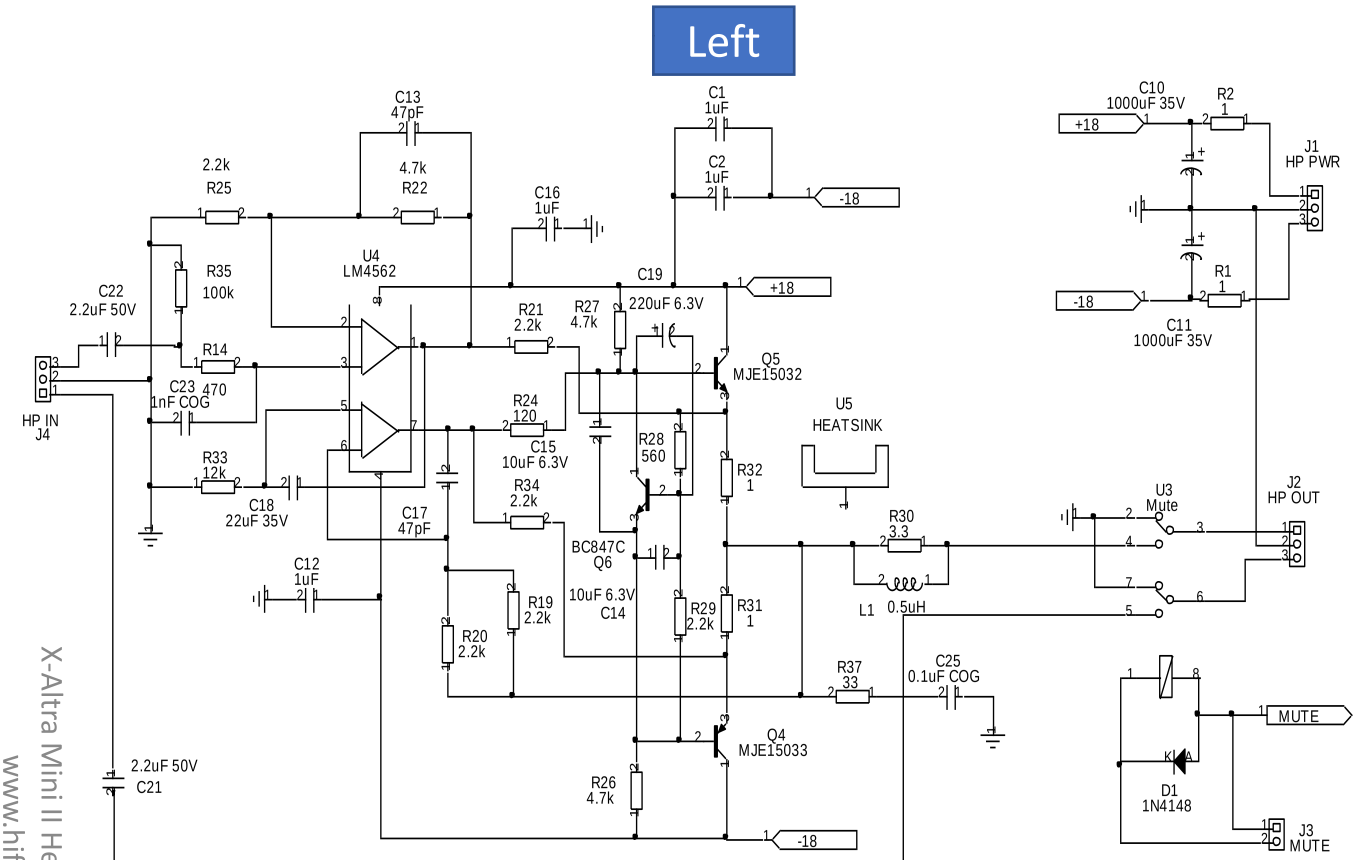
www.hifisonix.com

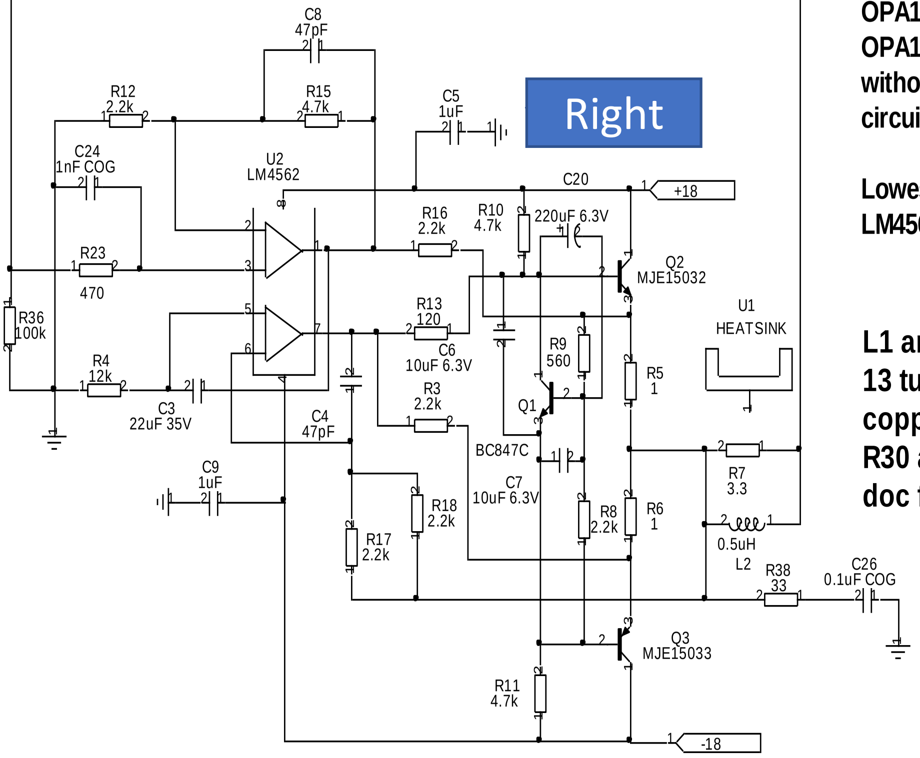
X-Altra HPA-1 Class A Headphone Amplifier Specifications

- Class A 13V pk~pk into 32 Ωs
- Class AB 13V pk~pk to 21 V pk~pk
- Output power : 32 Ω = 1.75 Watts; 300 Ω 187.5 mW; 93.75 mW into 600 Ω
- Very high damping factor of ~3000 into 32 Ohms with the addition of L1 and L2 – see schematic for details)
- Very low distortion – see measurements later in this document
- Rise/fall time <500ns (see measurements)
- Frequency Response 2Hz to 330 kHz; 20Hz to 20 kHz -0.1dB*
- Full power bandwidth 450 kHz (20V pk-pk into 33 Ω)
- Power consumption +-15V at 90 mA per channel; short circuit output current c. 300 mA
- Gain = 3.13x. Can easily be changed to higher values as required

*the frequency response with the input bandwidth limiting filter disabled is 2 Hz to 2 MHz -3dB

X-Altra HPA-1 Headphone Amplifier schematic (Updated 15 May 2023)





Notes
For U2 and U4, you can use OPA1642, OPA1652, TL072 or NE5532 without circuit modification.

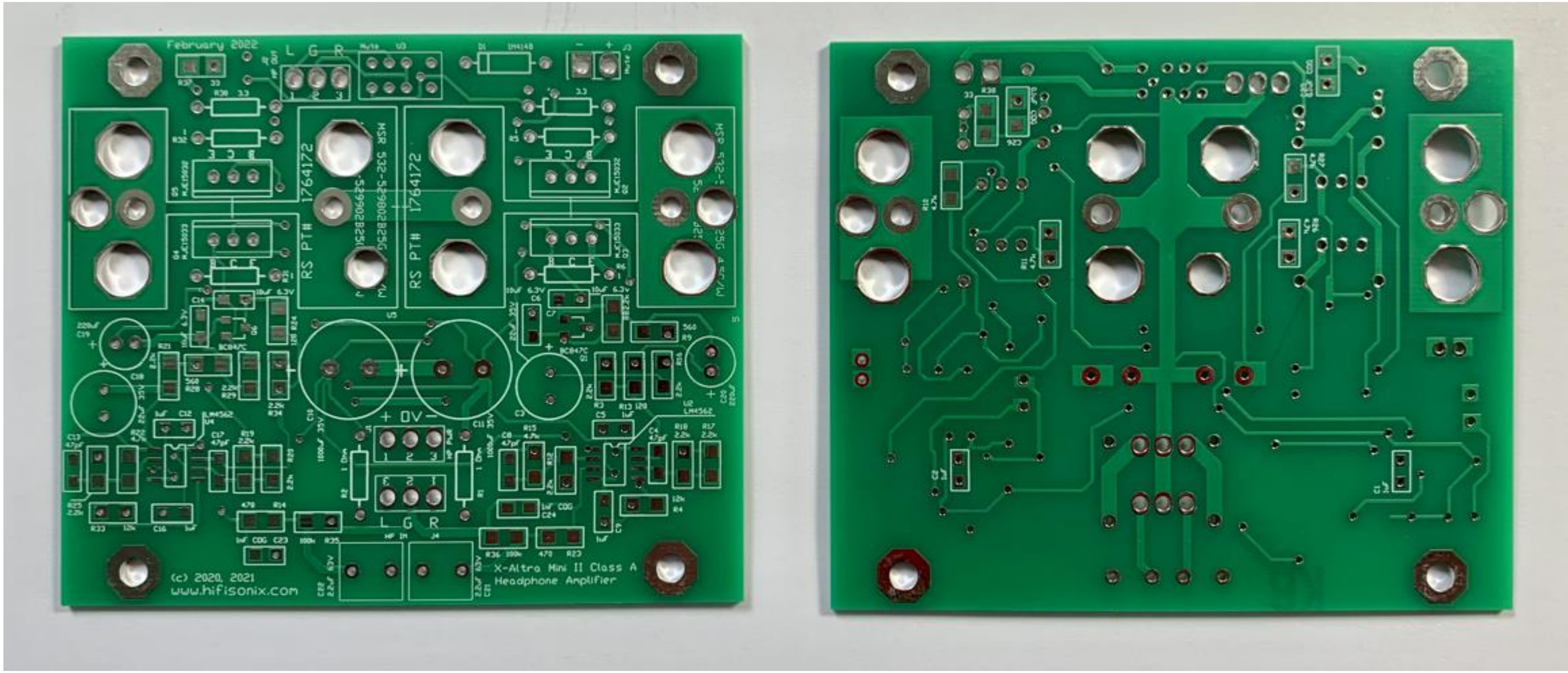
Lowest distortion is with LM4562

L1 and L2 are OPTIONAL: 13 turns 0.5mm diameter copper wire wound over R30 and R7. See build doc for details

www.hifisonix.com
May 2022

X-Altra HPA-1 Class A Headphone Amplifier

Picture of PCB – top side and bottom side



The large holes in the PCB allow airflow up through the vertically mounted heatsinks. The temperature rise above ambient for 45mm high heatsinks is about 8 C (Image updated 15 May 2023)

Circuit Description (refer to Left Channel – right channel is identical)

- The input signal is fed into U4 (LM4562 or OPA1642) non-inverting input pin 3 via DC blocking capacitors C21 and C22. Input signal bandwidth limiting is provided by the low-pass filters consisting of R14 and C23 (left channel) and R23 and C24 (right channel). R22 and R25 set the 1st stage gain at 3.13x with C13 providing some HF compensation. The first stage gain may be increased if required by reducing the value of R25 (see addendum 1).
- The output of the first stage appears at pin 1 of U4 and feeds into the second stage non-inverting input pin 5 via C18 (22uF bipolar capacitor) with R33 providing input bias. The opamp output at pin 7 feeds the output stage via R24 (120 Ωs). Q5 (MJE15032 and Q4 (MJE15033) form a push pull output stage.
- Q6 (BC847C) is arranged as a bias controller and keeps the output stage in class A with a standing current of 90mA +-5mA over temperature (180mA peak class A). If the output load current demand is higher than this, the OPS transitions to class AB. On a 32 Ω load, this will happen at about 13V pk~pk.

- The output stage current is measured across degeneration resistors R31 and R32 (1 Ω each) and scaled by R28 (560 Ωs) and R29 (2.2k). The OPS standing current *Iq* is

$$Iq = \frac{\left[Vbe_{Q6} . \frac{R29+R28}{R29}\right] - Vbe_{Q4}}{R31+R32}$$

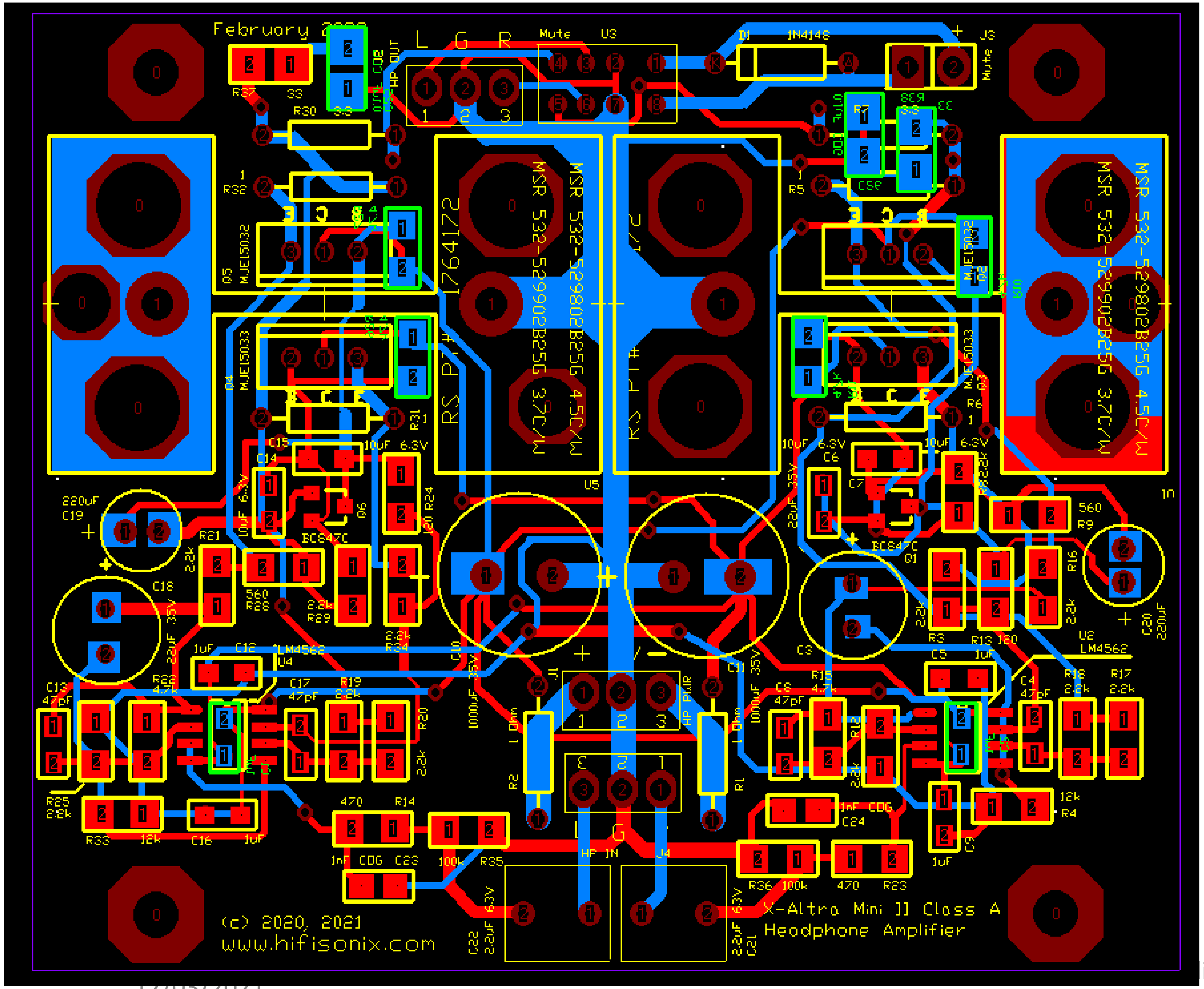
- For the values chosen and measured V_{be} = 0.625 for Q6 and 0.592 for Q4 it calculates to 96mA. Figures of 94mA and 96mA were measured after 1 hour warmup. Directly after switch-on, they measured 91mA and 92mA respectively.
- Note that for smaller values of R28 (which gives lower OPS standing current), the *spread in standing current increases* due to the variation in the Vbe of Q6 and Q4, which may be as great as 35 to 40mV between the two transistors, and the resistor tolerances.
- C14 and C15 provide filtering and decoupling, while C19 (220uF) bootstraps the bias controller circuit so that at LF and large output voltage swings, the bias control voltage remains constant. Without it, LF distortion increases because the bias control voltage collapses (See measurements later on) at high output voltage swings.

- R27 and R27 provide DC bias paths for the bias controller and OPS. These could be replaced with active current sources for even lower distortion, but at the measured levels, there is no point given the added complexity
- R21 and R34 bootstrap the opamp output stages into class A by tapping off the transistor side of the OPS emitter degeneration resistors so the complete headphone amplifier operates in class A – the opamp stages and the output stage. The first gain stage it bootstrapped to 30uA and the OPS driver opamp to 300uA. Both opamps remain in class A up to 20 V pk~pk output.
- Overall global loop feedback is taken from the junction of R31 and R32 via R19 and R20 (2.2k each) in parallel with loop compensation provided by C17 (47pF)
- The opamp rails are decoupled with C13, C16 and C1 and C2 (C2 for the RH channel) directly across the rails under each opamp.
- Bulk decoupling and isolation from the main power supply is provided by R1 and R2 (1 Ω) and C10 and C11 (1000uF 35V each).
- The amplifier output is coupled to the headphones via a 3.3 Ω resistor (R30) to isolate any load and cable capacitance and then via a muting relay (U3). L1 and L2 in parallel with R7 and R30 were added in September 2022 and result in dramatically lower output impedance of c. 10 milli-Ohms at 1kHz, providing a damping factor of over 3000 into 32 Ohms. This improves the bass performance on large diaphragm open back headphones.
- If you do not need the mute function, simply link the relay out, but be aware, at turn on and turn off, the amp will produce a loud 'plop' at the output. If you are using the recommended power supply, a mute function is incorporated on the PSU.

Some Questions Answered

- Can I use different opamps with this circuit?
  - There is no reason why any other ***dual unity gain stable*** opamp cannot be used with this circuit. However, you will have to check that the amplifier is stable, and it may entail adjustment of the value of C17. See Addendum 3 further opamp type measurements.
  - Measurements using the OPA1642 are provided on the HPA-1 webpage; the OPA1652 will also work well; the OPA16XX devices are high performance JFET/CMOS input opamps featuring very low distortion. TLO72 devices will also work, but the distortion will be about 5x higher.
- What size PSU will I need?
  - Since the standing current is high (2 x 95mA), the PSU should be oversized. A 12-15VA PSU is recommended at +-15V. The PSU must be regulated with eg 7815/7915 or LM317/337 type devices. The recommended PSU is here.
- How loud can the HPA-1 play?
  - Louder than is tolerable with negligible distortion. On 90 dB/mW sensitivity headphones, the X-Altra will generate 122 dB SPL which is about 6 dB greater than loud rock concert levels. Please use this web based tool to calculate your headphone requirements Headphone drive requirements and see addendum

Board Layout (the PCB has both channels on it)



The finished stereo PC board measures 87.5 mm x 72.5mm x 1.6mm thick.

The recommended PCB mount heatsinks stand 45 mm high.

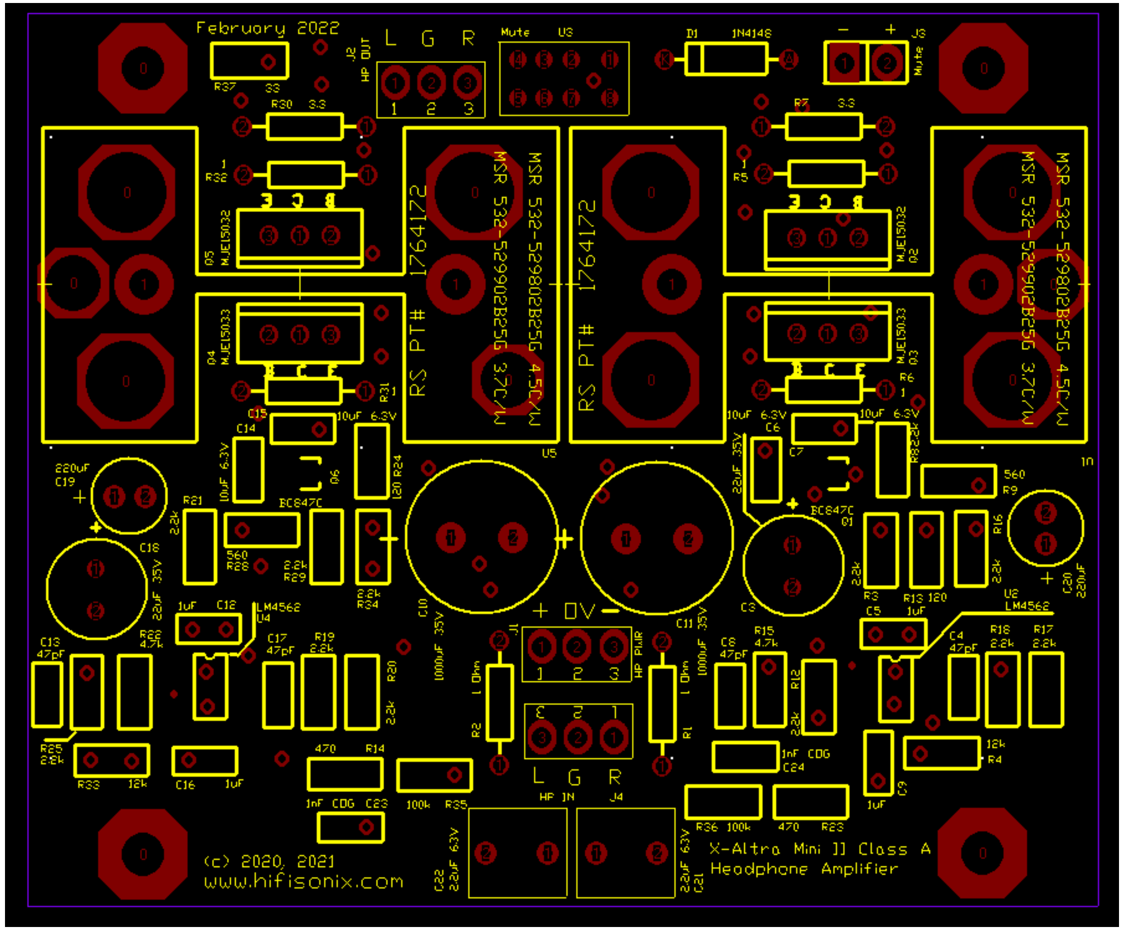
Attention: The leaded resistors are standard 6.5mm in length. Do not use 9.5 or 10 mm length resistors as they will not fit on the board.

All SMD resistors are 1206 thin film.

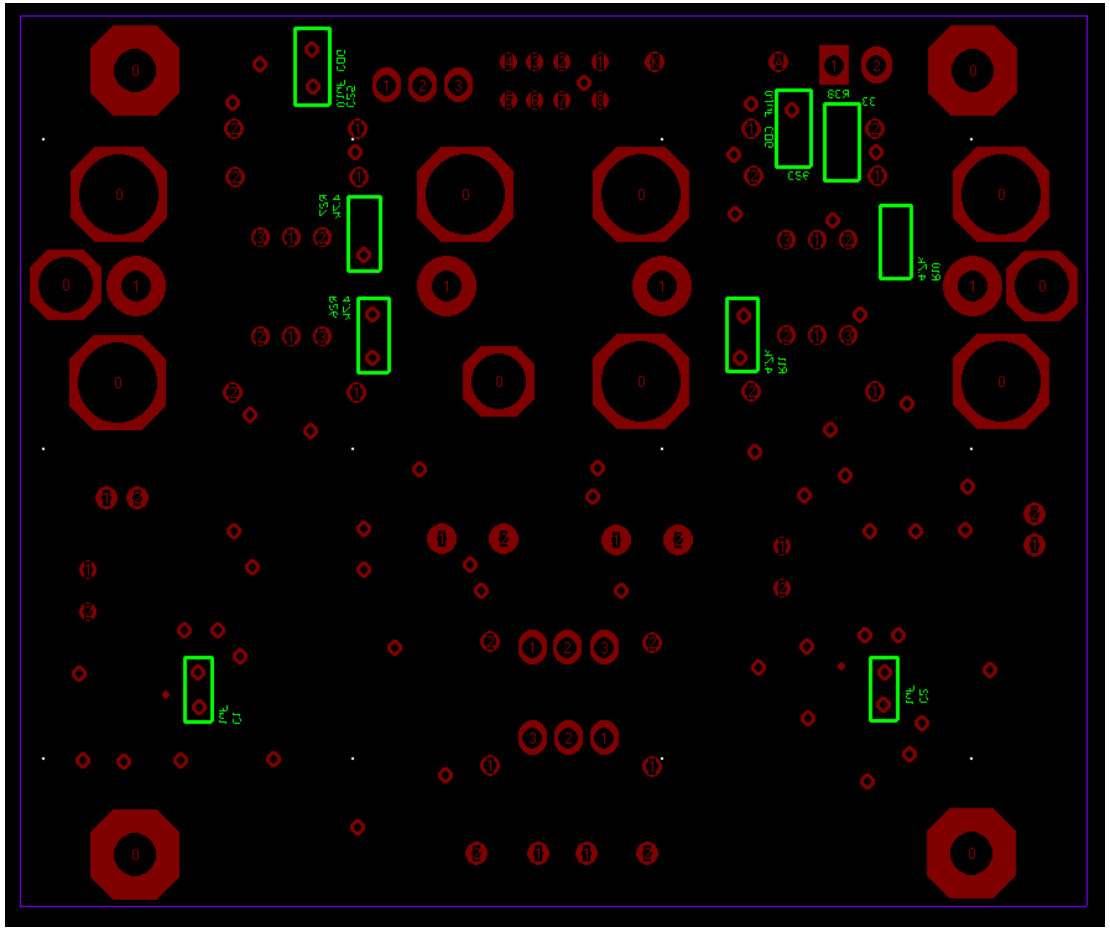
All SMD capacitors are 1206 or 0805

See BOM for specific Mouser part numbers.

Component Overlay

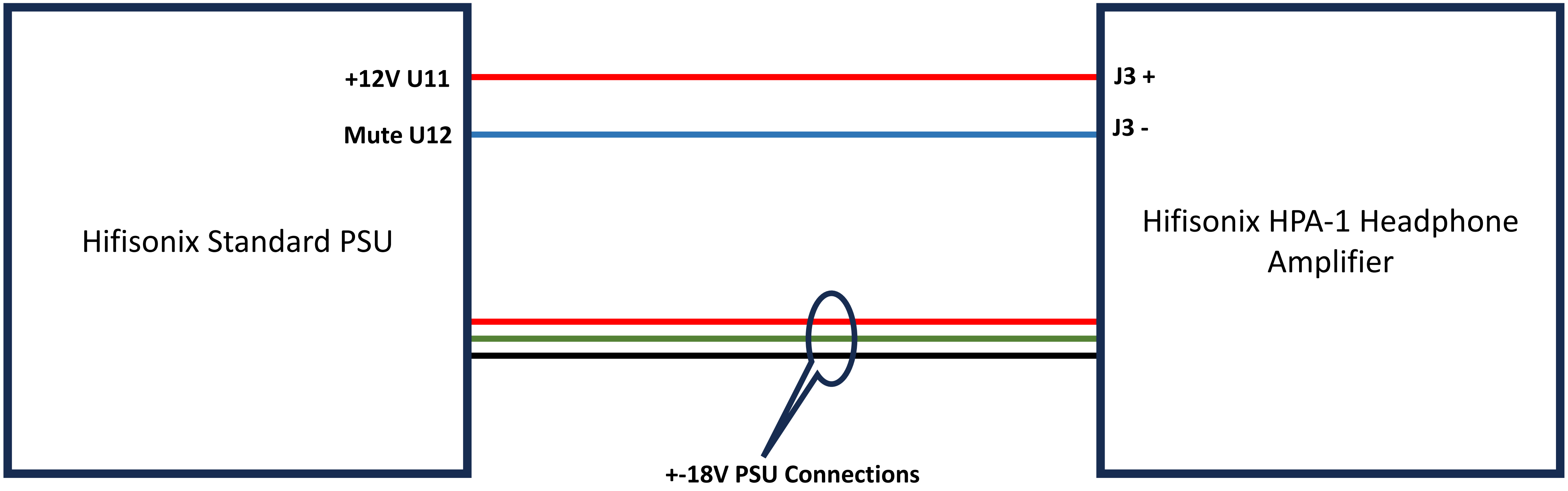


Top Side Overlay



Bottom Side Overlay

How to wire the HPA-1 to the Hifisonix Standard PSU to enable the Mute Relay Function



Calculating dB SPL given headphone sensitivity vs voltage drive parameters (accurate to within about 0.4 dB)

$$dB\ SPL = P_{sens} + 10_{log}[(V^2/R)*1000]$$

Where	SPL	= sound pressure level in dB
	P_{sens}	= headphone sensitivity in dB/mW
	V	= amplifier drive RMS voltage
	R	= rated headphone impedance

Example:-

Headphone sensitivity is 100 dB/mW and impedance is 32 Ω

Drive voltage from the amplifier is 5V RMS

The resultant SPL level is 100 + $10_{log}[(5^2/32)*1000]$ = 129 dB SPL (very loud – threshold of pain)

Attention: Extended exposure to SPL levels above 105 dB will lead to permanent hearing damage

dB SPL Levels - Reference

The chart on the right gives a good guide to SPL levels of everyday sounds.

Attention: Extended exposure to SPL levels above 105 dB will lead to permanent hearing damage

Chart courtesy 'Pulsar' Instruments Plc

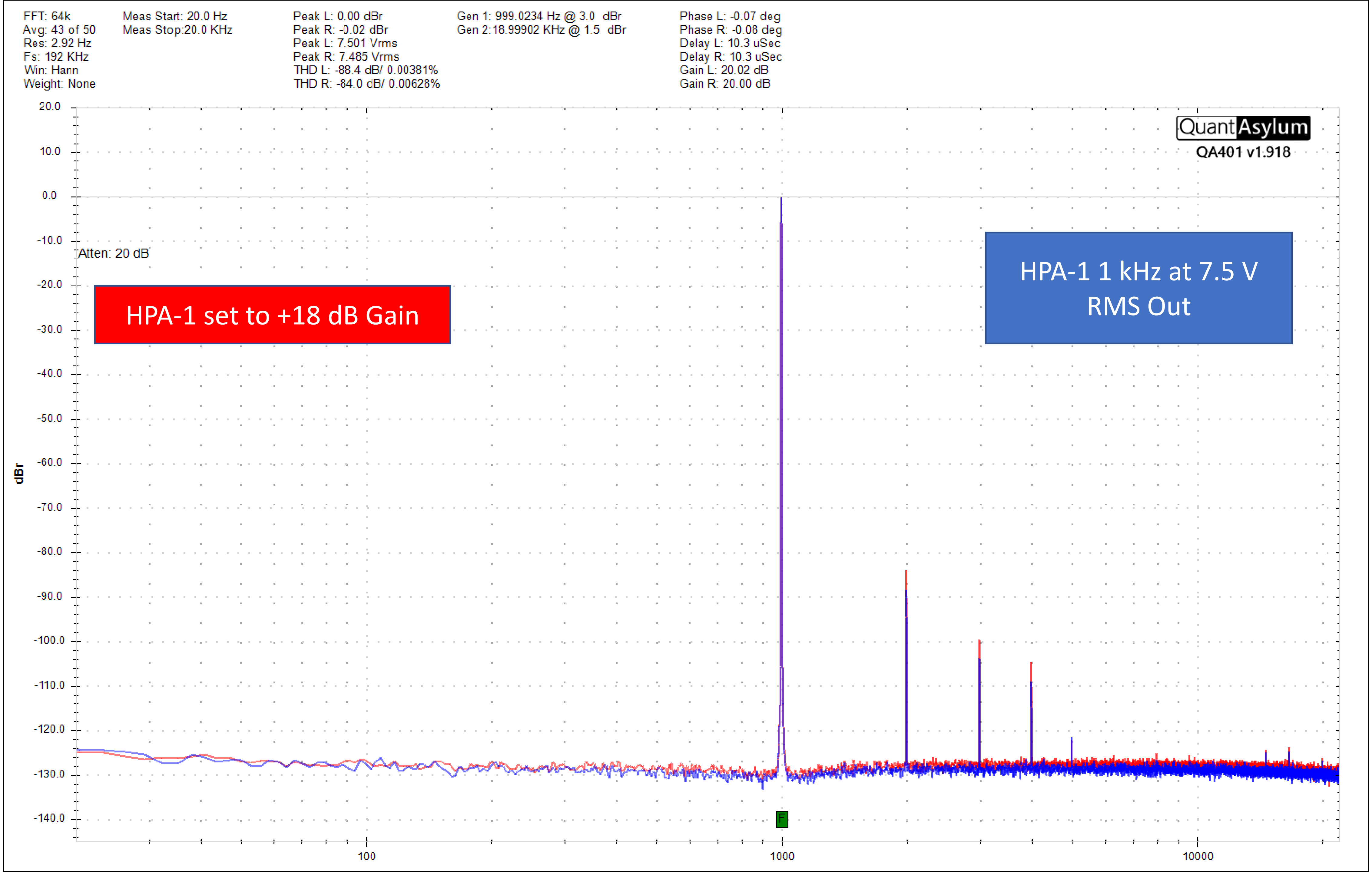
X-Altra HPA-1 Measurements

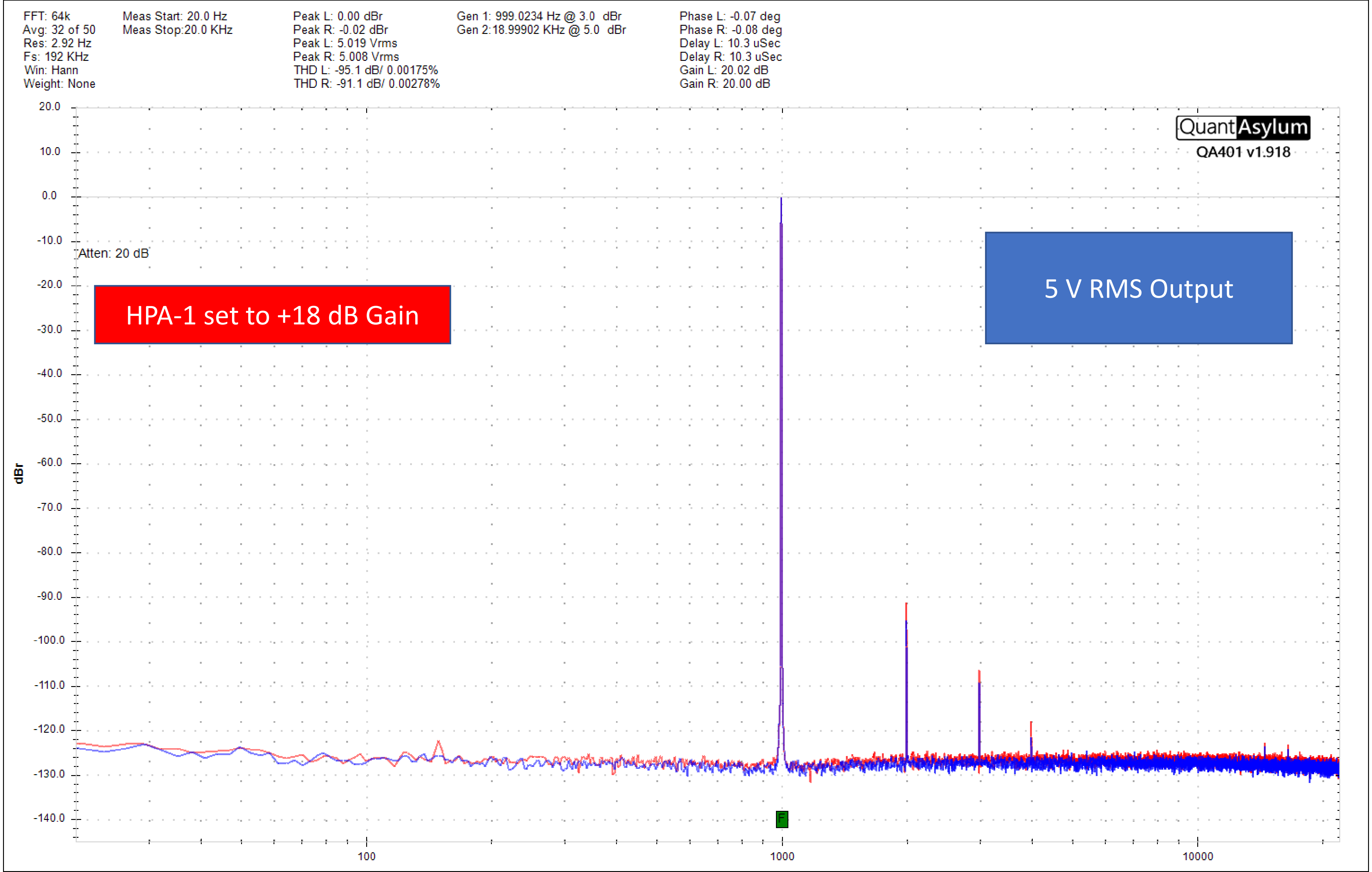
- All measurements were taken using a Quant Asylum QA401 with a 33 Ω resistive load on both channels.
- The standard gain of the HPA-1 is 10dB. Because the amplifier distortion is well below the QA401 (simulated at 400 parts per billion), a first set of tests was done with the HPA-1 first stage gain set to 7.84x (~18 dB).
- This ensured that the QA401 output was around 1 V RMS for >7 V RMS out from the headphone amplifier, therefore minimizing the distortion contribution from the analyser and enabling the HPA-1's true performance to be better gauged.
- A second set of measurements was then done with the standard gain of 10 dB
- The unit was powered by a 25W +-15 V linear PSU for all the tests

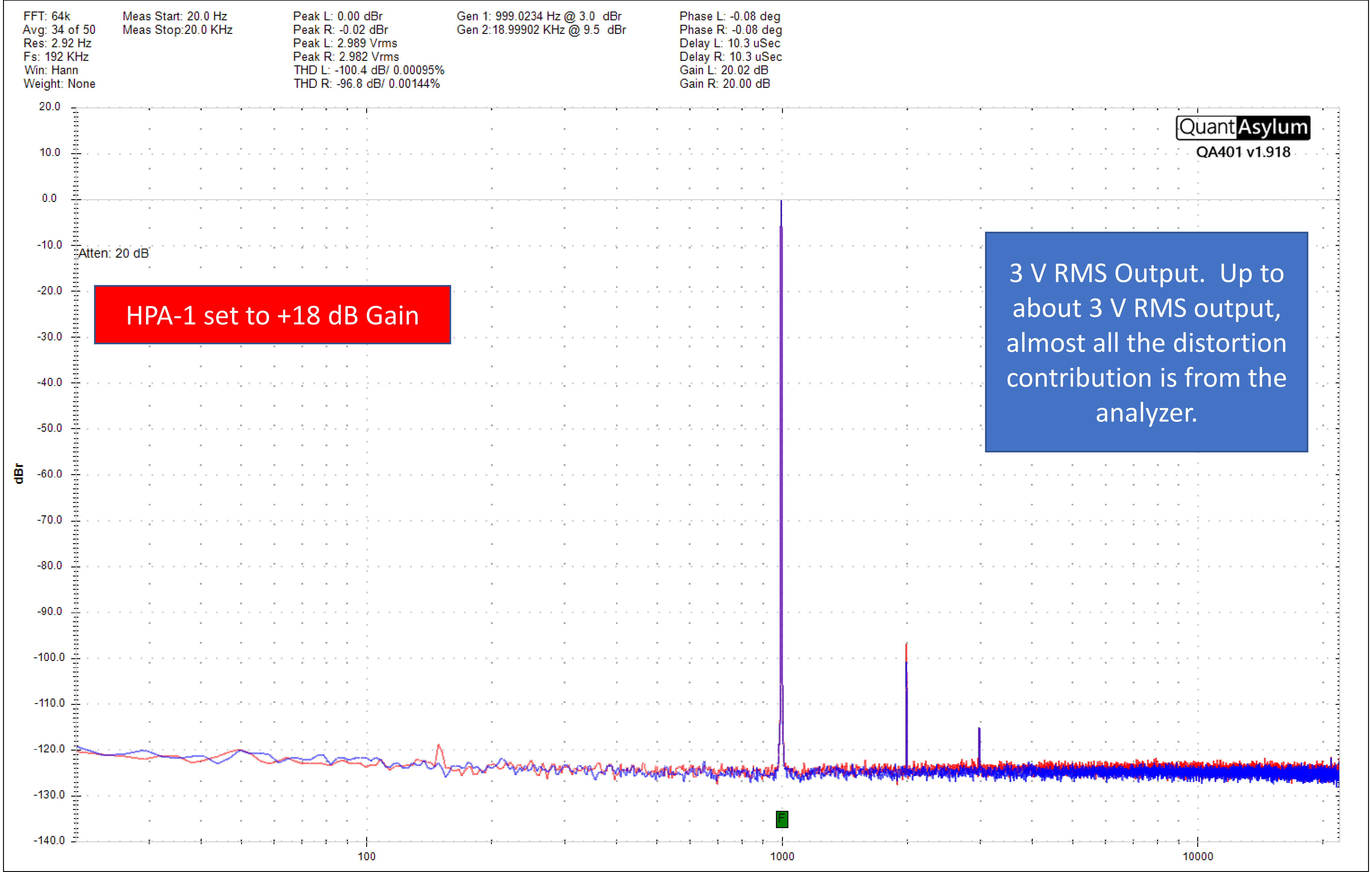
Andrew C. Russell

March 16/17 2021

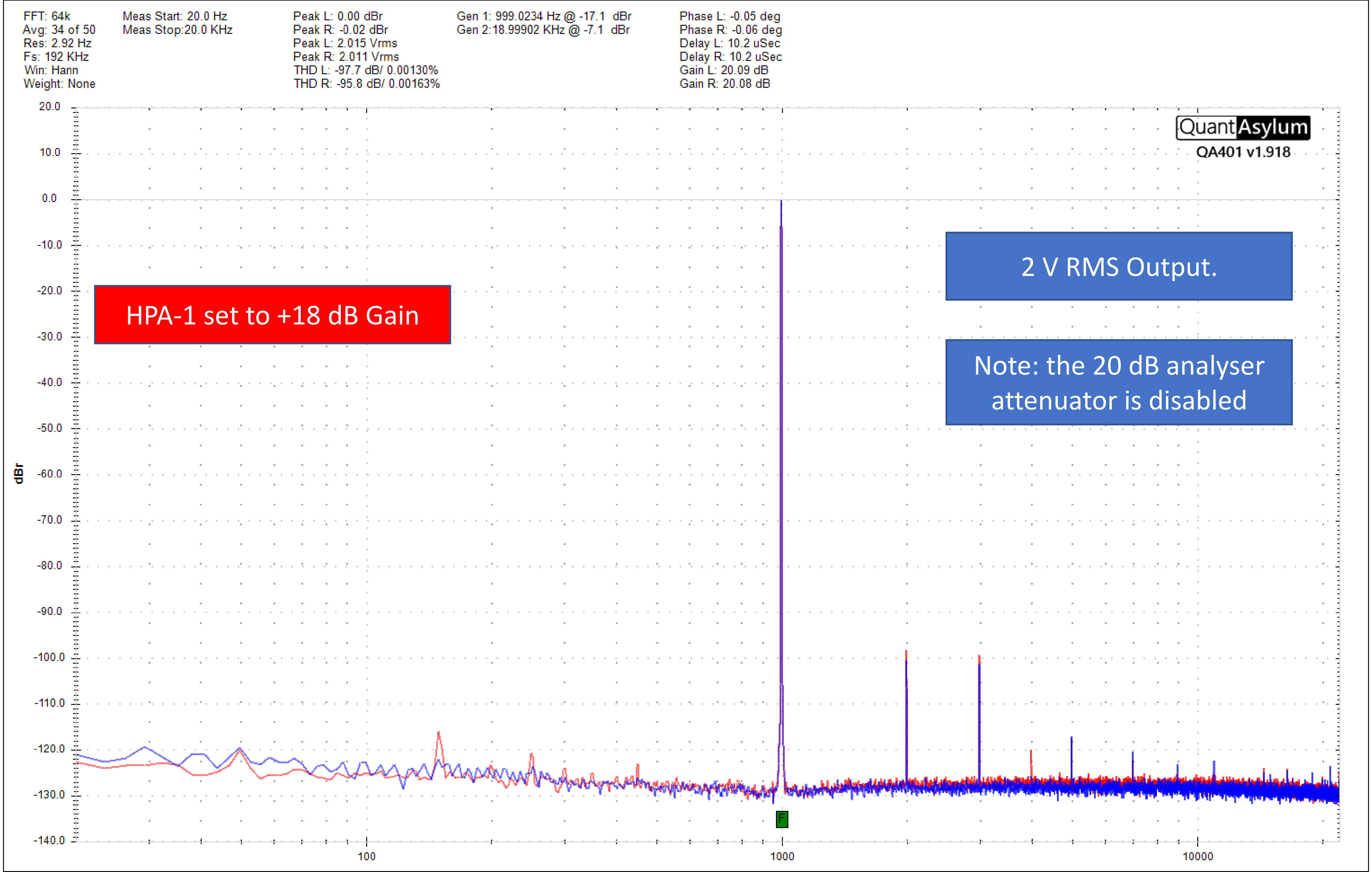

FFT: 64k
Avg: 26 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: 0.01 dBr
Peak L: 1.057 Vrms
Peak R: 1.058 Vrms
THD L: -101.0 dB/ 0.00090%
THD R: -101.8 dB/ 0.00081%
Gen 1: 999.0234 Hz @ 0.0 dBr
Gen 2:18.99902 KHz @ -1.5 dBr
Phase L: -0.01 deg
Phase R: -0.01 deg
Delay L: 10.1 uSec
Delay R: 10.1 uSec
Gain L: 2.99 dB
Gain R: 3.01 dB
QuantAsylum
QA401 v1.918
QA401 loop back test at for 1V RMS output. The analyser distortion is < 10 ppm
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
F
100
1000
10000

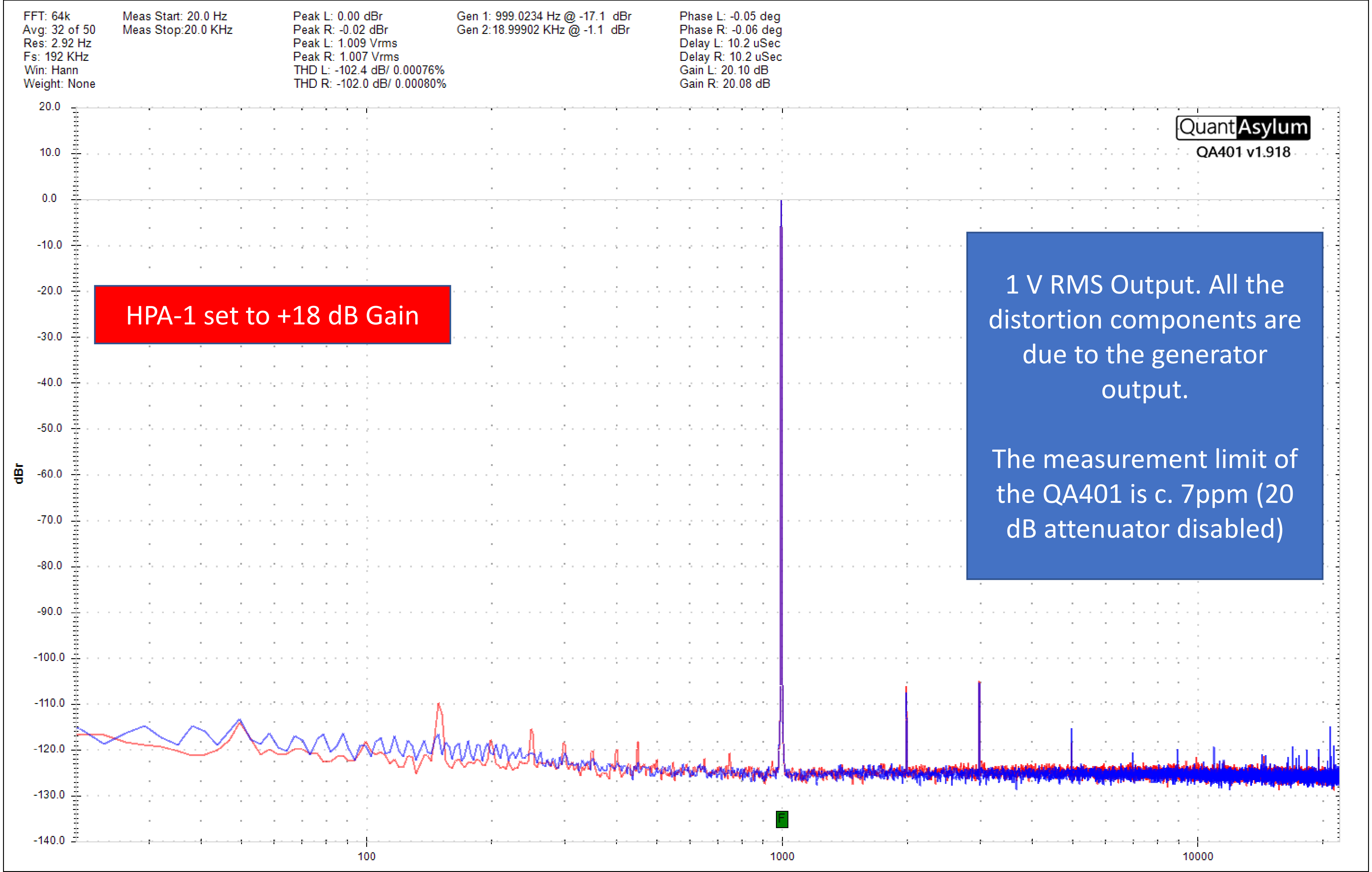

FFT: 64k
Avg: 43 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop: 20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 7.501 Vrms
Peak R: 7.485 Vrms
THD L: -88.4 dB/ 0.00381%
THD R: -84.0 dB/ 0.00628%
Gen 1: 999.0234 Hz @ 3.0 dBr
Gen 2: 18.99902 KHz @ 1.5 dBr
Phase L: -0.07 deg
Phase R: -0.08 deg
Delay L: 10.3 uSec
Delay R: 10.3 uSec
Gain L: 20.02 dB
Gain R: 20.00 dB
QuantAsylum
QA401 v1.918
Atten: 20 dB
HPA-1 set to +18 dB Gain
HPA-1 1 kHz at 7.5 V RMS Out
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F


FFT: 64k
Avg: 32 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 5.019 Vrms
Peak R: 5.008 Vrms
THD L: -95.1 dB/ 0.00175%
THD R: -91.1 dB/ 0.00278%
Gen 1: 999.0234 Hz @ 3.0 dBr
Gen 2:18.99902 KHz @ 5.0 dBr
Phase L: -0.07 deg
Phase R: -0.08 deg
Delay L: 10.3 uSec
Delay R: 10.3 uSec
Gain L: 20.02 dB
Gain R: 20.00 dB
QuantAsylum
QA401 v1.918
Atten: 20 dB
HPA-1 set to +18 dB Gain
5 V RMS Output
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F

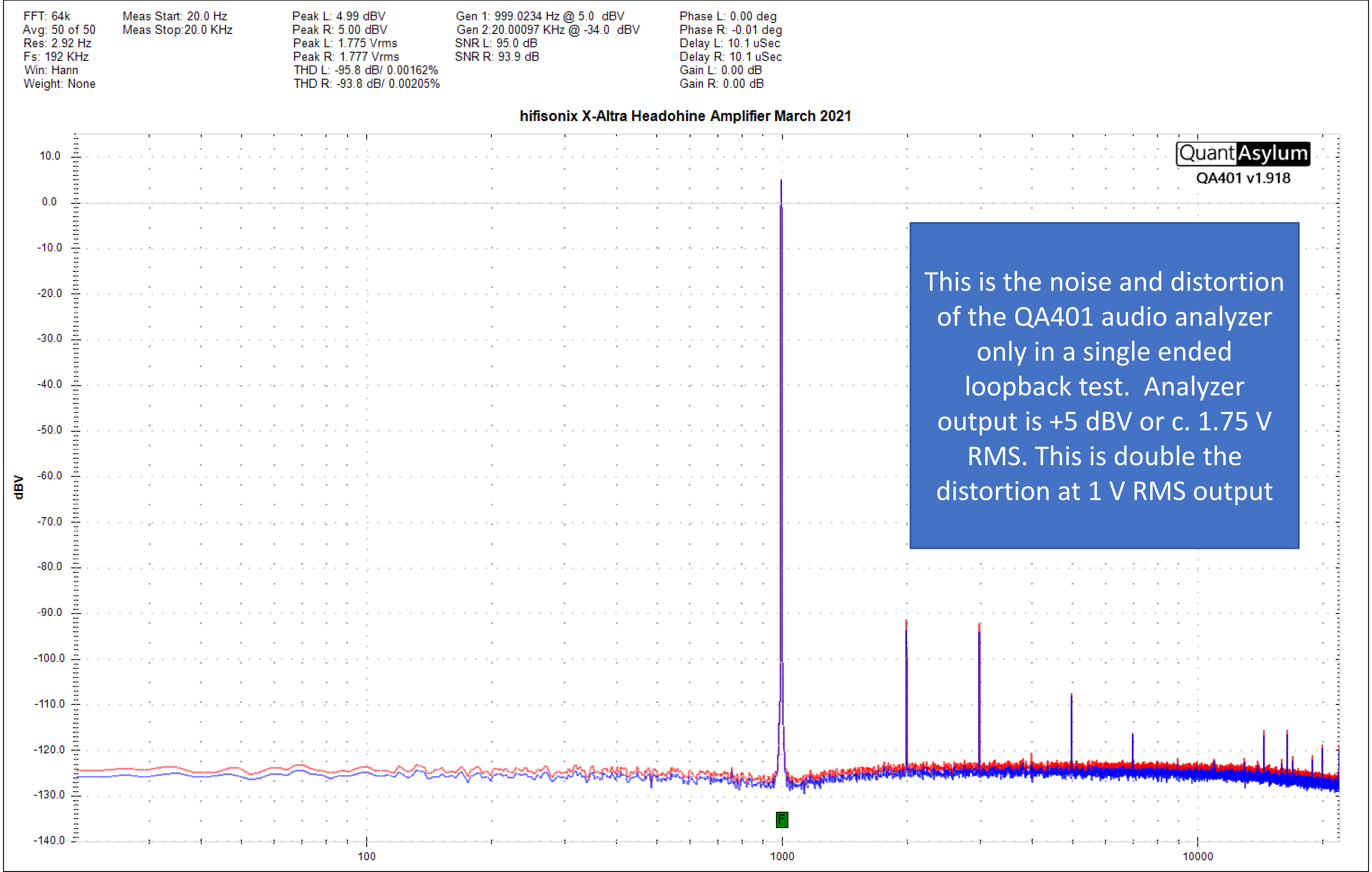


FFT: 64k
Avg: 34 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 2.989 Vrms
Peak R: 2.982 Vrms
THD L: -100.4 dB/ 0.00095%
THD R: -96.8 dB/ 0.00144%
Gen 1: 999.0234 Hz @ 3.0 dBr
Gen 2:18.99902 KHz @ 9.5 dBr
Phase L: -0.08 deg
Phase R: -0.08 deg
Delay L: 10.3 uSec
Delay R: 10.3 uSec
Gain L: 20.02 dB
Gain R: 20.00 dB
QuantAsylum
QA401 v1.918
Atten: 20 dB
HPA-1 set to +18 dB Gain
3 V RMS Output. Up to about 3 V RMS output, almost all the distortion contribution is from the analyzer.
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F


FFT: 64k
Avg: 34 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 2.015 Vrms
Peak R: 2.011 Vrms
THD L: -97.7 dB/ 0.00130%
THD R: -95.8 dB/ 0.00163%
Gen 1: 999.0234 Hz @ -17.1 dBr
Gen 2:18.99902 KHz @ -7.1 dBr
Phase L: -0.05 deg
Phase R: -0.06 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 20.09 dB
Gain R: 20.08 dB
QuantAsylum
QA401 v1.918
HPA-1 set to +18 dB Gain
2 V RMS Output.
Note: the 20 dB analyser attenuator is disabled
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F



FFT: 64k
Avg: 32 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 1.009 Vrms
Peak R: 1.007 Vrms
THD L: -102.4 dB/ 0.00076%
THD R: -102.0 dB/ 0.00080%
Gen 1: 999.0234 Hz @ -17.1 dBr
Gen 2:18.99902 KHz @ -1.1 dBr
Phase L: -0.05 deg
Phase R: -0.06 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 20.10 dB
Gain R: 20.08 dB
QuantAsylum
QA401 v1.918
HPA-1 set to +18 dB Gain
1 V RMS Output. All the distortion components are due to the generator output.
The measurement limit of the QA401 is c. 7ppm (20 dB attenuator disabled)
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F


FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 4.99 dBV
Peak R: 5.00 dBV
Peak L: 1.775 Vrms
Peak R: 1.777 Vrms
THD L: -95.8 dB/ 0.00162%
THD R: -93.8 dB/ 0.00205%
Gen 1: 999.0234 Hz @ 5.0 dBV
Gen 2:20.00097 KHz @ -34.0 dBV
SNR L: 95.0 dB
SNR R: 93.9 dB
Phase L: 0.00 deg
Phase R: -0.01 deg
Delay L: 10.1 uSec
Delay R: 10.1 uSec
Gain L: 0.00 dB
Gain R: 0.00 dB
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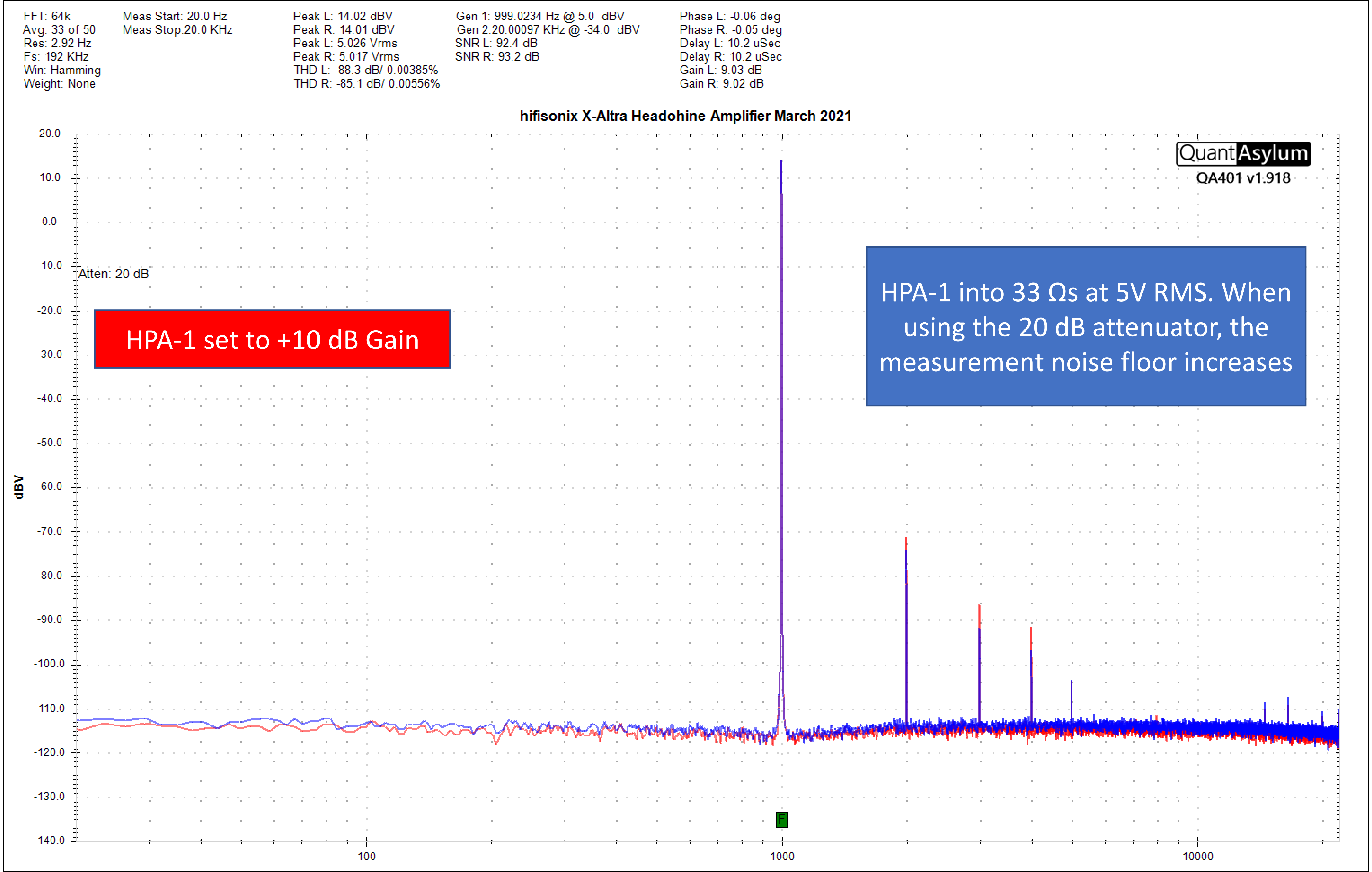
QuantAsylum
QA401 v1.918
dBV
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F
This is the noise and distortion of the QA401 audio analyzer only in a single ended loopback test. Analyzer output is +5 dBV or c. 1.75 V RMS. This is double the distortion at 1 V RMS output


FFT: 64k
Avg: 33 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 14.02 dBV
Peak R: 14.01 dBV
Peak L: 5.026 Vrms
Peak R: 5.017 Vrms
THD L: -88.3 dB/ 0.00385%
THD R: -85.1 dB/ 0.00556%
Gen 1: 999.0234 Hz @ 5.0 dBV
Gen 2:20.00097 KHz @ -34.0 dBV
SNR L: 92.4 dB
SNR R: 93.2 dB
Phase L: -0.06 deg
Phase R: -0.05 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 9.03 dB
Gain R: 9.02 dB
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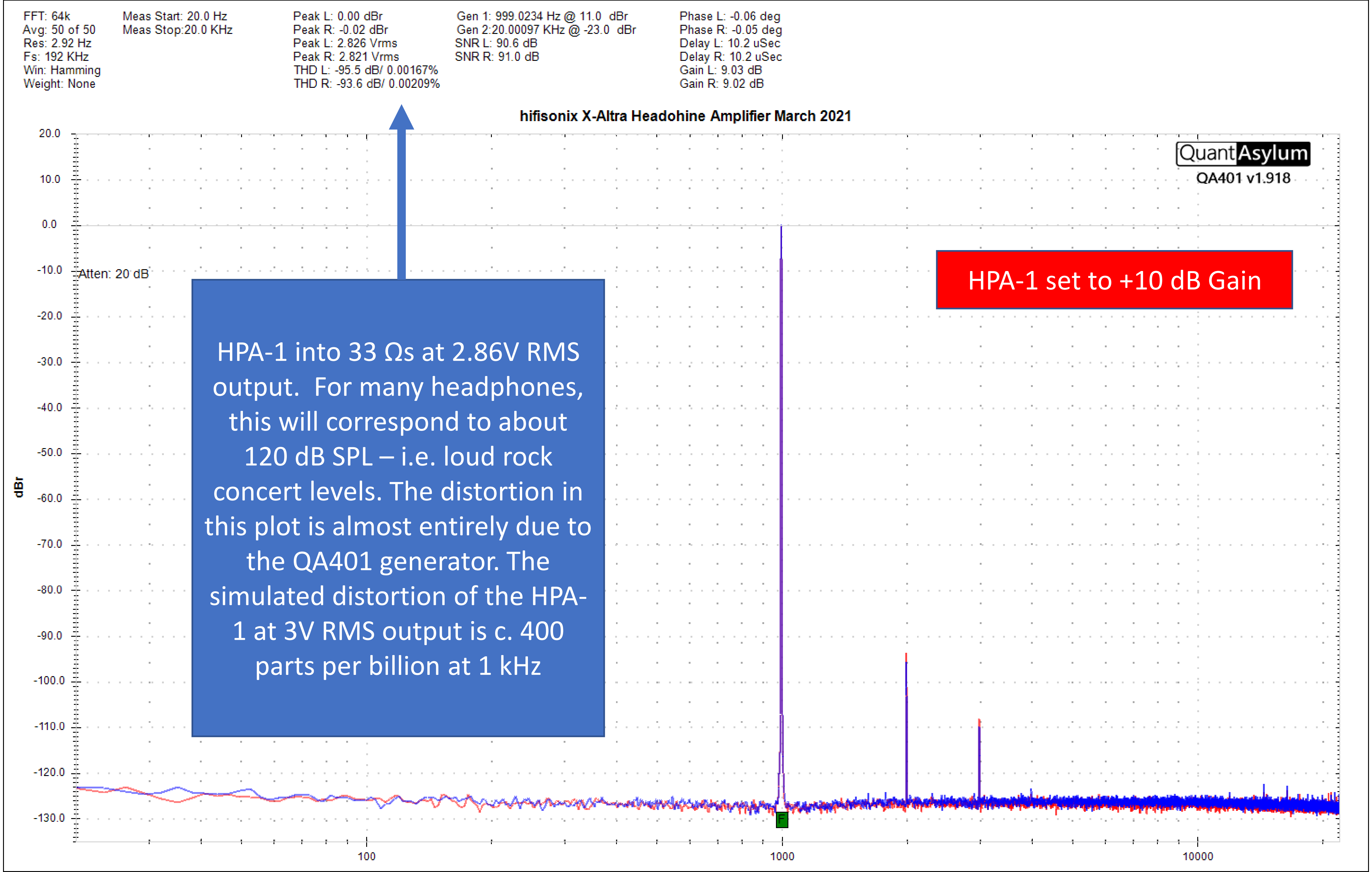
QuantAsylum
QA401 v1.918
Atten: 20 dB
HPA-1 set to +10 dB Gain
HPA-1 into 33 Ωs at 5V RMS. When using the 20 dB attenuator, the measurement noise floor increases
dBV
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F


FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 2.826 Vrms
Peak R: 2.821 Vrms
THD L: -95.5 dB/ 0.00167%
THD R: -93.6 dB/ 0.00209%
Gen 1: 999.0234 Hz @ 11.0 dBr
Gen 2:20.00097 KHz @ -23.0 dBr
SNR L: 90.6 dB
SNR R: 91.0 dB
Phase L: -0.06 deg
Phase R: -0.05 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 9.03 dB
Gain R: 9.02 dB
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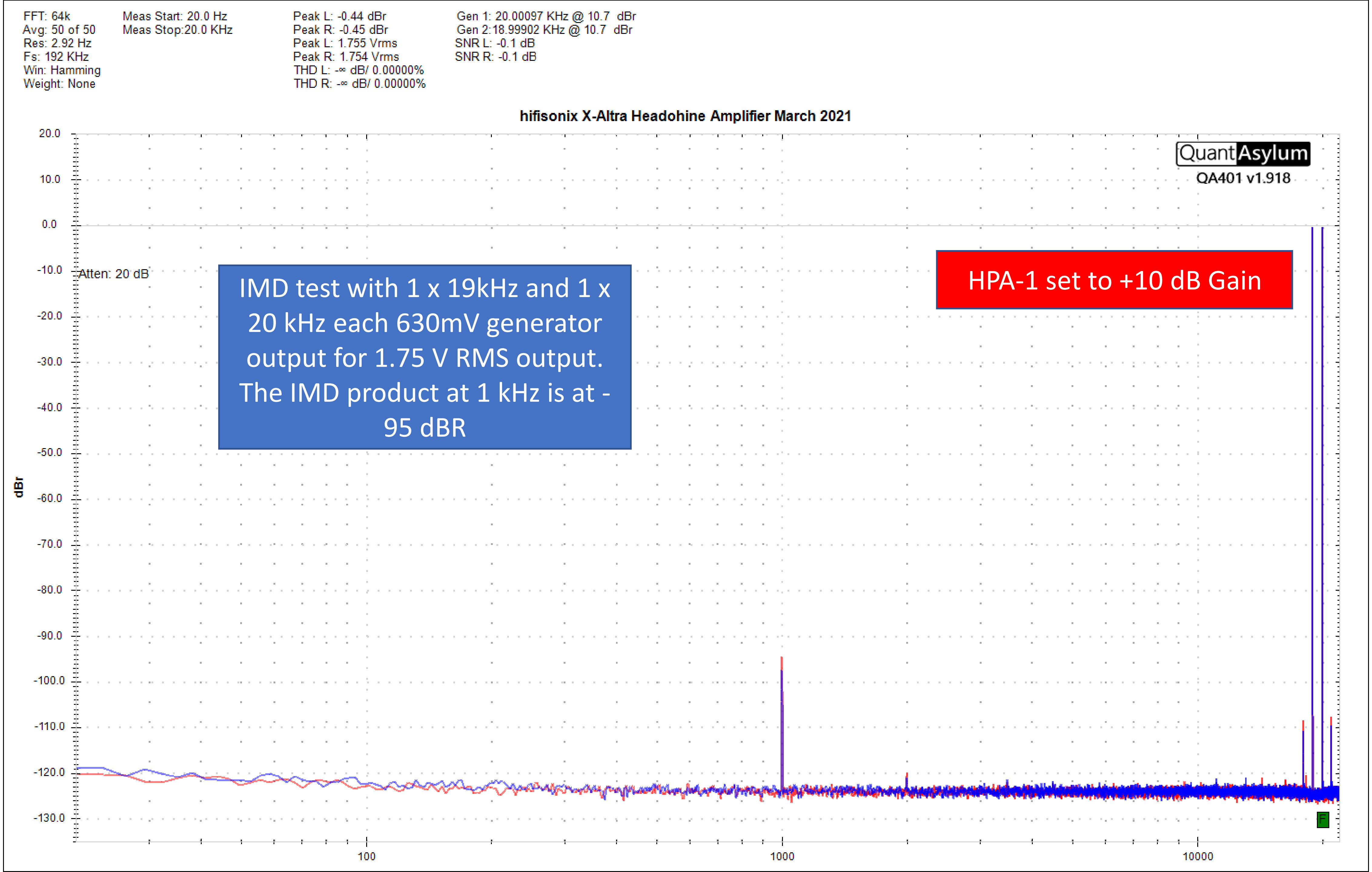
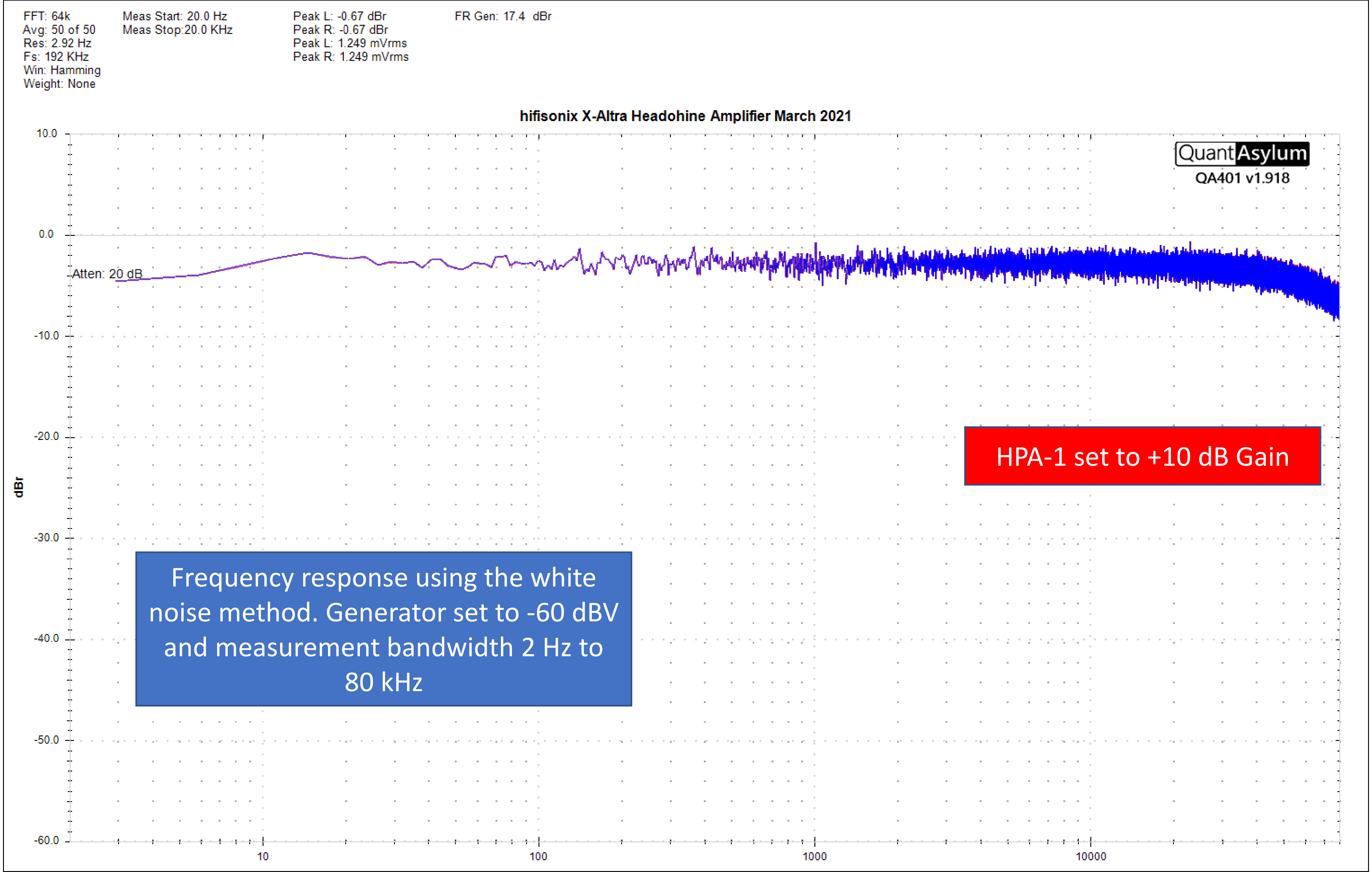
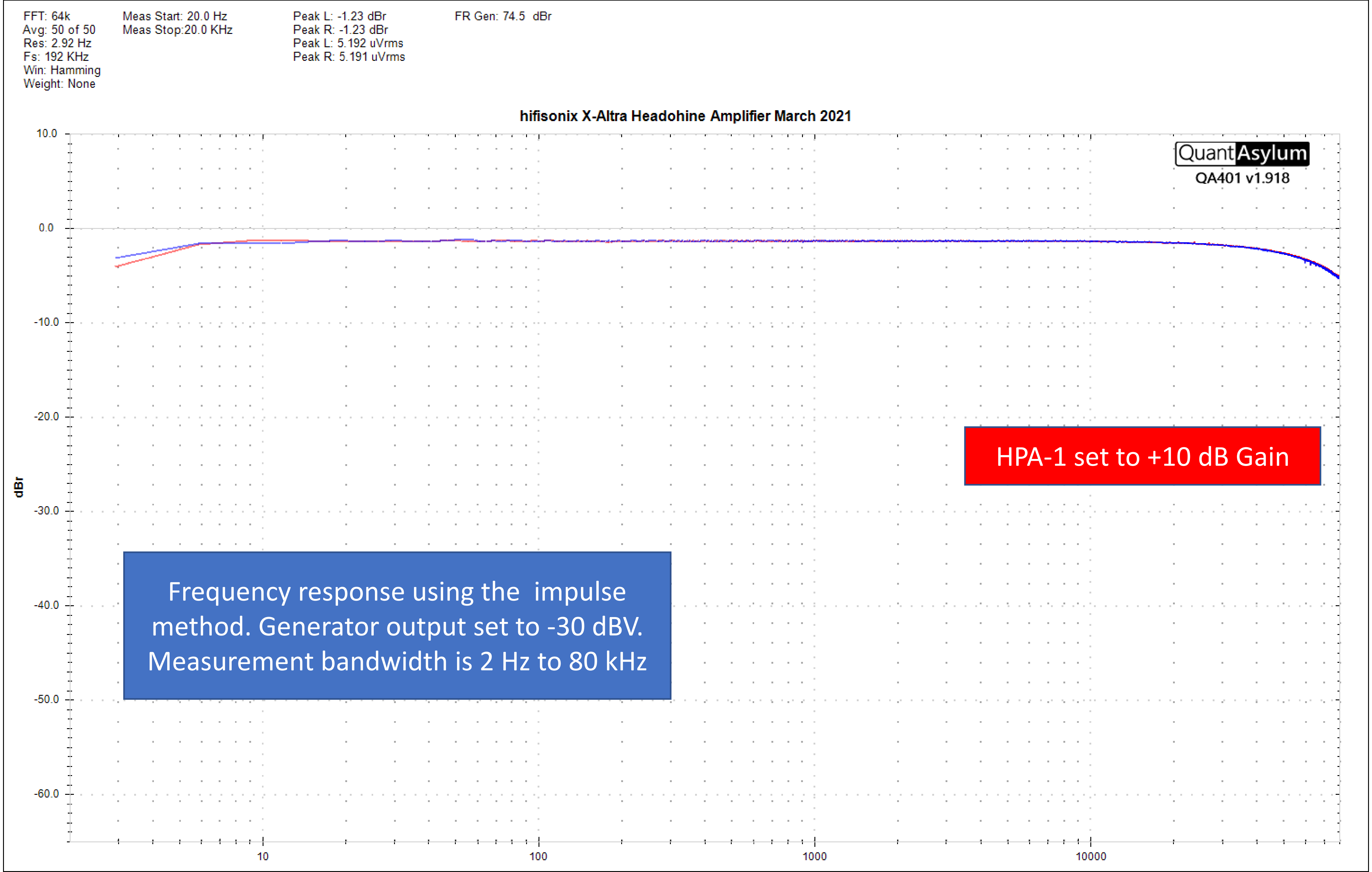
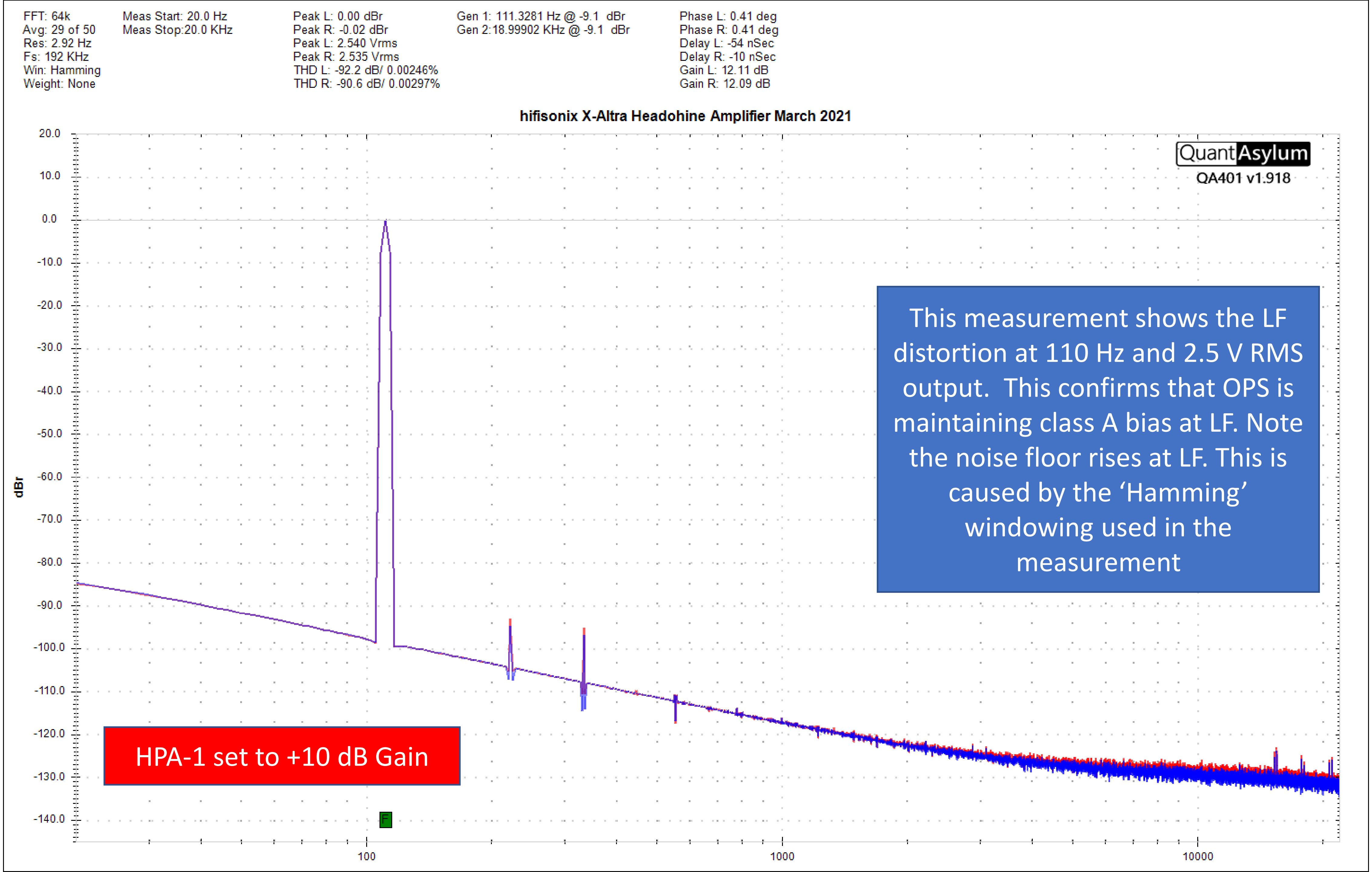
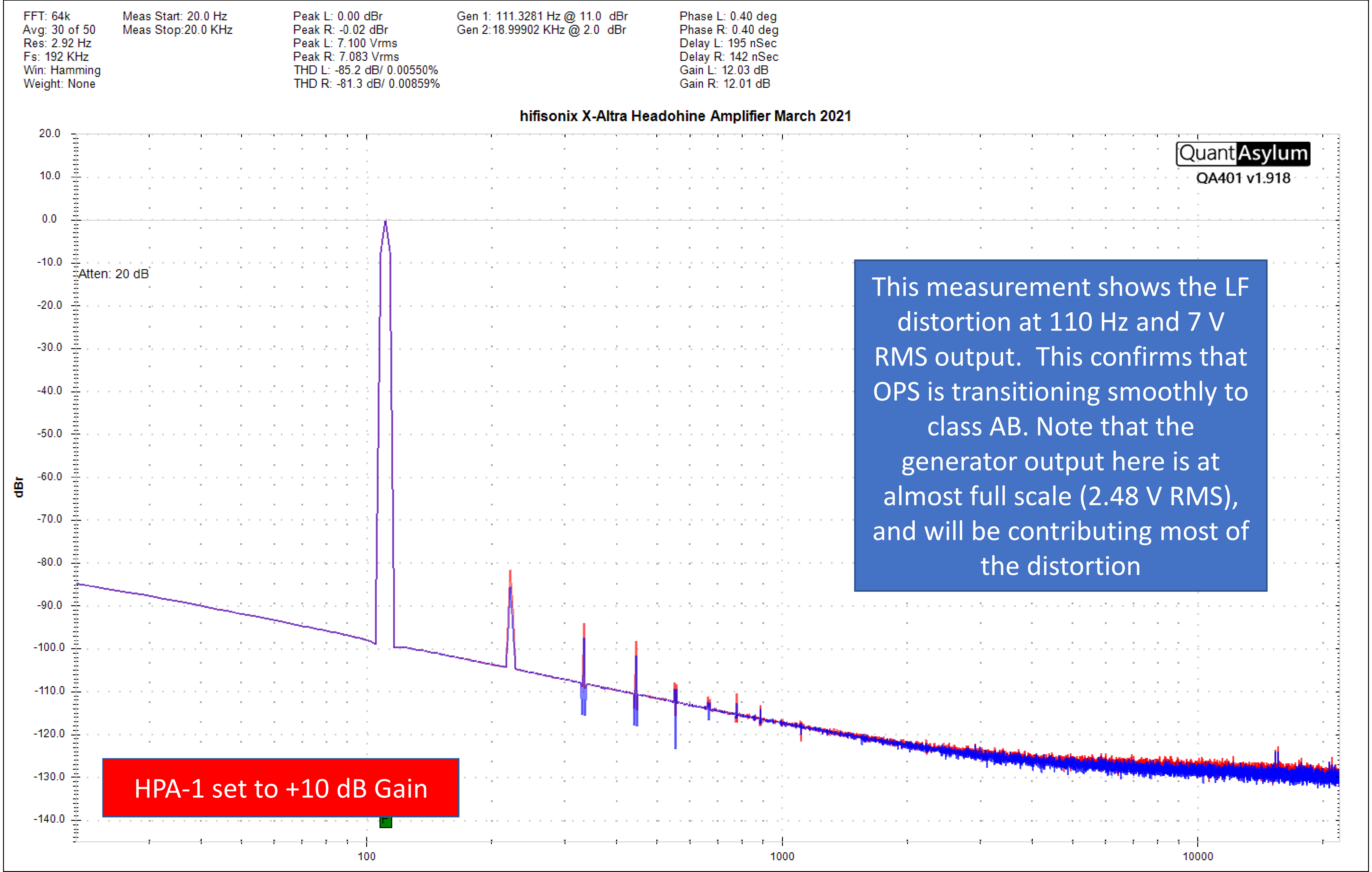
QuantAsylum
QA401 v1.918
Atten: 20 dB
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
100
1000
10000
HPA-1 set to +10 dB Gain
HPA-1 into 33 Ωs at 2.86V RMS output. For many headphones, this will correspond to about 120 dB SPL – i.e. loud rock concert levels. The distortion in this plot is almost entirely due to the QA401 generator. The simulated distortion of the HPA-1 at 3V RMS output is c. 400 parts per billion at 1 kHz

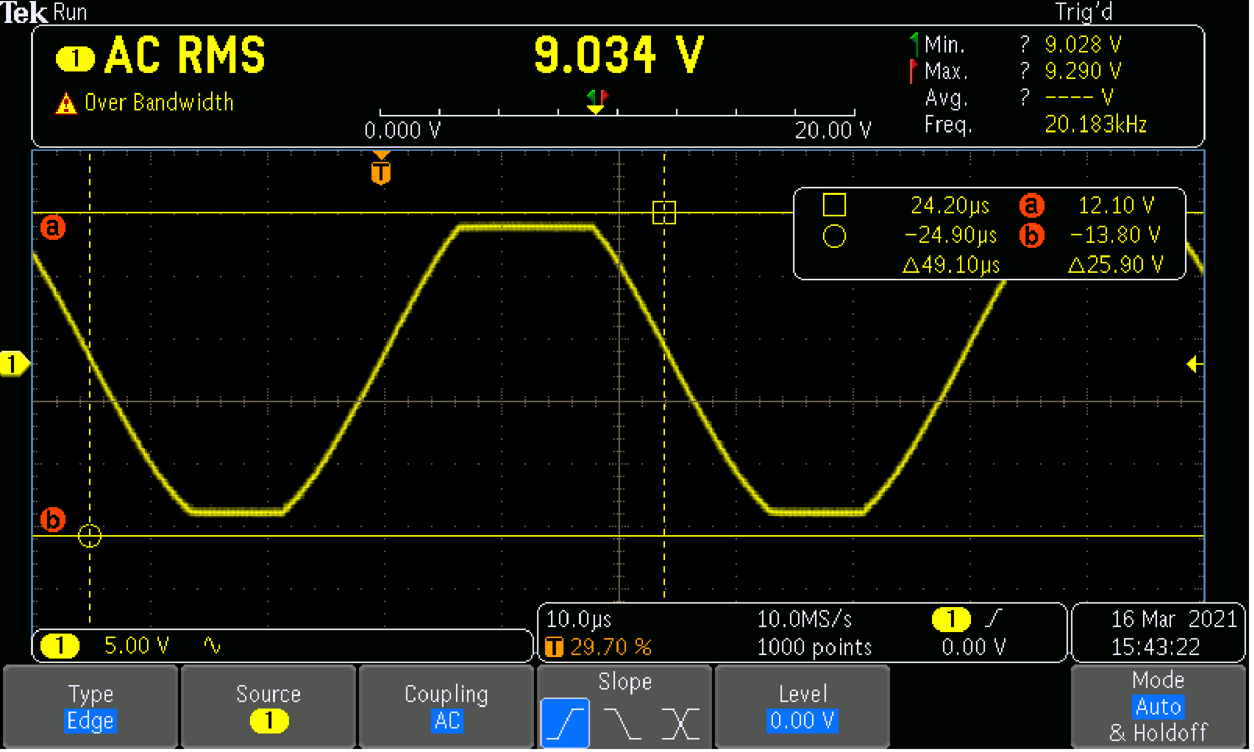

FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.44 dBr
Peak R: -0.45 dBr
Peak L: 1.755 Vrms
Peak R: 1.754 Vrms
THD L: -∞ dB/ 0.00000%
THD R: -∞ dB/ 0.00000%
Gen 1: 20.00097 KHz @ 10.7 dBr
Gen 2:18.99902 KHz @ 10.7 dBr
SNR L: -0.1 dB
SNR R: -0.1 dB
hifisonix X-Altra Headohine Amplifier March 2021
QuantAsylum
QA401 v1.918
Atten: 20 dB
IMD test with 1 x 19kHz and 1 x 20 kHz each 630mV generator output for 1.75 V RMS output. The IMD product at 1 kHz is at -95 dBR
HPA-1 set to +10 dB Gain
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
100
1000
10000
F

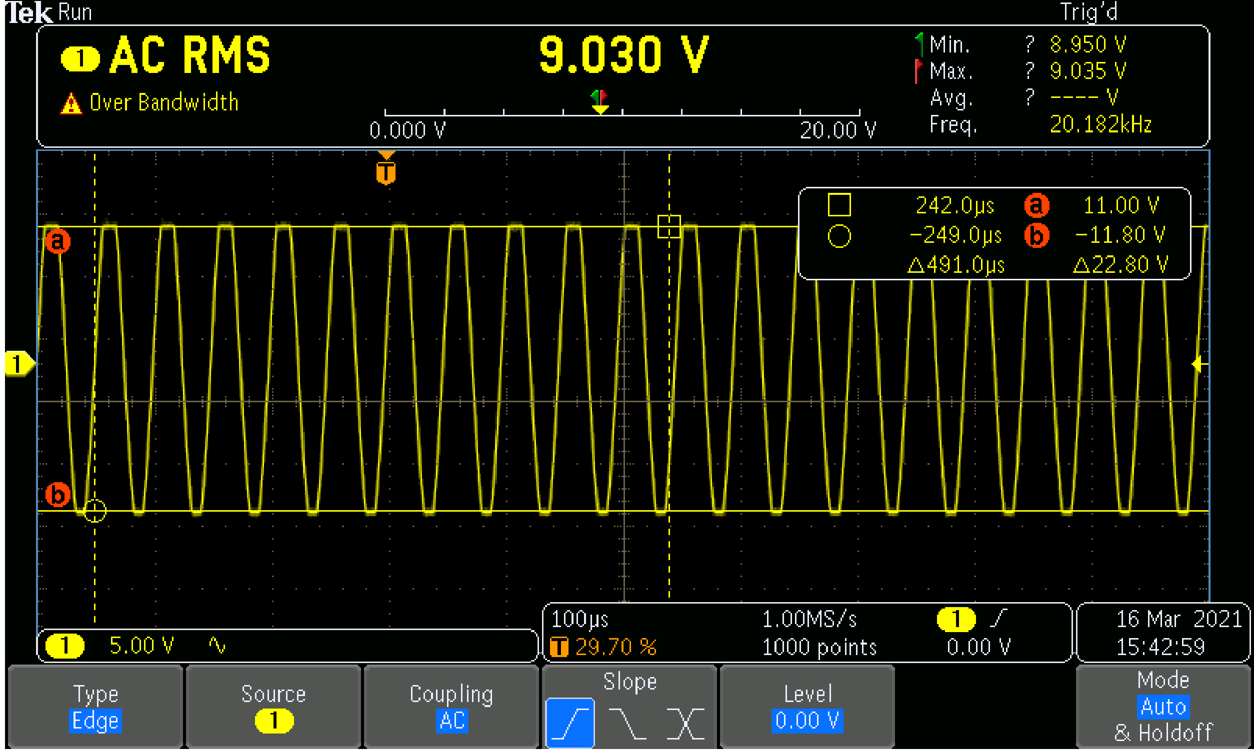

FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -0.67 dBr
Peak R: -0.67 dBr
Peak L: 1.249 mVrms
Peak R: 1.249 mVrms
FR Gen: 17.4 dBr
hifisonix X-Altra Headohine Amplifier March 2021
QuantAsylum
QA401 v1.918
Atten: 20 dB
dBr
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
10
100
1000
10000
HPA-1 set to +10 dB Gain
Frequency response using the white noise method. Generator set to -60 dBV and measurement bandwidth 2 Hz to 80 kHz


FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: -1.23 dBr
Peak R: -1.23 dBr
Peak L: 5.192 uVrms
Peak R: 5.191 uVrms
FR Gen: 74.5 dBr
hifisonix X-Altra Headohine Amplifier March 2021
QuantAsylum
QA401 v1.918
dBr
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
10
100
1000
10000
HPA-1 set to +10 dB Gain
Frequency response using the impulse method. Generator output set to -30 dBV. Measurement bandwidth is 2 Hz to 80 kHz

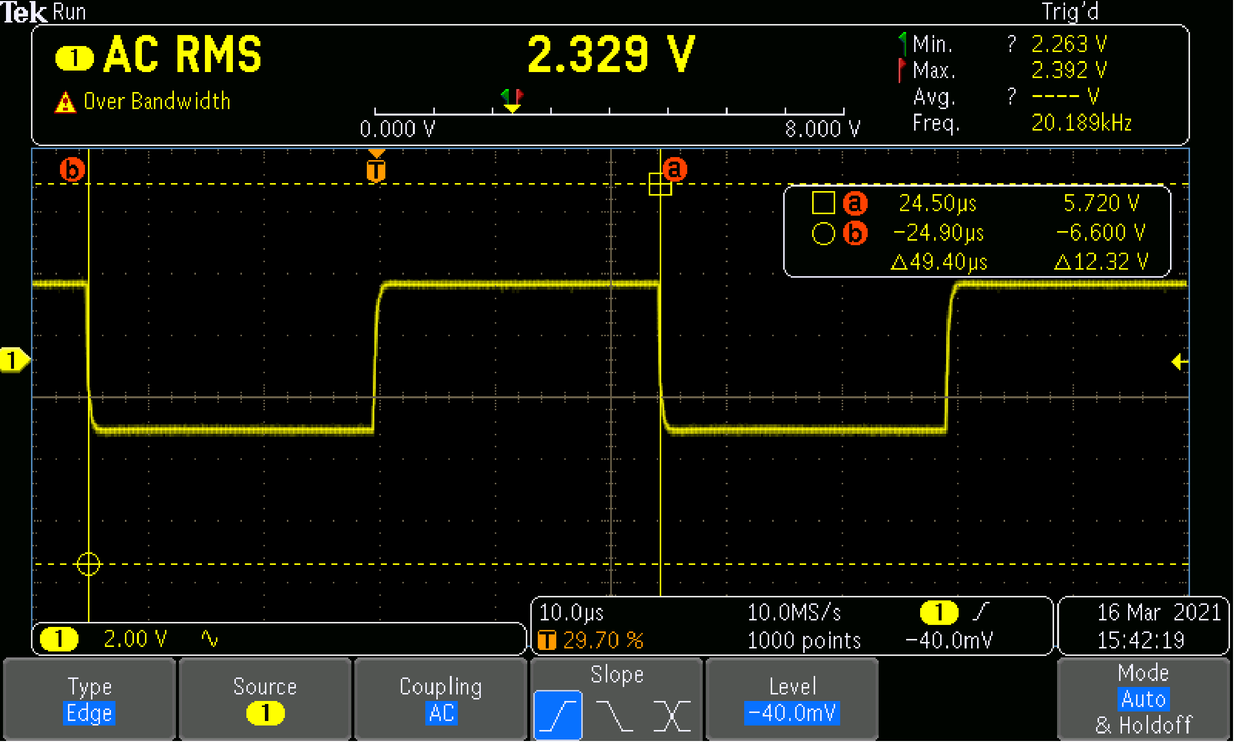

FFT: 64k
Avg: 29 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 2.540 Vrms
Peak R: 2.535 Vrms
THD L: -92.2 dB/ 0.00246%
THD R: -90.6 dB/ 0.00297%
Gen 1: 111.3281 Hz @ -9.1 dBr
Gen 2:18.99902 KHz @ -9.1 dBr
Phase L: 0.41 deg
Phase R: 0.41 deg
Delay L: -54 nSec
Delay R: -10 nSec
Gain L: 12.11 dB
Gain R: 12.09 dB
hifisonix X-Altra Headohine Amplifier March 2021
QuantAsylum
QA401 v1.918
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F
This measurement shows the LF distortion at 110 Hz and 2.5 V RMS output. This confirms that OPS is maintaining class A bias at LF. Note the noise floor rises at LF. This is caused by the 'Hamming' windowing used in the measurement
HPA-1 set to +10 dB Gain

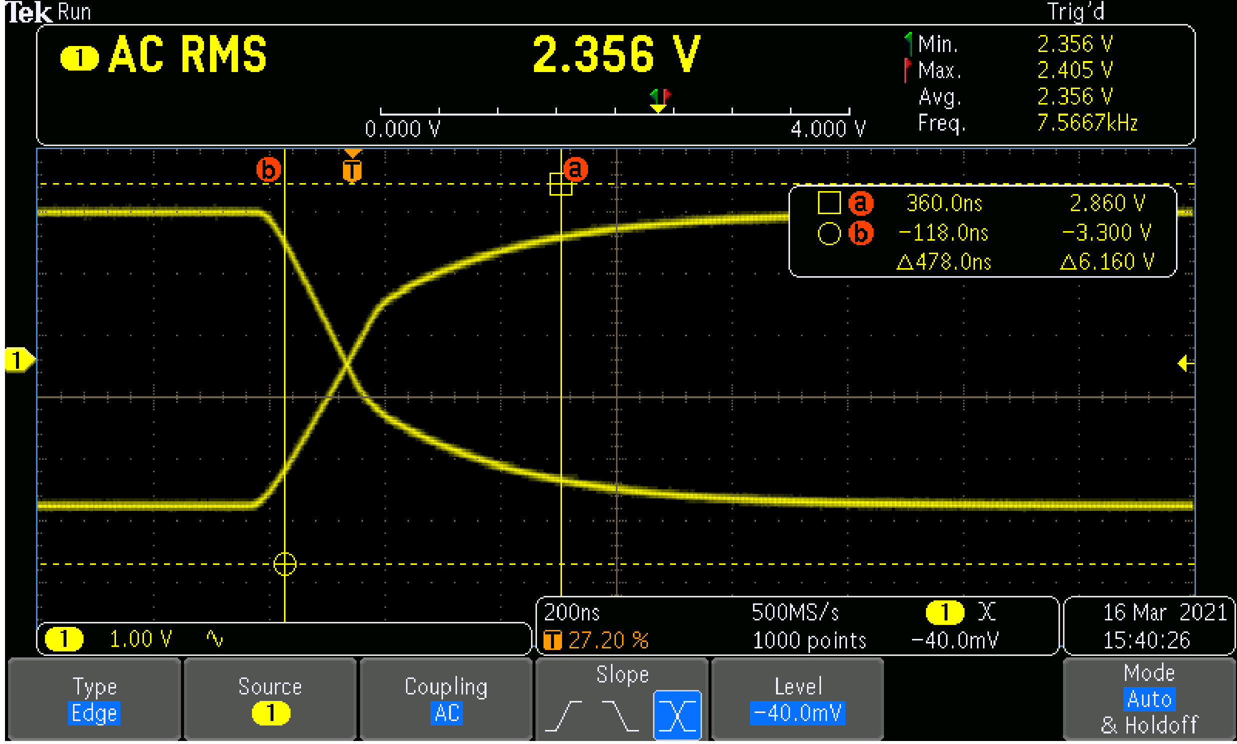

FFT: 64k
Avg: 30 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hamming
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 7.100 Vrms
Peak R: 7.083 Vrms
THD L: -85.2 dB/ 0.00550%
THD R: -81.3 dB/ 0.00859%
Gen 1: 111.3281 Hz @ 11.0 dBr
Gen 2:18.99902 KHz @ 2.0 dBr
Phase L: 0.40 deg
Phase R: 0.40 deg
Delay L: 195 nSec
Delay R: 142 nSec
Gain L: 12.03 dB
Gain R: 12.01 dB
hifisonix X-Altra Headohine Amplifier March 2021
QuantAsylum
QA401 v1.918
Atten: 20 dB
dBr
This measurement shows the LF distortion at 110 Hz and 7 V RMS output. This confirms that OPS is transitioning smoothly to class AB. Note that the generator output here is at almost full scale (2.48 V RMS), and will be contributing most of the distortion
HPA-1 set to +10 dB Gain
100
1000
10000





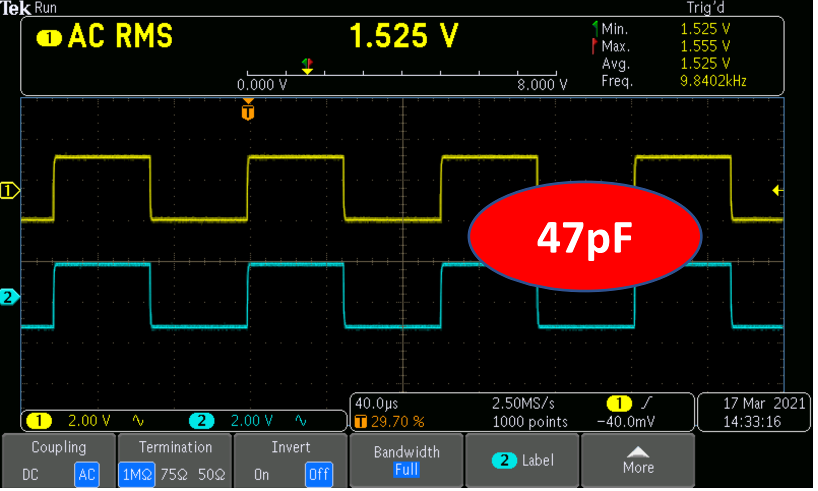
- Clipping is clean with no overhang (‘sticky rail’) or instability as the HPA-1 exits clipping.
- The positive full rail swing is slightly less than the negative swing due to the Class A biasing arrangement
- Clipping at c. 200 kHz remains clean

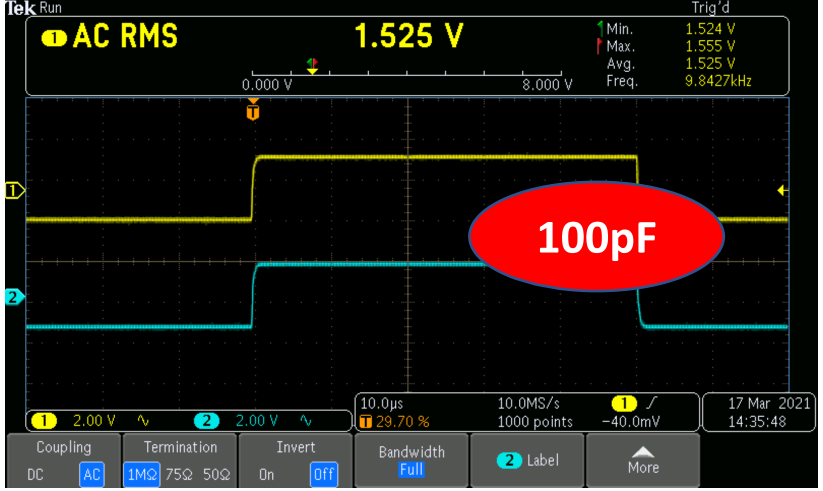


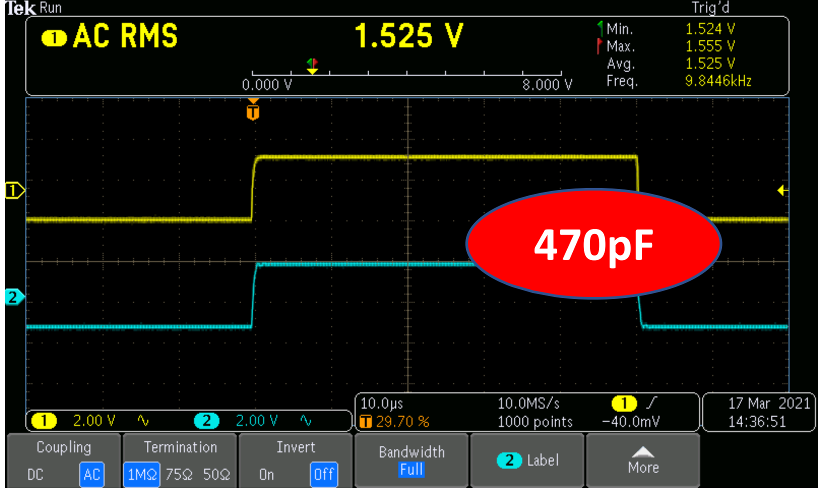


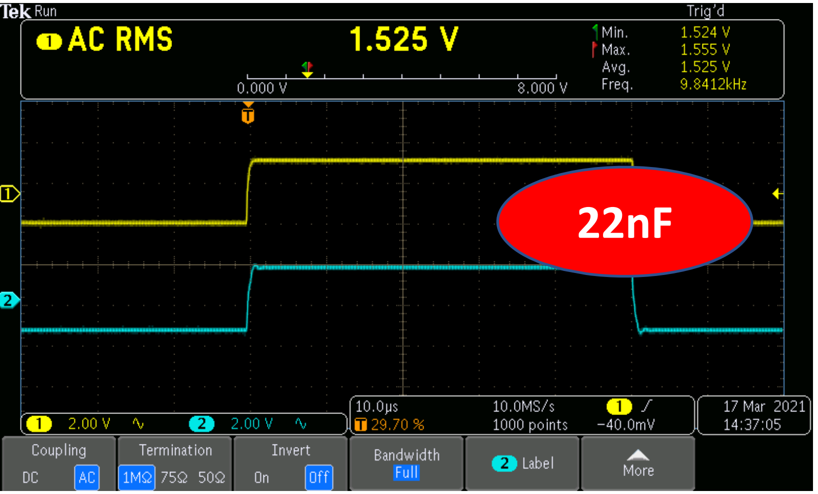
- Square wave response at 20 kHz is clean with no overshoot (note: this is into a purely resistive load)

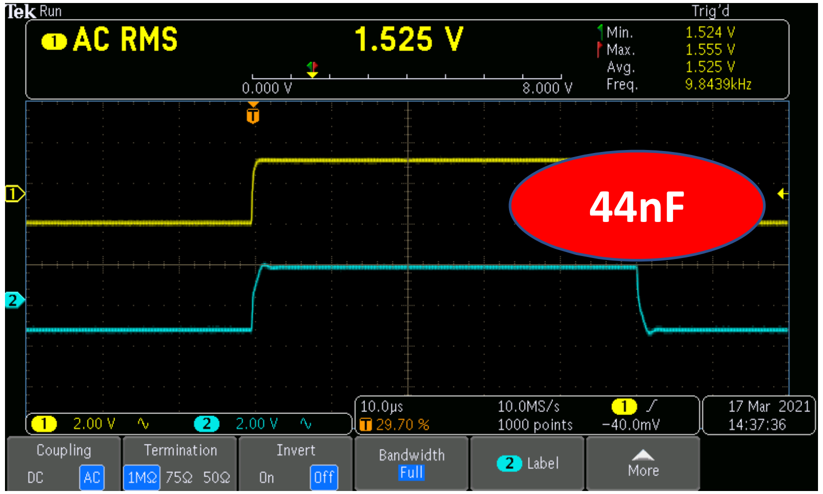
- Rise fall time is c. 500ns – the generator rise/fall time is about 50 ns

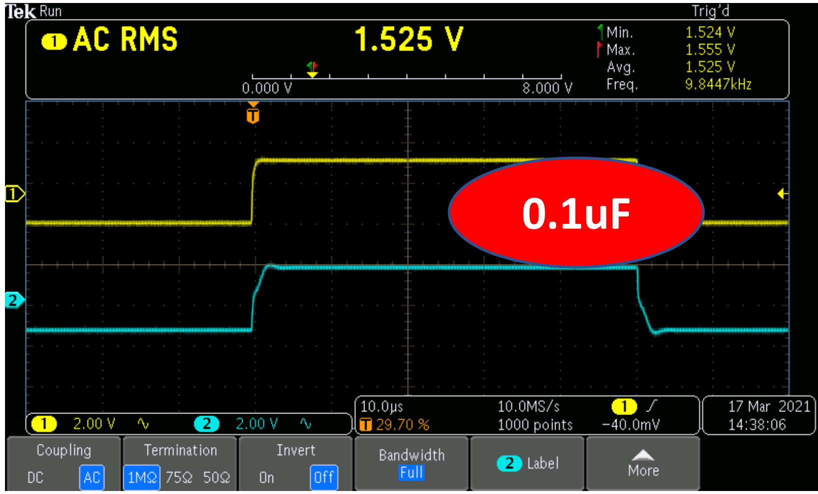






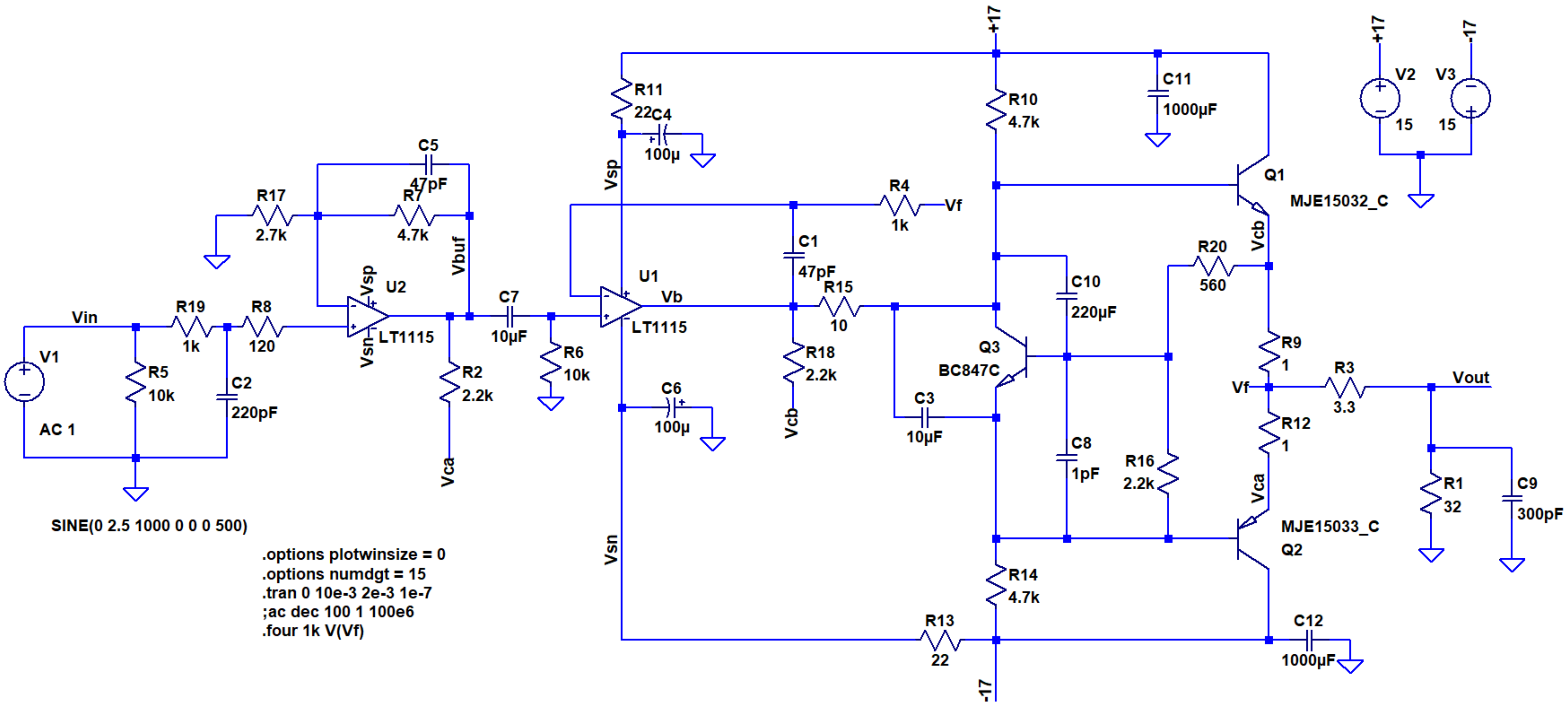


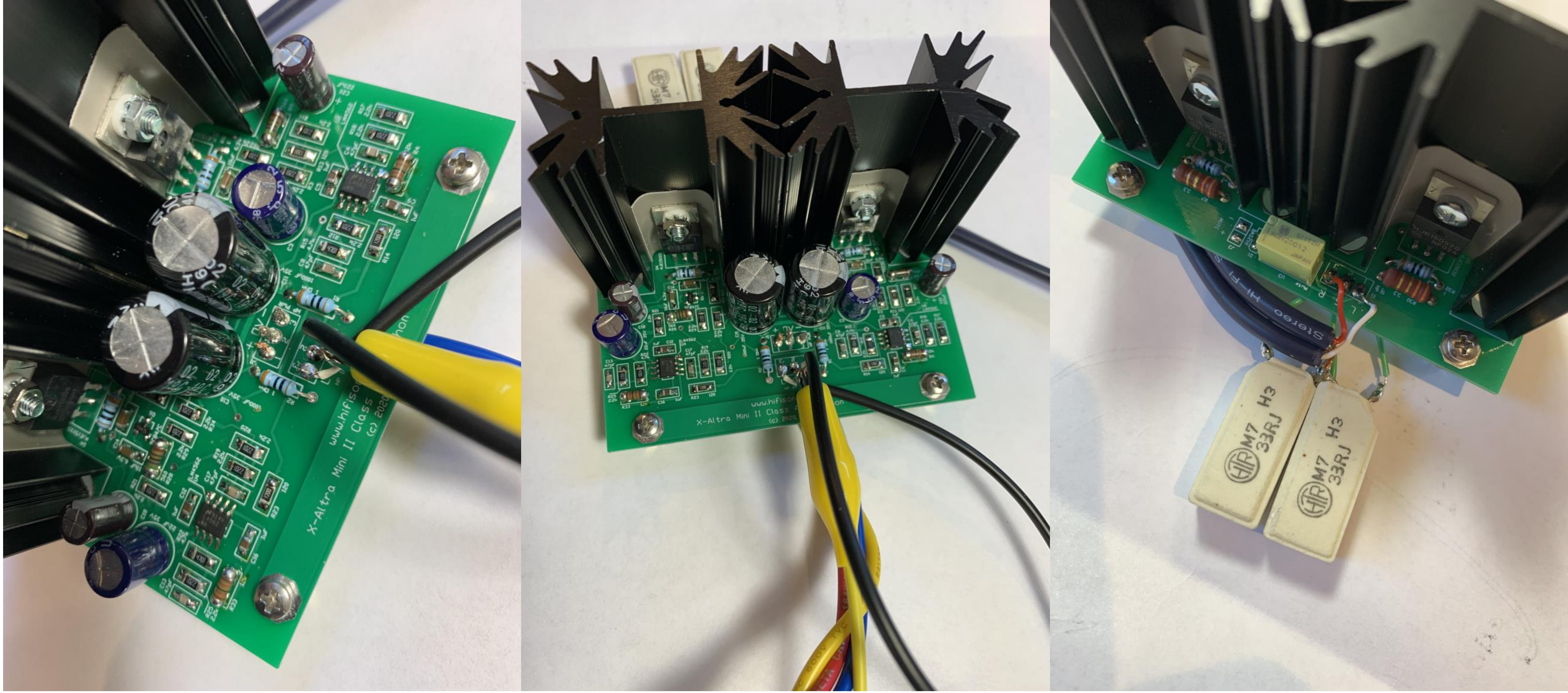




- The following capacitive load values in parallel with 32 Ω were tested without stability issues: 47pF, 100pF, 200pF, 470pF, 940pF, 10nF, 22nF, 44nF and 0.1uF.
- The scope shots above show the amplifier performance driving selected capacitive loads. The right channel does not have the capacitive load applied and acts as a visual reference. The HPA-1 is stable with any capacitive load up to the measured limit here of 0.1uF//32 Ωs.

LTspice Model used to develop HPA-1





Some pictures of the HPA-1 PCB taken during testing

HPA-1 Subjective listening tests

- I used an Ovation High Fidelity Model 1501 line level preamplifier, an OPPO BD103 BD player and Audio Technica ATH AD900 'Air' Headphones to do the subjective assessment.
- The HPA-1 headroom means that on most headphones, no matter how high the volume, the output remains clean and distortion free.
- The bass is particularly well articulated and attributable to the very high damping factor of over 3000 into 32 Ohm headphones. High damping factor and high current drive capability are especially important on large diaphragm open back headphones where the effective cone mass is high.
- Treble and mid-range are ultra clean with great definition and no hint of any sibilance.
- The HPA-1 will work well with any kind of music – rock, jazz and classical.

References and Further Reading

- https://blog.son-video.com/en/2016/08/understanding-the-impedance-and-sensitivity-of-audio-headphones/
- Understanding Headphone Power Requirements (ranecommercial.com)
- THE RELATIONSHIP OF VOLTAGE, LOUDNESS, POWER AND DECIBELS | Galen Carol Audio | Galen Carol Audio (gcaudio.com)
- Table chart sound pressure levels SPL level test normal voice sound levels pressure sound intensity ratio decibel comparison chart conversion of sound pressure to sound intensity noise sound units decibel level comparison of common sounds calculation compression rarefaction loudness decibel dB scale ratio factor unit examples - sengpielaudio Sengpiel Berlin

Addendum 1 - How to increase the gain of the X-Altra HPA-1

This is the standard X-Altra HPA-1 gain and suitable for normal 1V RMS line level outputs and c. 90 dB/mW Headphones

R12 and R25 Value in Ω	Gain Magnitude	Gain in dB
2200	3.14	9.9
1800	3.61	11.2
1500	4.13	12.3
1200	4.92	13.8
1000	5.70	15.1
820	6.73	16.6
680	7.91	18.0
560	9.39	19.5
470	11.00	20.8
390	13.05	22.3
330	15.24	23.7

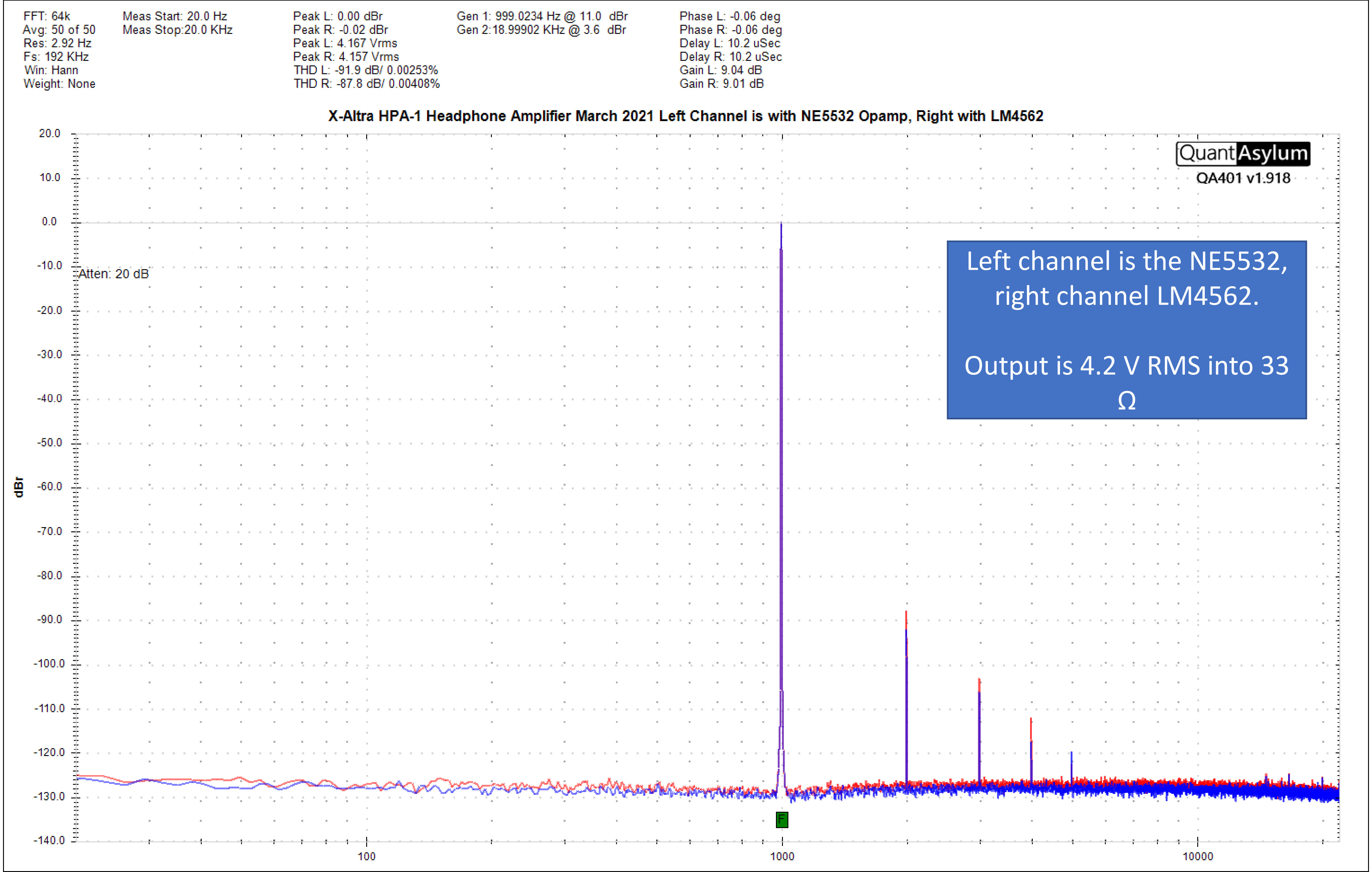
Addendum 2 – Loudness in SPL vs sensitivity for typical headphones (104dB/mW)

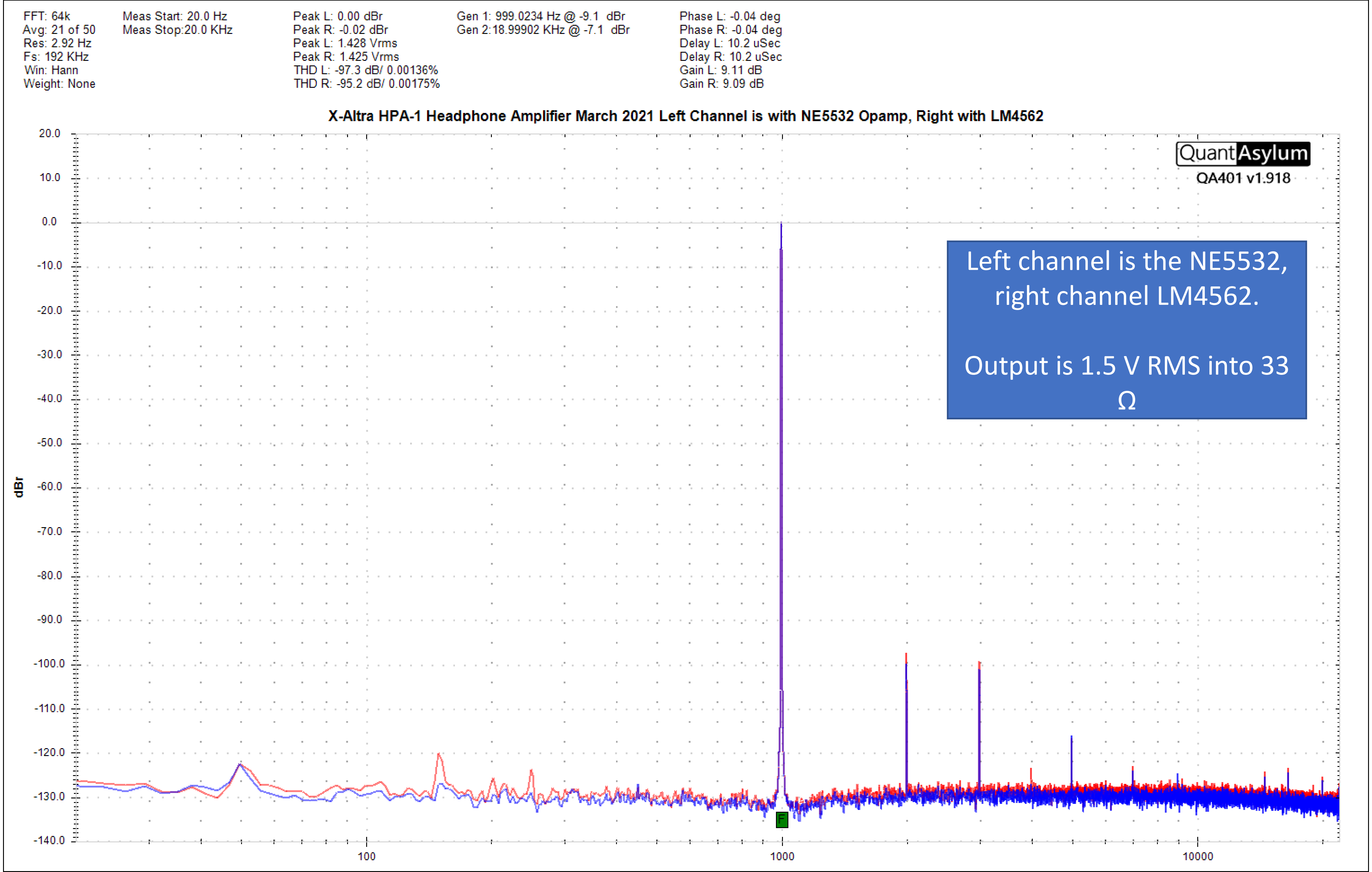
		600 Ohm - 104 db/mW			300 Ohm - 104 db/mW			80 Ohm - 104 db/mW			32 Ohm - 104 db/mW		
Listening Loudness		Voltage Needed	Current Needed	Power Needed	Voltage Needed	Current Needed	Power Needed	Voltage Needed	Current Needed	Power Needed	Voltage Needed	Current Needed	Power Needed 1
Safe	85 dB SPL	0.09 Vrms	0.15 mA	0.01 mW	0.06 Vrms	0.2 mA	0.01 mW	0.03 Vrms	0.38 mA	0.01 mW	0.02 Vrms	0.63 mA	0.01 mW
Moderate	100 dB SPL	0.49 Vrms	0.82 mA	0.4 mW	0.35 Vrms	1.17 mA	0.41 mW	0.18 Vrms	2.25 mA	0.41 mW	0.11 Vrms	3.44 mA	0.38 mW
Fairly Loud	110 dB SPL	1.55 Vrms	2.58 mA	4 mW	1.09 Vrms	3.63 mA	3.96 mW	0.56 Vrms	7 mA	3.92 mW	0.36 Vrms	11.25 mA	4.05 mW
Very Loud	115 dB SPL	2.75 Vrms	4.58 mA	12.6 mW	1.94 Vrms	6.47 mA	12.55 mW	1 Vrms	12.5 mA	12.5 mW	0.63 Vrms	19.69 mA	12.4 mW
Painful	120 dB SPL	4.89 Vrms	8.15 mA	39.85 mW	3.46 Vrms	11.53 mA	39.91 mW	1.79 Vrms	22.38 mA	40.05 mW	1.13 Vrms	35.31 mA	39.9 mW

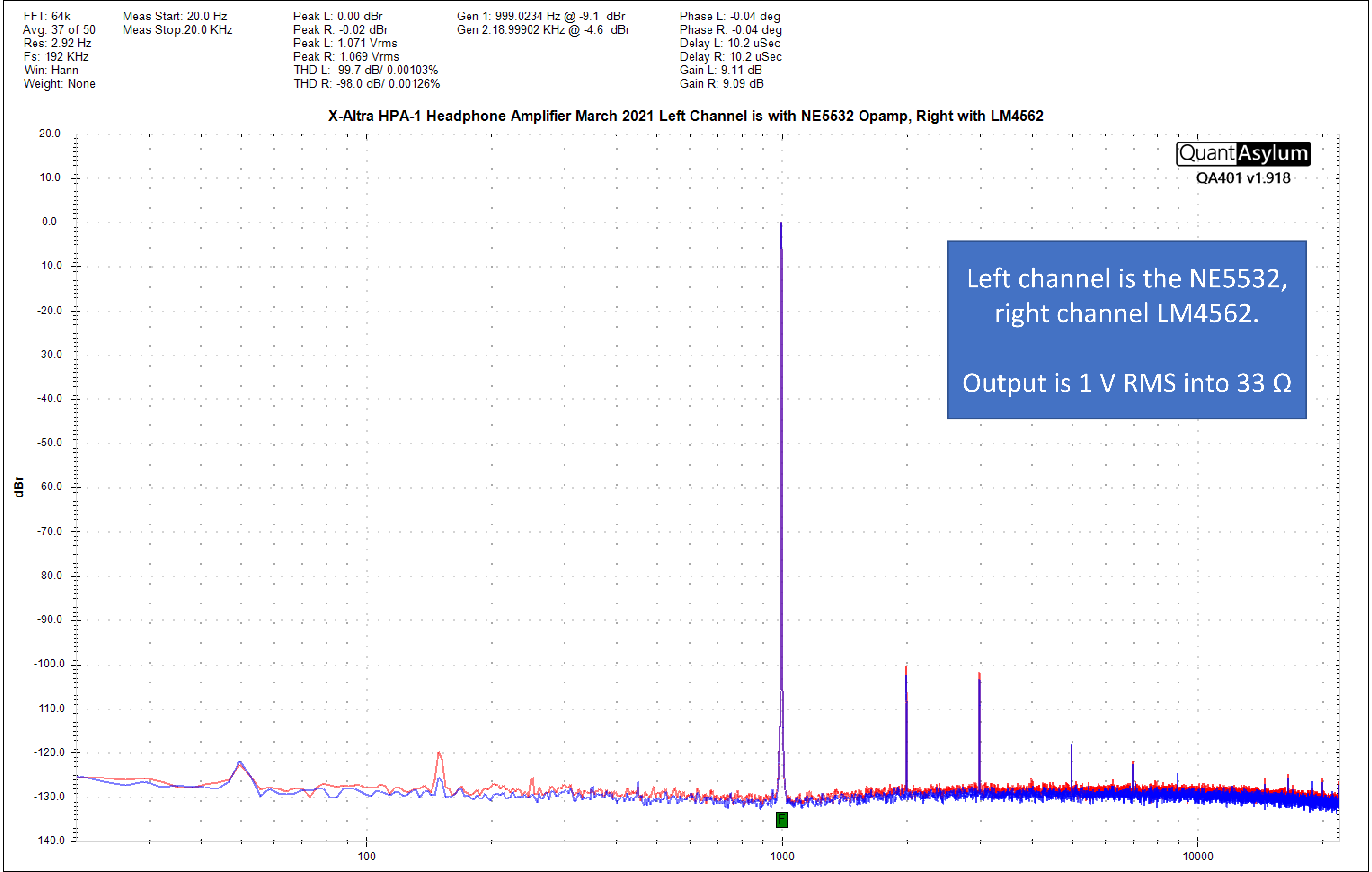
Table courtesy ‘Audio Science Review’

Addendum 3 – NE5532 Used in Left Channel, LM4562 in right channel - Measurements

- For these tests, the LH Channel opamp was replaced with a NE5532 workhorse opamp and some of the key measurements repeated.
- There is no difference in the 20Hz – 20 kHz distortion measurements between the NE5532 and the LM4562.
  - The right hand channel LM4562 distortion actually read a little higher than the NE5532 – this was due to differences in the analyser readings and a slightly lower distortion (few ppm) on the left hand channel which is evident from the original all LM4562 measurements done on the 16/17 March 2021.
- HF performance (i.e. >> 20 kHz) as expected is not as good as the LM4562 due the lower GBW
- The full power 20 V pk-pk power bandwidth using the NE5532 is 90 kHz vs 450 kHz for the LM4562. This frequency is onset of visually discenable slew rate limiting
- The capacitive load tests were also repeated and are virtually identical to the LM4562 results. The HPA-1 using the NE5532 is stable into any capacitive load from 47pF to 0.1uF //32 Ω
- Conclusion: the NE5532 may be used with the X-Altra HPA-1 and over the audio band will give similar measurement results to those where the LM4562 opamp was used.


FFT: 64k
Avg: 50 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 4.167 Vrms
Peak R: 4.157 Vrms
THD L: -91.9 dB/ 0.00253%
THD R: -87.8 dB/ 0.00408%
Gen 1: 999.0234 Hz @ 11.0 dBr
Gen 2:18.99902 KHz @ 3.6 dBr
Phase L: -0.06 deg
Phase R: -0.06 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 9.04 dB
Gain R: 9.01 dB
X-Altra HPA-1 Headphone Amplifier March 2021 Left Channel is with NE5532 Opamp, Right with LM4562
QuantAsylum
QA401 v1.918
Atten: 20 dB
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F
Left channel is the NE5532, right channel LM4562.
Output is 4.2 V RMS into 33 Ω


FFT: 64k
Avg: 21 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 1.428 Vrms
Peak R: 1.425 Vrms
THD L: -97.3 dB/ 0.00136%
THD R: -95.2 dB/ 0.00175%
Gen 1: 999.0234 Hz @ -9.1 dBr
Gen 2:18.99902 KHz @ -7.1 dBr
Phase L: -0.04 deg
Phase R: -0.04 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 9.11 dB
Gain R: 9.09 dB
X-Altra HPA-1 Headphone Amplifier March 2021 Left Channel is with NE5532 Opamp, Right with LM4562
QuantAsylum
QA401 v1.918
Left channel is the NE5532, right channel LM4562.
Output is 1.5 V RMS into 33 Ω
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F


FFT: 64k
Avg: 37 of 50
Res: 2.92 Hz
Fs: 192 KHz
Win: Hann
Weight: None
Meas Start: 20.0 Hz
Meas Stop:20.0 KHz
Peak L: 0.00 dBr
Peak R: -0.02 dBr
Peak L: 1.071 Vrms
Peak R: 1.069 Vrms
THD L: -99.7 dB/ 0.00103%
THD R: -98.0 dB/ 0.00126%
Gen 1: 999.0234 Hz @ -9.1 dBr
Gen 2:18.99902 KHz @ -4.6 dBr
Phase L: -0.04 deg
Phase R: -0.04 deg
Delay L: 10.2 uSec
Delay R: 10.2 uSec
Gain L: 9.11 dB
Gain R: 9.09 dB
X-Altra HPA-1 Headphone Amplifier March 2021 Left Channel is with NE5532 Opamp, Right with LM4562
QuantAsylum
QA401 v1.918
Left channel is the NE5532, right channel LM4562.
Output is 1 V RMS into 33 Ω
dBr
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
-100.0
-110.0
-120.0
-130.0
-140.0
100
1000
10000
F